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Regional Anaesthesia Techniques in Liver and Kidney Transplantation: A Narrative Review in Donors and Recipients

Alessandro De Cassai, Burhan Dost, Serkan Tulgar, Bahadır Çiftçi, Sandeep Diwan, Yavuz Gürkan

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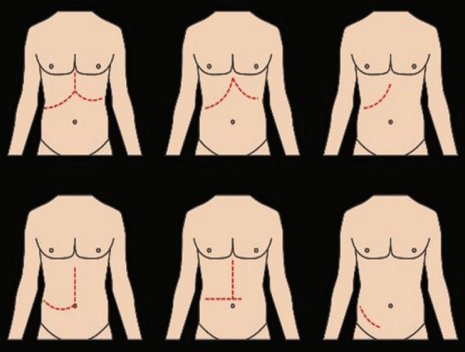

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The Evolving Role of Regional Anaesthesia in Organ Transplantation: Raising the Bar in Perioperative Outcomes

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Only a few decades ago, liver and kidney transplantation were procedures performed in a limited number of highly specialized centers by exceptionally skilled surgeons and anaesthesiologists. At a time when case volumes were low and perioperative management remained highly demanding, the primary goal was straightforward: to ensure the survival of both the recipient and, in living donor transplantation, the donor, while minimizing major perioperative complications. As surgical techniques became more refined and transplant procedures gradually shifted toward less invasive approaches, the priorities of the perioperative team also began to change. Mortality and major morbidity were no longer the only endpoints. Attention gradually shifted to the quality of postoperative recovery. Effective analgesia, prevention of postoperative nausea and vomiting, and early mobilization became the main targets of perioperative care. Interestingly, all three were closely linked. Better pain control facilitated early mobilization, while reduced opioid consumption translated into less postoperative nausea and vomiting.

It was therefore natural for anaesthesiologists, as the physicians responsible for perioperative care, to seek opioid-sparing analgesic strategies. Interfascial plane blocks arrived at the right time. Although they may not provide the same density of blockade as neuraxial techniques, they may avoid some of the limitations and risks associated with neuraxial analgesia. More importantly, when incorporated into a multimodal analgesic regimen, they have the potential to provide meaningful clinical benefits while reducing reliance on opioids. Reflecting the growing interest in interfascial plane blocks, this issue features a letter to the editor by Özen et al., describing the combined use of ultrasound-guided rectointercostal and transversalis fascia plane blocks for postoperative analgesia in a pediatric renal transplant recipient, alongside a comprehensive narrative review by De Cassai et al., discussing regional anaesthesia techniques for both donors and recipients in liver and kidney transplantation and the role of interfascial plane blocks in postoperative pain management.

These articles also remind us that regional anaesthesia is far more than the technical execution of a block learned through a traditional apprenticeship model. Selecting the appropriate technique requires an understanding of the surgical procedure itself, the differences between donor and recipient operations, the tissues involved, and the mechanisms underlying postoperative pain. This knowledge must then be integrated with detailed anatomy and the pharmacology and pharmacokinetics of local anaesthetics and adjuvant drugs. It is this combination of surgical insight, anatomical knowledge, and sound clinical judgment that continues to advance the field of regional anaesthesia.

The value of this approach becomes even more evident in the most challenging clinical scenarios. In this issue, Akin et al. present a case report describing the combined use of M-TAPA and pecto-intercostal fascial block for analgesia management in the intensive care unit in a high-risk patient who underwent simultaneous liver transplantation and coronary artery bypass grafting surgery. Such cases illustrate that interfascial plane blocks are not limited to routine postoperative pain control; when applied with the same anatomical and clinical rigor, they can also serve as valuable tools in the analgesic management of complex, high-risk patients in the intensive care setting.

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We believe that the future of regional anaesthesia lies not in asking whether a block has never been used for a particular operation or whether a previously unexplored fascial plane can be injected, but in selecting the right technique for the right patient, with the right indication, based on a sound understanding of surgical anatomy and pain mechanisms. We are proud to consider and publish manuscripts that contribute to this rational, patient-centered evolution of regional anaesthesia.

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Editorial
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From Publication to Scientific Communication: The Expanding Role of Social Media in the Future of TJAR

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[*]: Editorial roles: Burhan Dost and Ceyda Özhan Çaparlar serve as Social Media Editors of the Turkish Journal of Anaesthesiology and Reanimation.

In an era characterised by the rapid evolution of scientific knowledge and shifting patterns of access to scholarly information, social media have assumed an increasingly important role in academic publishing.[1] As the influence of traditional print media continues to decline and digital platforms emerge as the predominant channels for disseminating scientific content, the judicious, ethical, and strategic use of social media by academic journals has transitioned from an optional consideration to an operational imperative.[2] Given that many anaesthesiologists, researchers, and trainees now update their knowledge not only through traditional journal publications but also through social media platforms, (e.g., Instagram, LinkedIn, Facebook, and X), these platforms represent an important opportunity to reach wider and more diverse audiences. In addition to increasing the visibility of published articles, social media may facilitate scientific discussions, engage early-career researchers, and strengthen a journal's national and international academic identity.

Importantly, the publication of an article should not be regarded as the endpoint of its scientific journey. Rather, it marks the beginning of a broader process of scientific communication that includes dissemination, interpretation, and meaningful engagement with the scientific community. Dissemination involves extending the reach of published research beyond conventional journal readership. Interpretation involves presenting complex findings in accessible, accurate, and contextually appropriate formats without compromising their scientific meaning. Engagement involves creating opportunities for readers, authors, reviewers, clinicians, and professional societies to interact with the research and with one another. Together, these processes can transform a published article from a static academic output into a dynamic resource for scientific communication.

In this context, social media can serve as an effective bridge between published evidence and clinical awareness, particularly in anaesthesiology, where emerging evidence frequently informs perioperative care and clinical decision-making. For the *Turkish Journal of Anaesthesiology and Reanimation* (TJAR), social media represents an important opportunity to strengthen its academic visibility and international reach. As a journal covering anaesthesiology, intensive care, pain medicine, perioperative medicine, regional anaesthesia, and patient safety, the TJAR has already begun using digital platforms to highlight high-quality research, promote educational content, and foster interaction among authors, readers, reviewers, editors, and professional societies. The journal's recent Instagram metrics demonstrate sustained growth in audience reach, engagement, and visibility beyond its existing follower base (Figure 1), providing a practical example of how a structured social media strategy can extend the dissemination of scientific content beyond the publication of an article.[3]

The culture of scientific communication is currently undergoing a significant transformation. Traditionally, journals have disseminated newly published articles primarily through text-based announcements that direct readers to the original publication. However, digital audiences increasingly expect concise, visually organised, and platform-adapted scientific content that communicates the key message before encouraging further reading. In some cases, journals incorporate animation, narration, or even music to capture attention and improve engagement. This shift reflects a broader transition from simply announcing publications to actively communicating science (Figure 2). Within this evolving communication landscape, artificial

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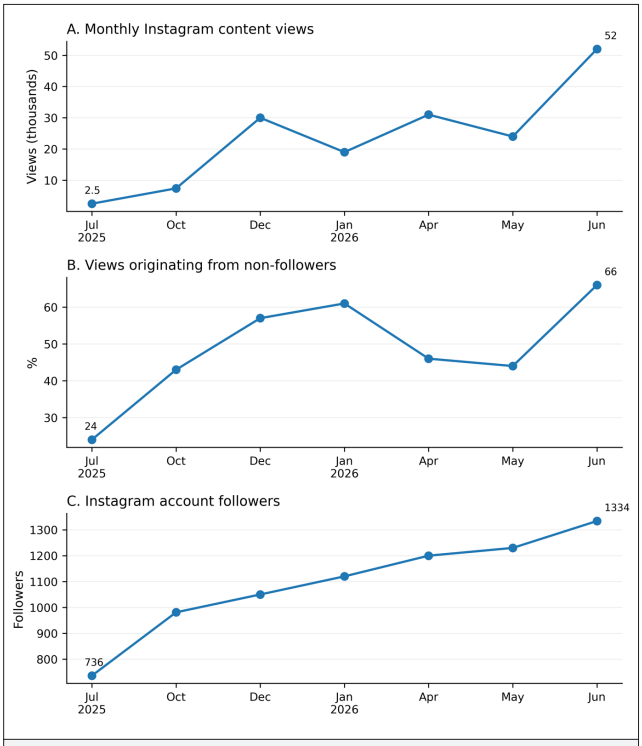

Figure 1. Instagram performance metrics of the *Turkish Journal of Anaesthesiology and Reanimation* (TJAR). (A) Monthly content views. (B) Percentage of views originating from non-followers. (C) Growth in Instagram account followers.

intelligence (AI) has emerged as a valuable technology. AI-assisted tools can facilitate the preparation of visual abstracts, identify key messages, improve language clarity, adapt content for different audiences, and optimise the timing and format of social media posts.[4] When integrated within a robust editorial workflow, these tools may improve the efficiency and consistency of scientific communication, while allowing editorial teams to focus on scientific quality and strategic communication. Nevertheless, AI should complement—not replace—editorial expertise. Human oversight remains essential to ensure scientific accuracy, contextual integrity, ethical compliance, transparency, and fidelity to the original publication.[5] The objective is not to generate more content but to communicate high-quality science more clearly, responsibly, and effectively.

As anaesthesiology continues to evolve, journals must evolve alongside it. Moving beyond traditional publication models, social media has become an integral component of scientific communication, rather than simply a promotional tool. For TJAR, this transformation represents more than a communication strategy; it reflects a broader editorial vision of connecting research with clinicians, researchers, and the wider academic community. By combining scientific excellence, responsible digital communication, active community engagement, and thoughtful integration of AI-supported tools, the TJAR can further strengthen its position as a visible, accessible, and internationally engaged journal in the field of anaesthesiology.

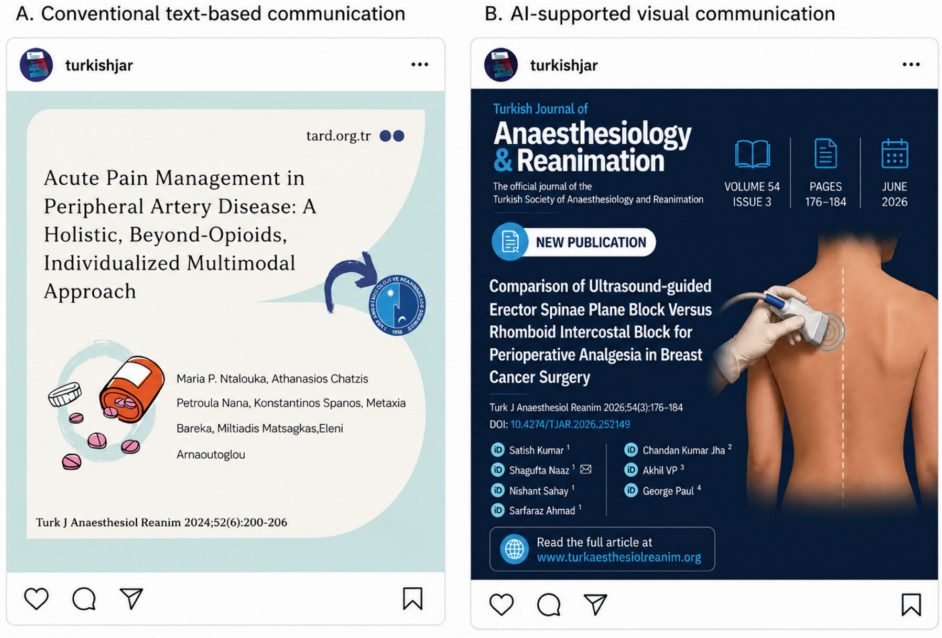

Figure 2. Evolution of social media communication in *Turkish Journal of Anaesthesiology and Reanimation* (TJAR). (A) Earlier text-oriented social media post primarily presenting bibliographic information. (B) Contemporary visual communication integrating structured layouts, medical illustration, and AI-supported design tools.

AI, artificial intelligence.

Footnotes

Editorial disclosure: Burhan Dost and Ceyda Özhan Çaparlar serve as Social Media Editors, and Zekeriya Alanoğlu serves as Editor-in-Chief of the Turkish Journal of Anaesthesiology and Reanimation. The manuscript was handled independently in accordance with the journal's editorial policies.

Declaration Regarding the Use of AI and AI-Assisted Technologies: ChatGPT version 5.6 (OpenAI) was used solely for language editing and improving the clarity of the manuscript. The authors reviewed and approved the final text and take full responsibility for its content.

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Review Article
Regional Anaesthesia

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Regional Anaesthesia Techniques in Liver and Kidney Transplantation: A Narrative Review in Donors and Recipients

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Abstract

Advances in surgical techniques and perioperative care have driven increasing interest in regional anaesthesia as part of multimodal analgesia strategies. In liver and kidney transplantation, however, the adoption of regional techniques remains limited due to concerns regarding altered coagulation, cardiovascular instability, and graft perfusion. This narrative review aims to synthesize current evidence on the feasibility, safety, and clinical utility of neuraxial and fascial plane blocks in both transplant recipients and living donors. A narrative review of the literature was conducted, focusing on regional anaesthesia techniques used in transplantation. The review integrates anatomical considerations, sources of postoperative pain, patient-specific comorbidities, and clinical evidence related to neuraxial anaesthesia and ultrasound-guided fascial plane blocks, including erector spinae plane block, quadratus lumborum block, transversus abdominis plane block, modified thoracoabdominal nerve block, external oblique intercostal block, and emerging techniques. Neuraxial anaesthesia can provide effective analgesia in carefully selected transplant patients, particularly in living donors, but its use is constrained by dynamic coagulation abnormalities and hemodynamic instability, especially in recipients. Fascial plane blocks offer a favorable risk-benefit profile, providing effective somatic and, in some cases, visceral analgesia while preserving hemodynamic stability and minimizing bleeding risk. Evidence supports their opioid-sparing effects and feasibility across a range of transplant procedures. Regional anaesthesia represents a valuable component of multimodal analgesia in liver and kidney transplantation when tailored to surgical incision patterns, sources of pain, and patient-specific physiological considerations. Fascial plane blocks, in particular, appear well suited to transplant populations and may facilitate enhanced recovery while maintaining graft-protective priorities.

Keywords: Fascial plane blocks, kidney transplantation, liver transplantation, pain management, regional anaesthesia

Main Points

- Regional anaesthesia techniques, particularly fascial plane blocks, provide effective opioid-sparing analgesia for patients undergoing liver or kidney transplantation.
- The use of regional techniques can facilitate early extubation and support enhanced recovery after surgery protocols in the transplant population.
- Clinicians should carefully consider the timing of block performance and the patient's coagulation status, especially in the context of liver transplantation and potential graft dysfunction.
- Standardization of regional anaesthesia protocols for transplant surgery is still needed, requiring further large-scale prospective clinical trials.

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Introduction

Advances in surgical practice have shifted operative techniques from open surgery toward laparoscopic and robotic approaches and have prompted parallel evolution in anaesthetic and analgesic strategies.[1] Traditional neuraxial techniques are increasingly being shifted toward, or replaced by, ultrasound-guided fascial plane blocks that provide procedure-specific, mechanism-based analgesia.[2] Improved understanding of pain pathways and surgical anatomy has facilitated the development of regional anaesthesia techniques targeted at the source of postoperative pain, supporting enhanced recovery and opioid-sparing perioperative care.[3]

Research continues to clarify the selection of appropriate regional techniques for specific surgical procedures, and experience with techniques such as erector spinae plane block (ESPB), rectus sheath block, and ilioinguinal block has contributed to a surgery-specific approach to regional analgesia.[4]

Despite their growing use, regional anaesthesia techniques remain underutilized and insufficiently described in transplant recipients.[5] This population is characterized by critical illness, complex physiology, and heightened concern for graft perfusion and survival. Consequently, anaesthetic management often prioritizes hemodynamic stability and organ protection, potentially limiting the adoption of regional techniques.

This narrative review aims to synthesize current evidence on regional anaesthesia techniques in patients undergoing liver and kidney transplantation, including both living donors and transplant recipients.

Search Strategy

As this manuscript was designed as a narrative review rather than a systematic review, a formal protocol-driven study selection process was not undertaken. We chose this approach because, in contrast to a systematic review, which uses a predefined protocol and an exhaustive study-selection framework to answer a specific question, this narrative review aims to provide a clinically oriented synthesis of current evidence.Nevertheless, to enhance transparency, we consider it important to report the literature search strategy we employed. The authors performed a structured literature search in PubMed/MEDLINE, Scopus, EMBASE, and Web of Science using combinations of free-text terms, keywords, and relevant MeSH terms related to regional anaesthesia and transplantation. Search terms included "regional anaesthesia," "neuraxial anaesthesia," "epidural," "spinal anaesthesia," "fascial plane block," "ESPB," "quadratus lumborum block (QLB)," "transversus abdominis plane block (TAPB)," "modified thoracoabdominal nerve block through the perichondrial approach (M-TAPA)," "external oblique intercostal block," "liver transplantation," "kidney transplantation," "living donor hepatectomy," and "donor nephrectomy." We aimed to include articles published in any language addressing kidney or liver transplantation in adult and pediatric populations that evaluated the efficacy of any regional anaesthesia technique compared with another regional anaesthesia technique or with standard care. Given the narrative nature of this review, no restrictions were applied to study design: randomized controlled trials, prospective and retrospective cohort studies, case series, and case reports were considered eligible. In addition, all studies potentially relevant to the topic and identified through the bibliographic search were reviewed. Publications were included according to their relevance to the topic, with emphasis on studies addressing anatomical rationale, feasibility, safety, analgesic outcomes, and perioperative recovery in transplant donors and recipients. Reference lists of selected studies were also reviewed for additional relevant articles. The literature search was last updated on 21 January 2026.

Unless otherwise explicitly stated, references to "transplantation" refer to both donors and recipients, while "transplant recipients" refers to recipients of liver and kidney transplants.

As this manuscript is a review of existing literature and does not involve original research on human subjects or animals, institutional ethics committee approval was not required.

Potential Comorbidities of Interest and How They may Affect Regional Anaesthesia

• Impaired coagulation and hemorrhage risk

End-stage renal disease (ESRD)

These patients may exhibit qualitative platelet dysfunction. Uremic patients commonly develop a bleeding diathesis that is primarily related to abnormalities of primary hemostasis, particularly defective platelet function and impaired platelet-vessel wall interactions.[6] The dysfunction is due to increased intracellular cyclic adenosine monophosphate levels, reduced thromboxane A_2 production, increased synthesis of prostacyclin, and abnormalities in von Willebrand factor.[7]

Moreover, many patients continue to receive heparin or exhibit residual anticoagulant effects despite guidelines recommending against its use in patients with impaired coagulation.[8]

End-stage liver disease (ESLD)

Patients with ESLD have historically been considered to be at high risk of hemorrhagic complications; however, it is now well recognized that they are also prone to thrombotic events, reflecting the complex and rebalanced nature of hemostasis in this population.[9] Typical laboratory abnormalities include thrombocytopenia, prolongation of prothrombin time and

activated partial thromboplastin time, and reduced plasma fibrinogen levels.

Thrombocytopenia is caused by hypersplenism secondary to portal hypertension, bone marrow suppression caused by toxic exposures, reduced thrombopoietin production, and immune-mediated platelet destruction.[10,11]

Alterations in platelet function have also been described in ESLD, but the available evidence remains conflicting, with studies reporting severe platelet dysfunction, paradoxical platelet hyperreactivity, or mixed phenotypes, leaving the true clinical impact of qualitative platelet abnormalities incompletely understood.[12,13]

Additional caution is warranted in patients with portal hypertension, as engorgement of epidural and paravertebral venous plexuses may increase the risk of bleeding complications during neuraxial techniques.[14]

• Increased risk of local anaesthetic systemic toxicity (LAST)

ESRD

Patients with ESRD are at an increased risk of LAST due to altered protein binding, metabolic derangements, and impaired drug handling. Uremia and chronic metabolic acidosis reduce the binding of local anaesthetics to plasma proteins, increasing the free, pharmacologically active fraction in the circulation.[15] In addition, reduced renal clearance promotes the accumulation of active metabolites of certain local anaesthetics, particularly lidocaine and prilocaine.[16] Electrolyte abnormalities, especially hyperkalemia and hypocalcemia, and uremic cardiomyopathy lower the threshold for arrhythmias and cardiovascular instability, thereby increasing the likelihood that toxic plasma concentrations will result in severe neurologic and cardiac manifestations.[17]

ESLD

Patients with ESLD are at increased risk of LAST primarily because of impaired hepatic metabolism and reduced plasma protein binding. Loss of functional hepatocyte mass and decreased hepatic blood flow lead to prolonged elimination half-life and higher systemic drug exposure. Hypoalbuminemia and reduced α1-acid glycoprotein levels further increase the unbound, active fraction of local anaesthetics in plasma.[18] Finally, cirrhotic cardiomyopathy, hyponatremia (and other electrolyte imbalances), and autonomic dysfunction predispose these patients to exaggerated myocardial depression and malignant arrhythmias once toxic concentrations are reached, increasing the severity of both neurologic and cardiovascular manifestations of LAST.[19]

• Cardiovascular impairment

ESRD

Cardiovascular disease is highly prevalent and includes uremic cardiomyopathy,[20] left ventricular hypertrophy, ischemic heart disease, and heart failure, all of which increase the likelihood of severe hypotension after sympathetic blockade from spinal or epidural anaesthesia. Autonomic neuropathy, particularly in diabetic patients,[21,22] can further blunt compensatory hemodynamic responses. Electrolyte abnormalities, especially hyperkalemia, metabolic acidosis, and volume overload, increase the risk of arrhythmias and alter physiologic responses to local anaesthetics.[23]

ESLD

Cirrhotic cardiomyopathy is characterized, in patients with cirrhosis, by reduced cardiac contractile responsiveness to physiological and pharmacological stress, diastolic dysfunction, and electrophysiological abnormalities, despite the absence of overt structural heart disease.[24] It is caused by chronic systemic vasodilation, altered β-adrenergic signaling, and increased circulating cardiodepressant substances, all of which impair myocardial contractility and stress adaptation.[25] All these alterations render these patients particularly susceptible to profound, poorly tolerated hypotension following spinal or epidural sympathectomy.

Surgical Incisions

Surgical incision is a major determinant of postoperative pain severity and analgesic requirements in solid organ transplantation. In both liver and kidney transplantation, the choice of surgical incision is driven by the need to achieve adequate operative exposure and vascular control, while simultaneously influencing the extent of abdominal wall disruption, neural injury, and postoperative recovery.

In adult liver transplantation, wide upper abdominal incisions are most commonly employed. The classic Mercedes-Benz incision consists of bilateral subcostal incisions joined by a short vertical midline extension below the xiphoid process. This approach provides excellent exposure of the suprahepatic vena cava and hepatic hilum, but is associated with extensive muscle division and bilateral intercostal nerve involvement.[26] A related alternative is the Chevron (rooftop) incision, which comprises bilateral subcostal incisions without a vertical midline component. Although slightly less disruptive to midline structures, the Chevron incision still involves broad dissection of the upper abdominal wall.[27]

In selected cases, particularly in living-donor liver transplantation or limited recipient procedures, a J-shaped subcostal incision, formed by a unilateral subcostal incision with a short cranial midline extension, may be used to provide adequate surgical exposure while limiting bilateral abdominal wall trauma.[28] Less commonly, unilateral subcostal (Kocher-type) incisions may be employed for

restricted re-exploration or specific donor procedures, resulting in reduced surgical trauma but more limited exposure.[29]

In addition, several modified incisions have been described for specific clinical scenarios. Inverted T (cruciate) incisions, combining bilateral subcostal incisions with a longer midline extension, are occasionally used in multivisceral transplantation or complex reoperative settings.[29] Hockey-stick or reverse L-shaped incisions, which extend a unilateral subcostal incision inferolaterally, are frequently reported in living-donor hepatectomy to balance exposure with abdominal wall preservation.[29] Combined upper and lower abdominal approaches, such as a Mercedes incision with an additional Gibson extension, may be required in simultaneous liver-kidney transplantation.

In contrast, kidney transplantation is typically performed through a lower abdominal extraperitoneal approach. The Gibson incision, an oblique incision made parallel to the inguinal ligament in the iliac fossa, is the standard approach. This incision allows direct access to the iliac vessels and bladder while avoiding entry into the peritoneal cavity. Variants, such as the Rutherford-Morrison incision, extend the Gibson approach cranially to improve exposure in obese patients or in cases of complex vascular anatomy.[30] Although smaller than liver transplant incisions, these lower abdominal approaches traverse multiple muscle layers and are closely related to the ilioinguinal, iliohypogastric, and genitofemoral nerves. Figure 1 shows the types of incisions used in transplantation surgery.

Source of Pain in Kidney and/or Liver Transplantation

In both transplant recipients and living donors, postoperative pain after liver or kidney transplantation has both somatic and visceral origins. The somatic component is generally easier to anticipate, as it arises directly from the surgical incision, drain sites, and trocar or camera port entry points.[31] These nociceptive inputs are transmitted primarily by the thoracoabdominal, subcostal, iliohypogastric, and ilioinguinal nerves through their anterior and lateral cutaneous branches, depending on the location and extent of abdominal wall trauma. However, abdominal wall innervation is not strictly segmental.[32] Owing to frequent interconnections and overlap between adjacent nerves and fascial planes, targeting individual nerves in isolation is often insufficient. Instead, fascial plane blocks, which allow the spread of local anaesthetic across multiple neural pathways, are particularly well-suited to interrupting the somatic component of pain in transplant surgery. In addition to incisional nociception, postoperative discomfort in transplant surgery may arise from muscle retraction, sustained tension, and altered abdominal wall mechanics, which may not be perceived as sharp pain but as tightness, pressure, or

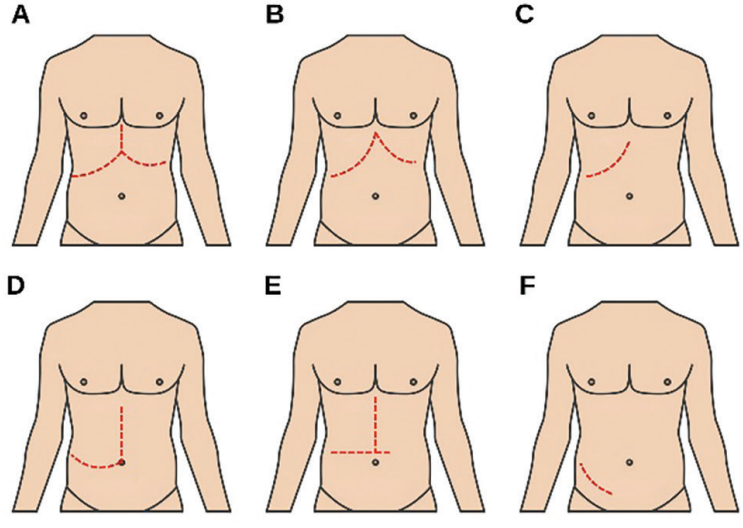

Figure 1. Surgical incision types used in adult liver and kidney transplantation.

(A) Mercedes-Benz incision, consisting of bilateral subcostal incisions joined by a short vertical midline extension below the xiphoid process. (B) Chevron (rooftop) incision, composed of bilateral subcostal incisions without a vertical midline component. (C) Kocher incision, a unilateral subcostal incision providing limited upper abdominal exposure, used in selected liver procedures. (D) Makuuchi incision (J-shaped or reverse L configuration), combining a unilateral subcostal incision with a vertical midline extension, frequently used in living-donor hepatectomy and selected liver transplantation cases. (E) Inverted T (cruciate) incision, consisting of a long midline incision with bilateral subcostal extensions, typically reserved for complex, preoperative, or multivisceral transplantation. (F) Gibson incision, an oblique lower abdominal extraperitoneal incision commonly used for kidney transplantation.

discomfort. From an anatomical perspective, the ilioinguinal and iliohypogastric nerves, which contribute to the motor innervation of the lower abdominal wall musculature, may play a role in this component of postoperative distress.

In liver transplantation, visceral pain is mediated primarily through the celiac and hepatic plexuses.[33] The principal sources of visceral nociception include incision or stretching of the hepatic capsule, trauma to surrounding perihepatic tissues, diaphragmatic irritation, and manual manipulation of the gallbladder, biliary structures, and hepatic hilum. Irritation of the diaphragmatic peritoneum may result in referred shoulder pain transmitted via afferent fibers of the phrenic nerve.[34] Although the anatomical sources of visceral nociception are similar, the relative contribution of these mechanisms differs between living donors and transplant recipients. In living liver donors, partial hepatectomy involves direct incision of the hepatic parenchyma and the Glisson capsule, whereas the remaining innervated liver tissue remains with the patient, resulting in a more pronounced, localized visceral pain component.[35] In contrast, the transplanted liver in recipients is denervated, thereby limiting direct capsular and parenchymal nociceptive input; visceral discomfort in this context is more commonly related to ischemic and inflammatory stimuli, including ischemia-reperfusion injury, and is often perceived as a diffuse, systemic sensation of pain and fatigue rather than as focal visceral pain.[35]

Visceral innervation of the kidney is primarily mediated through the renal plexus, with afferent fibers originating from the T10-L1 spinal segments and traveling alongside the sympathetic nerves.[36] Compared with that of the liver, renal visceral innervation is anatomically less complex and more segmentally organized, resulting in a relatively more predictable pattern of visceral pain. In living kidney donors, the entire organ is removed together with its fibrous capsule; therefore, renal capsular nociceptive input is effectively eliminated, and postoperative visceral discomfort primarily originates from manipulation of surrounding retroperitoneal structures rather than from the kidney itself.[37] In kidney transplant recipients, the transplanted kidney itself is not a direct source of visceral pain, as the organ is denervated and its capsule does not share afferent connections with the recipient. Instead, visceral discomfort instead arises from surgical manipulation of recipient tissues, including the iliac vessels, ureterovesical anastomosis, bladder wall, and surrounding pelvic and retroperitoneal structures. From a visceral perspective, kidney transplantation in both living donors and recipients is generally associated with a less pronounced visceral pain component than nephron-sparing procedures such as partial nephrectomy, in which the kidney and its capsule remain in situ and continue to generate capsular and parenchymal nociceptive input.

Although the visceral component may play a relatively minor role in liver transplant recipients, kidney transplant recipients, and living donors compared with other abdominal or renal procedures, it remains clinically relevant and cannot be disregarded. In addition to surgical tissue injury, pain in this population is further influenced by non-surgical sources, including arterial cannulation, urinary and nasogastric catheters, central venous access, and other invasive monitoring devices, all of which contribute to the overall pain burden.

Neuraxial Blocks

Neuraxial anaesthesia is not the gold standard for kidney or liver transplantation. Nevertheless, an increasing body of evidence supports its feasibility and safety in carefully selected patients, especially in living-donor kidney and liver transplantation settings.[38] This evolution reflects a shift from a historical contraindication toward selective use in specific patients.[38]

Several potential benefits of neuraxial anaesthesia have been proposed for patients undergoing kidney and liver transplantation. Although the available literature—particularly large randomized controlled trials—remains limited, recent reviews suggest that these theoretical advantages may be maximized when coagulation status and hemodynamic parameters are carefully optimized.[39] In this regard, thromboelastography (TEG) has increasingly been adopted as a point-of-care modality for real-time assessment of coagulation during transplantation[40] and may facilitate individualized hemostatic management. However, to date, no specific evidence or clinical guidelines support using TEG to guide placement or removal of neuraxial catheters in transplant recipients.[41]

Living kidney donor

In living-donor nephrectomy, neuraxial anaesthesia, in the context of multimodal analgesic techniques within enhanced recovery pathways, may reduce postoperative opioid use and improve recovery; moreover, epidural analgesia has been shown to provide effective pain control, early ambulation, and increased patient satisfaction.[42,43] Moreover, in a retrospective cohort of patients neuraxial anaesthesia has been also associated with a significantly lower incidence of delayed graft function in recipients, suggesting a potential protective effect on early graft performance (Table 1).[44]

Kidney recipient

In carefully selected patients with acceptable coagulation, combined spinal-epidural or spinal anaesthesia has been associated with stable hemodynamics and effective analgesia in renal transplant populations.[38,45] However, cohort data indicate that a subset of patients may still require conversion to general anaesthesia.[45] These effects may translate into clinically relevant improvements, as observed in other

Table 1. Comparison of Neuraxial and Fascial Plane Blocks in Transplantation

Technique	Pros	Cons/risks	Clinical considerations
Neuraxial techniques (epidural/spinal)	Provides superior analgesia, reduces opioid consumption, and attenuates surgical stress. Facilitates early GI recovery and improves respiratory function.	Risk of epidural hematoma due to dynamic coagulation abnormalities. Potential for profound hypotension impacting graft perfusion.	Feasible in carefully selected patients, particularly living donors. Requires real-time coagulation monitoring (e.g., TEG/ROTEM).
Fascial plane blocks (US-guided)	Favorable safety profile in high-risk populations with altered hemostasis. Performed in superficial planes where bleeding is easily managed. Preserves hemodynamic stability.	Primarily targets somatic pain; visceral coverage varies by technique. Evidence level is still evolving for some novel blocks.	Ideal for ERAS protocols and patients with significant cardiovascular vulnerability.

GI, gastrointestinal; ERAS, enhanced recovery after surgery; TEG, thromboelastography; ROTEM, rotational thromboelastometry; US, ultrasound

surgical settings, including better respiratory function, earlier mobilization, and enhanced recovery.[46-51] Although direct evidence in kidney transplantation remains limited, these benefits may support the rationale for considering neuraxial anaesthesia as a component of perioperative management in selected kidney transplant recipients, particularly those at increased risk of postoperative pulmonary, cardiovascular, or opioid-related complications (Table 1).

Living liver donor

Patients undergoing living liver donation may experience a high degree of postoperative pain, which has been reported to be greater than that observed in patients undergoing comparable hepatic resections for malignant disease.[52] The coagulation status following donor hepatectomy is complex and characterized by a paradoxical profile: conventional coagulation tests often indicate hypocoagulability, whereas TEG may demonstrate a sustained hypercoagulable state persisting up to postoperative day 10.[53] This imbalance—driven by reduced anticoagulant activity alongside preserved or increased procoagulant factors—predisposes donors to thrombotic complications such as portal vein thrombosis and deep vein thrombosis, despite elevated international normalized ratio values.[53] Consequently, TEG may better inform decisions than conventional tests do regarding the initiation and duration of postoperative thromboprophylaxis in these patients.[41]

Epidural analgesia has been shown to provide superior,[54] or at least equivalent[55] postoperative pain control and improved pulmonary function in living liver donors compared with intravenous patient-controlled analgesia, without a significant increase in complications in retrospective cohort studies (Table 2).

Liver Recipient

Liver transplant recipients frequently benefit from TEG assessment, as these patients exhibit complex and dynamic coagulopathies that are not adequately captured by standard laboratory tests.[56] However, TEG has good specificity for hypocoagulability—patients identified as hypocoagulable are at increased risk of bleeding—but limited sensitivity; a normal TEG does not reliably exclude the risk of bleeding. These risks may be further exacerbated in patients with portal hypertension, who can bleed despite apparently normal coagulation parameters due to the presence of extensive collateral circulation and engorged epidural veins.

However, some retrospective series, encompassing hundreds of patients at centers offering epidural analgesia during liver transplantation, suggest that neuraxial techniques may be administered in carefully selected individuals, although the benefit in terms of pain score reduction in these patients remains uncertain (Table 2).[57]

Fascial Plane Blocks

Fascial plane blocks may offer a more favorable risk-benefit profile anaesthesiathan neuraxial anaesthesia for kidney and liver transplantation. In fact, fascial plane blocks are performed in anatomically superficial planes, distant from the neuraxis, where bleeding is more likely to be clinically apparent and amenable to compression or conservative management.[58-60]

Moreover, fascial plane blocks largely avoid the sympathectomy, which may adversely affect perfusion of newly transplanted organs, especially during the vulnerable reperfusion phase.[61]

Liver transplantation: donor and recipient

ESPB is a paraspinal fascial plane block. Its proposed mechanism involves cranio-caudal spread of local anaesthetic to the paravertebral and epidural spaces, resulting in both visceral and somatic analgesia.[62,63] ESPB can be performed at any vertebral level; however, when used for liver transplantation, it is most commonly administered between T7 and T9.[31,39,64]

Clinical studies in living liver donors and recipients have shown that ESPB reduces postoperative pain scores and opioid consumption compared with standard analgesic regimens.[65,66] Continuous ESPB has demonstrated postoperative opioid requirements comparable to those of intrathecal morphine, while providing lower pain scores at 48-72 hours and a reduced incidence of opioid-related adverse

Table 2. Summary of Regional Anaesthesia Techniques in Liver Transplantation

Technique	Population	Clinical efficacy & reported benefits	Evidence level/studies	Complications
Epidural analgesia	Donors & recipients	Superior pain control and improved pulmonary function compared to IV PCA.	Extensive retrospective series (e.g., 685 recipients).	Risk of hematoma in coagulopathy.
ESPB	Donors & recipients	Reduced opioid consumption and lower pain scores. Earlier return of bowel function in pediatric cases.	Randomized controlled trials and feasibility studies.	None reported in transplant patients to date.
QLB	Recipients	Shorter extubation times and reduced intraoperative blood transfusion requirements.	Randomized trials and single-center retrospective studies.	Theoretical risk of organ injury or motor block.
TAPB	Donors & recipients	Effective somatic analgesia and potential reduction in extubation times.	Meta-analysis of three studies; several case series.	None reported.
M-TAPA	Donors & recipients	Reduces opioid use and side effects; performed in supine position.	Prospective randomized controlled study (donors).	None reported.
EOIB	Donors & recipients	Comparable to subcostal TAPB for lateral incisions.	Small series and randomized trials.	Theoretical risk of pneumothorax.

IV PCA, intravenous patient-controlled analgesia; ESPB, erector spinae plane block; QLB, quadratus lumborum block, TAPB: transversus abdominis plane block, M-TAPA: modified thoracoabdominal nerve block through perichondrial approach, EOIB: external oblique intercostal plane block, US: ultrasound

effects, such as nausea, vomiting, and pruritus.[67] In pediatric liver transplantation, continuous ESPB has been associated with lower opioid consumption and earlier return of bowel function.[68,69] To date, no ESPB-related complications have been reported in liver transplantation, and complications related to ESPB overall remain exceedingly rare.[70] QLB is performed between the psoas major and the quadratus lumborum muscles.[64] Following injection, the local anaesthetic spreads anteriorly and cranially through the thoracolumbar fascia to reach the paravertebral region, providing somatic and visceral analgesia across the T7-L1 dermatomes.[31,71]

A randomized controlled trial on laparoscopic hepatectomy suggests that QLB may provide effective postoperative analgesia than opioid-based analgesia alone.[72] In a retrospective cohort of transplant recipients, QLB has also been linked to shorter extubation times, reduced pain scores, and lower intraoperative blood transfusion requirements.[73] Although no complications have been reported in liver transplant patients, caution is advised because the block is deep, particularly in patients with coagulation abnormalities. In addition, the anatomical proximity to the kidney and liver poses a theoretical risk of organ injury, and motor block may occur secondary to paravertebral spread.[74]

TAPB is performed by injecting local anaesthetic into the fascial plane between the transversus abdominis and internal oblique muscles.[64,75] TAPB provides somatic analgesia only, covering the T6-T10 dermatomes, without visceral analgesic effects.[31] Multiple approaches have been described, resulting in variable spread. In liver transplantation, the subcostal approach may be preferable to the lateral approach because it reportedly provides better coverage of the upper abdominal incision.[31]

Both single-shot and continuous catheter-based techniques have been described in this population[78] and a meta-analysis of three studies demonstrated that TAPB provides effective postoperative analgesia.[76,77] To date, no TAPB-related complications have been reported in liver transplant patients.

The M-TAPA is performed at the costal margin of the 9th or 10th intercostal space.[79] This technique blocks both the anterior and lateral branches of the thoracoabdominal nerves (with more intense blockade of the anterior branches), providing dermatomal coverage from T5 to T12.[31] This distribution is consistent with the typical surgical approaches used in liver transplantation, including upper midline and lateral abdominal incisions.[31]

In living liver donors, M-TAPA has been associated with reduced opioid consumption, lower pain scores, a decreased need for rescue analgesia, and fewer opioid-related side effects compared with control groups.[80] Case series of liver transplant recipients have also demonstrated effective analgesia with this technique.[81] A notable advantage of M-TAPA over ESPB and QLB is that it can be performed in the supine position, eliminating the need for patient repositioning.[31,80,81]

External oblique intercostal plane block (EOIB) is performed by injecting local anaesthetic into the plane between the external oblique muscle and the ribs at the 6th-9th costal levels.[82] EOIB targets both the lateral (predominantly) and the medial branches of the thoracoabdominal nerves, providing sensory coverage from T6 to T11.[83] This block is particularly

useful for providing analgesia for lateral abdominal incisions commonly used during liver transplantation.[84] Depending on the incision pattern, EOIB may be used as a standalone technique or combined with other blocks, such as M-TAPA or TAPB.

Comparative studies have shown that EOIB provides analgesia comparable to that of subcostal TAPB, with similarly low opioid requirements and pain scores.[85] Case reports and small series support its efficacy in both donors and recipients, including when continuous catheter techniques are used.[86-88] Combined approaches, such as EOIB with rectointercostal block, have also been reported to provide effective postoperative analgesia in living donor surgery.[89] No EOIB-related complications have been reported to date, although caution is warranted regarding the potential risk of pneumothorax due to anatomical proximity.

Although emerging evidence, as discussed above, suggests potential benefits for these patients, at present no major guidelines formally recommend the routine use of fascial plane blocks for patients undergoing liver transplantation, primarily because of limited studies and heterogeneity of results (Table 2).

Kidney transplantation: donor and recipient

Effective postoperative in kidney transplantation requires coverage of the T10-L1 dermatomes (Table 3).[31,90]

In renal transplantation, TAPB is most often used as part of a combined anterior abdominal wall strategy, rather than as a standalone technique, due to its limited midline coverage[31,90] and its combined use with recuts sheath block have been proposed by some authors. Clinical a randomized study demonstrates that this combination provides analgesia comparable to epidural analgesia, with similar quality-of-recovery scores and a lower incidence of side effects[91] while other studies show that it can be effectively incorporated into multimodal analgesic regimens for renal transplant recipients.[92] No TAPB-related complications have been reported following renal transplantation.

Anterior QLB provides combined somatic and visceral analgesia via paravertebral spread of local anaesthetic, with dermatomal coverage typically extending from T7 to L1, making it well suited to renal transplantation.[31,71,90]

Multiple clinical studies have demonstrated that anterior QLB significantly reduces postoperative pain scores and opioid consumption compared with either local infiltration alone or systemic analgesia alone among renal transplant recipients and donors.[93,94] Continuous catheter techniques have also been successfully employed, particularly in pediatric recipients, resulting in sustained opioid-sparing effects.[95] QLB has additionally been incorporated into enhanced recovery after surgery pathways for donor nephrectomy, and novel formulations such as liposomal bupivacaine have been reported in selected pediatric cases.[96,97]

Among fascial plane techniques, anterior QLB may provide superior analgesic efficacy compared with ESPB in renal transplantation, particularly with respect to opioid reduction.[98]

No complications have been reported following QLB in renal transplant patients. Nevertheless, as a deep block, QLB warrants caution in patients with coagulopathy.[90]

ESPB is a paraspinal fascial plane block that can be performed at the T8-T10 levels for renal surgery.[90]

Clinical studies indicate that ESPB reduces postoperative opioid consumption following renal transplantation compared with standard analgesic regimens.[99] Case series have also reported effective analgesia in living-donor nephrectomy.[100] However, comparative data suggest that anterior QLB may offer superior analgesic efficacy and greater opioid-sparing effects than ESPB.[99] No ESPB-related complications have been reported following renal transplantation.

Table 3. Summary of Regional Anaesthesia Techniques in Kidney Transplantation

Technique	Population	Clinical efficacy & reported benefits	Evidence level/studies	Complications
TAPB (+rectus sheath)	Recipients	Analgesia comparable to epidural with fewer side effects.	Randomized non-inferiority trials.	None reported.
Anterior QLB	Donors & recipients	Superior pain control and reduced opioid consumption compared to ESPB or systemic analgesia.	Randomized controlled trials.	None reported.
ESPB	Donors & recipients	Effective opioid-sparing effects with a favorable safety profile.	Case reports and comparative studies.	None reported.
QIPB	Donors	Novel technique for lower abdominal wall analgesia.	Emerging evidence (case reports and small series).	None reported.

TAPB, transversus abdominis plane block; QLB, quadratus lumborum block; ESPB, erector spinae plane block; QIPB, quadro-iliac plane block

The quadro-iliac plane block (QIPB) is a novel fascial plane technique performed at the level at which the quadratus lumborum muscle attaches to the iliac crest. Local anaesthetic spreads between the quadratus lumborum and erector spinae muscles, potentially providing analgesia to the lower abdominal wall.[101] A case series suggests that QIPB may provide effective postoperative analgesia following living-donor nephrectomy.[102] Further prospective studies are required to establish its efficacy, safety, and performance relative to established techniques in renal transplantation (Table 3).

Conclusion

Regional anaesthesia is increasingly used in liver and kidney transplantation to improve analgesia, reduce opioid requirements, and support recovery while maintaining hemodynamic stability. Neuraxial techniques may be feasible in selected patients, but are limited by coagulation disturbances and cardiovascular risk, particularly during liver transplantation. Ultrasound-guided fascial plane blocks represent a safer and anatomically suitable alternative in high-risk populations. Further prospective comparative studies are needed to define optimal strategies and guide their integration into standardized transplant care pathways.

Footnotes

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ERAS Protocol Elements and Neurosurgery-Specific Considerations: A Narrative Review

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Abstract

Enhanced recovery after surgery (ERAS) is a structured, evidence-based, multimodal perioperative framework designed to reduce surgical stress and accelerate recovery. Although these pathways are widely established across surgical specialties, their implementation in neurosurgery presents unique challenges because recovery-enhancing interventions must be balanced against neurological protection, haemodynamic stability, intracranial physiology, and procedure-specific safety considerations. This narrative review synthesises current evidence regarding ERAS implementation across cranial and spinal neurosurgical procedures, including elective craniotomy, spine surgery, pituitary surgery, vascular neurosurgery, and selected paediatric and geriatric populations. While available studies consistently demonstrate reductions in hospital length of stay, opioid consumption, and resource utilisation without increasing perioperative complications, interpretation of these findings is limited by substantial heterogeneity in protocol design, outcome definitions, and adherence reporting, and by the scarcity of long-term neurological and patient-reported outcomes. Beyond summarising existing evidence, this review proposes a conceptual framework distinguishing two fundamentally different ERAS paradigms within neurosurgery: a function-driven model predominantly applicable to spine surgery, where recovery acceleration is the principal objective, and a safety-constrained model characteristic of cranial neurosurgery, where neurological monitoring, intracranial pressure management, and haemorrhagic risk frequently limit implementation of conventional ERAS elements. This distinction provides a physiological and clinical rationale for procedure-specific adaptation rather than uniform application of these principles. The review further argues that the benefits of ERAS arise primarily from pathway standardisation, multidisciplinary coordination, and high protocol adherence rather than from isolated perioperative interventions. By identifying the limitations of current evidence and highlighting the need for neurosurgery-specific outcome measures, standardised reporting, and protocol stratification by surgical pathology, this review offers a framework for future research and more tailored implementation of ERAS pathways within neurosurgical practice.

Keywords: Craniosynostosis, craniotomy, enhanced recovery after surgery, geriatric, neurosurgery, pituitary surgery, spine surgery

Main Points

- Enhanced recovery after surgery (ERAS) in neurosurgery should be viewed as a multidisciplinary model of care in which standardised perioperative pathways and high adherence to protocols are the main drivers of improved outcomes.
- Current evidence shows that ERAS is both safe and feasible for craniotomy and spinal surgery without increasing perioperative complications.
- Consistent benefits include reduced length of hospital stay, decreased opioid consumption, earlier mobilization, and lower healthcare costs.
- ERAS protocols must be tailored to the specific procedure and patient population, as neurosurgical contexts vary significantly in their physiological and clinical priorities.
- Despite these advantages, the existing evidence base remains limited by substantial heterogeneity and a predominance of single-center studies, highlighting the need for multicenter research and evaluation of long-term outcomes.

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Introduction

Enhanced recovery after surgery (ERAS) comprises a structured, evidence-based, multimodal approach to perioperative care that integrates preoperative, intraoperative, and postoperative interventions to reduce surgical stress, improve patient safety, and accelerate recovery. Since its introduction in colorectal surgery, ERAS pathways have been successfully adopted across numerous surgical specialties, consistently reducing postoperative morbidity, hospital length of stay (LOS), healthcare costs, and opioid consumption while improving patient-centred outcomes.[1,2]

Despite these advances, implementation of ERAS in neurosurgery has progressed more cautiously than in other surgical disciplines and remains less standardized. Spine surgery was the earliest neurosurgical domain to adopt ERAS principles, largely because its perioperative objectives—including pain control, early mobilisation, and functional recovery—align closely with conventional ERAS goals.[3-5] In contrast, cranial neurosurgery involves additional physiological and clinical constraints, including preservation of neurological function, maintenance of intracranial homeostasis, precise haemodynamic management, prevention of seizures, and mitigation of haemorrhagic risk.[6,7] These considerations frequently necessitate modification or selective application of standard ERAS elements.

Although an expanding body of evidence supports the feasibility and safety of ERAS pathways across a wide range of neurosurgical procedures, including elective craniotomy, spine surgery, pituitary surgery, vascular neurosurgery, and in selected paediatric and geriatric populations, the current literature remains fragmented.[8-12] Most studies focus on short-term metrics such as LOS, opioid consumption, and complication rates, while relatively little attention has been paid to long-term neurological recovery, patient-reported outcomes, protocol adherence, and the mechanisms through which ERAS interventions influence neurosurgical outcomes. Furthermore, existing reviews frequently treat neurosurgical ERAS as a homogeneous concept, despite substantial differences in physiological priorities, perioperative risks, and recovery objectives across neurosurgical subspecialties.

Rather than simply summarizing the literature, this narrative review proposes a conceptual framework that distinguishes two complementary but fundamentally different ERAS paradigms within neurosurgery. We suggest that spine ERAS is primarily a function-driven model, in which the principal goal is accelerated recovery and restoration of mobility, whereas cranial ERAS represents a safety-constrained model, in which recovery-enhancing interventions must be balanced against neurological monitoring requirements and procedure-specific risks. By examining ERAS through this lens, we aim to provide a more nuanced interpretation of current evidence, identify limitations of existing research, and highlight priorities for future protocol development and outcome assessment.

Accordingly, ERAS in neurosurgery should be viewed not as a uniform protocol but as a flexible, procedure-specific framework whose effectiveness depends on adapting core recovery principles to distinct neurosurgical physiological and clinical contexts.

Methods of the Search Strategy

This narrative review was conducted using a structured literature search in PubMed, Scopus, and Google Scholar to identify studies published between January 2010 and January 2025. The search strategy combined medical subject headings and free-text keywords related to enhanced recovery pathways in neurosurgical practice. Search terms included "enhanced recovery after surgery," "ERAS," "perioperative medicine," "neurosurgery," "craniotomy," "spine surgery," "pituitary surgery," "vascular neurosurgery," "paediatric neurosurgery," "craniosynostosis," "geriatric neurosurgery," "multimodal analgesia," and "tranexamic acid (TXA)." Terms were combined using Boolean operators (and/or) and adapted to the indexing structure of each database. Representative search strings included ("enhanced recovery after surgery" or "ERAS") and ("neurosurgery" or "craniotomy" or "spine surgery"), with additional procedure-specific searches performed for specialised populations and interventions.

The review sought to address three principal clinical questions: (1) the effectiveness of ERAS pathways across different neurosurgical subspecialties; (2) the extent to which ERAS protocols require adaptation according to procedure-specific physiological and safety considerations; and (3) the current evidence gaps limiting broader implementation and standardisation of neurosurgical ERAS programmes.

Eligible publications addressing ERAS concepts, protocols, implementation strategies, or outcomes in neurosurgical populations included randomised controlled trials, prospective and retrospective observational studies, systematic reviews, meta-analyses, clinical practice guidelines, and high-quality narrative reviews. Studies were limited to human subjects and to publications in English. Editorials, commentaries, conference abstracts, letters without original data, duplicate publications, and studies not directly related to neurosurgical ERAS pathways were excluded.

Titles and abstracts were independently screened by three authors, and full-text assessment of potentially eligible articles was then performed. Disagreements regarding study eligibility were resolved through discussion and consensus. Attention was paid to studies reporting clinically relevant

outcomes, including length of hospital stay, postoperative complications, opioid consumption, mobilisation, readmission rates, patient satisfaction, functional recovery, and neurological outcomes.

Because of substantial heterogeneity in study design, patient populations, protocol composition, outcome definitions, and reporting methods, quantitative pooling of data was not considered appropriate. Consequently, findings were synthesised using a narrative approach, with an emphasis on identifying recurring themes, procedure-specific adaptations, areas of consensus, and unresolved controversies.

As this work was designed as a narrative rather than a systematic review, no formal risk-of-bias assessment or evidence grading process was performed. Nevertheless, methodological quality was considered during evidence interpretation by prioritising higher-level evidence, including randomised trials, systematic reviews, meta-analyses, and clinical guidelines. The strength of conclusions was therefore based on the consistency of findings across studies, methodological rigor, and relevance to neurosurgical practice. A total of 58 studies met the eligibility criteria and were included in the final synthesis (Figure 1).

A limitation of this review is the absence of systematic application of formal quality-assessment and risk-of-bias tools, reflecting its narrative methodology. Although higher-level evidence was preferentially considered during synthesis, the conclusions remain dependent on the quality and heterogeneity of the available literature and should therefore be interpreted with appropriate caution.

Results and Evidence Synthesis

ERAS Protocols for Craniotomy: Evidence, Components, and Outcomes

The application of ERAS principles to craniotomy remains one of the most challenging areas in neurosurgical perioperative care. Unlike spinal surgery, cranial surgery poses unique constraints related to neurological protection, intracranial dynamics, haemodynamic stability, seizure risk and haemorrhagic complications. Consequently, ERAS protocols for craniotomy require substantial adaptation and cautious validation.

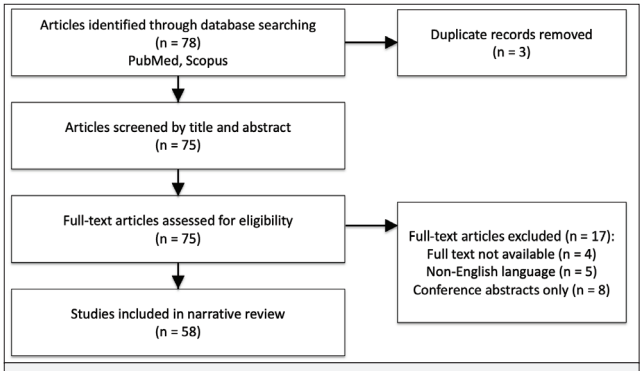

Figure 1. Study selection flow diagram.

Conceptual foundations and early frameworks

The first structured effort to adapt ERAS principles to craniotomy was undertaken by Hagan et al.,[13] who applied the grading of recommendations assessment, development and evaluation methodology to evaluate both evidence quality and recommendation strength. The proposed framework incorporated 17 perioperative components, including patient counselling, nutritional optimisation, thromboprophylaxis, analgesia, normothermia, fluid management, early mobilisation, and audit processes. Although the framework represented an important step toward standardising perioperative care in cranial neurosurgery, its evidentiary foundation was uneven. Several recommendations were supported by moderate- to high-quality evidence, whereas others were largely derived from extrapolation of data from surgical populations outside neurosurgery. This finding highlighted a fundamental challenge in the early development of ERAS protocols for craniotomy: the need to balance physiological plausibility and established perioperative principles against the relative scarcity of procedure-specific evidence.

Table 1 summarises the levels of evidence and strengths of recommendation for individual ERAS components, as proposed by Hagan et al.[13]

Importantly, this framework established the conceptual rationale for ERAS implementation in cranial surgery, but also identified critical gaps that require prospective validation before widespread adoption could be justified.

Feasibility and safety of ERAS in elective craniotomy

Subsequent investigations have shifted from conceptual development toward evaluating whether ERAS pathways can be implemented safely and effectively in clinical practice. Early evidence from Elayat et al.[14] demonstrated a lower proportion of patients requiring prolonged intensive care unit (ICU) admission (>48 h) following ERAS implementation, although no significant reduction in overall hospital LOS was observed. While interpretation is constrained by the study's non-randomised design and limited sample size, the findings provide initial evidence that ERAS principles could be incorporated into elective craniotomy pathways without compromising patient safety.

Further studies have strengthened this observation. Feng et al.[15] reported improved postoperative recovery parameters without an increase in complications among patients managed within an ERAS framework, while Kaewborisutsakul et al.[16] demonstrated that greater

Table 1. Summarized Level of Recommendation and Evidence for All ERAS Protocol Elements[13]

Intervention/ERAS item	Evidence level	GRADE recommendation
Preoperative counselling	Low	Strong
Preoperative smoking & alcohol cessation	Moderate	Strong
Preoperative enteral nutrition/immunonutrition	Moderate	Strong/weak
Preoperative fasting and carbohydrate loading	Low	Strong
Antithrombotic prophylaxis	High	Strong
Scalp shaving	Moderate	Weak against
Antibiotic prophylaxis	High	Strong
Scalp infiltrations & blocks	Moderate	Strong
Anaesthetic protocol choices	Variable	Mixed/conditional
Non-opioid analgesia	Mixed	Mixed
PONV prophylaxis	Various	Strong for certain agents
Minimally invasive craniotomies	Very low	Weak
Normothermia/hypothermia avoidance	High	Strong
Fluid balance monitoring	Low	Strong
Urinary drainage	Moderate	Strong
Postoperative artificial nutrition	Moderate	Strong
Early mobilization	High	Strong
Audit	Moderate	Strong

ERAS, enhances recovery after surgery; PONV, postoperative nausea and vomiting

compliance with ERAS components was associated with superior recovery outcomes and shorter hospitalisation. The latter finding is particularly important because it suggests that implementation fidelity may be as influential as protocol composition itself. Collectively, these studies indicate that ERAS pathways can be safely implemented across diverse elective craniotomy populations, with no consistent evidence of increased perioperative morbidity. The consistency of safety findings across different institutions and study designs represents one of the most robust observations in the existing literature.

Effects on LOS, mobilisation, and resource utilisation

Hospital LOS remains the most consistently reported outcome in studies evaluating ERAS after craniotomy. In a controlled implementation study involving glioma patients, Wang et al.[17] reported shorter LOS and earlier mobilisation among patients managed within an ERAS pathway. Because patient allocation was based on treatment period rather than randomisation, temporal and practice-related confounding cannot be excluded. Similar reductions in LOS were subsequently reported in both retrospective and randomised studies.[15,18]

Although the magnitude of LOS reduction varies across studies, the direction of effect has been remarkably consistent. This consistency suggests that accelerated recovery and earlier discharge represent genuine benefits of ERAS implementation rather than isolated institutional findings. Notably, studies reporting the most favourable outcomes generally incorporated early mobilisation, structured discharge planning, multimodal analgesia, and minimisation of unnecessary ICU utilisation, suggesting that coordinated pathway integration rather than any single intervention may drive improvements in perioperative efficiency.

In addition to reducing LOS, ERAS pathways have been associated with lower ICU utilisation and earlier mobilisation.[14-18] However, conclusions regarding economic benefit should be interpreted cautiously. While shorter hospitalisation implies potential cost savings, formal economic analyses remain limited, and cost-related outcomes have not been systematically evaluated across studies.

Pain control, opioid use, and patient-reported outcomes

Optimisation of postoperative pain control is one of the most clinically relevant components of craniotomy ERAS pathways. Evidence from randomised studies indicates that ERAS protocols can improve multiple patient-centred recovery outcomes beyond traditional surgical metrics.

In a randomised controlled trial involving 151 patients, Wang et al.[18] demonstrated reductions in pain intensity, postoperative nausea and vomiting (PONV), opioid consumption, and hospitalisation costs among patients managed within an ERAS programme. Similarly, Liu et al.[19] reported improved patient satisfaction and enhanced recovery measures without an increase in complications, while Qu et al.[20] observed lower postoperative pain scores and shorter LOS in ERAS-treated patients.

A notable finding across these studies is the consistent improvement in pain-related outcomes despite variations in protocol composition. This suggests that the benefit is unlikely to be attributable to a specific analgesic intervention. Rather, multimodal opioid-sparing strategies, including scalp nerve blocks, non-opioid analgesics, and structured PONV prophylaxis, appear to exert complementary effects that facilitate recovery. These observations support the concept that ERAS functions as an integrated care model in which cumulative gains from multiple interventions may be more important than the effect of any individual component.

The adaptability of ERAS principles is further illustrated by the work of Chen et al.,[21] who successfully applied an ERAS-oriented strategy for awake craniotomy, using monitored anaesthesia care and scalp blocks, demonstrating that protocolised recovery pathways can be incorporated even into highly specialised cranial procedures.

Protocol composition and heterogeneity

Despite broadly favourable outcomes, substantial heterogeneity exists among published craniotomy ERAS protocols. Variations in carbohydrate loading practices, fluid management strategies, thromboprophylaxis timing, analgesic approaches, mobilisation targets, and nutritional interventions complicate direct comparisons between studies and limit the ability to identify the specific components responsible for the observed benefits.

This limitation was highlighted in the systematic review by Zangi et al.,[22] which confirmed improvements in LOS and recovery-related outcomes but also emphasised considerable methodological heterogeneity, reliance on predominantly single-centre studies, and a lack of protocol standardisation. Although the overall direction of evidence favours ERAS implementation, the relative contribution of individual pathway elements remains insufficiently defined.

Nevertheless, some patterns emerge across the literature. Early mobilisation, multimodal opioid-sparing analgesia, structured PONV prophylaxis, standardised perioperative care pathways, and avoidance of unnecessary ICU admission are among the components most consistently associated with improved recovery outcomes. In contrast, evidence supporting the independent contribution of interventions such as preoperative carbohydrate loading, specific fluid management strategies, thromboprophylaxis timing, and nutritional optimisation remains limited and is frequently extrapolated from broader surgical populations. As a result, current evidence is stronger for the ERAS pathway as a comprehensive perioperative strategy than for many of its individual components.

Summary of evidence and evidence mapping

Current data consistently support the feasibility and safety of ERAS pathways in elective craniotomy and suggest meaningful improvements in short-term recovery outcomes, particularly with respect to mobilisation, pain control, ICU utilisation, and hospital LOS.

Several conclusions can therefore be considered relatively well established. ERAS protocols can be implemented safely without increasing perioperative complications, and can facilitate earlier mobilisation, improve patient-reported recovery metrics, reduce opioid requirements, and shorten hospitalisation in selected elective craniotomy populations. These findings have been reproduced across observational studies, randomised trials, and systematic reviews.[14-22]

However, important uncertainties remain. It remains unclear which individual ERAS components contribute most to the observed benefits, whether outcomes are driven primarily by specific interventions or overall protocol adherence, and how findings can be generalised across different neurosurgical populations and healthcare systems. Furthermore, most available studies focus on short-term perioperative outcomes, leaving the effects on long-term neurological recovery, quality of life, functional independence, and cost-effectiveness insufficiently defined.

Future research should therefore prioritise multicentre validation studies, greater protocol standardisation, and evaluation of patient-centred long-term outcomes. Such work will be essential to determine not only whether ERAS improves recovery after craniotomy, but also which components provide the greatest value and should be prioritised in routine clinical practice. Table 2 summarises the study characteristics and ERAS components.

ERAS Protocols in Specific Neurosurgical Situations

Neurosurgery encompasses heterogeneous patient populations and procedures that differ substantially from the surgical settings in which ERAS protocols were originally developed. Consequently, successful implementation often requires adaptation of core ERAS principles rather than strict adherence to a uniform protocol. Across paediatric, geriatric, pituitary, and vascular neurosurgery, the literature suggests that, while the overarching goals of reducing physiological stress and facilitating recovery remain consistent, the interventions and outcome priorities differ based on patient characteristics and procedural risks.[23]

Table 2. Individual Studies on ERAS Protocol for Craniotomy

Study	Country	Design	n	Comparator	Key ERAS components (structured)	Key findings	Major limitations
Hagan et al.,[13]	USA	Narrative proposal	N/A	None	Preop counselling; carb loading; multimodal analgesia; thromboprophylaxis; normothermia; early mobilization	Proposed 17-component neurosurgical ERAS framework	Conceptual; no clinical data
Liu et al.,[19]	China	RCT	140 (70/70)	Conventional care	Preop education; carb loading; absorbable sutures; multimodal analgesia; PONV prophylaxis; early mobilization	Improved patient satisfaction; shorter LOS; no ↑ complications	Single centre; unblinded
Qu et al.,[20]	China	RCT	129 (64/65)	Conventional care	Multimodal analgesia; scalp block; PONV prophylaxis; early mobilization; early feeding	Reduced pain scores; shorter LOS	Single centre; discharge bias possible
Elayat et al.,[14]	India	Non-randomized controlled trial	70	Conventional care	Family education; carb loading; scalp block; limited opioids; GDFT; early catheter removal; thromboprophylaxis	Reduced ICU stay; no significant LOS difference	Non-randomized; confounding risk
Feng et al.,[15]	China	Retrospective cohort	100 (50/50)	Conventional care	Education; carb loading; scalp block; PONV prevention; early mobilization; early catheter removal	Improved recovery indicators; no ↑ complications	Retrospective; moderate sample
Wang et al.,[17]	China	Controlled implementation study	151 (80/71)	Time-separated conventional cohort	Preop optimization; carb loading; GDFT; scalp block; early drain removal; early feeding; thromboprophylaxis	Reduced LOS; earlier mobilization & oral intake; no ↑ complications	Not fully randomized; glioma-specific
Wang et al.,[18]	China	RCT	151 (76/75)	Conventional care	Education; carb loading; GDFT; multimodal analgesia; PONV prophylaxis; early mobilization; thromboprophylaxis	Reduced LOS, pain, PONV, and hospitalization cost	Single centre; no long-term outcomes
Chen et al.,[21]	China	Prospective single-arm feasibility	20	None	Monitored anaesthesia care; scalp nerve block; opioid minimization; early recovery focus	Demonstrated feasibility of ERANS in awake craniotomy	No comparator; small sample
Kaewborisutsakul et al.,[16]	Thailand	Retrospective adherence study	100	High vs low adherence	Education; carb loading; multimodal analgesia; minimal shaving; early feeding; thromboprophylaxis	Higher adherence associated with improved LOS and recovery	Observational; confounding risk
Zangi et al.,[22]	Iran	Systematic review	10 studies	N/A	Synthesized multimodal ERAS elements across trials	Reported reduced LOS; highlighted protocol heterogeneity	Predominantly single-centre data; heterogeneous designs

LOS, length of stay; ERANS, enhanced recovery after neurosurgery; PONV, postoperative nausea and vomiting; ERAS, enhanced recovery after surgery; GDFT, goal-directed fluid therapy; RCT, randomized controlled trial; ICU, intensive care unit; USA, United States of America; N/A, not applicable

These specialised applications highlight both the flexibility of ERAS principles and the need for procedure-specific strategies.

Paediatric neurosurgery

Paediatric neurosurgery presents unique challenges for ERAS implementation due to age-dependent physiology, limited physiological reserve, developmental considerations, and the central role of caregivers in perioperative care. Consequently, paediatric ERAS pathways prioritise physiological stability and family-centred care rather than accelerated discharge.[24]

The most structured experience pertains to craniosynostosis surgery. A protocol incorporating standardised haemodynamic management, normothermia maintenance, multimodal analgesia, and blood-conservation strategies was associated with reduced opioid consumption, shorter hospitalisation, and fewer postoperative complications, although statistical significance was limited by sample size.[25]

Available evidence suggests that temperature regulation, blood loss prevention, caregiver involvement, and structured pain assessment are among the most relevant ERAS components in this population. In contrast, traditional adult ERAS targets such as rapid discharge appear to be less important. However, evidence remains limited, and the relative contribution of individual interventions is uncertain.[24,25]

Geriatric neurosurgery

The growing number of elderly patients undergoing neurosurgical procedures has increased interest in ERAS strategies tailored to frailty, multimorbidity, and reduced physiological reserve.[26] Given the strong influence of baseline functional status on recovery, current recommendations emphasise assessment of frailty, cognitive function, nutritional status, and social support.[26] Several ERAS elements may require modification in this population; for example, carbohydrate loading may be limited by impaired glucose tolerance, while pharmacological thromboprophylaxis must be balanced against haemorrhagic risk.[26] Observational studies suggest that protocols incorporating frailty assessment, minimisation of invasive devices, multimodal analgesia, delirium prevention, and early mobilisation may improve functional recovery and reduce LOS without increasing complications.[27] Nevertheless, evidence remains largely observational, and uncertainty persists regarding which interventions contribute most substantially to improved outcomes.

Pituitary surgery

Pituitary surgery represents one of the clearest examples of procedure-specific ERAS adaptation. In contrast to conventional ERAS pathways, recovery priorities are centred on endocrine stability, fluid-electrolyte balance, and neurological safety rather than on gastrointestinal recovery alone.[28]

Across published studies, several components appear to be consistently important, including preoperative endocrine optimisation, minimally invasive endoscopic approaches, goal-directed fluid therapy, avoidance of routine nasal packing and of lumbar drains, structured patient education, and intensive postoperative endocrine monitoring.[28-30] These interventions address the unique physiological challenges of pituitary surgery and distinguish pituitary ERAS pathways from broader cranial ERAS models.

Barrette et al.[29] identified 19 recommendations for transsphenoidal surgery; more than one-third were supported by low-quality evidence, highlighting the need for further research. Similarly, studies by Pan et al.,[30] Liu et al.,[31] and Hughes et al.[32] demonstrated shorter hospitalisation, improved recovery, high patient satisfaction, and the feasibility of ambulatory management in selected patients. Although protocol composition varied, the consistency of findings suggests that multidisciplinary care, endocrine surveillance, and patient education are among the most impactful ERAS elements in this setting.

Intracranial aneurysm surgery

ERAS pathways for unruptured intracranial aneurysm surgery require substantial modification because neurological protection takes precedence over accelerated recovery.[12] Key adaptations include optimisation of blood pressure, careful antiplatelet management, selective use of carbohydrate loading and thromboprophylaxis, intraoperative neurophysiological monitoring, and strict postoperative haemodynamic and neurological surveillance.[12] These measures reflect the need to balance ERAS principles with procedure-specific safety considerations.

Evidence remains more limited than that for elective craniotomy or pituitary surgery. National-level data suggest that ERAS principles can be incorporated safely without increasing neurological complications,[12] while the randomised study by Pandit et al. demonstrated shorter ICU stay, lower intraoperative fentanyl requirements, and higher patient satisfaction despite no significant reduction in overall LOS.[33] These findings suggest that outcomes such as ICU utilisation and patient experience may be more sensitive measures of ERAS success in neurovascular surgery than hospital LOS alone.

Summary of evidence and evidence mapping

Across specialised neurosurgical populations, ERAS implementation appears feasible and safe when protocols are adapted to procedure-specific physiological priorities. However, the literature consistently demonstrates that a

uniform approach is unlikely to be appropriate. Instead, successful implementation depends on targeting the dominant determinants of recovery within each population, including physiological stability in paediatric patients, prevention of frailty and delirium in geriatric patients, endocrine homeostasis in pituitary surgery, and neurological protection in aneurysm surgery.

Several conclusions are reasonably well established. Tailored ERAS pathways improve perioperative efficiency and recovery without increasing complications. Multidisciplinary care, patient education, early mobilisation when appropriate, and protocol adherence emerge as recurring determinants of success across populations.[23-33]

Nevertheless, important uncertainties remain. Evidence is predominantly derived from single-centre studies; protocol heterogeneity is substantial; comparative data identifying the most influential ERAS components are limited. Furthermore, long-term neurological, functional, and quality-of-life outcomes remain insufficiently studied, highlighting priorities for future research.

ERAS in Spine Surgery: Elements, Evidence, and Outcomes

ERAS protocols were adopted earlier in spine surgery than in cranial neurosurgery, and consequently have accumulated a larger evidence base. Spine surgery, therefore, represents the most mature neurosurgical application of ERAS as a perioperative care model integrating optimisation, standardisation, and multidisciplinary coordination to enhance recovery. Nevertheless, substantial heterogeneity in protocol composition, surgical case-mix, adherence reporting, and outcome definitions limits direct comparison across studies and complicates identification of the most influential ERAS components.[34,35]

A useful framework is to consider spine ERAS across the preoperative, intraoperative, and postoperative phases, while recognising that observed benefits likely arise from coordinated pathway implementation rather than from any single intervention.[34,35] The ERAS Society consensus for lumbar spinal fusion provides the most comprehensive evidence-based framework currently available.[36]

Preoperative spine ERAS: risk modification and expectation management

Preoperative ERAS strategies focus on reducing modifiable risk factors and improving patient engagement. Core elements include patient education, optimisation of comorbidities, nutritional assessment, anaemia correction, and smoking and alcohol cessation.[36,37] Although high-quality studies evaluating individual components are limited, these interventions are consistently incorporated into successful ERAS pathways and considered important enablers of postoperative mobilisation and recovery.[36,37]

Intraoperative spine ERAS: homeostasis, blood conservation, and minimising "recovery barriers"

Intraoperative ERAS strategies aim to preserve physiological homeostasis, minimise surgical stress, and remove barriers to recovery. Common components include normothermia, goal-directed fluid therapy, appropriate antimicrobial prophylaxis, minimisation of drains and urinary catheters, and, when appropriate, minimally invasive surgical techniques.[36,37] Among these interventions, blood conservation strategies and the avoidance of unnecessary postoperative devices appear to be most consistently associated with improved recovery and earlier mobilisation.

Postoperative spine ERAS: mobilisation, catheter/drain avoidance, and rehabilitation

Postoperative ERAS pathways prioritise early mobilisation, early oral intake, multimodal analgesia, PONV prevention, and prompt removal of drains and urinary catheters.[37] These interventions act synergistically to facilitate functional recovery and discharge readiness.

Across observational studies, the most consistent findings are reductions in hospital LOS and opioid consumption.[38-40] Similar benefits have been observed in elderly and complex-fusion populations, suggesting that the effectiveness of ERAS extends beyond low-risk procedures.[39] However, the magnitude of LOS reduction varies according to baseline institutional practices and discharge pathways.[40]

The impact on postoperative complications is less consistent. While some studies report lower complication rates, others demonstrate comparable outcomes between ERAS and conventional care.[38,40] Importantly, available evidence consistently indicates that ERAS does not increase adverse events.[38-40] In contrast, readmission rates and pain scores often remain unchanged despite reductions in opioid consumption and LOS, suggesting that ERAS primarily improves perioperative efficiency and functional recovery rather than all postoperative outcomes.[40]

Overall, current evidence suggests that early mobilisation, multimodal analgesia, minimisation of catheters and drains, and pathway adherence are among the ERAS components most consistently associated with improved outcomes in spine surgery (Table 3).

TXA as a spine ERAS blood conservation strategy

Blood conservation is one of the most extensively studied intraoperative ERAS domains in spine surgery, with TXA being one of the interventions most strongly supported by evidence.

Efficacy of TXA

Multiple meta-analyses consistently demonstrate that intravenous TXA reduces intraoperative blood loss and transfusion requirements across complex spine procedures.[41-45] The consistency of findings across randomised and pooled analyses suggests that TXA is one of the few individual ERAS interventions with reproducible and clinically meaningful benefits.

Dosing Uncertainty of TXA

Despite consistent efficacy, optimal dosing remains uncertain. Although higher-dose regimens may provide greater blood-loss reduction, substantial heterogeneity in surgical procedures, bleeding risk, and co-interventions limits definitive recommendations regarding the ideal dosing strategy.[46-48]

TXA Safety

The principal concern surrounding TXA remains thromboembolic safety. Current evidence generally demonstrates no significant increase in thromboembolic events, although many studies may be underpowered to detect rare complications.[49] Consequently, while TXA appears safe in most patients and is increasingly incorporated into ERAS pathways, a risk-stratified approach remains appropriate, particularly in patients with elevated thromboembolic risk.[49]

Analgesia as the functional "engine" of spine ERAS

Multimodal analgesia is arguably the most important postoperative component of spine ERAS because effective pain control directly influences mobilisation, rehabilitation, and discharge readiness.[50,51] Evidence consistently supports opioid-sparing multimodal strategies, with network meta-analysis demonstrating superior reductions in opioid consumption and pain scores when multiple analgesic classes are combined.[52] These findings reinforce a central ERAS principle: recovery benefits arise from synergistic multimodal approaches rather than reliance on any single drug. Intravenous lidocaine may reduce opioid requirements and improve longer-term recovery outcomes, although concerns regarding toxicity and limited monitoring data have restricted widespread adoption.[53,54] Meta-analytic evidence supports ketamine as an effective opioid-sparing adjunct in adult spine surgery, although benefits appear to be influenced by timing of administration and the patient population.[55,56] Both agents have mechanistic and clinical rationales as components of multimodal analgesia, but spine-specific ERAS evidence remains less robust than that for ketamine or TXA.[57,58]

Collectively, the available evidence indicates that multimodal analgesia is a major driver of ERAS success in spine surgery. However, uncertainty remains regarding the optimal combination of agents and dosing strategies, as well as their relative contribution to recovery outcomes.

Summary of evidence and evidence mapping

Current evidence supports the implementation of ERAS in spine surgery as safe and effective, particularly in reducing LOS, opioid consumption, and resource utilisation. Among individual interventions, multimodal analgesia, early mobilisation, avoidance of unnecessary drains and catheters, and TXA-supported blood conservation appear to have the strongest evidence base.[34-58]

However, important uncertainties remain. Protocol heterogeneity, variable reporting of adherence, and differences in outcome definitions limit the identification of the relative contributions of individual ERAS components. Furthermore, while short-term recovery benefits are well established, evidence regarding long-term functional outcomes, quality of life, and cost-effectiveness remains comparatively limited. Future studies should focus on standardising protocols and determining which ERAS interventions provide the greatest incremental benefit across different spine surgery populations.

Discussion

This narrative synthesis demonstrates that ERAS pathways in neurosurgery are feasible, safe, and associated with consistent improvements in perioperative efficiency. The most frequently reported benefits include reduced hospital LOS, decreased opioid consumption, and improved coordination of perioperative care.[1-7,16,18,34,35,37,40] However, LOS should not be interpreted as a direct measure of recovery, because it is influenced by organisational, social, and health-care system factors. More clinically meaningful outcomes include functional recovery, neurological preservation, avoidance of complications, quality of recovery, and patient satisfaction, although these remain less consistently reported across studies. These benefits are most evident in spine surgery, where ERAS implementation is more mature, but are increasingly observed in elective cranial procedures and in selected high-risk populations when neurosurgery-specific adaptations are applied.[13-22,24-32]

ERAS as a Care-Delivery Model

A key insight emerging from this review is that ERAS benefits arise primarily from changes in care delivery rather than from isolated interventions. Multimodal analgesia, standardised perioperative workflows, early mobilisation, and avoidance of unnecessary invasive devices act synergistically to reduce variability and facilitate recovery.[16,34,36,37] Evidence that improved outcomes are associated with higher ERAS adherence further supports interpreting ERAS as an

integrated care model in which implementation quality is as important as protocol content.[16,28,40]

This framework is particularly relevant in neurosurgery, where uncoordinated application of individual interventions may carry risk. ERAS pathways mitigate these risks by embedding individual interventions within coordinated multidisciplinary perioperative planning that balances recovery objectives with neurological safety.[13,36] Importantly, the value of ERAS should be assessed not only by efficiency metrics but also by its ability to preserve neurological function, enhance patient experience, and support high-quality recovery.

LOS

The reduction in LOS should be interpreted with caution. Discharge criteria vary substantially across institutions, and LOS is influenced by non-medical factors such as social support, rehabilitation availability, and healthcare infrastructure. The inability to blind care providers and discharge planners may further amplify apparent LOS benefits. These limitations suggest that LOS should be interpreted primarily as a process outcome reflecting care coordination and system efficiency, rather than a direct surrogate for improved neurological recovery or long-term functional outcomes. Future studies should therefore place greater emphasis on patient-centred endpoints, including functional status, quality of recovery, neurocognitive outcomes, and patient-reported measures.

Cranial versus Spine ERAS

Fundamental differences between cranial and spinal surgery preclude a uniform ERAS standardisation. Spine ERAS pathways are largely function-driven, with outcomes closely linked to pain control, early mobilisation, blood conservation, and rehabilitation engagement.[34-40] In this context, opioid-sparing multimodal analgesia and blood loss mitigation strategies, particularly TXA, play a central role in accelerating recovery.[43,45-47,52]

Collectively, the spine surgery literature suggests that ERAS should be understood not as a set of isolated interventions but as an integrated perioperative care model. Improved outcomes appear to result from coordinated, standardised practices and high levels of adherence, rather than from any single component. Broader neurosurgical experience further indicates a dose-response relationship between pathway adherence and clinical outcomes, underscoring that the quality of implementation is at least as important as the specific elements included. Accordingly, institutions seeking to maximise the benefits of ERAS in spine surgery should emphasise multidisciplinary collaboration, structured education, and continuous audit and feedback alongside the adoption of evidence-based clinical practices. While LOS reductions are frequently reported, improvements in mobilisation, functional recovery, and patient experience may provide a more meaningful assessment of pathway effectiveness.

In contrast, ERAS in craniotomy is constrained by safety considerations. Neurological monitoring, intracranial dynamics, haemodynamic precision, seizure prevention, and haemorrhagic risk constrain the applicability of traditional ERAS elements.[13-16,18-22] LOS reductions observed in cranial ERAS should therefore be interpreted as markers of improved care coordination rather than direct surrogates of neurological recovery.[15-18,22] Greater attention to neurological outcomes, quality of recovery, and patient-reported measures is needed to determine the true clinical impact of cranial ERAS pathways.

ERAS in Special Neurosurgical Populations

Paediatric, geriatric, pituitary, and vascular neurosurgery further illustrate the need for adaptive ERAS implementation. In paediatric populations, caregiver engagement, thermal stability, blood-loss prevention take precedence over early discharge.[8,24,25] In geriatric patients, frailty assessment, delirium prevention, and individualised metabolic and anticoagulation strategies are central determinants of recovery.[11,26,27] Pituitary surgery ERAS prioritises endocrine and fluid balance,[28] while aneurysm surgery mandates meticulous haemodynamic and neurological surveillance.[12]

Across these settings, meaningful ERAS outcomes extend beyond LOS to include physiological stability, preserved function, neurological outcomes, avoidance of complications, quality of recovery, and patient or caregiver satisfaction.[12-33]

Interpreting Apparent Contradictions

Several findings in the current literature appear contradictory but can be explained by differences in outcome selection and protocol implementation. Whilst LOS is consistently reduced, readmission rates and pain scores are often unchanged.[34,40] This suggests that ERAS primarily optimises in-hospital recovery processes rather than post-discharge trajectories. Although multimodal analgesia reliably reduces opioid consumption, improvements in pain scores are variable.[38,50,52] The literature on TXA highlights a tension between strong evidence of efficacy in reducing blood loss and ongoing debate about thromboembolic safety in high-risk populations.[43,45-49] These observations highlight the importance of evaluating ERAS through a broader range of patient-centred outcomes rather than relying predominantly on LOS-based measures.

Implications for Practice and Research

From a clinical perspective, these findings support broader ERAS adoption in neurosurgery, provided that implementation is deliberate, multidisciplinary, and adaptable.[36,40] Future research should prioritise multicentre

trials, standardised reporting of ERAS components and adherence to them, and greater emphasis on patient-reported outcomes, quality of recovery, functional status, and long-term neurological outcomes.[16,22,40] Such measures are likely to provide a more comprehensive assessment of the true value of ERAS pathways than hospital LOS alone. Figures 2 and 3 summarises key ERAS protocol elements for neurosurgery and spine surgery.

Clinical Implications and Practical Recommendations

Current evidence suggests that ERAS implementation in neurosurgery should focus on a limited number of high-impact interventions rather than uniformly adopting all traditional ERAS elements. Across both cranial and spinal procedures, the components most consistently associated with improved outcomes include preoperative patient education, multimodal opioid-sparing analgesia, prevention of PONV, maintenance of normothermia, goal-directed fluid management, early nutrition, early mobilization, and multidisciplinary coordination. The benefits of ERAS appear to result primarily from the coordinated application of these measures within a standardized pathway rather than from any single intervention.

In spine surgery, ERAS primarily aims to accelerate recovery and restore functional independence. The most influential components include multimodal analgesia, perioperative blood conservation strategies such as TXA administration, avoidance of unnecessary drains and urinary catheters, and structured early mobilization. These measures facilitate earlier ambulation, reduce opioid-

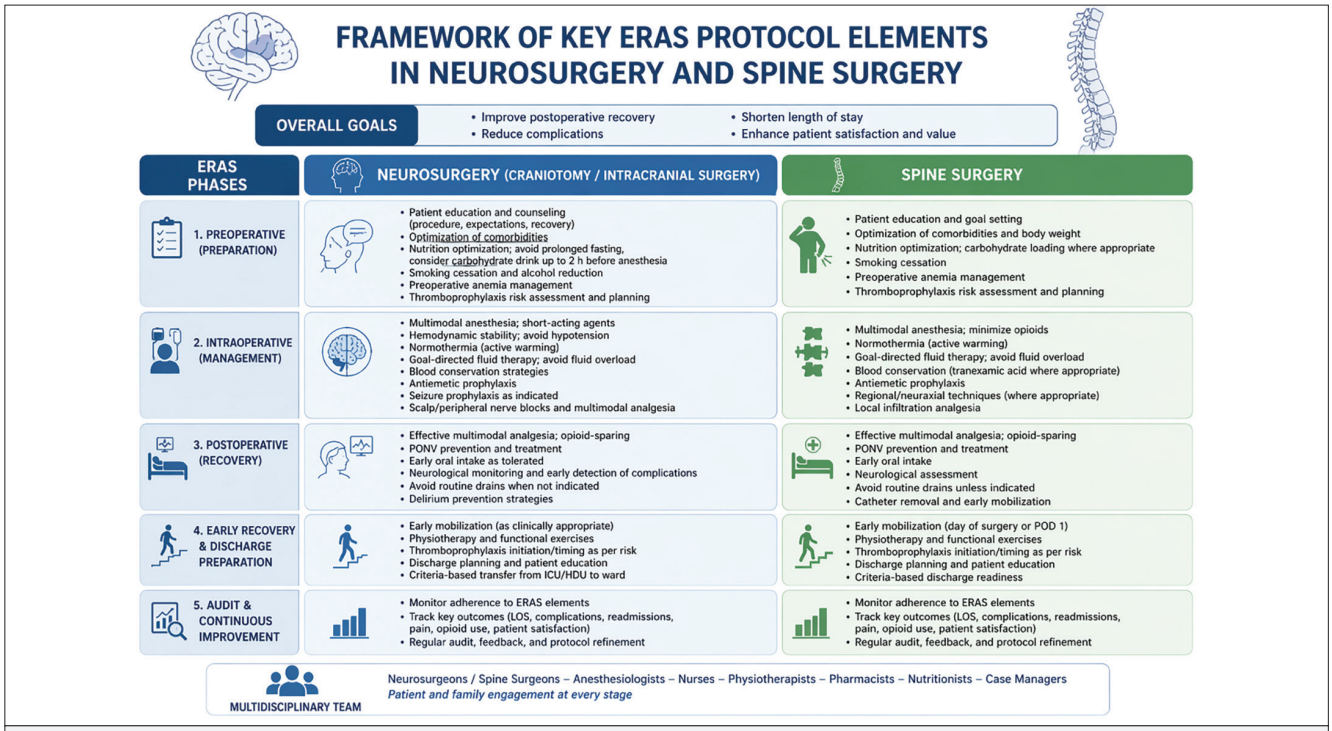

Figure 2. The framework summarizing all specific ERAS protocol elements in neurosurgery and spine surgery.

ERAS, enhanced recovery after surgery; ICU, intensive care unit; LOS, length of stay.

Table 3. Specific ERAS Element for Spine Surgical Procedures

Preoperative	Intraoperative	Postoperative
Education	Minimally invasive spine surgery	Early mobilization
Smoking cessation	Multimodal analgesia	Early oral intake
Anaemia correction	Minimize bleeding (blood pressure control, TXA)	
Preoperative chronic medication and diseases optimization	Hypothermia, PONV, infection prophylaxis	
Nutritional supplementation	Minimize use of drains, urinary catheter	

ERAS, enhanced recovery after surgery; PONV, postoperative nausea and vomiting; TXA, tranexamic acid

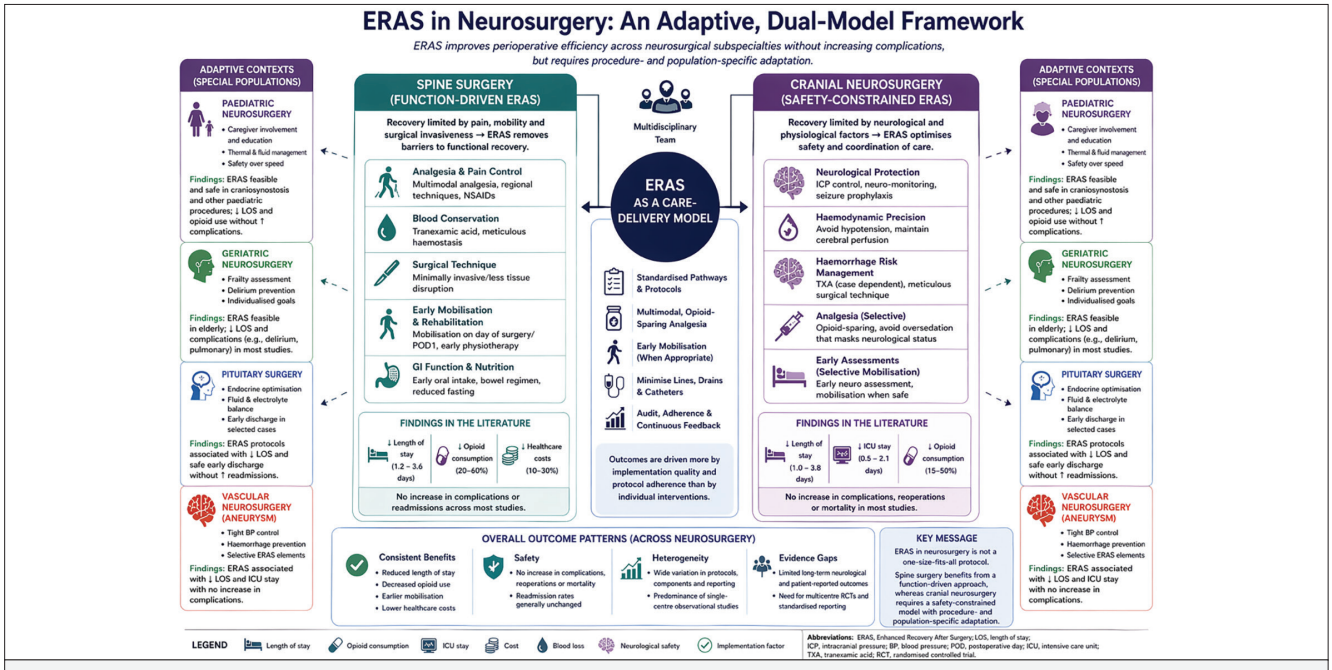

Figure 3. Adaptive ERAS framework in neurosurgery: function-driven and safety-constrained pathways.

ERAS, enhanced recovery after surgery; ICU, intensive care unit; LOS, length of stay.

related adverse effects, shorten the hospital stay, and promote a faster return to daily activities.

In cranial neurosurgery, ERAS pathways must balance recovery enhancement with neurological safety. Key interventions include meticulous haemodynamic management, structured neurological monitoring, opioid-sparing analgesia, prevention of PONV, and mobilization after neurological stability has been established. Accordingly, success should be evaluated not only by LOS but also by preservation of neurological function, functional independence, cognitive recovery, and quality of life.

Special populations require procedure-specific adaptations. In paediatric neurosurgery, caregiver involvement, temperature management, and blood conservation are particularly important. In geriatric patients, frailty assessment, nutritional optimization, delirium prevention, and early mobilization are likely to have the greatest impact on recovery. Pituitary surgery requires careful endocrine and fluid-electrolyte management, whereas aneurysm surgery depends heavily on strict haemodynamic control and neurological surveillance.

For institutions implementing neurosurgical ERAS programs, priority should be given to patient education, multimodal analgesia, maintenance of physiological homeostasis, early mobilization, minimization of unnecessary invasive devices, and continuous multidisciplinary audit. Successful implementation requires close collaboration among surgeons, anaesthesiologists, nurses, physiotherapists, nutrition specialists, and rehabilitation teams. Institutions should adopt standardized perioperative pathways, monitor protocol adherence through regular audit and feedback, and adapt protocols according to procedure-specific requirements and local resources.

Importantly, outcome assessment should extend beyond hospital LOS and include measures of functional recovery, neurological outcomes, patient-reported outcomes, complication rates, and quality of life. These metrics more accurately reflect the true clinical value of ERAS and its potential to improve long-term recovery and patient-centred outcomes in neurosurgical practice.

Conclusion

Current evidence supports ERAS as a safe and effective perioperative care framework for selected neurosurgical populations when implemented with procedure-specific adaptations. Across neurosurgical subspecialties, these pathways enhance recovery efficiency and reduce opioid exposure without compromising neurological safety.

However, ERAS should not be applied as a uniform protocol across all neurosurgical procedures. Rather, it should be understood as a flexible care model that upholds core recovery principles while adapting to procedure-specific physiological demands and safety considerations, particularly for cranial surgery and vulnerable patients.

Future progress will depend on robust, multicentre evaluation; standardised reporting of ERAS components and of adherence; and a stronger focus on long-term neurological and patient-reported outcomes. Ultimately, the success of ERAS in neurosurgery will rely on thoughtful, adaptive implementation in which the quality and consistency in application take precedence over rigid standardisation across diverse clinical settings.

Footnotes

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Burnout in Anaesthesiology: A Nationwide Cross-sectional Study of Anaesthesiologists and Residents in Türkiye

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Abstract

Objective: To determine the prevalence of burnout and to identify factors associated with it among anaesthesiology attendings and residents in Türkiye.

Methods: We conducted a nationwide cross-sectional survey of anaesthesiology departments in Türkiye between September and December 2024. Burnout was assessed using the Maslach Burnout Inventory-Human Services Survey (Turkish version). Burnout syndrome was defined as high emotional exhaustion and depersonalization combined with low personal accomplishment; high-risk status was defined as high emotional exhaustion or depersonalization, regardless of personal accomplishment. Sociodemographic, occupational, and workplace factors were collected, and associations were analysed using univariable and multivariable logistic regression.

Results: Among the 921 respondents (53% residents, 46% attendings; median age 33 years, interquartile range: 29-43; 53% female), 71.6% were at high-risk for burnout, and 36.7% met the criteria for burnout syndrome. Residents comprised a significantly greater proportion of physicians with burnout syndrome (68% vs. 45%; $P < 0.001$) and of those at high-risk for burnout (61% vs. 34%; $P < 0.001$). In the final multivariable model, younger age, female gender, low workplace satisfaction, perceived understaffing, and inadequate personal support were significantly associated with burnout syndrome. The combination of being female and being a resident is associated with higher odds of burnout (interaction $P=0.034$).

Conclusion: The prevalence of burnout among the Turkish anaesthesiology workforce is extremely high and is especially pronounced among female residents and among those who are younger, work in understaffed settings, or experience job dissatisfaction. Targeted, system-level reforms that ensure fair pay, improved staffing, and supportive leadership, coupled with nationwide longitudinal monitoring, are needed to protect clinician well-being and patient safety.

Keywords: Anaesthesiology, burnout, Maslach Burnout Inventory, Türkiye, wellbeing, workforce

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Main Points

- In a national survey of 921 anaesthesiology attendings and residents in Türkiye, 71.6% were at high-risk for burnout and 36.7% met the criteria for burnout syndrome.
- Burnout was higher in residents than in attending physicians and decreased with age (6% lower odds per year).
- Female residents were at higher risk.
- Low workplace satisfaction, inadequate staffing, and inadequate support were associated with burnout and intent to resign.

Introduction

Burnout syndrome, first described by Freudenberger, arises from unmanaged chronic stress.[1] It is commonly described in the Maslach framework as emotional exhaustion, depersonalization/cynicism, and reduced professional efficacy.[2] The World Health Organization describes burnout as an occupational phenomenon resulting from chronic workplace stress that has not been successfully managed, characterized by exhaustion, increased mental distance or negativism toward one's job, and reduced professional efficacy.[3]

Burnout rates vary across medical specialties, with anaesthesiology experiencing particularly high levels due to the specialty's demanding nature. Given these serious patient safety implications, anaesthesiologists are particularly vulnerable due to their critical role in leading clinical teams under high-pressure conditions. Inadequate staffing further intensifies individual workload and workplace stress.[4] Unpredictable operating room (OR) schedules, prolonged work hours, and limited time outside the OR restrict opportunities for peer interaction and non-work-related social engagement. Additionally, working in small, shared spaces with few anaesthesiology colleagues and rotating through rapidly changing multidisciplinary teams, which are occasionally marked by conflict, can exacerbate isolation, erode social networks, and leave providers feeling disconnected and undervalued.

Ineffective management of work stress adversely affects physical and emotional health. Physicians report higher burnout rates than the general workforce, reflecting role-specific demands.[5] The American Society of Anesthesiologists warns that clinician burnout compromises patient safety by increasing medical errors, lowering patient satisfaction, and increasing healthcare costs[6,7]-and estimates that burnout-driven errors contribute to 210,000-400,000 preventable deaths annually.[8,9] Addressing burnout is therefore both a patient-safety imperative and a workforce-sustainability priority.

The prevalence of burnout varies across cultures and countries, but rates in anaesthesiology have been consistently high worldwide. In the United States, Afonso et al.[10] reported that in March 2020, 59.2% of anaesthesiologists were at high-risk for burnout and 13.8% met clinical criteria, increasing to 67% and 18.9% in November 2022.[11] High rates have been observed internationally.[12-17] Although Turkish data are sparse, existing studies show substantial burnout symptoms,[18] including pre-pandemic studies in İstanbul[19] and Central Anatolia,[20] supporting the need for a comprehensive national evaluation.

This study aims to determine burnout levels among anaesthesiology residents and attendings in Türkiye and identify factors associated with burnout. In Türkiye, residents (trainees) are physicians in specialty training, whereas attendings are fully trained specialist anaesthesiologists (consultant-level).

Methods

Ethical approval for this study was granted by the University of Health Sciences Türkiye, Bakırköy Dr. Sadi Konuk Training and Research Hospital, Non-Interventional Scientific Research Ethics Committee (approval no: 2024-08-13, date: 19.08.2024). Participation was voluntary and anonymous, and informed consent was implied through the completion of the survey. No identifying personal information was collected. This manuscript adheres to the STROBE guidelines.[21]

Design

This cross-sectional, correlational study collected data at a single point in time to examine the relationships between various variables and burnout.

Participants

The target population for this study consisted of attending anaesthesiologists and residents in Türkiye. Participant recruitment took place between September 30 and December 17, 2024. Survey invitations were distributed via the official email list of the Turkish Anaesthesiology and Reanimation Association. To further improve accessibility and participation, the survey was also directly shared with anaesthesiology departments throughout the country.

Survey Questionnaire

The survey instrument was structured into two primary sections. The first section collected sociodemographic, occupational, and personal information, including age, gender, marital status, number of children, professional rank

(resident or attending), type of hospital (university, training, or other), years in practice, weekly work hours, number of night shifts per month, and whether the participant was working in a mandatory service region. The first section also incorporated an optional component assessing job satisfaction, perceived adequacy of workplace and personal support, staffing levels, and intent to resign.

The second section used the 22-item Maslach Burnout Inventory-Human Services Survey (MBI-HSS) Turkish form, a validated tool for assessing burnout .[2,22] While the original MBI utilizes a 7-point Likert scale ("never" to "every day"), the Turkish version adopted a 5-point Likert scale ("never" to "all the time") based on its linguistic and cultural fit, as the original anchors were deemed less intuitive for Turkish respondents.[22]

The MBI evaluates burnout dimensions on a continuum and does not provide universally accepted diagnostic cut-off values. To allow comparison with large prior studies of physician burnout[23] and with prior anaesthesiology burnout literature using MBI-based categorical definitions[10,11] we applied a previously published classification framework to define high-risk for burnout and burnout syndrome. Because the published thresholds were derived from the original 7-point scoring format (0-6) and the Turkish MBI in our study used a 5-point format (0-4), we proportionally rescaled the cut-off values before classification (original cut-off x4/6). Burnout syndrome was defined as high emotional exhaustion (scores of 18-36 in the MBI-HSS emotional exhaustion component), high depersonalization (scores of 7-20 in the MBI-HSS depersonalization component), and low personal accomplishment (scores of 0-22 in the MBI-HSS personal accomplishment component). A high-risk of burnout was defined as high emotional exhaustion or high depersonalization, regardless of the level of personal accomplishment. The detailed numeric definitions of burnout and high-risk for burnout syndrome are noted in Supplementary Metarial 1. Completion of the MBI was a requirement for inclusion in the final dataset.

Preliminary findings from this study were presented at a workshop titled "how to write a manuscript" during the Turkish Anaesthesiology and Reanimation Association annual meeting in december 2024. Workshop participants contributed to the development of a preliminary manuscript and are acknowledged as members of the burnout workgroup in Supplementary Metarial 2.

Statistical Analysis

Descriptive statistics are reported as frequencies (%) for categorical variables, and as means and standard deviations or medians and interquartile ranges (IQRs) for continuous variables, according to their distribution. Age was analysed as a continuous variable; all other questionnaire variables were considered categorical. Variables with sparse categories were collapsed or dichotomized a priori (e.g., work hours and number of night shifts per month). Specifically, working hours per week was dichotomized at 50-hour cut-off based on previous reports indicating an average of 49 to 51 working hours per week for anaesthesiologists in Türkiye.[20,24] Additional variables (years in the same hospital, years in practice, job satisfaction, and number of children) were grouped into three categories. Univariable associations between each factor and burnout outcomes were assessed using the Wilcoxon rank-sum test for continuous variables and the chi-square test or Fisher's exact test for categorical variables. The variables that were significantly associated with burnout outcomes in the univariable analysis were included in separate multivariable analyses to determine factors associated with burnout and a high-risk of burnout.[25] The final multivariable model was fitted following stepwise and purposeful variable selection methods[25] using $P < 0.1$ to obtain the adjusted odds ratios and 95% confidence intervals (CIs) for the associations between each of the factors with burnout syndrome and being at high-risk for burnout as outcomes. The $P < 0.1$ threshold was recommended as a liberal criterion to retain a covariate in purposeful variable selection, as this criterion ensures potentially relevant covariates were not dropped too early in the iterative variable selection process.[25] As an exploratory analysis, we assessed two-way interactions among predictors—gender, working hours, residency type, and number of children—in relation to the outcome of burnout syndrome, using separate logistic regression models that included interaction terms. If the interaction terms were significant under a liberal criterion with $P < 0.1$, [25,26] the ORs and 95% CIs were calculated for different levels of the interacting variables in relation to the outcome. All analyses were conducted using R statistical software (version 4.1.1, Posit Software, USA). The results of the final model are interpreted at a 0.05 level of significance.

Results

Study Population

Between September 30 and December 17, 2024, the survey was accessed 2,593 times. Of those, 1,143 participants began the survey, and 921 completed the mandatory MBI section (222 were excluded due to incomplete MBI). The questionnaire consisted of two sections: an optional sociodemographic and work-life section and a required MBI. Of the 921 respondents, 486 (53%) were anaesthesiology residents, 427 (46%) were attendings, and 8 (1%) did not select a category; the median age was 33 years (IQR: 29-43), and 53% were female. Participants represented all seven regions, with the majority from the Marmara (34%) and Central Anatolia (24%) regions, which is consistent with regional population densities and the number of healthcare

facilities. Most participants were employed at state university hospitals (43%) or state training hospitals (36%) (Table 1 and Supplementary Table S1).

Univariable analysis of Burnout Syndrome and High-risk for Burnout

Based on responses to the MBI-HSS, emotional exhaustion was experienced by 56.4% of respondents, depersonalization by 57.1%, and a low sense of personal accomplishment by 73.7%. Furthermore, 659 participants (71.6%) were identified as at high-risk for burnout, while 338 (36.7%) met the criteria for burnout syndrome. Residents constituted a higher proportion of physicians with burnout than of those in the no-burnout group (68% vs. 45%, $P < 0.001$). Similarly, a greater proportion of physicians at high-risk for burnout were residents (61% vs. 34%, $P < 0.001$) (Table 2).

Table 1. Demographics

Characteristic	n = 921[1]
Geographic region	
Aegean Region	105 (12%)
Black Sea Region	57 (6.3%)
Central Anatolia Region	213 (24%)
Eastern Anatolia Region	116 (13%)
Marmara Region	308 (34%)
Mediterranean Region	74 (8.2%)
Southeastern Anatolia Region	28 (3.1%)
Age (yr)	33 (29.43)
Gender	
Female	489 (53%)
Male	427 (47%)
Marital status	
Single	256 (28%)
Married	620 (68%)
Divorced or widowed	34 (3.7%)
Number of status	
0	478 (53%)
1	209 (23%)
>2	222 (24.3%)
Seniority Status	
Resident	486 (53%)
Attending	427 (46.4%)
Years working as a physician	
0-5 years	306 (33%)
6-10 years	256 (28%)
11-20 years	158 (17%)
21+ years	197 (21.7%)
Years working in the same hospital	
0-2 years	392 (43%)
3-5 years	317 (35%)
6-11 years	105 (11.4%)
12+ years	103 (11.1%)

[1]: n (%); Median (Q1, Q3)

Most physicians in both the burnout and high-risk groups were female (58% and 56%, respectively). Burnout was more common among younger and single respondents (median age 31 vs. 35 years for those with and without burnout syndrome, $P < 0.001$; and 32 vs. 39 years for the high-risk and not-high-risk groups, $P < 0.001$). Singles comprised 35% of the burnout group versus 24% of the no-burnout group, and 31% of the high-risk group versus 21% of the not-high-risk group ($P=0.001$ and $P=0.008$, respectively). A higher proportion of physicians with burnout was without children (66% vs. 45%, $P < 0.001$). Working >50 hours/week was more common among those with burnout (74% vs. 58%) and those at high-risk (69% vs. 49%) (both $P < 0.001$). Similarly, job dissatisfaction was more common in the burnout group: 27% reported being "not satisfied at all" with their workplace, compared with 8.8% of those without burnout; conversely, only 17% of those with burnout reported being "satisfied/very satisfied" versus 56% of those without burnout ($P < 0.001$). A higher proportion of participants with burnout had been working in the same hospital for 0-2 years (45% vs. 41%, $P < 0.001$) and for 3-5 years (41% vs. 31%, $P < 0.001$). Perceived inadequate workplace support (34% vs. 16%, $P < 0.001$) and perceived inadequate personal life support (20% vs. 12%, $P < 0.001$) were also significantly associated with burnout. Poor hospital infrastructure (i.e., limitations in facility resources, equipment, and supplies needed to deliver care) was more commonly reported by physicians with burnout; 35% of the burnout group reported suboptimal physical conditions at their institutions, compared with 17% in the non-burnout group ($P < 0.001$). Additionally, a higher proportion of physicians with burnout perceived an insufficient number of anaesthesiology attendings (25% vs. 10%, $P < 0.001$), had insufficient time and financial resources for social activities (21% vs. 9.3%, $P < 0.001$), and were "likely" (24% vs. 13%, $P < 0.001$) *or* "very likely" (10% vs. 3.6%, $P < 0.001$) to resign within two years (Table 3).

Among attendings, no significant association was found between simply working at a mandatory service location and burnout; however, those who believed that it negatively affected their work were marginally more likely to meet the criteria for burnout syndrome (65% vs. 38%, $P=0.066$) and significantly more likely to be at high-risk for burnout (60% vs. 21%, $P=0.006$) (Supplementary Table S2). Additionally, while the number of calls taken per month

Table 2. Summary of Questions Based on all Respondents (Q1-Q25, except Q8-Q12) by Burnout Groups

	Burnout syndrome			High-risk for burnout		
Characteristic	**Yes** n = 338[1]	**No** n = 583[1]	***P* value**[2]	**Yes** n = 659[1]	**No** n = 262[1]	***P* value**[2]
Age (yr)	31 (29, 35)	35 (30, 47)	<0.001	32 (29, 39)	39 (32, 50)	<0.001
Gender			0.038			0.014
Female	195 (58%)	294 (51%)		367 (56%)	122 (47%)	
Male	142 (42%)	285 (49%)		289 (44%)	138 (53%)	
Marital status			0.001			0.008
Single	116 (35%)	140 (24%)		201 (31%)	55 (21%)	
Married	208 (63%)	412 (71%)		424 (65%)	196 (76%)	
Divorced/widowed	8 (2.4%)	26 (4.5%)		26 (4.0%)	8 (3.1%)	
Number of children			<0.001			<0.001
0	220 (66%)	258 (45%)		389 (60%)	89 (34%)	
1	58 (17%)	151 (26%)		140 (22%)	69 (27%)	
≥2	54 (16%)	168 (29%)		121 (19%)	101 (39%)	
Seniority status			<0.001			<0.001
Resident	227 (68%)	259 (45%)		399 (61%)	87 (34%)	
Attendings	109 (32%)	318 (55%)		255 (39%)	172 (66%)	
Years working as a physician			<0.001			<0.001
0-5 years	153 (45%)	153 (26%)		255 (39%)	51 (20%)	
6-10 years	104 (31%)	152 (26%)		199 (30%)	57 (22%)	
10+ years	80 (24%)	275 (47%)		202 (31%)	153 (59%)	
Years working in the same hospital			<0.001			<0.001
0-2 years	152 (45%)	240 (41%)		292 (44%)	100 (39%)	
3-5 years	139 (41%)	178 (31%)		252 (38%)	65 (25%)	
6+ years	47 (14%)	161 (28%)		114 (17%)	94 (36%)	
Work hours per week			<0.001			<0.001
<50 hours	89 (26%)	246 (42%)		202 (31%)	133 (51%)	
>50 hours	249 (74%)	334 (58%)		455 (69%)	128 (49%)	
Satisfaction with workplace			<0.001			<0.001
Not satisfied at all	90 (27%)	51 (8.8%)		134 (20%)	7 (2.7%)	
Somewhat satisfied	190 (56%)	205 (35%)		333 (51%)	62 (24%)	
Satisfied/very satisfied	57 (17%)	323 (56%)		188 (29%)	192 (74%)	

[1]: Median (Q1, Q3); n (%); [2]: Wilcoxon rank sum test; Pearson's chi-squared test

was not significantly associated with burnout syndrome, it was significantly associated with being at high-risk for burnout (*P*=0.030), with more than five calls per month corresponding to a higher proportion at high-risk for burnout (36% vs. 26%).

Among residents, those with 0-5 years of total physician experience (including time before residency) were marginally more likely to meet the criteria for burnout syndrome (66% vs. 58%, *P*=0.059) and significantly more likely to be at high-risk for burnout (63% vs. 48%, *P*=0.005) (Supplementary Table S3). Additionally, among attendings, total years of physician experience were significantly associated with both burnout syndrome and being at high-risk for burnout. A significantly higher proportion of attendings with burnout or at high-risk for burnout had a total of 6-10 years of physician experience (32% vs. 19%, *P*=0.003; 25% vs. 18%, *P*=0.016, respectively) (Supplementary Table S4).

Table 3. Summary of Questions Based on All Respondents by Burnout Groups

	Burnout syndrome			High-risk for burnout		
Characteristic	**Yes** n = 338[1]	**No** n = 583[1]	***P* value**[2]	**Yes** n = 659[1]	**No** n = 262[1]	***P* value**[2]
Support at work			<0.001			<0.001
Don't feel supported at all	116 (34%)	95 (16%)		190 (29%)	21 (8.0%)	
Feel a little supported	161 (48%)	241 (41%)		313 (48%)	89 (34%)	
Feel supported	60 (18%)	204 (35%)		142 (22%)	122 (47%)	
Feel very supported	1 (0.3%)	41 (7.1%)		13 (2.0%)	29 (11%)	
Support outside hospital			<0.001			<0.001
Don't feel supported at all	66 (20%)	69 (12%)		120 (18%)	15 (5.8%)	
Feel a little supported	138 (41%)	181 (31%)		251 (38%)	68 (26%)	
Feel supported	99 (29%)	231 (40%)		204 (31%)	126 (49%)	
Feel very supported	34 (10%)	96 (17%)		80 (12%)	50 (19%)	
Sufficient anaesthesiologist staffing			<0.001			<0.001
Not sufficient	83 (25%)	58 (10%)		122 (19%)	19 (7.3%)	
Some shortcomings but manageable	131 (39%)	169 (29%)		229 (35%)	71 (27%)	
Sufficient	98 (29%)	251 (43%)		233 (36%)	116 (44%)	
More than sufficient	24 (7.1%)	102 (18%)		71 (11%)	55 (21%)	
Adequate physical conditions			<0.001			<0.001
Not sufficient	118 (35%)	100 (17%)		186 (28%)	32 (12%)	
Some shortcomings but manageable	157 (47%)	261 (45%)		316 (48%)	102 (39%)	
Sufficient	49 (15%)	170 (29%)		123 (19%)	96 (37%)	
More than sufficient	13 (3.9%)	50 (8.6%)		32 (4.9%)	31 (12%)	
Consider changing hospital	245 (73%)	236 (41%)	<0.001	411 (63%)	70 (27%)	<0.001
Probability of resigning within 2 years			<0.001			<0.001
Very unlikely	40 (12%)	191 (33%)		125 (19%)	106 (41%)	
Unlikely	67 (20%)	166 (29%)		155 (24%)	78 (30%)	
Neutral	116 (34%)	126 (22%)		196 (30%)	46 (18%)	
Likely	80 (24%)	76 (13%)		129 (20%)	27 (10%)	
Very likely	35 (10%)	21 (3.6%)		52 (7.9%)	4 (1.5%)	
Time and finances for social activities			<0.001			<0.001
Not sufficient	70 (21%)	54 (9.3%)		113 (17%)	11 (4.2%)	
Slightly sufficient	170 (50%)	213 (37%)		306 (47%)	77 (30%)	
Moderately sufficient	90 (27%)	279 (48%)		226 (34%)	143 (55%)	
More than sufficient	8 (2.4%)	33 (5.7%)		13 (2.0%)	28 (11%)	

[1]: Median (Q1, Q3); n (%); [2]: Wilcoxon rank sum test; Pearson's chi-squared test

Among residents, the number of years working at the same hospital was not associated with burnout syndrome or high-risk for burnout (*P*=0.2 and *P*=0.6, respectively). However, among attendings, years working at the same hospital were significantly associated with both outcomes. A higher proportion of attendings with burnout (30% vs. 18%, *P*=0.009) and of attendings at high-risk for burnout had been working in the same hospital for 3-5 years. By contrast, fewer attendings with burnout (37% vs. 50%, *P*=0.009) and at high-risk for burnout (42% vs. 55%, *P*=0.016) had worked 6+ years at the same hospital.

Among other factors we investigated, we found no significant association between burnout and either geographic region or hospital type.

Multivariable Analysis

In the multivariable models, age remained significantly associated with both burnout syndrome and a high-risk of burnout. Specifically, each additional year of age was associated with a 6% reduction in the odds of burnout syndrome (OR=0.94, 95% CI=0.91-0.96, *P* < 0.001) and an 8% reduction in the odds of being at high-risk for burnout (OR=0.92, 95% CI=0.89-0.95, *P* < 0.001). Working 3-5 years at the same hospital was associated with 60 % higher odds of burnout syndrome compared with working 0-2 years (OR=1.60, 95 % CI=1.10-2.34; *P*=0.015), and 78% higher odds of being at high-risk for burnout (OR=1.78, 95% CI=1.14-2.79, *P*=0.012). Male respondents showed lower odds of experiencing burnout syndrome than female respondents (OR=0.72, 95% CI=0.51-1.01, *P*=0.057). Greater workplace satisfaction was associated with lower odds of burnout. Specifically, compared with those who were "not satisfied at all", respondents who reported being "satisfied" or "very satisfied" had 71% lower odds of having burnout syndrome (OR=0.29, 95% CI=0.16-0.49, *P*<0.001) and 91% lower odds of being at high-risk for burnout (OR=0.09, 95% CI=0.03-0.22, *P* < 0.001). Respondents who rated their time and financial situation as "moderately sufficient" for social activities had roughly half the odds of meeting burnout syndrome criteria compared with those who found them "not sufficient" (OR=0.51, 95% CI=0.30-0.87; *P*=0.014). Although the overall effect of this variable narrowly missed conventional significance for burnout syndrome (global *P*=0.051), it was significantly associated with being at high-risk for burnout (global *P*=0.011). Specifically, respondents who rated their financial situation as "moderately sufficient" had 58% lower odds of being at high-risk (OR=0.42, 95% CI=0.19-0.86, *P*=0.023), and those who reported it as "more than sufficient" had 82% lower odds (OR=0.18, 95% CI=0.05-0.57, *P*=0.005) (Table 4).

In addition, strong perceived personal life support was associated with lower odds of both burnout syndrome (OR=0.50, 95% CI=0.26-0.95, *P*=0.035) and high-risk of burnout (OR=0.31, 95% CI=0.14-0.69, *P=0.005)* compared with poor support. The perceived adequacy of anaesthesiology attendings also played a significant role in the multivariable analysis. Respondents who considered the number of attendings "more than sufficient" had significantly lower odds of burnout compared with those who deemed it "not sufficient" (OR=0.41, 95% CI=0.21-0.80, *P*=0.009). Respondents with burnout were more likely to report an intention to resign within two years. Compared with those who were "very unlikely" to resign within the next two years, those who selected " neutral" had 2.69 times higher odds of experiencing burnout (OR=2.69, 95% CI=1.64-4.46, *P* < 0.001); those who were "likely" to resign had 3.67 times higher odds (OR=3.67, 95% CI=2.10-6.51, *P* < 0.001); and those who were "very likely" to resign had 4 times higher odds (OR=4.00, 95% CI=1.84-8.95, *P* < 0.001).

No subspecialty demonstrated significantly different odds of experiencing burnout syndrome. Neuro-anaesthesiologists were marginally less likely to have burnout (OR=0.41, 95% CI=0.14-1.04, *P*=0.076) and had marginally lower odds of a high-risk status (OR=0.46, 95% CI=0.20-1.02, *P*=0.059) (Table 4) (Supplementary Table 5).

Subgroup and Interaction Effects

The exploratory subgroup analysis showed a significant gender-by-seniority (attending vs. resident) interaction (*P*=0.034), suggesting that the association between seniority and burnout syndrome varied by gender. Specifically, among attendings, gender was not associated with burnout, whereas among residents males were less likely than females to have burnout syndrome (OR=0.54, 95% CI=0.37-0.78, *P*=0.001), suggesting that being a female resident is associated with higher odds of burnout. Within the same interaction model, when gender groups are examined separately, attendings have significantly lower odds of burnout than residents (OR=0.63, CI=0.41-0.97, *P*=0.038), whereas, females had even lower odds of burnout compared to residents (OR=0.33, CI=0.22-0.50, *P* < 0.001) (Supplementary Table S6).

Work-life Balance Improvements

Respondents identified several changes that would most benefit their work-life balance: improving physical conditions (60.2%), increasing flexibility in work-hours (51.5%), reducing weekly work-hours (54.6%), increasing the number of vacation days (51.4%), ensuring a sufficient number of anaesthesiology attendings (30.6%), improving workplace culture (58%), increasing support from leadership (62.9%), limiting work-related communication outside work-hours (23.7%), improving salary (79.9%), providing soft skills training (26.7%), assisting with child/elder care (18%), and improving the efficiency of electronic medical records (34.4%) (Table 5).

Table 4. Multivariable Analysis of Burnout Syndrome and High-Risk for Burnout Syndrome, after Stepwise Model Building Process and Purposeful Variable Selection

	Burnout syndrome			High-risk for burnout		
Characteristic	**OR**[1]	**95% CI**	***P* value**	**OR**	**95% CI**	***P* value**
Age (year)	0.94	0.91, 0.96	<0.001	0.92	0.89, 0.95	<0.001
Gender						
Female	—	—				
Male	0.72	0.51, 1.01	0.057			
Years working in the same hospital			0.043			0.029
0-2 years	—	—		—	—	
3-5 years	1.60	1.10, 2.34	0.015	1.78	1.14, 2.79	0.012
6+ years	1.51	0.80, 2.87	0.2	1.65	0.90, 3.08	0.11
Satisfaction with workplace			<0.001			<0.001
Not satisfied at all	—	—		—	—	
Somewhat satisfied	0.71	0.44, 1.13	0.2	0.22	0.07, 0.57	0.004
Satisfied/very satisfied	0.29	0.16, 0.49	<0.001	0.09	0.03, 0.22	<0.001
Support outside hospital			0.014			0.001
Don't feel supported at all	—	—		—	—	
Feel a little supported	1.19	0.72, 1.97	0.5	0.61	0.29, 1.24	0.2
Feel supported	0.77	0.47, 1.29	0.3	0.33	0.15, 0.66	0.002
Feel very supported	0.50	0.26, 0.95	0.035	0.31	0.14, 0.69	0.005
Sufficient anaesthesiologist staffing			0.041			
Not sufficient	—	—				
Some shortcomings, but manageable	0.85	0.52, 1.38	0.5			
Sufficient	0.66	0.40, 1.09	0.11			
More than sufficient	0.41	0.21, 0.80	0.009			
Probability of resigning within 2 years			<0.001			0.002
Very unlikely	—	—		—	—	
Unlikely	1.54	0.92, 2.59	0.10	1.50	0.93, 2.40	0.10
Neutral	2.69	1.64, 4.46	<0.001	2.32	1.38, 3.93	0.002
Likely	3.67	2.10, 6.51	<0.001	3.31	1.71, 6.62	<0.001
Very likely	4.00	1.84, 8.95	<0.001	2.53	0.83, 9.63	0.13
Time and finances for social activities			0.051			0.011
Not sufficient	—	—		—	—	
Slightly sufficient	0.76	0.46, 1.25	0.3	0.59	0.27, 1.22	0.2
Moderately sufficient	0.51	0.30, 0.87	0.014	0.42	0.19, 0.86	0.023
More than sufficient	0.99	0.30, 3.01	>0.9	0.18	0.05, 0.57	0.005
Neuro anaesthesiology	0.41	0.14, 1.04	0.076	0.46	0.20, 1.02	0.059
General anaesthesiology				1.62	1.01, 2.62	0.046

OR, odds ratio; CI, confidence interval

Table 5. Summary of Work Life Balance Items

Items that would improve work life balance	Summary statistics
Improving physical conditions	554 (60.2%)
Flexibility in work hours	474 (51.5%)
Reducing weekly work hours	503 (54.6%)
Increasing the number of vacation days	473 (51.4%)
Having sufficient number of anaesthesiology attendings	282 (30.6%)
Improving workplace culture	534 (58%)
Increased support from leadership	579 (62.9%)
Limiting work related communication outside work hours	218 (23.7%)
Improving salary	736 (79.9%)
Soft skills trainings	246 (26.7%)
Assistance with child/elder care	166 (18%)
Improving efficiency with the electronic medical records	317 (34.4%)

Discussion

This national study highlights the scale of burnout within the Turkish anaesthesiology workforce. Overall, 71.6% were at high-risk, and 37% met the criteria for burnout syndrome. Burnout was more common in residents than in attendings: roughly four in five residents were at high-risk, and nearly half met the burnout criteria, compared with about three in five and one in four, respectively, among attendings. These rates generally exceed those reported elsewhere. Reported attending burnout rates were lower in Italy (10.2%),[17] France (24%),[13] Poland (18%).[14] Similarly, burnout rates of 25% among United Kingdom trainees,[27] and 18% overall in the Netherlands[28] are below our estimates. Even countries with heavy workload pressures, such as Portugal[15] and Egypt,[12] report lower rates. China reported a 69% burnout rate, but this figure is likely to reflect the use of lower thresholds for emotional exhaustion and depersonalization scores.[4] In the United State (U.S.) attending burnout rose from 13.8% in 2020[10] to 18.9% in 2022[11] post-pandemic–still well below the 37% observed in our study.

Previous studies from Türkiye provide useful context, but they are mostly single-center or regional, or they focus on selected groups (e.g., residents); some findings differ from those in our cohort. These studies likewise show a substantial burden of burnout and occupational stress among anaesthesiology physicians.[19,20,29-31] For example, Bıçak and Çelik[29] found no gender differences in burnout or job satisfaction among specialists in Diyarbakır, whereas burnout risk in our cohort was more pronounced in female residents. In trainee studies, Büget et al.[30] highlighted workload, training conditions, and the working environment as key stressors, and Abut et al.[19] reported associations with gender and marital status that differed from our findings. We observed no subspecialty differences, unlike reports from algology and anaesthesiology settings.[20] Recent nationwide data also suggested lower burnout among anaesthesiologists with children, and higher imposter syndrome levels among women.[31] We did not find an association between having children and burnout. Overall, these discrepancies indicate heterogeneity across Turkish studies, likely reflecting differences in populations, institutions, sample sizes, and measurement and analytic approaches. Smaller studies may also be more sensitive to sampling variation, and associations observed in such studies may not persist after multivariable adjustment in larger cohorts.

We found that Türkiye recorded the highest rate of low personal accomplishment (73.7%) and one of the highest depersonalization scores (57.1%) among published anaesthesiology cohorts. By comparison, Portugal reported 44.8% low personal accomplishment and 90.9% depersonalization,[15] while Egypt reported 58.2% and 56.1%, respectively.[12] While the depersonalization in Egypt is comparable to ours, low personal accomplishment in our cohort remains notably higher. Consistent with this, a pan-European workforce survey ranked Türkiye first for exhaustion,[32,33] supporting the need for system-level reform rather than relying on individual resilience alone.

Younger physicians had higher odds of burnout syndrome with each additional year of age was associated with a 6% reduction in the odds of burnout, mirroring findings from the U.S,[10,11] Portuguese attendings[15] and İstanbul trainees.[19] Total years in practice were not associated with burnout. Instead, tenure at a single institution emerged as an associated factor, those with 3-5 years at the same hospital had higher odds of burnout syndrome (OR=1.60) and high-risk status (OR=1.78) than those with ≤2 years, whereas staff with ≥6 years did not. This resembles the mid-career peak described by Dyrbye et al.[34] whereas our data suggests a mid-tenure peak within one institution. To our knowledge, no study of anaesthesiology burnout has stratified years of practice into finer brackets or demonstrated a significant continuous association; nor has any broader medical study evaluated single-institution tenure, which would add a novel perspective. Mid-tenure clinicians may experience unique pressures: evolving roles, increasing clinical and administrative responsibilities, plateauing promotion opportunities, and an institutional culture warranting further investigation.

Türkiye's standard 40-45 hours/week refers to scheduled daytime work rather than an upper limit and does not include night-call duties, which are regulated separately in specialty training: night-call is scheduled ≥3 days apart, ≤8/month, and post-call trainees have no clinical duty the next day. As a result, "weekly work-hours" may not capture total workload, complicating comparisons with systems

where total duty time is explicitly capped (e.g., the European Working Time Directive, 48 hours/week on average) and helping explain why workload can, in practice, approach or exceed the U.S. residency limit (80 hours/week averaged) when night call is frequent.[34-36] In this context, we found no association between work-hours and burnout, consistent with reports from Portugal,[15] France,[37] and UK trainee cohort.[27] Conversely, Li et al.[4] found higher burnout among those working >60 hours/week in China, and Afonso's U.S. data showed that >40 hours/week were associated with burnout and high-risk status.[11] Overall, these mixed findings suggest that the work-hours-burnout relationship is context-dependent, shaped by how hours are defined (scheduled hours vs. total workload, including night call) and by organizational factors that affect recovery time and staffing support.

Residents reported higher burnout rates than attendings, mirroring data from the U.S.[11,38] and an Egyptian academic center,[12] but contrasting with Dutch[28] and Chinese[4] studies where junior attendings had higher rates. This pattern may reflect the demands of residency, including long hours, frequent on-call duties, a steep learning curve, and limited autonomy. Among residents, we observed lower odds of burnout in male residents, similar to U.S. data.[38] Female residents may face added pressures from more emotionally demanding patients and family interactions, difficulty declining additional tasks, and completing domestic responsibilities, which can reduce the time available for rest and recovery. By contrast, female attendings may be buffered by greater autonomy, established professional networks, and institutional support, which could attenuate gender differences seen during training. Mitigating these stressors requires equitable task assignments, robust mentorship, and flexible scheduling to support work-life balance.

Staffing shortages and workplace dissatisfaction showed the strongest associations with burnout. One-third of clinicians experiencing burnout reported a high likelihood of leaving their positions, which represents an alarming threat amid ongoing staff shortages. 80% of respondents called for higher salaries, and over half identified needs such as better leadership engagement, improved working conditions and workplace culture, greater scheduling flexibility, and more vacation time. In China, where compensation is also relatively low, insufficient pay has been associated with burnout.[4] Consistent with U.S. studies,[38,39] respondents reporting adequate income and time for personal life had roughly half the odds of burnout, underscoring the protective role of work-life balance and fair compensation. Perceived personal support was the only non-work-related factor associated with lower odds of burnout, reinforcing that organizational factors outweigh individual ones, as also noted in U.S. studies.[10,11]

The strengths of our study include the large, diverse national sample and the use of the validated Turkish version of the MBI, enabling comparisons with prior studies. To our knowledge, this is the first nationwide study to estimate burnout prevalence and explore associated factors among Turkish anaesthesiology attendings and residents.

Study Limitations

This study has limitations. The cross-sectional design and self-reported data limit causal inference and may introduce reporting bias. Voluntary participation raises the possibility of selection bias and non-response bias. Individuals with higher burnout or stronger views may have been more likely to respond, inflating estimates of burnout prevalence, whereas those with severe burnout may have been less able or willing to participate, deflating estimates of burnout prevalence, respectively. Because we lack data on non-responders and cannot calculate response rates, the direction and magnitude of any bias are uncertain. Comparisons with prior Turkish studies should be interpreted cautiously due to differences in study populations, settings, sample sizes, and measurement instruments.

The classification of burnout is another limitation. Although the Turkish MBI has been psychometrically validated, commonly used categorical cut-offs vary across studies and are not clinically or culturally validated diagnostic thresholds.[40] We therefore applied a widely used MBI-based classification framework from the physician literature and rescaled the original 7-point thresholds to the Turkish 5-point format for comparability.[10,11,40] These adapted cut-offs were not re-validated in our Turkish sample, and any misclassification is most likely near the thresholds.

Conclusion

Turkish anaesthesiologists—particularly younger clinicians, mid-tenure staff, and female residents—face among the highest levels of burnout worldwide, associated with systemic stressors such as heavy workloads, understaffing, and inadequate compensation. Leadership must systematically address these pressures by translating them into concrete, monitored action plans designed to measurably improve clinician well-being and, ultimately, patient care.

Ethics

Ethics Committee Approval: Ethical approval for this study was granted by the University of Health Sciences Türkiye, Bakırköy Dr. Sadi Konuk Training and Research Hospital, Non-Interventional Scientific Research Ethics Committee (approval no: 2024-08-13, date: 19.08.2024).

Informed Consent: Participation was voluntary and anonymous, and informed consent was implied through the completion of the survey.

Footnotes

Authorship Contributions: Concept - O.K., G.S., A.T.; Design - O.K., G.S., Y.T., Y.L., S.U., S.S., B.T.Ç., M.K., Se.S., A.A.K., A.T.; Data Collection and/or/Processing - O.K., T.L., Se.S.; Analysis and/or/ Interpretation - O.K., G.S., Y.T., Y.L., S.U., S.S., B.T.Ç., M.K., Se.S., A.A.K., A.T.; Literature Review - O.K., G.S., Y.T., S.U., S.S., B.T.Ç., M.K., Writing - O.K., G.S., Y.T., Y.L., S.U., S.S., B.T.Ç., M.K., Se.S., A.A.K., A.T.

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Supplemantary Material 1: https://d2v96fxpocvxx.cloudfront.net/353d5d5c-62fa-4c66-b2ed-311e6d47e107/content-images/2921948b-d444-4948-abe6-d8725ac62638.pdf

Supplemantary Material 2: https://d2v96fxpocvxx.cloudfront.net/353d5d5c-62fa-4c66-b2ed-311e6d47e107/content-images/2151a14e-d1f9-442f-9547-9a0593767ff4.pdf

Supplemantary Tables: https://d2v96fxpocvxx.cloudfront.net/bda9171a-fae8-4995-8276-2138323f1e16/content-images/16a94bde-dd76-4585-a564-e2c50d65fb23.pdf

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Post-Sepsis Outcomes: Risk Factors for 90-Day Mortality and Infection Site-Pathogen Similarity in Recurrent Sepsis

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Abstract

Aim: Post-sepsis outcomes remain poorly defined, with recurrent infections and late mortality posing significant clinical challenges. To identify clinical and laboratory predictors of 90-day post-sepsis mortality and to evaluate infection site and pathogen similarity in recurrent sepsis.

Methods: This retrospective cohort study included 300 adult patients hospitalized with sepsis or septic shock at a tertiary care center (2018-2022). Demographic, clinical, laboratory, and microbiological data were analyzed. Multivariate bootstrap logistic regression identified independent predictors of mortality, and receiver operating characteristic analysis assessed diagnostic performance. Recurrent episodes were examined for infection site and for microbial concordance with the index hospitalization.

Results: Of 183 discharged patients, 60 (32.8%) died within 90 days. Non-survivors were older, had higher Charlson Comorbidity Index scores, had longer intensive care unit (ICU) stays, had lower albumin and procalcitonin levels, and were less likely to achieve microbiological clearance by day 7. In multivariate analysis, only hypoalbuminemia independently predicted mortality (P=0.012). Receiver operating characteristic analysis showed the highest area under the curve for 1/procalcitonin (0.694), followed by age (0.665) and 1/albumin (0.647). Among recurrent sepsis cases, 55.9% had infections at the same site, but identical pathogens were detected in only 5.9%.

Conclusion: Advanced age, comorbidity burden, prolonged ICU stay, delayed microbiological response, and hypoalbuminemia are associated with increased 90-day post-sepsis mortality. Although pathogen concordance was uncommon, a low culture yield indicates that some recurrent episodes may be relapses caused by undetected similar pathogens. When culture-negative episodes are also considered, the true similarity rate between initial and recurrent infections is likely even higher.

Keywords: Infection site similarity, post-sepsis mortality, post-sepsis syndrome, recurrent sepsis

Main Points

- Ninety-day post-discharge mortality remained high among sepsis survivors, affecting approximately one-third of patients.
- Hypoalbuminemia was the only independent predictor of 90-day mortality in multivariate analysis.
- More than half of recurrent sepsis episodes involved the same anatomical infection site, whereas recurrence with the same pathogen was uncommon.
- Structured post-discharge follow-up may help identify high-risk sepsis survivors and detect recurrent infections at an earlier stage.

Introduction

Sepsis is a life-threatening systemic inflammatory syndrome that often leads to multiple organ dysfunction as a result of an uncontrolled host response to infection.[1] While acute in-hospital mortality remains a significant concern, increasing attention has been directed toward post-discharge outcomes, with studies reporting that up to 40% of sepsis survivors are readmitted within the first year-most commonly due to infectious complications.[2] However, it remains unclear whether these infections represent true recurrences or new infectious events, complicating both diagnosis and clinical management.[3]

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The post-sepsis period is frequently marked by persistent immune dysregulation. An initial pro-inflammatory cytokine surge is often followed by a compensatory anti-inflammatory response that includes lymphocyte apoptosis, decreased human leukocyte antigen-DR isotype expression, and regulatory T-cell expansion.[4-6] This immunosuppressive state may persist long after hospital discharge, predisposing patients to new infections and increasing late mortality.[4] Furthermore, recurrent sepsis episodes are more common in sepsis survivors compared to the general population, with rates as high as 35% observed within eight years of the initial episode.[7]

Given these long-term vulnerabilities, it is essential to identify predictors of post-discharge mortality and to characterize the patterns of recurrent sepsis. In this retrospective cohort study, we aimed to investigate the clinical risk factors associated with 90-day mortality following hospital discharge in patients diagnosed with sepsis or septic shock and assess whether recurrent episodes involved infection sites and causative microorganisms similar to those at the initial presentation.

Methods

Study Design/Data Source

This single-center, retrospective observational cohort study was conducted at University of Health Sciences Türkiye, Kayseri City Training and Research Hospital. We reviewed records of patients who were hospitalized with sepsis or septic shock between June 1, 2018, and December 31, 2022. Ethics approval for this study was obtained from University of Health Sciences Türkiye, Kayseri City Training and Research Hospital (approval no: 67, date: 24.11.2022). Was conducted in accordance with the principles of scientific ethics.

Operational Definitions

Patients were analyzed retrospectively over the period from six months prior to admission to 90-days after discharge. Mortality within 90-days post-discharge was recorded. The cause and date of death were obtained from the Kayseri Provincial Health Directorate (petition no: 233655996, date: 08.01.2024). Patients discharged after treatment were categorized into two groups: those who died within 90-days and those who survived.

Data Collection

Patients with sepsis or septic shock were identified by reviewing discharge summaries, epicrisis notes, and infectious disease consultation notes. Due to potential inaccuracies in diagnostic coding, manual chart reviews were performed to ensure correct case identification.

Sepsis was diagnosed according to the 2016 SCCM/ESICM Sepsis-3 guidelines. Inclusion criteria were age ≥18 years. Exclusion criteria were: pregnancy, concurrent Coronavirus disease-2019 infection, and a history of sepsis within 90-days of the index hospitalization.

Collected data included: Demographic and clinical characteristics: age, gender, comorbidities, total hospital stay, ICU stay, primary infection site, presence of healthcare-associated infections.

- Severity scores: APACHE II, sequential organ failure assessment score (SOFA), glasgow coma scale (GCS), Charlson Comorbidity Index (CCI).

- ICU management parameters: vasopressor use, invasive mechanical ventilation, 7-day microbiological and clinical responses.

Laboratory parameters:

- Hematological: white blood cell count, hemoglobin

- Biochemical: serum creatinine, serum albumin (ALB), alanine aminotransferase, aspartate aminotransferase.

- Inflammatory biomarkers: C-reactive protein, procalcitonin (PCT).

Statistical Analysis

Statistical analyses were performed using SPSS for Windows, version 22.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were generated for each group.

- Categorical variables were expressed as frequencies and percentages (%).

- Continuous variables were assessed for normality using the Shapiro-Wilk test and visual inspection of histograms.

- Normally distributed variables were reported as mean ± standard deviation.

- Non-normally distributed variables were expressed as median (interquartile range).

A P value ≤0.05 was considered statistically significant.

Univariate analyses were performed to evaluate factors associated with 90-day post-discharge mortality. Variables with $P < 0.10$ in univariate analysis were included in a multivariate model. Multivariate analysis was performed using bootstrap logistic regression with 1,000 resamples to estimate regression coefficients, standard errors, confidence intervals, and P values.

The diagnostic performance of selected variables was assessed using receiver operating characteristic (ROC) curve analysis. Variables for ROC analysis were selected based on clinical relevance and statistical significance in univariate or multivariate analyses. The area under the curve (AUC) and 95% confidence intervals were calculated. Optimal cut-off values were determined using the Youden Index, and corresponding sensitivity and specificity values were reported.

For patients with recurrent sepsis, distributions of infection sites and causative microorganisms were compared between episodes, and the similarity of infection sites and microorganisms across recurrent episodes was calculated.

Results

A total of 300 patients were included in the study. Among them, 183 patients were discharged alive, of whom 60 (32.8%) died within 90-days after discharge, while 123 (67.2%) remained alive during the follow-up period. Baseline demographic, clinical, and laboratory characteristics of patients, stratified by survival status are presented in Table 1. The mean age of the cohort was 75.2±14.2 years, and non-survivors were significantly older than survivors [77.7±12.6 vs. 71.1±16.1 years; crude odds ratio (cOR)=1.032, 95% CI: 1.008-1.058, *P*=0.010]. Gender distribution was similar across groups (*P*=0.792).

The median ICU length of stay was significantly longer in non-survivors than in survivors [6.5 (4-12) vs. 5 (3-11) days; cOR=1.044, 95% CI: 1.006-1.083, *P*=0.024], whereas the total hospital stay did not differ significantly (*P*=0.106). Non-survivors had higher CCI scores than survivors [5 (4-7) vs. 4 (3-6); cOR=1.133, 95% CI: 1.008-1.273, *P*=0.036]. Comorbidities and infection patterns were similar, with a non-significant trend toward more healthcare-associated infections in non-survivors.

Regarding laboratory parameters, non-survivors had significantly lower ALB levels (29.0±4.4 vs. 31.4±5.7 g/L; cOR=0.916, 95% CI: 0.859-0.977, *P*=0.007) and lower median PCT levels [0.3 (0.18-1.37) vs. 3.0 (0.57-27) ng/mL; cOR=0.974, 95% CI: 0.953-0.996, *P*=0.020].

Clinical scores and treatment variables were similar between groups, but the 7-day microbiological response was significantly lower in non-survivors (45.0% vs. 52.0%, *P*=0.044).

In the multivariate bootstrap logistic regression analysis (Table 2), low albumin level was identified as an independent risk factor for 90-day post-sepsis mortality (B=-0.107, 95% CI: -0.243 to -0.029, *P*=0.012). Other variables, including gender, ICU length of stay, CCI, PCT, creatinine, and SOFA score, were not statistically significant predictors after adjustment.

Diagnostic Performance

The ROC analysis results for selected variables are presented in Figure 1 and Table 3. Among the tested variables, 1/PCT had the highest discriminative ability for predicting 90-day mortality (AUC=0.694, 95% CI: 0.591-0.798, *P*=0.001) with a cut-off value of 2.17 (sensitivity: 61.5%, specificity: 77.6%). Age also showed moderate predictive value (AUC=0.665, *P*=0.005, cut-off: 81.5 years), followed by 1/albumin (AUC=0.647, *P*=0.013, cut-off: 0.0293). CCI and ICU length of stay demonstrated low discriminatory performance, with AUC values close to 0.5.

Similarity Rates of Infection Site and Microorganism Agents of Recurrent Sepsis Cases

Five patients included in the study presented with sepsis on three occasions within 270 days. A total of 68 consecutive episodes of recurrent sepsis were recorded. During the initial hospitalization, respiratory tract infections were most common (36.5%), whereas during the second or third hospitalization, urinary tract infections were most frequent (27%) (Table 4).

In terms of causative microorganisms, culture-negative sepsis was observed in 38% of initial admissions and 29% of recurrent admissions. Gram-negative bacteria were the most common pathogens in both episodes (35% and 38%, respectively), followed by fungi (14% and 12%). No statistically significant differences were observed among pathogen distributions ($P > 0.05$ for all). Among patients with recurrent sepsis, 55.9% had infections at the same anatomical site as during their initial hospitalization, whereas 44.1% had infections at different anatomical sites.

Table 5 presents the similarity rates for both infection sites and causative microorganisms in these recurrent episodes. Among patients with recurrent sepsis, the infection site was similar in 38 patients (60.3%) and different in 30 patients (39.7%). When microbial consistency was compared, similar microorganisms were detected in 5.9% of patients with recurrent infections at the same site and in 2.9% of those with infections at different sites. Notably, 27.9% of recurrent infections at the same site were caused by different microorganisms, indicating that site similarity does not necessarily predict microbiological consistency.

Table1. Baseline Demographic, Clinical, and Laboratory Characteristics of the Study Population According to 90-Day Post-Discharge Survival Status

	Patients included in the study n=300	Discharged patients n=183		cOR (95% CI)	*P* value
		Dead n=60	Survivor n=123		
Age/year, mean ± SD	75.2±14.2	77.7±12.6	71.1±16.1	1.032 (1.008-1.058)	0.010
Gender, male (%)	154 (51.3)	29 (48.3)	62 (50.4)	1.086 (0.586-2.015)	0.792
Total length of hospitalization/day, median (IQR)	12 (7-19.5)	15 (9-26)	13 (9-18)	1.022 (0.995-1.049)	0.106
ICU length of stay/day median (IQR)	7 (3-13)	6.5 (4-12)	5 (3-11)	1.044 (1.006-1.083)	0.024
CCI, median (IQR)	5 (3-7)	5 (4-7)	4 (3-6)	1.133 (1.008-1.273)	0.036
Comorbidities (%)					
Hypertension	144 (48)	29 (48.3)	55 (44.7)	1.157 (0.623-2.147)	0.645
Neurological disease	134 (44.7)	32 (53.3)	50 (40.7)	1.669 (0.896-3.107)	0.107
Diabetes mellitus	108 (36)	25 (41.7)	43 (35)	1.329 (0.706-2.503)	0.379
Cardiovascular disease	94 (31.3)	23 (38.3)	33 (36.8)	1.695 (0.880-3.266)	0.115
Chronic renal failure	58 (19.3)	7 (11.7)	21 (17.1)	0.642 (0.256-1.606)	0.343
Chronic lung disease	56 (18.7)	11 (18.3)	24 (19.5)	0.926 (0.420-2.043)	0.849
Malignancy	38 (12.7)	10 (16.7)	12 (9.8)	1.850 (0.750-4.565)	0.182
Pathologies of the urinary system	34 (11.3)	7 (11.7)	18 (14.6)	0.770 (0.303-1.959)	0.584
Infection site (%)					
Urinary tract infection	109 (36.3)	21 (35)	49 (39.8)	0.528 (0.428-1.545)	0.528
Respiratory system	102 (34)	23 (38.3)	33 (26.8)	1.695 (0.880-3.266)	0.115
Skin and soft tissue	39 (13)	7 (11.7)	16 (13)	0.883 (0.343-2.278)	0.797
Gastrointestinal system	22 (7.3)	7 (11.7)	9 (7.3)	1.673 (0.591-4.734)	0.332
Central nervous system	17 (5.7)	-	13 (10.6)	-	-
Multiple regions	11 (3.7)	2 (3.3)	3 (2.4)	1.979 (0.224-8.483)	0.729
Healthcare-associated infection (%)	149 (49.7)	34 (56.7)	57 (46.3)	1.514 (0.813-2.819)	0.191
Laboratory parameters					
WBC, 10^9/μL median (IQR)	12.4 (8.9-16.9)	11.9 (8.5-15.5)	12.2 (9-15.3)	1 (1-1)	0.852
HGB, g dL^{-1} mean ± SD	11±2.2	11±2.3	11.9±2	0.887 (0.766-1.027)	0.108
CRE, mg dL^{-1} median (IQR)	1.3 (0.85-2.1)	0.96 (0.79-1.57)	1.2 (0.83-2.2)	0.772 (0.574-1.038)	0.087
ALB, g L^{-1} mean±SD	29±5.6	29±4.4	31.4±5.7	0.916 (0.859-0.977)	0.007
ALT, U L^{-1} median (IQR)	13 (8-26)	13 (9-21)	16 (10-28)	1.002 (0.993-1.011)	0.632
CRP, mg L^{-1} median (IQR)	160 (88-234)	139 (79-238)	149 (80-242)	0.998 (0.995-1.001)	0.208
PCT, ng mL^{-1} median (IQR)	1.5 (0.35-17)	0.3 (0.18-1.37)	3 (0.57-27)	0.974 (0.953-0.996)	0.020
Clinical score values of the patients at admission					
APACHE II median (IQR)	21 (15-27)	16 (11-24)	17 (13-25)	0.990 (0.950-1.031)	0.617
SOFA median (IQR)	5 (3-8)	3 (2-5)	4 (2-7)	0.887 (0.782-1.007)	0.063
GCS median (IQR)	12 (9-14)	13 (11-14)	13 (11-14)	0.992 (0.873-1.126)	0.898
Diagnosis and clinical follow-up course of patients at presentation (%)					
Septic shock	96 (32)	8 (13.3)	19 (15.4)	0.842 (0.346-2.052)	0.705
Administration of vasopressor	136 (45.3)	7 (11.7)	17 (13.8)	0.824 (0.322-2.108)	0.686
Invasive mechanical ventilation	113 (37.7)	1 (1.7)	1 (0.8)	-	-
Seventh-day clinical response	163 (54.3)	49 (81.7)	100 (81.3)	1.025 (0.462-2.270)	0.952
Seventh-day microbiological response	126 (42)	27 (45)	64 (52)	0.328 (0.111-0.971)	0.044

ALB, serum albumin; ALT, alanine aminotransferase, APACHE II, Acute Physiology and Chronic Health Evaluation II; CCI, Charlson comorbidity index; CRE, serum creatinine; CRP, C-reactive protein; cOR, crude odds ratio (95% confidence interval); GCS, Glasgow Coma scale; HGB, hemoglobin; ICU, intensive care unit; IQR, interquartile range; PCT, procalcitonin; SD, standard deviation; SOFA, sequential organ failure assessment score; WBC, white blood cell count

Table 2. Bootstrap Logistic Regression Analysis and Odds Ratios for 90-Day Post-Sepsis Mortality

Variable	B	Bootstrap SE	Bootstrap *P* value	95% CI lower	95% CI upper
Gender, male	0.394	0.603	0.458	-0.748	1.617
ICU, length of stay	0.012	0.037	0.653	-0.076	0.073
CCI	0.084	0.098	0.303	-0.066	0.328
ALB	-0.107	0.054	**0.012**	-0.243	-0.029
PCT	-0.025	0.152	0.108	-0.43	-0.003
CRE	-0.127	0.309	0.569	-0.911	0.354
SOFA	0.012	0.121	0.901	-0.229	0.234
Constant	2.232	1.909	0.157	-0.969	6.829

ALB, serum albumin; CCI, Charlson comorbidity index; CRE, serum creatinine; ICU, intensive care unit; PCT, procalcitonin; SOFA, sequential organ failure assessment score

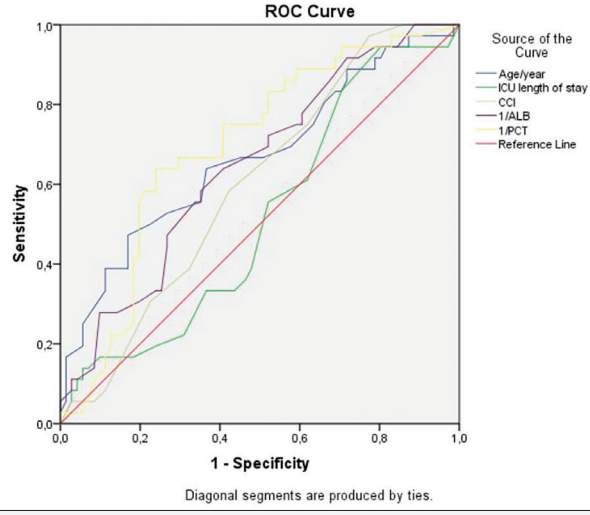

Figure 1. ROC curve.

ROC, receiver operating characteristic; CCI, Charlson comorbidity index; ICU, intensive care unit; 1/ALB, 1/serum albumin level; 1/PCT, procalcitonin level.

Table 3. ROC Analysis Results: Diagnostic Performance of Clinical Variables in Predicting Mortality

Variable	AUC	Std. error	*P* value	95% lower	95% CI upper	Cut-off	Sensitivity (%)	Specificity (%)
Age	0.665	0.057	0.005	0.553	0.778	81.5	50	74.9
ICU length of stay	0.516	0.058	0.784	0.402	0.63	3.5	87.5	34.5
CCI	0.599	0.055	0.095	0.491	0.707	2.5	96.7	20.3
1/ALB	0.647	0.055	0.013	0.539	0.755	0.0293	93.1	28.6
1/PCT	0.694	0.053	0.001	0.591	0.798	2.17	61.5	77.6

CCI, Charlson comorbidity index; ICU, intensive care unit; 1/ALB, 1/serum albumin level; 1/PCT, procalcitonin level

Table 4. Comparison of Infection Sites and Causative Microorganisms in Recurrent Sepsis Patients			
	Initial hospitalization of patients with recurrent sepsis	**Second or third hospitalization of patients with recurrent sepsis**	***P***
Number of patients, n	n=63	n=68	
Infection sites (%)			
Respiratory system	23 (36)	23 (34)	0.748
Urinary tract infection	22 (35)	27 (40)	0.572
Gastrointestinal system	5 (8)	3 (4)	0.400
Skin and soft tissue	10 (16)	11 (16)	0.962
Central nervous system	1 (2)	2 (3)	-
Multiple regions	2 (3)	2 (3)	-
Causative microorganisms in recurrent sepsis patients (%)			
Culture is negative	24 (38)	20 (29)	0.293
Gram-negative bacteria	22 (35)	26 (38)	0.694
Gram-positive bacteria	3 (5)	8 (12)	0.149
Polymicrobial	5 (8)	6 (9)	0.855
Fungus	9 (14)	8 (12)	0.668

Table 5. Similarity Rates of Infection Site and Causative Microorganism in Recurrent Sepsis Patients		
Microorganism reproduction	**Infection site**	
	Similar site infection (%)	**Infection of different regions (%)**
	n=38	**n=30**
Culture negative/reproduction	6 (8.8)	9 (13.2)
Reproduction/culture negative	4 (5.9)	8 (11.8)
Culture negative/culture negative	5 (7.3)	4 (5.9)
Reproduction/reproduction	23 (33.8)	9 (13.2)
Similar microorganism	4 (5.9)	2 (2.9)
Different microorganism	19 (27.9)	7 (10.3)

Discussion

While numerous studies have explored sepsis, there is a paucity of research focusing on mortality in the post-sepsis period. In the literature, patients who were followed for sepsis and discharged following recovery were evaluated, and one-third of them were readmitted to the hospital within the first 90-days after discharge. Sepsis is the most common cause of readmission.[8] This study investigated post-discharge outcomes among patients who survived sepsis, focusing on 90-day mortality and recurrent sepsis.

Recently, the sepsis survival campaign was established to reduce sepsis-related mortality, and efforts have been made to implement best practices for patient care. The long-term causes of death due to sepsis have been investigated and compared with those of individuals who do not have sepsis; as a result, mortality after sepsis is higher than that in those without sepsis.[9] The severity of the previous infection, the reaction of the immune system, the cytokine storm that occurs during sepsis, and the reprogramming of cells cause organ dysfunction. Many mechanisms persist after discharge from the hospital and are considered part of post-sepsis syndrome. The most important symptoms observed in post-sepsis syndrome are new or recurrent infections, cardiovascular diseases, changes in protein metabolism, inflammation, immune suppression, fluid accumulation, and cognitive changes. In a review by Gritte et al.[10] published in 2021, the mortality at 90-days after sepsis was between 27.5-41.3%. In Türkiye, 90-day mortality after sepsis was analyzed in 79 cases and was found to be 31.2%.[11] In this study, the 90-day post-discharge mortality rate was 32.8%, similar to that reported in other studies.

Many epidemiological studies investigating the causes of post-discharge mortality in patients with sepsis have observed that disease severity increases with age. Age and CCI were reported as important risk factors in a study conducted in France investigating the causes of one-year readmission and mortality of patients after sepsis.[12] Similarly, in this study, the mean age and CCI of patients who died 90-days after discharge were higher than those of survivors, which is consistent with other studies.

In a study by Gürsoy et al.[11] examining 90-day mortality after sepsis, the duration of ICU stay was higher in patients who died than in those who survived. In this study, similar to data from Türkiye, ICU length of stay was significantly greater in patients who died after discharge than in patients who ssurvived.

It has long been recognized that serum ALB albumin levels are associated with increased mortality in critically ill patients. Rabi et al.[13] demonstrated that low albumin levels were strongly associated with higher mortality rates in ICUs, with patients in the low-albumin group showing a general mortality of 71% compared to 52% in the higher-albumin group, and a 28-day mortality of 50% versus 39%. Similarly, Tie et al.[14] reported that persistently low albumin trajectories in sepsis patients were linked to the poorest outcomes, whereas patients with increasing albumin levels over time had markedly better prognoses. In contrast, stable high albumin levels (>30 g L^{-1}) were not associated with significant changes in mortality. Although hypoalbuminemia is linked to worse outcomes, evidence does not yet support routine therapeutic albumin infusion. A 2024 systematic review and meta-analysis concluded that human albumin administration did not significantly reduce overall, ICU, or 90-day mortality in patients with sepsis (pooled RR ~1.0). However, subgroup analysis suggested potential benefit in septic shock when using 20% albumin at higher doses, particularly compared to crystalloids (RR ≈ 0.89-0.90; P ≈ 0.03).[15] In our study, ALB also emerged as an independent predictor of 90-day post-sepsis mortality, which is consistent with recent evidence highlighting its prognostic importance in septic patients.

In our study, median PCT levels were significantly lower in non-survivors than in survivors, and the reciprocal of PCT (1/PCT) demonstrated the highest discriminative ability to predict 90-day post-sepsis mortality (AUC=0.694). In contrast to our findings, the majority of published studies have reported that elevated PCT levels are associated with worse outcomes in sepsis. In particular, persistently elevated or non-declining PCT levels have been associated with increased short-term mortality in patients with sepsis and septic shock.[16] Meta-analytic evidence indicates that failure to reduce PCT by at least 25% within the first days of therapy is associated with a threefold increase in mortality (pooled RR ~ 3.05; AUC ~ 0.79).[17] Conversely, some authors have proposed that low PCT concentrations in late or recurrent sepsis may reflect sepsis-induced immunosuppression, a state associated with higher long-term mortality.[18] Our findings support this hypothesis, suggesting that low PCT in post-sepsis patients may indicate impaired host immune responses rather than low infection severity. Although the univariate analysis in our study supported the latter hypothesis, the association between low PCT and 90-day mortality did not remain statistically significant in multivariate analysis, indicating that the prognostic value of low PCT may be confounded by factors such as comorbidity burden and nutritional status. Therefore, while biologically plausible, low PCT should not yet be considered an independent long-term mortality predictor, and further prospective studies are warranted to clarify its role.

A notable observation was that the seventh-day microbiological response was significantly lower in deceased patients, indicating that persistent or inadequately treated infection may contribute to adverse outcomes. This finding is supported by previous research highlighting the importance of early and effective source control in reducing sepsis-related mortality.[19] Inadequate microbiological clearance may not only reflect treatment failure but may also predispose patients to recurrent infections and sepsis relapse.

While total hospital length of stay did not differ significantly between groups, ICU stay was longer among patients who died. This may reflect greater initial illness severity, prolonged organ support, or increased risk of nosocomial complications. However, severity scores at admission, such as APACHE II, SOFA, and GCS, were not significantly associated with post-discharge mortality, suggesting that in-hospital physiological instability may not fully capture the long-term vulnerability of sepsis survivors.

It is not always possible to differentiate between infectious and non-infectious causes in patients readmitted after sepsis. Studies on this subject are limited. DeMerle et al.[20] in a study of patients with sepsis who were followed up and readmitted within 90-days after discharge, the source of infection was similar in 68.6% of 137 patients with recurrent sepsis, the sites of infection were different in 31% and the focus of infection could not be identified in 12%. In a different study conducted by Arshad et al.[21] in which readmitted patients were examined within 180 days after discharge, recurrent sepsis was detected in 53 patients, with 58% having similar sites of infection and 42% having different sites of infection. Five patients included in this study presented with sepsis or septic shock on three occasions within 270 days, and 68 consecutive episodes of sepsis were recorded. The site of infection was the same in 55.9% of patients, whereas 44.1% had infections at different sites.

In studies examining 90-day post-discharge sepsis-related hospitalizations, the initial hospitalizations and post-discharge readmissions of patients were compared, and similar site infections and similar microorganisms were observed in 19% (1), 22.6%[22] of patients, respectively, while in a different study examining 180-day post-discharge readmissions, it was shown to be 21%[21] and in this study it was found to be 5.9%. These findings suggest that recurrent sepsis is not merely a continuation of the initial infection but may represent a new infectious insult in a host with persistent immunologic dysfunction.

Study Limitations

This study has several limitations. First, it was conducted in a single tertiary care center and had a retrospective design, which may restrict the generalizability of the findings and introduce the risk of missing data or unmeasured confounders. Second, because a high proportion of sepsis cases were culture-negative, pathogen-specific comparisons in recurrent episodes were limited. Third, long-term

functional outcomes and quality-of-life measures were not assessed, leaving important aspects of post-sepsis recovery unaddressed. Finally, immunological and inflammatory biomarkers were not evaluated; assessing them could have provided deeper insights into the mechanisms underlying recurrent sepsis and post-sepsis mortality.

Conclusions

This study demonstrates that advanced age, a higher CCI, a prolonged ICU stay, hypoalbuminemia, unexpectedly low PCT levels, and an inadequate microbiological response are significant predictors of 90-day post-discharge mortality in sepsis survivors. More than half of the patients with recurrent sepsis experienced infections at the same anatomical site. Although microbial concordance was observed in only a small proportion of cases, the low rate of positive cultures raises the possibility that some of these episodes may nevertheless represent relapses caused by similar pathogens that were not detected by microbiological methods. This pattern may reflect both persistent immunosuppression and limitations of culture-based diagnostics in the post-sepsis setting. These findings highlight the need for structured, multidisciplinary post-discharge follow-up, early infection detection, prompt and effective source control, and targeted interventions for high-risk individuals. Further prospective studies integrating advanced microbiological and molecular techniques are warranted to better characterize pathogen recurrence and to develop preventive strategies that reduce both recurrence and long-term mortality.

Ethics

Ethics Committee Approval: Ethics approval for this study was obtained from University of Health Sciences Türkiye, Kayseri City Training and Research Hospital (approval no: 67, date: 24.11.2022).

Informed Consent: Because the study was designed retrospectively no written informed consent form was obtained from the patients.

Footnotes

Authorship Contributions: Surgical and Medical Practices - E.A.F.; Concept - E.A.F.; Design - E.A.F., İ.Ç.; Data Collection and/or/Processing - E.A.F., İ.Ç.; Analysis and/or/ Interpretation - E.A.F.; Literature Review - E.A.F., İ.Ç.; Writing - E.A.F., İ.Ç.

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Gender Representation at Turkish Anaesthesiology and Reanimation Congresses: Trends in Speakers, Session Chairs, and Society Leadership from 2015 to 2024

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Abstract

Objective: This study evaluated gender representation among speakers, session chairs, and society leadership roles at the Turkish Society of Anaesthesiology and Reanimation (TARK) Congresses between 2015 and 2024, focusing on temporal patterns and subspecialty-based variation.

Methods: This retrospective observational analysis of conference sessions included all scientific sessions listed in official TARK congress programmes from 2015 to 2024. Names, roles, and session topics were extracted from publicly available documents. In the absence of self-identified gender data, participants were categorised as women or men using names, academic titles, congress documents, and publicly accessible institutional or professional information, when clarification was required. Gender proportions were compared using chi-square tests. Temporal patterns were evaluated using logistic regression analyses, and subspecialty-specific analyses were performed using intensive care as the reference category. The leadership composition of the society was evaluated descriptively.

Results: A total of 2,627 congress roles were analysed, including 966 session chairs and 1,661 speakers. Women accounted for 50.3% of session chairs and 50.8% of speakers, with no statistically significant temporal change during the study period. Marked variation was observed across subspecialties. Women were least represented in intensive care sessions (30.9%) and most represented in obstetric and paediatric anaesthesia sessions (82.1%), reflecting a higher relative representation of women speakers in the latter than in intensive care. Leadership composition varied across terms, with no persistent predominance of either gender according to the descriptive assessment.

Conclusion: Gender representation at TARK congresses remained numerically balanced over the ten-year study period; however, the absence of a significant temporal increase and the presence of persistent subspecialty clustering suggest a stable but uneven distribution across academic areas.

Keywords: Anaesthesiology congresses, gender representation, invited speakers, session chairs, women in anaesthesiology

Main Points

- Women accounted for approximately half of both speaker and session-chair roles at Turkish Society of Anaesthesiology and Reanimation Congresses between 2015 and 2024, with no significant temporal change in proportional representation.
- Gender representation varied markedly across subspecialties, with women representing 30.9% of speakers in intensive care and 82.1% in obstetric and paediatric anaesthesia.
- Compared with intensive care, women had substantially higher relative representation in obstetric/paediatric anaesthesia, neuroanaesthesia, and cardiothoracic anaesthesia.
- Overall numerical balance should not be interpreted as definitive evidence of equitable opportunity because year-matched workforce and society-membership denominators were unavailable.

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Introduction

Scientific meetings play a pivotal role in academic visibility, professional networking, and career advancement. Roles such as chairing sessions and giving invited talks are visible markers of academic recognition and may contribute to professional networking, academic visibility, and leadership trajectories. Beyond conferences, academic visibility and gender representation have also been examined using archival approaches in other scholarly contexts, such as authorship and editorial board composition in medical journals. For women academics in particular, visibility on scientific platforms represents an important component of professional development and sustained academic engagement. Nevertheless, accumulating evidence indicates that gender inequities persist in academic medicine and that these disparities are reflected in representation patterns at scientific conferences.[1,2]

Despite the increasing proportion of women physicians in anaesthesiology, their representation as speakers and session chairs at scientific congresses has not consistently mirrored this growth. At the annual meetings of the American Society of Anesthesiologists (ASA), women have constituted only 22-25% of invited speakers, and additional imbalances have been reported in session chair roles.[3] Similarly, analyses of the Canadian Anesthesiologists' Society (CAS) meetings have shown that women accounted for merely 28.5% of invited speakers, with nearly half of sessions composed exclusively of men.[4] These disparities appear even more pronounced across subspecialties. For example, women's representation in cardiovascular anaesthesia sessions has been reported as low as 5% at certain meetings.[5]

Data from Asia reflect comparable trends. At the annual meetings of the Japanese Society of Anesthesiologists (JSA), women constituted only 17.9% of the speakers, despite representing approximately 40% of society members.[6] Moreover, the finding that 44% of sessions consisted entirely of male speakers suggests gender-related barriers to accessing academic leadership and highlights potential structural imbalances in invitation and selection processes.

Programme committees, society leadership, and session coordinators play a critical role in constructing conference programmes. Prior studies have shown that sessions coordinated or chaired by women have significantly higher proportions of women speakers.[7] This observation underscores the potential influence of gender diversity in programme coordination and session leadership on scientific visibility and representation patterns, and highlights the importance of inclusive approaches in congress programme planning.

In Türkiye, the Turkish Society of Anaesthesiology and Reanimation (TARK) Congress is one of the largest national scientific meetings in anaesthesiology and an important indicator of academic representation at the national level. However, to date, no study has systematically examined the long-term distribution of women and men among speakers and session chairs at TARK meetings. Given the steadily increasing proportion of women physicians in Türkiye, evaluating how women's visibility is reflected in national scientific platforms is highly relevant to understanding patterns of academic representation and professional visibility.

Accordingly, this study aimed to examine gender representation among speakers and session chairs at the TARK congresses held between 2015 and 2024, with attention to session types, subspecialty areas, and society leadership structures. In addition to descriptive analyses, temporal patterns and subspecialty-based variation were analysed. In this respect, the present study constitutes one of the few long-term, data-driven analyses addressing representation patterns across speaking, chairing, and leadership roles in anaesthesiology congresses in Türkiye.

Methods

Ethics Statement

Ethical approval for this study was obtained from the Non-Interventional Research Ethics Committee of the University of Health Sciences Türkiye, Elazığ Fethi Sekin City Hospital (approval no: 2026/25-10, date: 05.03.2026). The study was conducted using publicly available congress programme data and did not involve patient records, clinical interventions, private personal health information, or direct contact with individuals. All analyses were performed at the aggregate level, and no individual-level judgements or evaluations were made.

Study Design and Data Sources

This retrospective observational study evaluated the gender distribution of speakers and session chairs at national congresses organised by the TARK. The analysis covered congress programmes held between 2015 and 2024.

All scientific sessions, panels, and lectures listed in the official annual TARK congress programmes during the study period were included. Non-scientific events, social programme activities, opening and closing ceremonies without scientific presentations, industry-sponsored promotional sessions without identifiable academic speakers, and entries with insufficient role information were excluded from the analysis. Multiple appearances by the same individual in different roles or sessions were counted as separate congress roles because the unit of analysis was role-based representation, not unique individuals. Data were extracted from publicly available official congress programme documents. For each congress year, the following

information was collected: the names of session chairs and speakers; session titles; presentation types; and the names of the TARK president and members of the organising committee. Programme documents were converted from PDF format to a standardised data-extraction form, and all entries were independently verified by a second investigator to ensure accuracy.

Gender Classification and Subspecialty Grouping

In the absence of self-identified gender data in the congress programmes, participants were categorised as women or men using a structured, multi-step verification procedure. First, the participant names and academic titles listed in the official congress programmes were reviewed. For gender-neutral, uncommon, abbreviated, or otherwise uncertain names, the original congress PDF files were re-examined, and publicly accessible online sources were reviewed when available. These sources included institutional webpages, professional profiles, and publicly available photographs or biographical information. The final classification was made after cross-checking the sources and reaching agreement among the investigators.

This procedure was used only for aggregate-level analysis of gender representation and was not intended to define individual gender identity. Because self-identified gender information was not available, gender was analysed using a binary women/men framework, consistent with previous retrospective analyses of conference programmes. The potential for misclassification, particularly for gender-neutral names and participants with limited publicly available information, was considered a methodological limitation.

Sessions were grouped into major subspecialties based on session titles. When a session covered more than one topic, classification was based on the primary session theme. Subspecialty classifications were also reviewed for consistency, and uncertain classifications were resolved by consensus.

Study Variables and Analytical Objectives

The primary study variables were congress year, participant role, gender category, session type, and subspecialty area. The primary outcomes were the annual proportions of women and men serving as session chairs and speakers at TARK congresses between 2015 and 2024. Secondary outcomes included temporal trends in gender representation, subspecialty-based variation among speakers, and the gender composition of TARK leadership, including society presidents and organising committee members.

Because the study used retrospective congress programme data, the analyses were designed to describe and compare representation patterns rather than test causal hypotheses. The analytical objectives were: (i) to determine the overall distribution of women and men among session chairs and speakers, (ii) to evaluate whether gender representation changed over the ten-year study period, (iii) to examine whether speaker representation differed across anaesthesiology subspecialties, and (iv) to describe the gender composition of society leadership during the corresponding period. Leadership data were analysed descriptively and not used to infer a causal relationship between leadership composition and the selection of speakers or session chairs.

Statistical Analysis

Statistical analyses were performed using SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA) and R version 4.3.1. Categorical variables were summarised as counts (n) and percentages (%). Comparisons of women's and men's representation in session chair and speaker roles were conducted using Pearson's chi-square test when expected cell frequencies were adequate; when expected cell frequencies were low, Fisher's exact test was applied.

To assess temporal patterns in gender representation, logistic regression analyses were performed separately for session chairs, speakers, and all congress roles combined, with congress year entered as a continuous covariate and gender category (women vs. men) as the dependent variable. These models were used to evaluate whether the proportion of women changed over time, rather than to infer causal relationships or individual-level probabilities.

Subspecialty-specific logistic regression analyses were also performed to compare gender representation across subspecialties, with intensive care sessions as the reference category. Odds ratios (ORs) with 95% confidence intervals (CIs) were reported as measures of relative representation within the analysed congress roles.

All statistical tests were two-sided, and a P value <0.05 was considered statistically significant.

Results

A total of 2,627 congress roles were analysed across TARK congresses held between 2015 and 2024, including 966 session chair roles and 1,661 speaker roles. Because the analysis was role-based, individuals who appeared in more than one session or role during the study period were counted separately for each congress role. The proportions of women and men were similar in both roles. Women accounted for 50.3% of session chairs (486/966), while men accounted for 49.7% (480/966). Similarly, among speakers, women represented 50.8% (843/1,661) and men 49.2% (818/1,661) of all roles (Table 1).

Figure 1 illustrates the annual distribution of women and men among session chairs and speakers. Across the study period, women's representation fluctuated between approximately 30% and 60% in both roles, without a

Table 1. Overall Distribution of Women and Men Among Session Chairs and Speakers

Role	Total n	Women (%)	Men (%)	*P* value
Speakers	1661	843 (50.75%)	818 (49.24%)	0.54
Session chairs	966	486 (50.31%)	480 (49.68%)	0.83

Pearson's chi-square test was used for group comparisons; $P<0.05$ was considered statistically significant

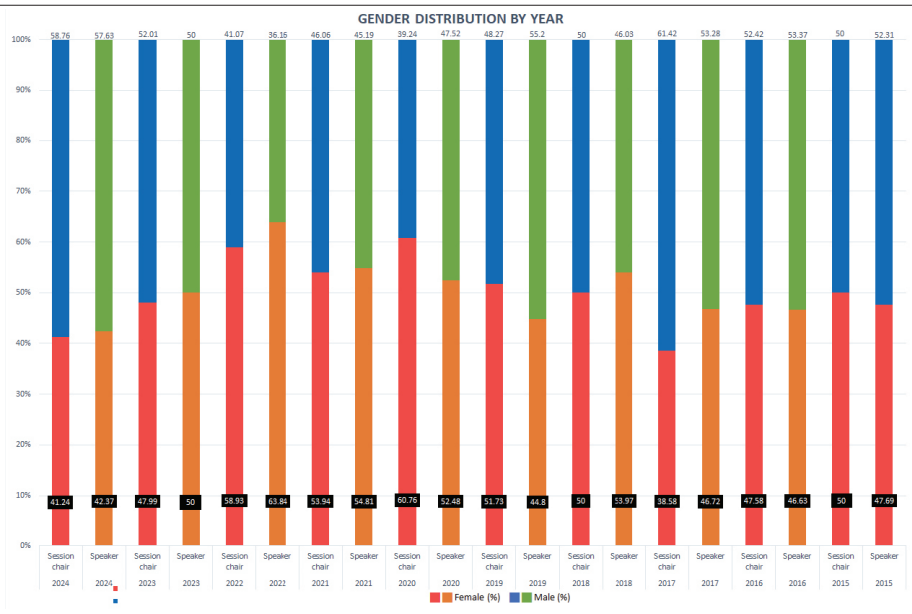

Figure 1. Annual distribution of women and men among session chairs and speakers at TARK Congresses (2015-2024). Bar charts present the annual proportions and absolute numbers of women and men serving as session chairs and speakers across TARK congresses between 2015 and 2024. The figure demonstrates year-to-year fluctuation without a consistent temporal increase or decrease in women's proportional representation.

TARK, Turkish Society of Anaesthesiology and Reanimation.

consistent upward or downward pattern. This descriptive pattern was consistent with the logistic regression results, which showed no statistically significant temporal change in women's proportional representation.

Logistic regression analysis was performed to evaluate changes over time in women's proportional representation (Table 2). For each one-year increase, the proportion of women did not change significantly. The OR was 1.01 for session chairs (95% CI: 0.96-1.05; $P=0.71$), 1.02 for speakers (95% CI: 0.99-1.06; $P=0.17$), and 1.01 when all roles were analysed together (95% CI: 0.98-1.04; $P=0.51$). These findings indicate that women's representation did not show a statistically significant change over the study period.

Within-subspecialty analyses revealed variation in the distribution of women and men speakers (Table 3). In intensive care sessions, the proportion of male speakers was markedly higher, at 69.0%. In contrast, women represented 82.1% of speakers in obstetric and paediatric anaesthesia sessions, 62.5% in neuroanaesthesia, and 55.6% in cardiothoracic anaesthesia. Within-category comparisons revealed statistically significant gender differences across intensive care, neuroanaesthesia, and obstetric and paediatric anaesthesia sessions (Table 3).

In subspecialty-specific logistic regression analyses comparing women's representation among speakers across subspecialties (Table 4), intensive care was used as the reference category. The highest proportional representation of women speakers was observed in obstetric/paediatric anaesthesia sessions (OR: 10.24; 95% CI: 5.09-20.60; $P<0.001$). Neuroanaesthesia (OR: 3.72; $P<0.01$) and cardiothoracic anaesthesia (OR: 2.79; $P<0.01$) were also associated with a significantly higher relative representation of women speakers compared with intensive care. Women's representation among speakers was also higher in pain medicine and regional anaesthesia sessions than in intensive care sessions, although the magnitude of these differences was smaller than that observed for obstetric/paediatric anaesthesia, neuroanaesthesia, and cardiothoracic anaesthesia.

Table 2. Temporal Change in Women's Representation in TARK Congress Roles (2015-2024), Logistic Regression Analysis

Role	OR	95% CI	*P* value
Speakers	1.02	0.99-1.06	0.17
Session chairs	1.01	0.96-1.05	0.71
All roles	1.01	0.98-1.04	0.51

Each row presents the estimated OR for a one-year increase in the year variable, along with the 95% CI and *P* value

OR, odds ratio; CI, confidence interval; TARK, Turkish Society of Anaesthesiology and Reanimation

Leadership data from the TARK for the period 2014-2025 were evaluated descriptively (Table 5). The gender composition of society presidents and executive board members varied across terms, with some periods showing greater representation of women and others greater representation of men in specific roles. Because these data were summarised at the term level and not linked to individual speaker- or session-chair selection decisions, no causal or directional inferences were made regarding the relationship between leadership composition and congress-role allocation.

Table 3. Distribution of Women and Men Speakers Within Anaesthesiology Subspecialties

Subspecialty	Total speakers n	Women speakers n (%)	Men speakers n (%)	*P* value
Intensive care	84	26 (30.95%)	58 (69.04%)	<0.001
Pain	106	48 (45.28%)	58 (54.71%)	0.33
Regional anaesthesia	80	38 (47.5%)	42 (52.5%)	0.65
Neuroanaesthesia	64	40 (62.5%)	24 (37.5%)	0.046
Cardiothoracic anaesthesia	81	45 (55.5%)	36 (44.4%)	0.32
Obstetric and paediatric anaesthesia	95	78 (82.1%)	17 (17.89%)	<0.001

Percentages indicate the distribution of women and men speakers within each subspecialty. *P* values indicate within-category comparisons of women and men speaker counts. A *P* value <0.05 was considered statistically significant

Table 4. Relative Representation of Women Speakers by Subspecialty (Logistic Regression Analysis)

Subspecialty	Total speakers n	Women speakers n (%)	Men speakers n (%)	OR	95% CI	*P* value
Intensive care	84	26 (30.95%)	58 (69.05%)	1 (ref.)	–	–
Pain	106	48 (45.28%)	58 (54.72%)	1.85	1.01-3.36	0.045
Regional anaesthesia	80	38 (47.50%)	42 (52.50%)	2.02	1.07-3.82	0.031
Neuroanaesthesia	64	40 (62.50%)	24 (37.50%)	3.72	1.87-7.38	<0.001
Cardiothoracic anaesthesia	81	45 (55.56%)	36 (44.44%)	2.79	1.47-5.27	0.002
Obstetric and paediatric anaesthesia	95	78 (82.11%)	17 (17.89%)	10.24	5.09-20.60	<0.001

ORs represent the relative representation of women speakers compared with intensive care sessions as the reference category. CI (95% CI) and *P* values are reported from the logistic regression model

OR, odds ratio; CI, confidence interval

Table 5. Descriptive Gender Distribution of Society Leadership Roles in the Turkish Society of Anaesthesiology and Reanimation (2014-2025)

Term	President n (W/M)	Secretary general n (W/M)	Treasurer n (W/M)	Board member n (W/M)
12.03.2023-23.02.2025	1/1	1/0	0/1	2/3
21.03.2021-12.03.2023	1/1	1/0	1/0	3/2
25.03.2018-21.03.2021	1/1	1/0	0/1	4/1
27.03.2016-25.03.2018	1/1	0/1	1/0	1/4
16.03.2014-27.03.2016	3/0	0/1	0/1	0/4

For each term, the number of women and men serving in listed leadership roles is presented descriptively. These data were not linked to individual speaker or session chair allocation decisions and were not used for causal inference. Categorisation was based on the same gender-classification procedure used for congress roles

W, women; M, men

Discussion

This study demonstrates that gender representation among session chairs and speakers at TARK congresses between 2015 and 2024 was numerically balanced overall; however, no significant improvement in women's proportional representation was observed over the study period. Similarly, gender representation has been evaluated through other indicators of academic visibility, including publication output and editorial leadership, thereby highlighting the broader relevance of representation beyond clinical performance. Across the ten-year period, women accounted for approximately 50% of both the 966 session chair roles and the 1,661 speaker roles. Subspecialty-level analyses revealed a higher proportion of men in intensive care sessions, whereas women were more frequently represented in obstetric/paediatric anaesthesia and neuroanaesthesia. The descriptive assessment of society's leadership showed variation across terms without a persistent predominance of either gender.

Interpretation of these congress-level findings requires consideration of the relevant reference population. Ideally, the proportions of women and men in roles at congresses should be compared with the gender distribution of registered society members or practising anaesthesiologists in Türkiye during the corresponding years. However, such year-matched and role-specific denominator data were not available for the present analysis. The only available national reference identified in the literature was derived from anaesthesiology and reanimation specialists working in educational institutions in Türkiye, among whom women constituted 57.7% of physicians. Therefore, an approximately 50% representation observed among TARK speakers and session chairs should be interpreted as numerical balance within congress roles, but not as definitive evidence of equitable opportunity relative to the broader workforce.[8]

The lack of a clear upward trend in the proportion of women serving as speakers or session chairs at TARK congresses over a decade suggests structural stability rather than progressive change, despite numerical parity. This pattern may be related to the recurrent use of established academic networks, invitation practices, and organisational routines carried over from previous years. In addition, subspecialty clustering, in which women concentrate in certain fields while remaining underrepresented in others, may partially explain why overall proportions remain stable despite balanced totals. These findings indicate that numerical equality alone does not necessarily translate into dynamic improvements and underscore the importance of addressing not only aggregate ratios but also distributional patterns and continuity in congressional representation.

Importantly, the absence of a significant temporal increase should not be interpreted as indicating a lack of informative findings. The main contribution of this study is the identification of a distinct national pattern in which overall numerical balance coexists with persistent subspecialty-based clustering. This finding adds context to the international literature, where the underrepresentation of women among invited speakers has commonly been reported, and suggests that aggregate parity alone may obscure uneven distribution across academic domains.

Compared with international literature, the findings of this study reveal a noteworthy contrast. Numerous studies across disciplines and countries have reported persistent underrepresentation of women among conference speakers, with some meetings showing a marked predominance of male speakers.[9-11] Such patterns have been observed even in specialties where women constitute a numerical majority, suggesting an association with broader structural gender inequities.[12] The findings demonstrated near parity between women and men across congress roles, while also revealing clear subspecialty-based clustering.

In Canada, retrospective analyses have shown persistent underrepresentation of women speakers at anaesthesiology conferences, with many sessions continuing to feature exclusively male speakers.[4] Similar concerns regarding reduced academic visibility and unequal representation have been reported across multiple specialties and conference settings.[11,13] In this context, the numerical balance observed at TARK congresses appears more favourable than the underrepresentation reported in several international studies. Nevertheless, the absence of a significant temporal increase in women's proportional representation suggests that this balance may reflect a stable, rather than progressively improving, structure.

Data from meetings of the ASA, the CAS, and the Society of Cardiovascular Anesthesiologists (SCA) consistently indicate insufficient representation of women among invited speakers.[3,4,14] The notably low proportion of women speakers reported at JSA meetings (17.9%)-lower than those reported for ASA, CAS, and SCA-highlights geographic variability in gender underrepresentation.[6] Conversely, some conferences have reported a higher-than-expected representation of women in specific fields, such as cardiothoracic anaesthesia.[15] The subspecialty-based findings require cautious interpretation. The lower proportion of women speakers in intensive care sessions and the higher proportion observed in obstetric/paediatric anaesthesia and neuroanaesthesia sessions may reflect an unequal distribution of academic visibility across subspecialty domains rather than a simple overall gender imbalance. However, these differences cannot be interpreted as direct evidence of discrimination or intentional exclusion. Several factors may contribute to such

clustering, including subspecialty workforce composition, clinical workload patterns, mentorship opportunities, academic networks, prior visibility in specific fields, and sociocultural expectations influencing career pathways. Because the present study did not include individual-level data on subspecialty membership, academic rank, workload, family responsibilities, or invitation processes, the mechanisms underlying these patterns could not be directly examined. Therefore, the observed subspecialty variation should be interpreted as a signal for further monitoring and targeted evaluation rather than as a causal explanation of gender-based opportunity differences.

The gender composition of scientific programme committees, session chairs, and organising boards has been identified as an important determinant of speaker representation. Prior studies have shown that the presence of at least one woman serving as a session chair or coordinator increases the likelihood that women will be invited as speakers.[7] Similarly, other reports indicate that inclusion of women in programme leadership roles is associated with greater representation of women speakers.[16-18] TARK leadership composition between 2014 and 2025 was evaluated descriptively and found to vary across terms, with no persistent predominance of either gender. Although previous studies have suggested that gender diversity among programme leaders or session coordinators may be associated with higher representation of women speakers, the present dataset did not allow direct testing of this relationship at the level of individual invitation or allocation decisions. Therefore, leadership findings should be interpreted as contextual, descriptive information rather than as evidence of a causal association with speaker or session chair representation.

Women's representation in medicine often declines at higher academic and leadership levels.[19] Because invited lectureships and moderator roles may contribute to academic visibility, disparities at scientific meetings can have implications for long-term academic advancement.[20] Previous studies from Canada and the United States have demonstrated persistent underrepresentation of women in anaesthesiology authorship, editorial boards, society leadership, and advanced academic ranks, suggesting the presence of broader structural barriers within academic medicine.[21-25]

Previous studies have also shown that although women may outnumber men in academic anaesthesiology positions, men continue to dominate departmental leadership roles, and women experience slower promotion rates and lower publication output.[8] These disparities have been attributed to factors such as disproportionate family and cultural responsibilities, long working hours, limited mentorship, and gender-based bias. Additionally, women have been reported to be less frequently nominated as speakers than their male counterparts.[26] The balanced representation observed at TARK congresses may reflect the relatively high proportion of women anaesthesiologists and their strong representation in academic anaesthesiology in Türkiye, making these congresses comparatively balanced in numerical gender representation at the national level.

From a practical perspective, these findings may inform future scientific programme planning. The scientific committee and the executive board may consider monitoring gender representation across congress roles, subspecialty areas, and high-visibility sessions annually. Transparent criteria for speaker and session-chair invitations, broader nomination pools, and attention to subspecialty-specific imbalances may help maintain balanced representation and avoid concentration in particular academic areas. In addition, encouraging the participation of early-career anaesthesiologists and ensuring diversity among programme committees may support more inclusive and sustainable academic visibility at future congresses.

An overall gender balance among session chairs and speakers at TARK congresses over a ten-year period represents a notable departure from the underrepresentation of women commonly reported in the international literature. Nevertheless, pronounced subspecialty clustering and persistent gender disparities in academic leadership at both national and international levels indicate that representation patterns remain uneven across subspecialties and academic leadership domains. Maintaining visibility across gender groups, preserving balanced representation within scientific and organising committees, and supporting early-career anaesthesiologists across subspecialties may contribute to more inclusive academic visibility at future congresses.

Study Limitations

This study has several limitations that should be acknowledged. First, the analysis was restricted to national TARK congresses and did not include other national or international anaesthesiology meetings; therefore, the findings may not be generalisable to all scientific meeting settings.

Second, self-identified gender information was not available in the congress programmes. Consequently, gender classification was performed using names, academic titles, congress documents, and publicly accessible institutional or professional information when clarification was required. Although a structured verification process was applied, the possibility of misclassification bias—particularly for gender-neutral names, international participants, or individuals with limited publicly available information—cannot be completely excluded. Gender representation was analysed within a binary women/men framework; non-binary gender identities could not be evaluated.

Third, year-matched denominator data for all practising anaesthesiologists or registered society members in Türkiye were not available. Therefore, the study could not determine whether congress representation was proportional to the eligible workforce across years, academic ranks, or subspecialties; the observed representation ratios should be interpreted cautiously.

Fourth, detailed participant-level information, including academic rank, institutional affiliation, years of experience, subspecialty workforce composition, workload characteristics, mentorship exposure, and invitation processes was not available. Accordingly, the study could not directly evaluate the mechanisms underlying subspecialty clustering patterns or representation differences.

Finally, because of the study's retrospective and descriptive design, the findings should not be interpreted as evidence of causal relationships between leadership composition, congress organisation, and speaker or session chair representation.

Conclusion

Gender representation among speakers and session chairs at the TARK congresses between 2015 and 2024 was numerically balanced overall, differing from the marked underrepresentation of women reported in many international anaesthesiology meetings. However, the absence of significant temporal improvement and the persistence of subspecialty-based clustering suggest that balanced overall representation does not necessarily indicate uniform distribution across all academic areas.

Because denominator data for the broader anaesthesiology workforce were unavailable, the findings should be interpreted as congress-level patterns of representation rather than as definitive evidence of equity of opportunity. Continued monitoring of representation trends, attention to subspecialty-specific imbalances, and inclusive scientific programme planning may support balanced academic visibility at future congresses.

Ethics

Ethics Committee Approval: Ethical approval for this study was obtained from the Non-Interventional Research Ethics Committee of the University of Health Sciences Türkiye, Elazığ Fethi Sekin City Hospital (approval no: 2026/25-10, date: 05.03.2026).

Informed Consent: Owing to the retrospective design, the requirement for written informed consent was waived.

Footnotes

Authorship Contributions: Concept - S.F.Ö., S.Ş.K.; Design - S.F.Ö., S.Ş.K.; Data Collection and/or/Processing - S.F.Ö., S.Ş.K.; Analysis and/or/Interpretation - S.F.Ö., S.Ş.K.; Literature Review - S.F.Ö.; Writing - S.F.Ö., S.Ş.K.

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Relationship of Ultrasonically Assessed Diaphragmatic Weakness with the Need for Postoperative Mechanical Ventilation in Older Adult Patients after Major Abdominal Surgeries: An Observational Study

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Abstract

Objective: This study aimed to analyze the association between preoperative diaphragmatic weakness in older adult patients and the need for postoperative mechanical ventilation after major surgery. We hypothesized that preoperative diaphragmatic weakness would significantly increase the need for postoperative mechanical ventilation.

Methods: It was a single-center, prospective, observational study that included 90 older adult patients aged more than 50 years who underwent abdominal surgery under general anaesthesia. A portable ultrasound was used to assess the percentage increase in the diaphragm thickening fraction (TFdi) during a maximal inspiratory effort, preoperatively and before extubation. The perioperative change in diaphragmatic function, the development of outcomes, i.e., extubation/mechanical ventilation, and the optimal cut-off of TFdi to predict outcomes were analyzed.

Results: The patients with a preoperative TFdi <35% had a higher requirement for mechanical ventilation (24.5% or 1:3) as compared to those with TFdi ≥35% (7.3% or 1:13). In multivariate linear regression analysis, TFdi (preoperative) was the only independent predictor of TFdi (before extubation), explaining a substantial proportion of the variance (adjusted R^2=0.71). The optimal cut-off value of TFdi (preoperative) ≤28.9 predicted intensive care unit stay with 73% sensitivity and 73% specificity, and a high negative predictive value (93.2%).

Conclusion: Our study found that a significant percentage of older adult patients had a preexisting diaphragmatic weakness that was associated with extubation failure and the need for postoperative mechanical ventilation.

Keywords: Assessment, diaphragm, general anaesthesia, older adult, postoperative complications, ultrasonography

Main Points

- Approximately half of the geriatric patients posted for major surgeries had diaphragmatic weakness before surgery.
- There was a statistically significant high association between preoperative and postoperative diaphragmatic weakness.
- The patients with poor diaphragm function in the preoperative period had a larger proportion of patients with higher requirement for mechanical ventilation.
- The preoperative ultrasound based diaphragm assessment was able to predict the need for postoperative mechanical ventilation with a high negative predictive value.

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Introduction

Primary sarcopenia is an age-related reduction in muscle mass.[1] If respiratory muscles, along with skeletal muscles, are involved, it is referred to as respiratory sarcopenia. Since it is a common finding in the older-adult population, it has been named "presbypnea," in which the prefix "presby-" means older adult and the suffix "-pnea" refers to respiration.[2] A reduction in transdiaphragmatic pressure of 20-41% and an overall reduction in respiratory muscle strength of 30% with age have been observed.[3] Factors that contribute to the pathology of diaphragmatic muscle weakness include undernutrition, cachexia, aspiration pneumonia, and chronic obstructive pulmonary disease (COPD).[4]

Studies have shown that, in critically ill patients, the diaphragm can be significantly weakened postoperatively because it is fatigued during invasive mechanical ventilation.[5] A systematic review by Powers et al.[6] in 2010 concluded that as little as 18 hours of mechanical ventilation can cause significant diaphragmatic atrophy. A fatigued diaphragm is associated with difficulty with extubation, weaning failure, increased risk of readmission, and increased 1-year post-surgery mortality.[7,8] Since diaphragmatic weakness can be a significant factor determining postoperative outcomes in elderly patients, it should be assessed using reliable methods to improve postoperative outcomes and to provide rehabilitation when necessary.

Ultrasound assessment of the diaphragm is a feasible modality due to the widespread availability of portable ultrasound. Various ultrasound-based approaches are available for diaphragmatic assessment. In the ABC Diaphragmatic Evaluation (ABCDE) approach, the percentage change in diaphragm thickness reflects the degree of effort exerted by the muscle. In normal individuals, the change ranges from 28-96%; in individuals with diaphragmatic paralysis, it ranges from 5-35%.[9] The ABCDE approach is a relatively new, less observer-dependent, and easy-to-perform method that allows more straight forward quantification of diaphragmatic weakness.

Despite a thorough literature search, we were unable to identify any study in which diaphragm function was assessed before surgery in older adult patients. This study aimed to analyze the association between diaphragmatic weakness in older adult patients scheduled for abdominal surgeries under general anaesthesia and the need for postoperative mechanical ventilation. We hypothesized that preoperative diaphragmatic weakness would significantly increase the need for postoperative mechanical ventilation.

Methods

Study Participants

This study is a prospective observational study. It was conducted after receiving approval from the Ethics Committee of the All India Institute of Medical Sciences in Rishikesh, India (approval no: AIIMS/EC/23/501, date: 08.12.2023). The study is registered in the Indian Clinical Trials Registry (CTRI/2025/05/087124). For this study, we followed the Helsinki Declaration of 1964, updated in 2013. The study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines. The inclusion criteria for our study were patients aged more than 50 years, of any sex, classified as American Society of Anesthesia (ASA) class I to III, and undergoing abdominal surgery under general anaesthesia. The exclusion criteria were refusal to consent for the procedure, patients with injury to chest or diaphragm or surgery of chest/diaphragm, severely compromised lung function i.e., severe COPD (GOLD class 3, 4), moderate to severe pulmonary arterial hypertension, acute respiratory distress syndrome with PaO_2/FiO_2 <150, any known cardiac disease (ischemic heart disease, valvular heart disease, congestive heart failure), altered Glasgow Coma Scale, already on mechanical ventilation, home oxygenation/ non-invasive ventilation and those in shock mean arterial pressure (MAP)<60 mm of Hg or requiring inotropes to maintain MAP>65 mm of Hg.

Diaphragm Assessment

The study protocol was explained to the patients. Written consent was obtained from those willing to participate in our study. After confirming adequacy of nil per oral status, patients were taken into the preoperative room; routine monitors [i.e., pulse oximeter, electrocardiogram (ECG), and non-invasive blood pressure (NIBP)] were attached, and the Mini Nutritional Assessment (MNA) score was calculated. Diaphragm function was assessed using the portable ultrasound machine (SonoSite Edge II Ultrasound System, Fujifilm inc.). Ultrasound was used to assess the percentage increase in diaphragm thickening fraction (TFdi) during a maximal inspiratory effort using the ABCDE approach.[9] In this approach, the patient is positioned supine. A linear high-frequency (5-13 MHz) ultrasound probe was used with a portable ultrasound machine (SonoSite Edge II Ultrasound System, Fujifilm inc.). The linear probe was placed on the anterior axillary line at the level of the nipple, first on the patient's right side. The probe slid downward until the diaphragm was visible during both inspiration and expiration. The change in diaphragm thickness was assessed during maximal inspiratory effort in a spontaneously breathing patient. As the diaphragm contracted during inspiration, diaphragm thickness increased. That was assessed in M-mode ultrasound and expressed as the percentage increase in thickness (TFdi). If the change in thickness was >35%, it was regarded as normal diaphragmatic function; if it was <35%, it was labelled as diaphragmatic weakness.[9] All assessments were performed by a single anaesthesiologist who was not involved in patient management. All the ultrasound scans were performed by a

single operator in our study. The operator was well trained in ultrasound assessment of the diaphragm and had already performed more than 100 ultrasound examinations in both the intensive care unit and the operation theatre.

Patients were then taken to the operating theatre. All the routine monitors, i.e., pulse oximeter, ECG, and NIBP, were attached. In addition to routine monitors, we connected the train-of-four (TOF) ratio and the bispectral index monitor to the patient. An epidural catheter was inserted at the discretion of the anaesthesiologist. Patients were preoxygenated, followed by administration of injection (inj.) fentanyl 1-2 μg kg^{-1}, propofol (1-2.5 mg kg^{-1}), or etomidate (0.2-0.3 mg kg^{-1}). Vecuronium 0.1 mg kg^{-1} i.v. was used. Patients were intubated and mechanically ventilated. The anaesthesia was maintained using sevoflurane with 40% oxygen. Inj. Vecuronium 0.02 mg kg^{-1} i.v. was given if a single twitch appeared on the TOF monitor. The total maintenance dose of inj. vecuronium was calculated.

After surgery, anaesthetic agents and muscle relaxants were discontinued. Inj. Neostigmine 0.35-0.5 mg kg^{-1} iv was administered. As the patient regained spontaneous respiratory efforts, they were switched to pressure support mode. Pressure support was gradually reduced, and when support reached 6-8 cm of H_2O with positive end-expiratory pressure of 5 cm of H_2O, diaphragm assessment (TFdi) was repeated. A lung ultrasound score was calculated for all patients to determine their lung condition and to assess the need for mechanical ventilation based on that score. We followed the BLUE protocol for postoperative lung ultrasound.

Patients were extubated when they met clinical criteria for extubation (i.e., regular respiration, stable vital signs, ability to follow commands, adequate hand grip, and ability to lift the head). Any patient not meeting the criteria was considered for elective mechanical ventilation at the discretion of the treating anaesthesiologist and the surgeon. All patients were transferred to the post-anaesthesia care unit, the intensive care unit, or the high-dependency unit, depending on ventilator availability.

Objectives and Variable Definitions

The primary objective was to determine the percentage of older adult patients with preoperative diaphragmatic weakness, as assessed by ultrasound, who required postoperative mechanical ventilation after abdominal surgery under general anaesthesia. The secondary objectives were to determine the perioperative change in diaphragmatic function (i.e., TFdi: preoperative versus before extubation); to assess the relationship between preoperative and intraoperative variables and diaphragmatic function; to evaluate the association of diaphragmatic function with outcomes (i.e., extubation and postoperative mechanical ventilation); and to determine the optimal cut-off of TFdi at the preoperative and before-extubation time points to predict extubation/postoperative mechanical ventilation.

Sample Size Calculation

Since we could not find any similar studies in the literature, we conducted a pilot study of 20 older adult patients to inform sample size calculation and found the prevalence of postoperative mechanical ventilation in patients with pre-operative diaphragmatic weakness, as assessed by ultrasound, to be 85% (13 patients had TFdi<35% and 11 required mechanical ventilation). Based on that, the sample size was calculated using the following formula:

$$n = Z2_{1-a/2}\, pq/L2$$

where: n = required sample size, Z (0.05)=1.96 (value from normal standard deviation (SD) reflecting the 95% confidence interval), p (prevalence rate)= 85%, q=1-p=15%, L=10% [least permissible error(absolute precision)]

$$\text{Hence sample size} = \frac{(1.96)2 \text{ X } 15 \text{ X } 85}{10 \text{ X } 10} = 48.96 = 49$$

A total of 49 patients with preoperative diaphragm weakness were required for our study. All older adult patients were recruited until we included a total of 49 patients with diaphragmatic weakness. A total of 90 patients were included in our study.

Statistical Analysis

Data were coded and recorded in a Microsoft Excel spreadsheet. The Statistical Package for the Social Sciences, version 23 (IBM Corp.), was used for data analysis. The Mann-Whitney U test was applied to skewed or non-normally distributed data to compare continuous variables between two independent groups. To assess associations between categorical variables, the chi-squared test was used. In cases where expected cell counts were less than 5 in more than 20% of the cells, Fisher's Exact test was applied instead. The strength of association between the two variables was measured using Cramer's V or the point-biserial correlation. Multivariate linear regression with an omnibus ANOVA was used to analyze the association between TFdi (preoperative) and preoperative variables, and between TFdi (before extubation) and intraoperative variables. receiver operating characteristic (ROC) curves were used to assess the diagnostic performance of a variable and to determine its optimal cut-off value. A P value <0.05 was considered statistically significant.

Results

Study Participants

We considered 103 patients for inclusion in our study. Of these, two patients refused to consent to the procedure, three patients had severely compromised lung function,

one patient had known cardiac disease, and one patient was on home oxygenation (Figure 1). A total of 96 patients were included in our study. However, six patients required postoperative mechanical ventilation—either at the request of the surgical team or because of severe shock—so reversal of muscle relaxation was not performed in these patients immediately after surgery, and they were excluded from the study. The remaining 90 patients received a trial of extubation and were thus included in our study (Figure 1).

The demographic profile of the patients is described in Table 1. Most patients underwent major abdominal, gynecological, or urological surgeries, as shown in Supplementary Table 1. The mean duration of surgery was 260.22 (109.02) minutes, and the mean duration of anaesthesia was 308.89 (124.34) minutes (Table 1).

Diaphragm Assessment

Forty-nine (54.4%) participants at the pre-operative time point and 66 (73.3%) before extubation had TFdi <35%. The mean (SD) TFdi (%) in the study population decreased from 36.84 (16.13) preoperatively to 29.84 (14.64) before extubation (Table 2). This change was statistically significant

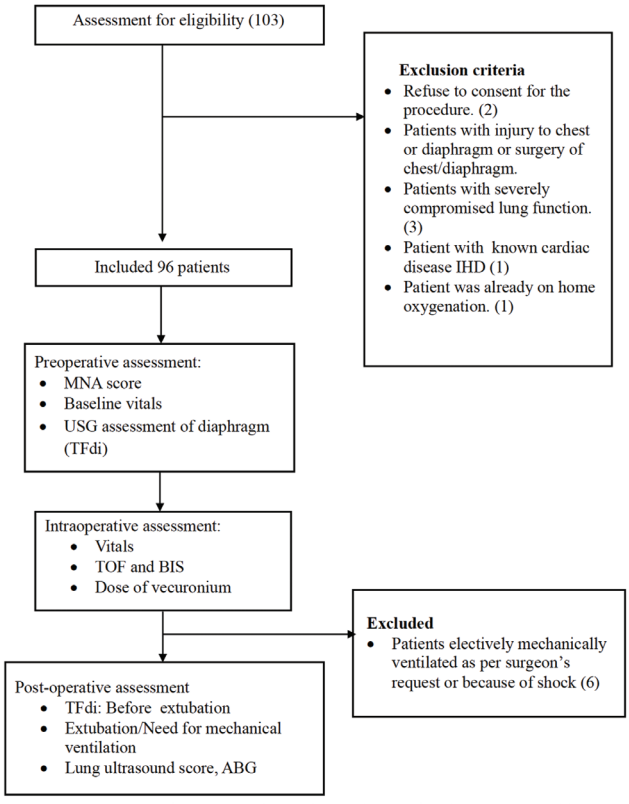


Figure 1. Methodology flowchart.

MNA, Mini Nutritional Assessment; TFdi, thickening fraction; BIS, bispectral index; TOF, train-of-four; USG, ultrasonography; ABG, arterial blood gas; IHD, ichemic heart disease.

(Friedman test: χ^2=79.4, P≤0.001). The association between TFdi (pre-operative) and TFdi (before extubation) is shown in Table 2. Participants in the TFdi group (pre-operative: <35%) had the larger proportion of TFdi before extubation (<35%). The strength of association between TFdi (pre-operative) and TFdi (before extubation), as measured by Cramer's V, was 0.56 (high association).

Relationship of Peri-Operative/Intraoperative Variables and Diaphragm Weakness

The multivariate linear regression analysis of TFdi (preoperative) and preoperative variables is shown in Supplementary Tables 2A-C. On analyzing the overall model performance, the R was 0.36, suggesting weak correlation with only 13% variability (R^2). The overall predictive ability of the model was poor. In the omnibus ANOVA, the MNA score had a P value of 0.032. The regression coefficient for the MNA score was estimated as 1.76 (95% CI: 0.15 to 3.36). For every 1 point increase in the MNA score, the TFdi (pre-operative) increases by ~1.76 units, after adjusting for all other variables.

For TFdi (before extubation), the multivariate linear regression analysis yielded R=0.87, indicating an excellent overall correlation and explaining 73% of the variance (Supplementary Tables 3A-C. In the omnibus ANOVA, TFdi (pre-operative) was significantly associated with TFdi (before extubation) (P < 0.001). For every 1% increase in TFdi (pre-operative), the TFdi (before extubation) increases by 0.77%, independent of perioperative and physiological variables.

Association of Diaphragm Weakness and Outcomes

The association between TFdi and outcomes such as extubation and postoperative mechanical ventilation was examined in Table 3. Significant differences in the distribution of patient outcomes were observed between the groups. 75.5% of the participants in the group TFdi (pre-operative) <35% had extubation while 92.7% of the participants in the group TFdi (pre-operative): ≥35% had extubation (Table 3). The Strength of association between the two variables (Cramer's V)=0.23 (low association). 77.3% of the participants in the group TFdi (before extubation) <35% had extubation while 100.0% of the participants in the group TFdi (before extubation) ≥35% had extubation (Table 3). The strength of association between the two variables (Cramer's V) was 0.27, indicating a low association.

ROC Curve for TFdi Pre-Operative and Before Extubation

The area under the ROC curve (AUROC) for pre-operative TFdi (%) predicting extubation was 0.751 (95% CI: 0.634-0.867), indicating fair diagnostic performance (Figure 2). This result was statistically significant (P=0.002). At a cut-

off of TFdi (pre-operative) ≥28.9, it predicts extubation: Yes, with a sensitivity of 73%, and a specificity of 73%. For TFdi (before extubation) predicting extubation (yes vs no), the AUROC was 0.777 (95% CI: 0.668- 0.885), indicating fair diagnostic performance (Figure 3). It was statistically significant (P = 0.001). At a cut-off of TFdi (before extubation) ≥30.1, it predicts extubation: Yes, with a sensitivity of 48%, and a specificity of 100%. However, 100% specificity may be due to a small number of events.

Predictive Ability of Pre-Operative Variables for Postoperative Outcome

We performed a binomial logistic regression analysis to assess whether combinations of preoperative variables can predict postoperative extubation or the need for mechanical ventilation (Supplementary Table 4A, 4B and Tables 4A-C, Supplementary Figure 1). The model demonstrated good overall fit. ASA class III status, lower MNA scores, and higher BMI were significantly associated with increased

Table 1. Demographic Profile of the Patients Included in the Study

Basic details	Mean (SD)	Median (IQR)	Min-max OR n (%)
Age (years)	63.7 (6.6)	64.0 (58.3-68.7)	52.0-80.0
Age			
50-59 years	27 (30.0%)		
60-69 years	44 (48.9%)		
70-79 years	18 (20.0%)		
80-89 years	1 (1.1%)		
Gender			
Male	36 (40.0%)		
Female	54 (60.0%)		
Weight (kg)	59.2 (10.5)	58.5 (52.0-68.0)	38.0-88.0
Height (cm)	160.7 (8.0)	159.0 (155.3-166.0)	144.0-182.0
BMI (kg/m²)	23.1 (3.8)	23.2 (20.7-25.6)	15.0-34.3
ASA			
I	25 (27.8%)		
II	53 (58.9%)		
III	12 (13.3%)		
Anaesthesia			
GA	28 (31.1%)		
GA+EA	62 (68.9%)		

SD, standard deviation; IQR, interquartile range; BMI, body mass index; ASA, American Society of Anesthesiologists; GA, general anaesthesia; EA, epidural anaesthesia; OR, odds ratio; Min-max, minimum-maximum

Table 2. Assessment of "TFdi (pre-operative)" & "TFdi (before extubation)" and the Association of "TFdi (pre-operative)" & "TFdi (before extubation)"

Timepoint	TFDI (%)			Mann-Whitney U		Rank biserial correlation
	Mean (SD)	Median (IQR)	Range	Static	*P* value	
Pre-operative	36.8 (16.1)	33.4 (21.6)	9.09-80.00	2943.50	0.002	-0.27
Before extubation	29.8 (14.6)	27.53 (18.9)	6.37-76.00			
TFdi	**<35%**	**≥35%**	**TFdi (before extubation)**	**Chi-squared test (χ^2)**	***P* value**	**Cramer's V**
<35%	47 (95.9%)	19 (46.3%)	66 (73.3%)	28.056	<0.001	0.56 (high association)
≥35%	2 (4.1%)	22 (53.7%)	24 (26.7%)			
TFdi (pre-operative)	49 (100%)	41 (100%)	90 (100%)			

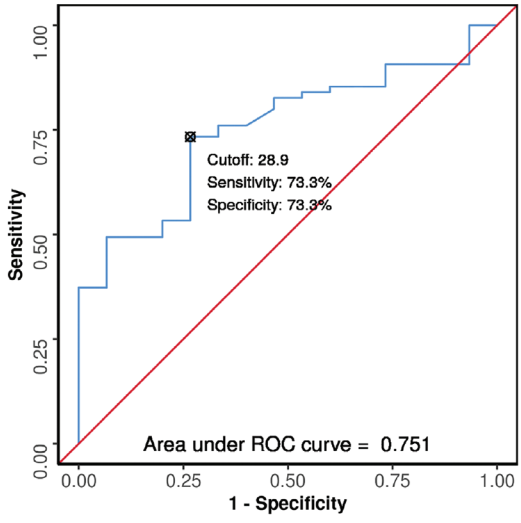
SD, standard deviation; IQR, interquartile range; TFdi, diaphragm thickening fraction

odds of postoperative mechanical ventilation. Preoperative TFdi showed a borderline association, which did not reach statistical significance. Overall, the model demonstrated accuracy of 90%, specificity of 96%, and sensitivity of 60%. An AUC of 0.93 indicated outstanding discrimination between patients likely to be extubated and those requiring postoperative mechanical ventilation.

Table 3. Association Between "TFdi (<35%)/TFdi (≥35%)" and "Extubation/Post-Operative Mechanical Ventilation"

Patient outcome	TFdi (pre-operative)			Chi-squared test	
	<35%	≥35%	Total	χ^2	*P* value
Mechanical ventilation	12 (24.5%)	3 (7.3%)	15 (16.7%)	4.740	0.029
Extubation	37 (75.5%)	38 (92.7%)	75 (83.3%)		
Total	49 (100%)	41 (100%)	90 (100%)		
Patient outcome	**TFdi (before extubation)**			**Fisher's exact test**	
	<35%	**≥35%**	**Total**	χ^2	*P* value
Mechanical ventilation	15 (22.7%)	0 (0.0%)	15 (16.7%)	6.545	0.009
Extubation	51 (77.3%)	24 (100%)	75 (83.3%)		
Total	66 (100%)	24 (100%)	90 (100%)		

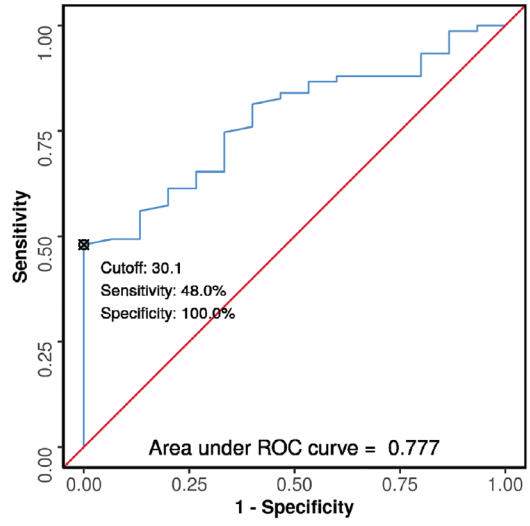
TFdi, diaphragm thickening fraction



Parameter	Value (95% CI)
Cutoff (p value)	≥ 28.9 (0.002)
AUROC	0.751 (0.634 - 0.867)
Sensitivity	73.3% (62-83)
Specificity	73.3% (45-92)
Positive Predictive Value	93.2% (84-98)
Negative Predictive Value	35.5% (19-55)
Diagnostic Accuracy	73.3% (63-82)
Positive Likelihood Ratio	2.75 (1.18-6.44)
Negative Likelihood Ratio	0.36 (0.22-0.59)
Diagnostic Odds Ratio	7.56 (2.16-26.49)

Figure 2. ROC curve analysis showing diagnostic performance of TFdi (%) (pre-operative) in predicting extubation: yes vs. extubation: no (n = 90).

ROC, receiver operating characteristic; TFdi, diaphragm thickening fraction.



Parameter	Value (95% CI)
Cutoff (p value)	≥ 30.1 (0.001)
AUROC	0.777 (0.668 - 0.885)
Sensitivity	48.0% (36-60)
Specificity	100.0% (78-100)
Positive Predictive Value	100.0% (90-100)
Negative Predictive Value	27.8% (16-42)
Diagnostic Accuracy	56.7% (46-67)
Positive Likelihood Ratio	Inf (NaN-Inf)
Negative Likelihood Ratio	0.52 (0.42-0.65)

Figure 3. ROC curve analysis showing diagnostic performance of TFdi (%) (before extubation) in predicting extubation: yes vs. extubation: no (n = 90).

ROC, receiver operating characteristic; TFdi, diaphragm thickening fraction.

Discussion

We conducted an observational study of 90 older adult patients. We found that the numbers (percentages) of patients with TFdi values below 35% were 49 (54.4%) in the preoperative period and 66 (73.3%) just before extubation. In multivariate linear regression analysis, the preoperative MNA score was the only variable independently associated with TFdi (preoperative), whereas TFdi (preoperative) was the only independent predictor of TFdi (before extubation), explaining a substantial proportion of the variance (adjusted Rz^2=0.71). The patients with a preoperative TFdi <35% had a higher requirement for mechanical ventilation (24.5% or 1:3) as compared to those with TFdi ≥35% (7.3% or 1:13). The optimal cut-off value of TFdi (preoperative) ≤28.9 predicted need for postoperative mechanical ventilation with 73% sensitivity and 73% specificity.

In our study, we found that the number and percentage of patients with TFdi values below 35% were 49 (54.4%) in the preoperative period and 66 (73.3%) just before extubation. We also found a significant reduction in mean TFdi values from the preoperative level (36.84) to just before extubation (29.84). Moury et al.[10] conducted a similar study in which they tested for TFdi in patients undergoing elective cardiac surgery. The mean (SD) preoperative value of TFdi was 36 (18) and decreased to 17 (14) during a spontaneous breathing trial (SBT) and 12 (11) on day +1 ($P < 0.0001$). In a study by Dres et al.,[11] the median TFdi of all subjects was 28%. Patients who passed SBT had higher TFdi values than those who failed SBT (33% vs. 19%). Lee et al.[12] conducted a study in pediatric patients, in which diaphragm thickness fraction (DTF) decreased markedly during the first 24 hours of mechanical ventilation.

In multivariate linear regression analysis, the pre-operative MNA score was the only variable significantly associated with TFdi (preoperative), whereas TFdi (preoperative) was the only independent predictor of TFdi (before extubation) and explained a substantial proportion of the variance (adjusted R^2=0.71). Uyar et al.[13] studied the mechanically ventilated intensive care unit (ICU) patients. They concluded that high protein intake (2.0 g kg^{-1} day^{-1}) significantly increased diaphragm and rectus femoris muscle thickness compared to standard protein intake, suggesting that high protein support may help prevent muscle atrophy in critical care.

In our study, TFdi was significantly associated with patient extubation or need for mechanical ventilation, both preoperatively (χ^2=4.740, P=0.029) and before extubation (χ^2=6.545, P=0.009). However, the strength of the association was low in both cases. In the study by Lee et al.[12] the DTF% of less than 17% was significantly correlated with extubation failure ($P < 0.001$). Cammarota et al.[14] found that patients who fail extubation had significantly increased diaphragmatic activation during SBT. Vivier et al.[15] found that the diaphragm excursion measured by bedside ultrasound along with airway pressure assessment was more accurate than electromyography in detecting patient ventilator asynchrony. However, studies by and Vetrugno et al.[16] reported that diaphragmatic excursion and thickening fraction were not reliable for predicting extubation and weaning failure, including in coronavirus disease-2019 patients. These results may be due to poor lung compliance and a low P/F ratio among the study patients.

In our study, the optimal cut-off value of TFdi (preoperative) ≥28.9 predicted extubation with 73% sensitivity and 73% specificity, and a high negative predictive value (93.2%), which indicates that patients with TFdi above this threshold are unlikely to require mechanical ventilation. In the study by Moury et al.,[10] the decrease in TFdi was correlated with increased length of stay in the ICU. The diaphragm thickening fraction (TFdi), measured by ultrasound, was below 20% in 70% of patients, indicating reduced diaphragmatic activity. Their ultrasound finding showed a moderate correlation with diaphragm strength (r=0.4, P=0.02), but it did not correlate with overall muscle strength. In a study by Dres et al.,[11] a TFdi threshold of 25.8% was identified as predictive of weaning failure (P< 0.001). Another study used a reduction of 25% or more in diaphragm excursion during the sniff test as a criterion for hemidiaphragmatic paralysis.[17]

Study Limitations

Our study had certain limitations. We included patients aged 50 years and older. However, the patient profile might have differed if only patients from an older age group (i.e., >65 years) had been included in our study. Secondly, although all ultrasound scans were performed in our study, the multivariate linear regression model for perioperative TFdi showed only a weak predictive ability, suggesting that there may be other factors, such as neuromuscular function and cardiopulmonary reserve, which were not analyzed in our study. Thirdly, several other perioperative factors independent of diaphragmatic function—such as epidural analgesia, residual neuromuscular blockade, opioid exposure, pulmonary comorbidities, frailty, nutritional impairment, and lung ultrasound findings—might have influenced the need for mechanical ventilation. Although we have briefly touched upon some of these factors, a detailed analysis of all of them was beyond the scope of this study. Further studies are required to evaluate the effect of adding an epidural to general anaesthesia. The sample size may have been insufficient for specific secondary objectives; therefore, further studies with larger sample sizes may be considered.

Conclusion

Our study found that a significant percentage of older adult patients scheduled for major elective abdominal procedures had a pre-existing diaphragmatic weakness that worsened further in the postoperative period. Lower preoperative TFdi was significantly associated with extubation failure and the need for postoperative mechanical ventilation. Better nutritional status was linked to higher TFdi values, indicating a possible relationship between nutrition and diaphragm strength. TFdi is a valuable and non-invasive indicator of diaphragmatic function and can help predict the need for postoperative mechanical ventilation in elderly patients.

Ethics

Ethics Committee Approval: It was conducted after receiving approval from the Ethics Committee of the All India Institute of Medical Sciences in Rishikesh, India (approval no: AIIMS/EC/23/501, date: 08.12.2023).

Informed Consent: This study is a prospective observational study and therefore exempts patient consent.

Footnotes

Authorship Contributions: Concept - J.S., D.S.; Data Collection and/or/Processing - J.S., R.K.; Analysis and/or/Interpretation - J.S., R.K.; Writing - D.S., B.G., S.A., M.D.

Declaration of Interests: The authors declare no conflicts of interest.

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Supplementary Materials Link: https://d2v96fxpocvxx.cloudfront.net/ae7a798f-afa1-42f4-9efd-6a2ed974293f/content-images/053a3bdd-435d-4864-b14b-89db6bb19517.pdf

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Original Article
Airway Management

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Comparison of the Blockbuster™ and Air-Q® Supraglottic Airway Devices as a Conduit to Blind Endotracheal Intubation in Paediatric Patients: A Randomised Control Trial

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Abstract

Objective: Only two devices [air-Q® intubating laryngeal airway (ILA) and AmbuAura-i] have been studied previously for blind endotracheal intubation (ETI) in paediatric patients. The aim of the study was to compare the success rate of blind ETI through Blockbuster™ laryngeal mask (LM) and air-Q® ILA in paediatric patients.

Methods: Eighty patients with the American Society of Anesthesiologists' physical status I and II, aged between six months and 10 years, were enrolled in this randomised controlled trial. The patients were intubated through either of the supraglottic airway devices (SADs) by visualised, blind intubation. The primary outcome was the first- attempt success rate of ETI. Secondary outcomes were the overall success rate of ETI, the oropharyngeal leak pressure, the fiberoptic glottic view, the time to intubation, and the complication rate.

Results: Blockbuster™ LM was having significantly higher first attempt success rate without any manipulation as compared to air-Q® ILA (55% vs. 32.5%; *P* value =0.042). Overall success rate was also significantly higher in Blockbuster™ LM (77.5% vs. 55%; *P* value =0.03). In subgroup analyses, Blockbuster™ LM demonstrated significantly higher first-attempt and overall intubation success rates in children aged 6 months to 5 years, while success rates were comparable between devices among children older than 5 years.

Conclusion: Blockbuster™ LM, having more than 50% success rate of first-attempt blind intubation through SAD, can be a helpful device in crises during airway management of children and, thus, an ideal SAD for difficult airway carts.

Keywords: Airway management, fiberoptic, intubation, paediatric anaesthesia, supraglottic device

Main Points

- Only two devices [air-Q® intubating laryngeal airway (ILA) and AmbuAura-i] have been studied for blind endotracheal intubation through supraglottic airway devices (SADs) in paediatric patients; air-Q® ILA has been found to have a better first attempt success rate among the two, ranging from 15-64%.
- Blockbuster™ laryngeal mask (LM) is a newer SAD with a significantly better first attempt and overall success rate of blind intubation in children than air-Q® ILA.
- Blockbuster™ LM having significantly higher oropharyngeal leak pressures than air-Q® ILA, is better suited as a ventilatory device in surgeries requiring higher airway pressures.

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Introduction

Airway management in children can sometimes be particularly challenging and may require essential skills. The reported incidence of difficult intubation is 0.24-4.7% and 0.07-0.7% in infants and older children, respectively.[1] As attempts at laryngoscopy increase in children, it is associated with high failure rates and incidence of severe respiratory complications responsible for perioperative morbidity and mortality.[2] According to the paediatric perioperative cardiac arrest registry, 27% of all cardiac arrests occur due to respiratory-related events.[3]

The use of supraglottic airway devices (SADs) as a conduit to endotracheal intubation (ETI) (with or without flexible bronchoscopic guidance) is an accepted technique that has gained recognition on the emergency pathway of the American Society of Anesthesiologists (ASA) paediatric difficult airway algorithm.[4] as well as in the Difficult Airway Society (DAS) guidelines.[5]

SADs can be used as a conduit for tracheal intubation, either with a fiberoptic bronchoscope (FOB) or blindly (without flexible bronchoscopic guidance). The success rate of ETI through these SADs ranges widely from 15% to 97%, depending on the type of SADs used, characteristics of patients, and operator-acquired skills.[6-8]

Based on various studies conducted in adults, the Fastrach laryngeal mask (LM) Airway or intubating LMA is recommended as a prototype standard reference device for blind ETI, owing to its great success[9] but its paediatric size is not available.[10] Only two devices [air-Q® intubating laryngeal airway (ILA) and AmbuAura-i] have been studied for blind ETI through SADs in paediatric patients; air-Q® ILA has been found to have a better first-attempt success rate between the two, ranging from 15-63%.[11-16]

Blockbuster™ LM has a success rate of 90% for blind ETI in adults.[8] Limited paediatric data are available, with recent evidence evaluating Blockbuster™ LM primarily as a conduit for fiberoptic-guided intubation in children.[17,18] However, its performance for blind intubation, which may be required in emergency or resource-limited settings, remains inadequately studied. The proposed study aims to answer the research question that which SAD (Blockbuster™ LM or air-Q® ILA) has a higher first-attempt success rate for blind ETI in paediatric patients. The results can be further extrapolated to the use of SAD when FOBs are limited.

The study's primary outcome was the first-attempt success rate of ETI. Secondary outcomes were the overall success rate of ETI, the number of attempts required for successful placement of SAD, the oropharyngeal leak pressure (OLP), the glottic view through a FOB, the time needed for successful intubation, and the incidence of peri- and post-procedural complications.

Methods

This single-center, parallel-group, randomized controlled trial received ethical approval from the All India Institute of Medical Sciences, Patna ethics committee (approval: AIIMS/Pat/IEC/PGTh, date: 25.03.2021). It was then conducted in a tertiary healthcare setting and registered in the Clinical Trials Registry of India (CTRI/ 2021/ 03/ 032076). Recruitment was performed between March and October 2021. Written informed consent was obtained from the patient's legal guardians, and oral assent was taken from the child wherever applicable. This manuscript adheres to the applicable CONSORT guidelines.

Paediatric patients with ASA-physical status (ASA-PS) I and II aged between 6 months and 10 years, weighing 5 to 30 kg, and scheduled for elective surgery under general anaesthesia were recruited for the study. Patients with an anticipated difficult airway, significant cardiopulmonary disease, obesity, airway surgery, or expected postoperative admission to the intensive care unit were excluded from the study. 104 patients were assessed for eligibility, and 80 were randomised into two equal groups.

A block randomisation sequence list was created online (https://www.sealedenvelope.com) by an individual not involved in the study. The opaque envelope method of concealment was used in the study. After enrollment, envelopes were opened by an independent person on the morning of surgery, and patients were allocated to two groups according to the sequence number in a 1:1 ratio.

Group 1: Airway secured with air-Q® ILA

Group 2: Airway secured with Blockbuster™ LM

Each group consisted of 40 patients. All the children were kept nil by mouth according to standard guidelines. No premedication was administered to the patient.

Inhalational induction with sevoflurane was performed, followed by administration of fentanyl at 2 μg kg^{-1}. The neuromuscular blockade was achieved with atracurium at 0.5 mg kg^{-1} after confirming mask ventilation. After ventilating the patient for 3 minutes, achieving a minimum alveolar concentration of 1.0-1.2, the airway was secured with an appropriately sized SAD according to the patient's weight per the allotted group. The air-Q® ILA sizes 1, 1.5 and 2 were used for the patient weight of (<7 kg), (7-17) kg and (17-30) kg, respectively. The Blockbuster™ LM sizes of 1.5, 2, and 2.5 were used for patient weights of (5-10) kg, (10-20) kg, and (20-30) kg, respectively.

All airway interventions were performed by the investigators, who were certified and trained anaesthesiologists. The performers had experience using other SADs (more than 100) in children as part of routine practice. The performers were trained on manikins with the SADs used in the study

and used them on a limited number of patients before the study.

The SADs were lubricated with a water-soluble agent and inserted using the recommended midline technique. A maximum of three SAD insertion attempts with minor airway interventionswas allowed. Successful placement of SAD was determined by achieving at least 5 ml kg^{-1} tidal volume, bilateral chest excursion, and a square-wave capnogram upon delivery of a positive-pressure breath, with a tidal-volume leak <10%. The OLP was measured by closing the expiratory valve of the circle system with a fresh gas flow of 3 L min^{-1} and noting the airway pressure at which equilibrium was reached. The pressure was not allowed to exceed 40 cm of H_2O.

Volume-controlled ventilation mode was used with a target tidal volume of 8-10 mL kg^{-1} and a respiratory rate of 14-20 times per minute to maintain an $EtCO_2$ between 30-40 mm of Hg. A paediatric FOB (Karl Storz, Tuttlingen, Germany) was fitted with a cuffed polyvinyl chloride endotracheal tube (ETT) of a size appropriate for the patient's age. The ETT was taped to the FOB so that the tip of the FOB did not extend beyond the ETT (Figure 1). The breathing circuit was disconnected at the patient end, and the ETT-loaded FOB was inserted through the SAD. During the visualisation of the laryngeal structures, a fiberoptic view through the opening of the SAD was recorded by a member of the anaesthesia care team. Scoring of the fibreoptic glottic view was based on Brimacombe's laryngeal view and was recorded as follows (Figure 2):[19]

1. Grade 0: failure to function of LMA where cords are not seen fibre-optically,

2. Grade 1: cords not seen, but the function of LMA is adequate,

3. Grade 2: The cords and the anterior epiglottis are visible,

4. Grade 3: cords plus posterior epiglottis are seen,

5. Grade 4: only cords are seen.

For glottic view grades 2, 3, and 4, we attempted ETI. We used a visualised blind technique for intubation, as previously described in the literature, to prevent injury to the delicate laryngeal structures of the child.[11,20,21] To reduce performer bias, the performer did not view the fiberoptic screen during intubation. The FOB did not guide the insertion of the ETT but, instead, followed its progress (Figure 1). The performer was also not allowed to use the fiberscope's lever. An assisting anaesthesiologist communicated with the performer regarding the advancement of the ETT by using only the terms "Go," "Slow," "Stop," and "Back" after the visualisation of the FOB laryngeal-view grade.

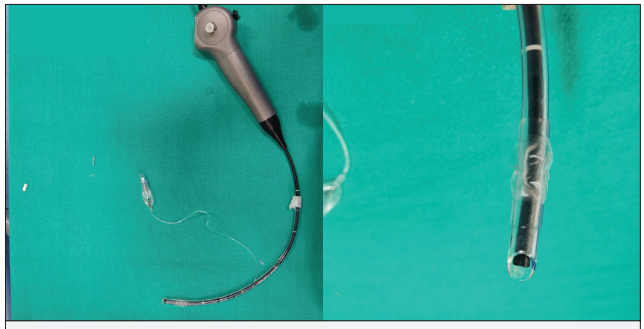

Figure 1. ETT fixation over the FOB for visualised blind intubation.

ETT, endotracheal tube; FOB, fiberoptic bronchoscope.

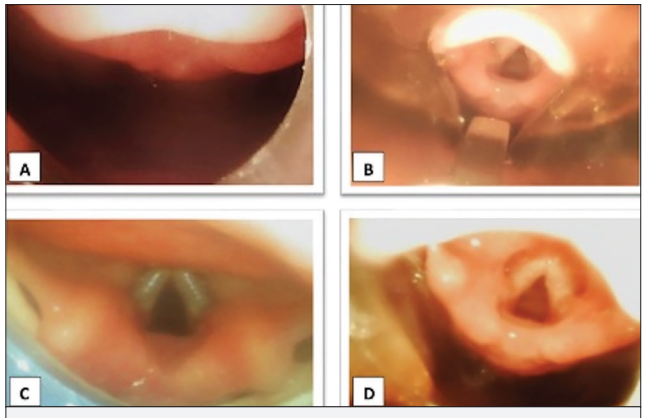

Figure 2. Brimacombe's grade for fibreoptic glottic view. A: Grade I; B: Grade II; C: Grade III; D: Grade IV.

The first successful attempt at ETI was defined when ETT was advanced directly into the glottic opening and confirmed by capnography. If the ETT deviated into extraglottic structures during the procedure, corrective manoeuvres, such as mandibular lift and rotation of the ETT, were used. If the grade improved, we proceeded with ETI; if the grade did not improve, it was considered a failed attempt at blind intubation. ETI, with corrective manoeuvres, was considered a subsequent attempt at intubation. Correction manoeuvres were also applied to the grade 1 glottic view.

Patients were ventilated for 3 minutes after successful ETI, after which the SAD was removed using the removal stylet. One visualised blind intubation attempt lasting no more than 2 minutes was allowed. The intubation was recorded as a failure:

1. The correct placement of the SADs was not achieved after three attempts despite minor airway interventions.

2. The tracheal tube was dislodged during SAD removal.

3. Deviation of ETT away from the laryngeal inlet despite using correction manoeuvres.

The various endpoints were defined as follows:

1. Time for the successful placement of SAD: From discontinuation of facemask ventilation to the rise of 1st square wave of the capnographic waveform.

2. Time for the successful insertion of the ETT: From discontinuation of the breathing circuit after SADs placement to 1st square wave of the capnographic waveform.

3. Time for the successful removal of SAD: From disconnection of the breathing circuit after successful ETI till reconnection of the breathing circuit to the ETT.

All outcome variables were noted in the data collection proforma by a member of the anaesthesia care team. Adverse events such as aspiration or regurgitation, hypoxia, bronchospasm, laryngospasm, desaturation (SpO_2<92%), coughing, blood-staining on the SAD, and trauma to teeth, tongue, or lips were recorded. Patients older than three years were observed for sore throat, postoperative nausea and vomiting, hoarseness, and dysphagia in the post-anaesthesia care unit. A follow-up twenty-four hours after surgery and interviews about side effects were conducted with the child and the parents.

Statistical Analysis

The authors conducted a pilot study on 12 patients in each group, the success rates of Blockbuster™ LM and air-Q® being 66% and 33%, respectively. The calculated sample size was 35 in each arm, considering a power of 80%, a 95% confidence interval, and a two-tailed alpha of 0.05. We planned to recruit 40 patients in each arm, allowing for dropouts.

All data were recorded on a standardised data collection sheet, and were analysed using the statistical software SPSS 26.0 (SPSS, Chicago, IL, USA). The normality of the data was tested using visual inspection of the Q-Q plot and the Shapiro-Wilk test. Descriptive parametric data were expressed as mean ± standard deviation and non-parametric data as median and interquartile range. Parametric continuous variables were compared using the independent-samples t-test. Non-parametric continuous variables were compared using the independent-samples Mann-Whitney U test. Categorical and ordinal data were compared using the chi-square test or Fisher's exact test. A post-hoc, age-based subgroup analysis was performed for outcomes including the first-attempt and overall success rates of ETI. A *P* value of < 0.05 was considered statistically significant.

Results

Of the 104 patients assessed for eligibility, 18 did not meet the inclusion criteria, and consent for participation in the study could not be obtained from the guardians of 6 patients. The remaining 80 patients were randomised to two study groups and underwent interventions per protocol, as represented in the CONSORT flow diagram (Figure 3).

Groups 1 and 2 each had 40 patients at the final analysis. There were no statistically significant differences between the groups regarding demographic data (age, gender, height, weight, body mass index, ASA-PS) (Table 1).

Group 2 had a significantly higher first-attempt success rate than Group 1 (55% vs. 32.5%; *P* value =0.042) (Table 2). The overall success rate of ETI was significantly higher in Group 2 than in Group 1 (77.5% vs. 55%; *P* value =0.03) (Table 2).

In the subgroup of children aged 6 months to 5 years (n = 57), the first-attempt success rate for ETI was significantly higher in Group 2 than in Group 1 (53.8% vs. 25.8%; *P*=0.030). The overall success rate was also significantly higher in Group 2 (73% vs. 45.2%; *P*=0.033). In children aged >5-10 years (n = 23), no statistically significant difference was observed between the two devices for either first-attempt success (57.1% vs. 55.5%; *P*=0.94) or for overall success rate (85.7% vs. 77.7%; *P*=0.624) (Table 3).

SAD was placed in a single attempt in all patients except one in Group 2, in whom placement was unsuccessful despite the maximum allowable attempts (three, per protocol). Failure to place the SAD was counted as an unsuccessful intubation attempt.

The OLP (in cm of H_2O) was significantly higher in Group 2 than the OLP of Group 1 (25.74±7.05 vs. 15.2±5.58; value =0.001) (Table 2).

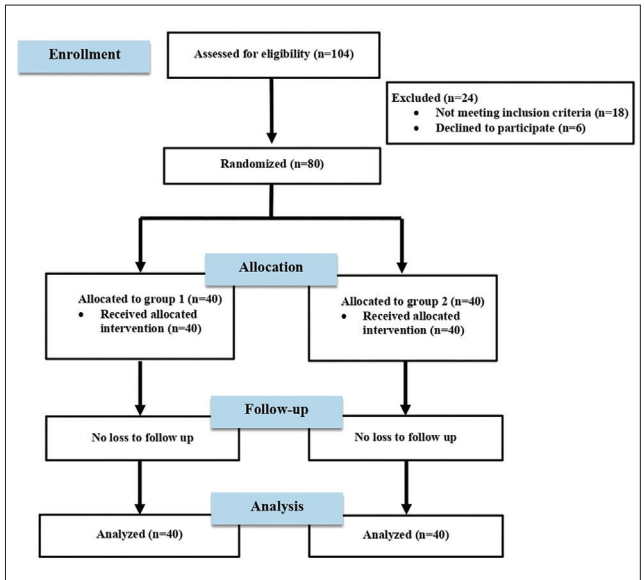

Figure 3. CONSORT flow diagram.

Table 1. Demographic Data

Characteristics	Group 1, n = 40	Group 2, n = 40	*P* value
Age (months)	46 (37-53)	54 (46-62)	0.138‡
Weight (kg)	14.27 (12.39-16.44)	15.78(14.08-17.47)	0.117‡
Height (cm)	98.7 (94.1-103.4)	103.4 (98.3-108.5)	0.174‡
BMI	14.13 (13.28-14.98)	14.51(13.59-15.42)	0.544‡
Sex (M/F)	24/16	28/12	0.482†
ASA-PS (I/II)	38/2	36/4	0.675¶
SAD size (1.5/2/2.5)	22/18	3/27/10	-

Values are presented as median (IQR) and frequency. $P < 0.05$ =Significant; †: chi square test, ‡: Mann whitney U test, ¶: Fisher exact test
BMI, body mass index; ASA-PS, American society of Anesthesiologists physical status; SAD, supraglottic airway device; IQR, interquartile range

Table 2. Device Characteristics

Outcomes	Group 1, n = 40	Group , n = 40	Relative risk, (95% CI)	*P* value
Primary outcome				
First attempt successful ETI	13/40 (32.5%)	22/40 (55%)	0.66 (0.44 to 0.99)	0.042†
Categorical secondary outcomes				
Overall success rate of ETI	22/40 (55%)	31/40 (77.5%)	0.67 (0.48 to 0.95)	0.03†
Successful SAD insertion	40/40 (100%)	39/40 (97.5%)	-	-
Good glottic visualisation (Grade 2-4)	25/40 (62.5%)	33/39 (84.6%)	0.73 (0.56 to 0.97)	0.026†
Successful ETI with maneuvers	8/40 (20%)	9/39 (23%)	0.86 (0.37 to 2.01)	0.785†
First attempt success with SAD sizes (1.5/2/2.5)	18%/50%/ -	67%/52%/60%	-	-
Continuous secondary outcomes			**Difference in means (95% CI)**	
Time for SAD insertion (seconds)	24 ±7 (n=40)	23±9 (n = 39)	0.77 (-2.84 to 4.38)	0.672§
OLP (cm of H_2O)	15.2±5.58 (n = 40)	25.74±7.05 (n = 39)	-10.5 (-13.4 to -7.7)	0.001§
			Difference in medians (95% CI)	
Time for SAD removal (seconds)	27 (22-32) n = 21	24 (21-36) n = 31	2 (-3 to 6)	0.484‡
Time for successful ETI (seconds)	60 (53-60) n = 21	50 (39-60) n = 31	5 (0 to 11)	0.019‡
Tidal volume leak in percentage	4 (0-6) n = 40	0 (0-0) n = 39	-	0.118‡

Values are presented as mean ± SD; median (IQR). $P < 0.05$ = Significant; †: chi square test, §: Independent sample t-test, ‡: Mann-whitney U test
CI, Confidence interval; OLP, oropharyngeal leak pressure; FOB, fiberoptic bronchoscopy; ETI, endotracheal intubation; SAD, supraglottic airway device; IQR, interquartile range; SD, standard deviation

Table 3. Subgroup Analysis of Successful Attempts

Outcomes	Group 1, n = 40	Group 2, n = 40	Relative risk, (95% CI)	*P* value
Age 6 months to 5 years (n = 57)				
First attempt successful ETI	8/31 (25.8%)	14/26 (53.8%)	1.81 (0.98 to 3.30)	0.030†
Overall Success rate of ETI	14/31 (45.2%)	19/26 (73%)	1.67 (1.04 to 2.68)	0.033†
Age >5 years to 10 years (n = 23)				
First attempt successful ETI	5/9 (55.5%)	8/14 (57.1%)	1.04 (0.37 to 2.90)	0.940†
Overall success rate of ETI	7/9 (77.7%)	12/14 (85.7%)	1.36 (0.43 to 4.26)	0.624†

Values are presented as frequency (percentage). $P < 0.05$ = Significant; †: chi square test
CI, confidence interval; ETI, endotracheal intubation

Table 4. Complications During Procedure

	Group 1, n = 40	Group 2, n = 40	*P* value
During SAD insertion	0	0	-
During removal of SAD (blood tinge at tip)	0, n = 40	1, n = 39	0.494¶
During extubation (laryngospasm/excessive cough)	4, n = 21	4, n = 31	1.000¶
Desaturation (SpO_2<90%)	0	0	-
Sore throat	6	5	0.745†
Hoarseness of voice	7	6	0.762†

Values are represented in frequency. Frequency was compared using a chi-square test † or ¶: Fisher exact test
n, number of patients; SAD, supraglottic airway device; SpO_2, oxygen saturation

FOB visualisation of vocal cords (Grades 2/3/4) was observed in 62.5% of Group 1 patients versus 84.6% of Group 2 patients (*P* value =0.026). This variation was statistically significant (Table 2).

The time (in seconds) required for successful insertion of ETT was significantly less in Group 2 [60 (53-60)] than in Group 1 [50 (39-60)] (*P* value =0.019) (Table 2).

The time required for SAD insertion, removal, and tidal volume leak was not statistically significant (Table 2).

The SAD sizes used in both groups are presented in Table 2. The statistical analysis of the sizes cannot be interpreted because the weight corresponding to specific sizes differed between the two groups , in accordance with the manufacturer's recommendations.

The number of patients successfully intubated after using corrective manoeuvres was 8 in Group 1 and 9 in Group 2 (Table 2).

There was no significant difference in the incidence of complications between the two groups (Table 4).

Discussion

In the present study, both the first attempt and overall success rate with Blockbuster™ LM were significantly better compared to air-Q® ILA (55% and 77.5% vs. 32.5% and 55%). The age-based subgroup analysis provides important insights into how paediatric airway development influences intubation success. Among children aged 6 months to 5 years, Blockbuster™ LM demonstrated significantly higher first-attempt and overall success rates than air-Q® ILA. This finding is clinically relevant because younger children have a relatively larger, floppier epiglottis, a higher, more anterior larynx, and reduced alignment of the SAD with the glottic opening. These anatomical features may favour devices with a guided tube-directing mechanism, such as the Blockbuster™ LM. In contrast, children older than 5 years have airway anatomy that is more adult-like, with improved laryngeal alignment and increased epiglottic rigidity, which likely explains the comparable success rates observed between the two devices in this age group.

In a previous study in adults, Blockbuster™ LM had a first-attempt blind ETI success rate of 90%.[8] The success rate of blind ETI through air-Q® ILA in paediatric patients is 15-63% in various studies.[11-16] and is the highest among all the SADs that have been studied in paediatric patients. Soni et al.[17] and Chauhan et al.[18] evaluated Blockbuster™ LM and air-Q® ILA as conduits for fiberoptic-guided intubation in children and reported comparable intubation success rates between the devices. In contrast, the present study focuses on visualised-blind intubation which is specifically relevant to emergency, resource-limited, and crisis airway scenarios, and additionally reports OLPs and a subgroup analysis of younger children.

Blockbuster™ LM is a newer SAD with unique features like a gastric inlet port and a guidance device that allows the ETT to be directed towards the laryngeal opening at 30-degree angle. These features are expected to increase the success rate of ETI.

As defined by TM Cook, the suffix "i" should be added to those devices that enable intubation (e.g., with success >50%),[22] and thus, these SADs can be helpful in situations where the use of FOBs is limited. Blockbuster™ LM, having a better success rate of blind intubation, can be a preferred device for managing crises during difficult airway management of children.

OLP is considered a good measure of airway protection, of successful SAD placement with a better seal, and of adequate positive pressure ventilation. In the present study, the OLP in Blockbuster™ LM was significantly higher than air-Q® ILA [25.9 (22-32) vs. 12 (11-20.2)]. Both SADs have an adequate OLP, with a tidal-volume leak of only 1-3%. W e suggest that both SADs can be used effectively as ventilatory devices. SADs are successfully being used as a primary ventilatory device in paediatric patients undergoing laparoscopic surgeries.[23] Blockbuster™ LM, due to better OLP, can be used as an effective device for surgeries

requiring higher ventilatory pressures, like laparoscopic surgeries, obese patients, and Trendelenburg position. A recent study has also shown better OLP of BlockbusterTM LM (24.72±6.81 cm H_2O), similar to our findings.[24]

Various manoeuvres have been described to facilitate insertion and ETI via SADs, such as mandibular lift, ETT rotation, and the Chandy manoeuvre. Intubation was successful in about 20% of patients in both groups after corrective manoeuvres were applied. Manoeuvres were not helpful for any patients with Grade I glottic views. Manoeuvres were unsuccessful in 70% and 47% with air-Q® ILA and Blockbuster™ LM, respectively. No injuries or complications occurred during the attempt at corrective manoeuvres. We suggest that correction manoeuvres should be applied on subsequent attempts after encountering resistance during the advancement of the ETT or after a failed first attempt.

There is a potential chance of airway trauma and epiglottic down folding during blind attempts of ETI in children.[25,26] Therefore, to avoid trauma to the delicate paediatric airway, we used a "visualised blind intubation" technique. The number of patients with an unsuitable glottic view (grade 1) was significantly higher in the air-Q® ILA group than in the Blockbuster™ LM group (37.5 % vs. 15.4 %). In the Blockbuster™ LM group, although the optimal glottic view was achieved in 84.6% of children, the intubation success rate was lower than expected. This might be due to the smaller size of the glottic opening in children compared to adults. Moreover, the Parker Flex-Tip tracheal tube is recommended by the manufacturers of Blockbuster™ LM for blind tracheal intubation. This use of the tube might have increased the success rate further.

SAD insertion was successful in the first attempt in all patients except one with Blockbuster™ LM. Meta-analysis on the use of air-Q® ILA in paediatric patients has also shown similar results, with a 100% success rate of device insertion in most of the studies.[13] Blockbuster™ LM in adult patients also had a 100% first-attempt success rate.[8] SAD insertion and removal times were similar between the two groups. ETT insertion time was significantly longer with air-Q® ILA compared to Blockbuster™ LM (60 vs. 50 seconds). However, this time difference of 10 seconds is clinically insignificant in routine practice.

Complications during ETI through SADs were neither statistically nor clinically significant.

Study Limitations

Our study has limitations that should be considered when interpreting our results. First, we have not included patients younger than six months of age in our research. The infants have large, floppy epiglottises, which prevent the visualisation of the glottis. Thus, the success rate in infants may be lower than in older children. Second, we selected patients with body weights ranging from 5 kg to 30 kg; therefore, the findings might not apply to underweight or overweight patients. Third, the subgroup analysis was post hoc and not powered a priori; therefore, these findings should be interpreted cautiously. Fourth, we have used a visualised-blind method of ETI, rather than truly blind ETI, to avoid airway injury. The visualised blind technique prevented us from advancing the ETT in the event that it deviated from the correct path. The true blind technique might have resulted in inadvertent, forceful insertion, which, at the expense of causing airway trauma, might have increased the first-attempt success rate. Fifth, because our study included patients with normal airways, the results may not apply to patients with difficult airways. We suggest further research comparing SADs as intubating devices in infants.

In general, it is advisable to use fiberoptic-guided intubation through an SAD. However, in some situations, fiberoptic-guided intubation may be difficult, such as when bleeding or secretions are present. In prehospital settings or by novice physicians, blind intubation through SAD may be attempted when a definitive airway is required during an emergency. Blind ETI through SAD is also helpful during airway crises in children.

Conclusion

Blockbuster™ LM, having a 50% to 77.5% success rate of blind intubation through SAD, can be a helpful device in crises and, thus, a preferred SAD for difficult airway carts. Both air-Q® ILA and Blockbuster LM have a first-attempt SAD insertion success rate of about 100% with non-significant tidal volume leak. Therefore, both devices can be used effectively for ventilation. Blockbuster™ LM has a significantly higher OLP than air-Q® ILA; therefore, BlockbusterTM LM can be used as a better ventilatory device in surgeries requiring higher airway pressure, like laparoscopic surgeries or obese patients.

Ethics

Ethics Committee Approval: This single-center, parallel-group, randomized controlled trial received ethical approval from the All India Institute of Medical Sciences, Patna ethics committee (approval: AIIMS/Pat/IEC/PGTh, date: 25.03.2021).

Informed Consent: Written informed consent was obtained from guardians.

Footnotes

Authorship Contributions: Surgical and Medical Practices - A.P., A.K., C.S., N.K.; Concept - A.P., A.K., C.S.; Design - A.P., A.K.; Data Collection or Processing - A.P., A.K., C.S., N.K., A.Ku., B.K., R.K.; Analysis or Interpretation - A.P., A.K., C.S., N.K., A.Ku., B.K., R.K.; Literature Search - A.P., A.K., C.S., N.K., Writing - A.P., A.K., C.S., N.K., A.Ku., B.K., R.K.

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Effect of a Structured Preoperative Educational Video on Maternal Anxiety in Elective Cesarean Section: A Randomized Controlled Trial Using EEG Biomarkers

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Abstract

Objective: Preoperative anxiety is common in patients undergoing elective cesarean section and may worsen perioperative outcomes. This study evaluated whether a structured preoperative educational video (SPEV) reduces maternal anxiety, as measured by the Amsterdam Preoperative Anxiety and Information Scale (APAIS) and the quantitative electroencephalography (QEEG)-derived theta-beta ratio (TBR).

Methods: Ninety primigravida women undergoing elective cesarean section with spinal anaesthesia were randomized to a video group (n = 45; SPEV plus routine counseling) or a control group (n = 45; routine counseling only). APAIS was measured at baseline and 30 minutes before surgery. Parietal TBR was recorded at baseline, 30 minutes before surgery, and 1 hour after surgery. Groups were compared using appropriate non-parametric tests, and the correlation between subjective and QEEG-derived measures was assessed.

Results: Baseline characteristics were comparable between groups. At 30 minutes before surgery, APAIS scores were lower in the video group than in the control group [11.0 (9.0-12.0) vs. 14.0 (12.0-16.0); $P < 0.001$). TBR was also lower before surgery (1.20 vs. 1.90; $P < 0.001$) and at 1 hour postoperatively (1.20 vs. 1.80; $P < 0.001$). A positive correlation between APAIS scores and TBR was observed 30 minutes before surgery ($P=0.48$, $P < 0.001$). Intraoperative midazolam requirement was lower in the video group (11.1% vs. 33.3%, $P=0.021$).

Conclusion: A SPEV significantly reduced preoperative anxiety in women undergoing elective cesarean section, as demonstrated by both subjective and QEEG-derived measures, and was associated with reduced intraoperative anxiolytic requirements.

Keywords: Cesarean section, education of patients, electroencephalography, anxiety, video-audio demonstration

Main Points

- A structured preoperative educational video significantly reduced maternal anxiety before an elective cesarean section compared with routine counseling alone.
- Anxiety reduction was demonstrated using both subjective assessment (Amsterdam Preoperative Anxiety and Information Scale) and objective neurophysiological measurement [quantitative electroencephalography-derived parietal theta-beta ratio (TBR)].
- Short, low-cost audiovisual education can be easily integrated into routine obstetric preoperative care using commonly available digital devices.
- Parietal TBR may serve as a reliable objective biomarker for preoperative anxiety.

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Introduction

Preoperative anxiety is a common psychological response among patients undergoing surgical procedures, affecting 60-80% of individuals scheduled for elective operations. In obstetric populations, particularly among women undergoing lower-segment cesarean section (LSCS), anxiety may be even more pronounced due to concerns about maternal safety and fetal well-being, fears related to anaesthesia, and unfamiliarity with the operating room environment. Such anxiety is clinically significant, as it has been associated with increased anaesthetic and analgesic requirements, higher postoperative pain scores, delayed recovery, impaired wound healing, prolonged hospital stay, and reduced patient satisfaction.[1-5]

Non-pharmacological strategies to reduce perioperative anxiety have gained increasing attention because of their safety, feasibility, and cost-effectiveness. Among these, structured educational interventions, particularly audiovisual tools, have emerged as promising approaches to improve patient understanding and preparedness. Educational videos provide standardized and easily comprehensible information regarding perioperative processes, thereby reducing uncertainty and enhancing patient confidence. In obstetric practice, such interventions may be especially beneficial, improving cooperation during regional anaesthesia and enhancing the overall perioperative experience.[6-12]

Despite growing evidence supporting the effectiveness of educational interventions, most studies assessing perioperative anxiety rely predominantly on subjective psychometric scales. Objective neurophysiological measures of anxiety remain underexplored in this setting. Quantitative electroencephalography (QEEG) has been increasingly investigated as a tool for assessing emotional and cognitive states, providing real-time insights into cortical activity associated with anxiety. In particular, the theta-beta ratio (TBR) has been proposed as a biomarker reflecting attentional control, emotional regulation, and stress-related cortical dynamics. However, few studies have evaluated, using both validated subjective anxiety scales and QEEG-derived biomarkers, the impact of preoperative educational videos on on women undergoing cesarean section.[13,14]

Therefore, this randomized controlled trial aimed to evaluate the effect of a structured preoperative educational video (SPEV) on preoperative anxiety among primigravida women undergoing elective LSCS with subarachnoid block (SAB). Anxiety was assessed using the Amsterdam Preoperative Anxiety and Information Scale (APAIS), and the assessment was complemented by quantitative QEEG analysis of the TBR as an objective biomarker of anxiety-related cortical activity. We hypothesized that exposure to a SPEV would significantly reduce both subjective anxiety scores and QEEG-derived TBR compared with routine counseling alone.

The primary objective of the study was to compare preoperative anxiety levels between the intervention and control groups, as measured by the APAIS 30 minutes before surgery. Secondary objectives included the comparison of QEEG-derived TBR at predefined perioperative time points, assessment of the correlation between subjective and objective measures of anxiety, and evaluation of intraoperative midazolam requirements between the two groups.

Methods

This randomized controlled trial was conducted over a period of six months in the maternity ward and operating theatre complex of the All India Institute of Medical Sciences, Bhopal New Delhi. The study was approved by the Institutional Ethics Committee of the All India Institute of Medical Sciences, Bhopal, New Delhi (approval no: IHEC-LOP/2023/IL0146, date: 02.01.2024). It was then conducted in accordance with CONSORT guidelines after prospective trial registration in the Indian Clinical Trials Registry (CTRI/2024/03/063964). Written informed consent was not required.

Primigravid women scheduled for elective LSCS under SAB were eligible for inclusion. Exclusion criteria included refusal to participate, visual or hearing impairment, requirement for general anaesthesia, history of psychiatric illness or anxiety disorder, use of psychotropic medications, and prior surgical experience. Eligibility was confirmed during pre-anaesthetic evaluation.

The sample size was calculated based on prior studies evaluating preoperative anxiety, assuming a moderate effect size (Cohen's d = 0.5), with a statistical power of 80% and a two-sided significance level (alpha) of 0.05.[15,16] The minimum required sample size was estimated to be 40 participants per group. To account for potential attrition or incomplete data, 45 participants were enrolled in each group, resulting in a total sample size of 90.

Participants were randomized in a 1:1 ratio to the video group (Group V) or the control group (Group C) using a computer-generated random number sequence. Allocation concealment was ensured using sequentially numbered, sealed opaque envelopes prepared by an investigator not involved in recruitment or outcome assessment. The study was single-blind: outcome assessors and QEEG analysts were blinded to group allocation. All participants received routine preoperative counseling and standard peri-anaesthetic care according to institutional protocol.

In Group V, on the day of hospital admission and approximately 24 hours before surgery, the SPEV was shown on a smartphone operated by the investigator after the baseline APAIS assessment. The video was shown in a

quiet counseling room in the maternity ward, with audio delivered via headphones or at low volume for clarity and privacy. The perioperative pathway and operating room events were explained in detail during the video presentation. The 6-minute video covered the patient journey, including pre-anaesthetic evaluation, transfer to the operating room, application of standard monitoring, administration of spinal anaesthesia, intraoperative events including fetal delivery, and postoperative recovery and monitoring.

The video was independently reviewed by two consultant anaesthesiologists and one obstetrician for clinical accuracy, completeness, and suitability for patient understanding. Informal pilot testing was conducted with a small group of patients who were not included in the final analysis to assess the clarity, comprehensibility, and duration. Feedback from experts and patients led to minor modifications in language and sequencing to improve patient comprehension. Following the video, participants were encouraged to ask questions, and the investigator provided clarifications.

Group C received standardized verbal counseling delivered by the same investigator. The counseling covered predefined domains that were identical to those in the video content, including pre-anaesthetic evaluation, transfer to the operating room, application of standard monitoring, administration of spinal anaesthesia, intraoperative events including fetal delivery, and postoperative recovery and monitoring. Verbal counseling was delivered according to a predefined script, lasted the same duration as the intervention group (6 minutes), and did not include any additional individualized information. This was done to minimize performance bias related to unequal attention.

Anxiety was assessed using the validated APAIS, which consists of six items scored on a five-point Likert scale.[17] Assessments were performed at two predefined time points: baseline (upon admission, approximately 24 hours before surgery) and 30 minutes before surgery. APAIS scoring was performed by an investigator blinded to group allocation.

QEEG recordings were obtained at the same time points using an 8-channel system with electrode placement based on the International 10-10 system. An 8-channel EEG system was selected to ensure feasibility in a perioperative clinical setting while maintaining adequate signal quality. Parietal electrodes (P3 and P4) were selected a priori based on evidence suggesting their involvement in anticipatory anxiety and internally directed attention. Recordings were performed with the participant in a seated, relaxed position, with eyes closed. Signals were acquired at a sampling frequency of 250 Hz, band-pass filtered between 0.5 and 45 Hz, and visually inspected to remove artifacts, including eye movements, muscle activity, and electrical noise. Segments with excessive artifacts were excluded from the analysis. Power spectral density was computed using the fast Fourier transform, and band power was calculated for theta (4-8 Hz), alpha (8-13 Hz), and beta (13-30 Hz) frequency bands. The TBR was calculated as the ratio of theta band power to beta band power. Although recordings were obtained from multiple regions, parietal TBR, derived from electrodes P3 and P4, was predefined as the primary QEEG parameter of interest because of its association with internally directed attention and anticipatory anxiety. QEEG analysis was performed by an investigator blinded to group allocation.

All patients underwent cesarean section under spinal anaesthesia, according to the institutional protocol. Standard monitoring, including electrocardiography, non-invasive blood pressure, and pulse oximetry, was applied. Intraoperative intravenous midazolam (1-2 mg) was administered when patients exhibited clinically significant anxiety, discomfort, or restlessness.

Following surgery, patients were transferred to the postoperative recovery area once fully awake and hemodynamically stable. The primary outcome was the between-group difference in APAIS score measured 30 minutes before surgery. Secondary outcomes were between-group differences in TBR at predefined perioperative time points, the correlation between APAIS and TBR, and the intraoperative midazolam requirement.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics. Normality of data distribution was assessed using the Shapiro-Wilk test. Continuous variables were expressed as medians (interquartile ranges) and compared between groups at each time point using the Mann-Whitney U test. Categorical variables were expressed as frequencies (percentages) and analyzed using the chi-square test or Fisher's exact test, as appropriate. The correlation between APAIS scores and TBR was assessed using Spearman's rank correlation coefficient. All tests were two-tailed; a *P* value was considered statistically significant.

Results

A total of 90 primigravida women undergoing elective LSCS were randomized equally into Group V (n = 45) and Group C (n = 45), with no loss to follow-up. The CONSORT flow diagram is presented in Figure 1. Baseline demographic, sociodemographic, and obstetric characteristics were comparable (Table 1). No major maternal or neonatal perioperative complications were observed in either group, and no patient required conversion to general anaesthesia.

Baseline APAIS scores were similar between the two groups, while 30 minutes before surgery, preoperative anxiety was significantly lower in Group V than in Group C (Table 2). Perioperative changes in APAIS score are illustrated in Figure 2.

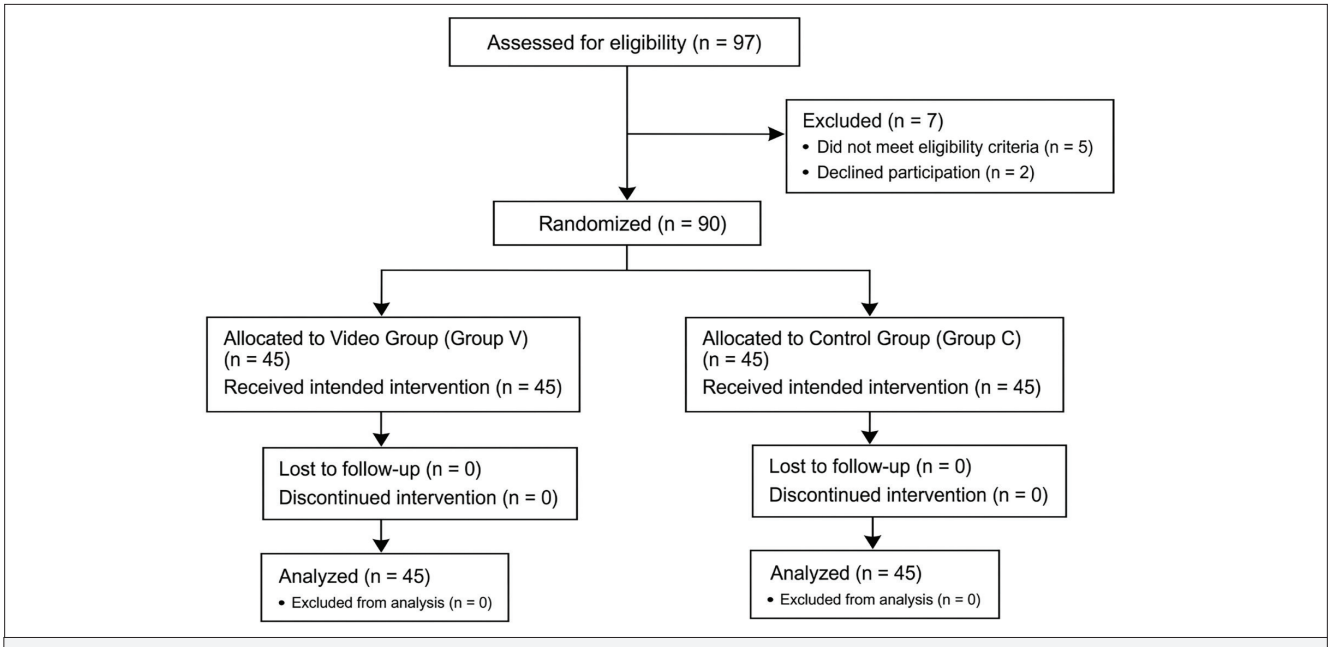

Figure 1. CONSORT flow diagram showing participant screening, randomization, allocation, follow-up, and analysis.

Table 1. Baseline Demographic, Sociodemographic, and Obstetric Characteristics

Variable	Group V (n = 45)	Group C (n = 45)	*P* value
A. Demographic characteristics			
Age (years), mean ± SD	27.8±4.9	26.9±4.7	0.384
BMI (kg m^{2-1}), mean ± SD	25.4±2.9	25.9±3.0	0.461
B. Sociodemographic characteristics			
Education level, n (%)			
Uneducated	4 (8.9%)	6 (13.3%)	
High school	15 (33.3%)	18 (40.0%)	
Graduate	18 (40.0%)	14 (31.1%)	0.721
Postgraduate	8 (17.8%)	7 (15.6%)	
Socioeconomic status, n (%)			
Lower	12 (26.7%)	15 (33.3%)	
Middle	24 (53.3%)	21 (46.7%)	0.684
Upper-middle	9 (20.0%)	9 (20.0%)	
Occupation, n (%)			
Housewife	30 (66.7%)	27 (60.0%)	
Government employee	8 (17.8%)	10 (22.2%)	0.793
Private sector employee	7 (15.6%)	8 (17.8%)	
Residence, n (%)			
Rural	24 (53.3%)	27 (60.0%)	0.672
Urban	21 (46.7%)	18 (40.0%)	
C. Obstetric characteristics			
Gestational age (weeks), mean ± SD	38.5±1.9	38.7±1.5	0.557
Previous hospitalization, n (%)	11 (24.4%)	13 (28.9%)	0.814

BMI, body mass index; SD, standard deviation

Table 2. Comparison of APAIS Scores Between Groups at Different Time Points

Time points	Group V (n = 45)	Group C (n = 45)	*P* value
Baseline	18.0 (17.0-20.0)	19.0 (17.0-20.0)	0.85
30 min before LSCS	11.0 (9.0-12.0)	14.0 (12.0-16.0)	<0.001

LSCS, lower-segment cesarean section; APAIS, Amsterdam Preoperative Anxiety and Information Scale

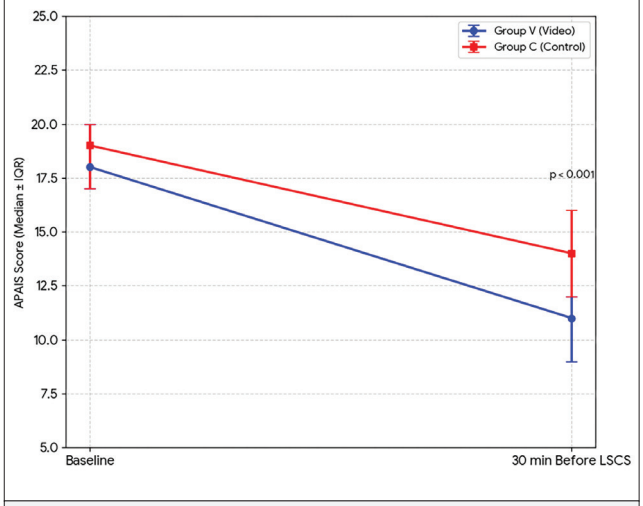

Figure 2. Perioperative changes in APAIS scores in the video and control groups.

APAIS, Amsterdam Preoperative Anxiety and Information Scale; LSCS, lower-segment cesarean section; IQR, interquartile range.

Baseline QEEG-derived TBR was comparable between the groups. However, during the immediate preoperative period, Group V demonstrated significantly lower TBR values than Group C, and this difference persisted at 1 hour after surgery (Table 3). Perioperative changes in TBR are illustrated in Figure 3.

A positive correlation between APAIS and TBR was observed at baseline (P=0.28, P=0.008) and became stronger in the immediate preoperative period (P=0.48, $P < 0.001$), as shown in Figure 4. The requirement for intraoperative midazolam was significantly lower in the video group than in the control group (11.1% vs. 33.3%, P=0.021).

Table 3. Comparison of QEEG Theta-Beta Ratio Between Groups at Different Time Points

Time points	Group V (n = 45)	Group C (n = 45)	*P* value
Baseline	1.82 (1.68-1.97)	1.83 (1.69-1.96)	0.94
30 min before LSCS	1.20 (1.00-1.50)	1.90 (1.70-2.00)	<0.001
1 hour after LSCS	1.20 (0.90-1.55)	1.80 (1.55-2.00)	<0.001

LSCS, lower-segment cesarean section; QEEG, quantitative electroencephalography

Discussion

This randomized controlled trial demonstrated that a SPEV significantly reduced maternal anxiety before elective cesarean section. The intervention was associated with lower APAIS scores, lower QEEG-derived TBR values, and reduced intraoperative midazolam requirements compared with standard counseling alone. Together, these findings suggest that improved perioperative understanding may translate into both psychological and clinically relevant benefits.

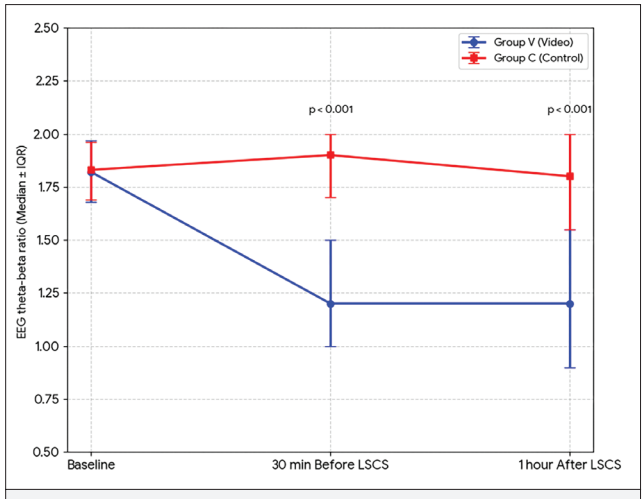

Figure 3. Perioperative changes in QEEG-derived TBR in the video and control groups.

LSCS, lower-segment cesarean section; QEEG, quantitative electroencephalography; IQR, interquartile range; EEG, electroencephalography; TBR, theta-beta ratio.

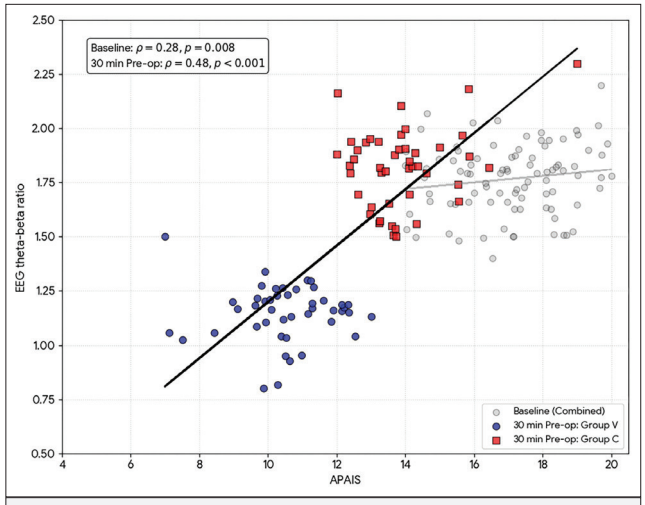

Figure 4. Scatter plots demonstrating the correlation between APAIS scores and QEEG-derived TBR at baseline and 30 minutes before surgery.

APAIS, Amsterdam Preoperative Anxiety and Information Scale; QEEG, quantitative electroencephalography; EEG, electroencephalography; TBR, theta-beta ratio.

Preoperative anxiety is particularly common in obstetric patients, in whom concerns regarding maternal safety, fetal well-being, anaesthesia, and the unfamiliar operating room environment may amplify distress. Previous studies have shown that heightened anxiety may be associated with increased anaesthetic and analgesic requirements, greater postoperative pain, delayed recovery, and lower patient satisfaction.[1-5] Accordingly, safe and scalable non-pharmacological strategies to reduce anxiety are of considerable clinical interest.

Non-pharmacological strategies, including structured counseling, relaxation techniques, and informational videos, have increasingly been investigated to reduce perioperative anxiety by improving patient knowledge and reducing uncertainty. Several randomized and quasi-experimental studies have demonstrated that structured audiovisual education about anaesthesia and surgical procedures can reduce self-reported anxiety and improve patient satisfaction.[6,7,15,16] In the context of elective cesarean delivery, educational videos explaining anaesthesia and perioperative processes have been shown to reduce maternal anxiety and enhance perioperative satisfaction.[8-12] Our findings are consistent with this body of evidence and extend previous work by incorporating an objective neurophysiological correlate of anxiety.

A notable strength of the present study is the parallel improvement observed in both subjective and objective outcomes. Women who viewed the video had lower APAIS scores 30 minutes before surgery and significantly lower TBR values during the immediate preoperative period and 1 hour after surgery. The persistence of this effect into the early postoperative period may indicate sustained attenuation of perioperative stress responses.

QEEG studies suggest that anxiety-related changes in TBR are region-specific. Frontal TBR has been associated with impaired attentional control and reduced top-down regulation, whereas temporal and parietal regions are associated with emotional arousal and internally directed attention.[13,14] However, findings are heterogeneous: both increased and decreased TBR have been reported, depending on underlying theta or beta activity. Temporal signals are also more susceptible to electromyographic artifacts, thereby limiting their reliability in perioperative settings. Frontal TBR, although useful for assessing executive control, may be less sensitive to anticipatory anxiety, which is characterized by rumination and expectancy.[14,18] In this context, parietal TBR may represent a more pragmatic marker of anticipatory anxiety in the perioperative environment.

In contrast, parietal TBR appears to be a more stable marker of internally directed attention and anticipatory processing, with evidence suggesting preferential involvement of posterior cortical networks in anxiety states.[19,20] In the present study, the observed reduction in parietal TBR following exposure to the educational video may reflect attenuation of anticipatory cognitive processing and emotional arousal during the immediate preoperative period. These findings support the concept that QEEG-derived biomarkers may provide complementary insights into perioperative emotional states.

The observed strengthening of the correlation between APAIS scores and TBR as surgery approached is also clinically relevant. It suggests that subjective anxiety and cortical arousal become more closely aligned during the period of greatest anticipatory stress. This supports the use of multimodal assessment strategies in perioperative anxiety research rather than relying solely on questionnaires.

The results of our study complement broader findings from research on digital and multimedia educational interventions aimed at reducing preoperative anxiety. A recent systematic review examining digital health education across multiple surgical contexts reported mixed but generally favorable effects, particularly when audiovisual information was combined with interactive elements or tailored patient education.[21] In other surgical populations, familiarization with perioperative pathways, including explanations of nursing care, operating room procedures, and anaesthesia techniques, has been associated with reduced anxiety and stabilized physiological parameters such as heart rate and blood pressure.[22] These findings support the premise that improving patient preparedness through structured perioperative education may enhance perioperative comfort.

From a practical perspective, this intervention is inexpensive, easy to deliver, reproducible, and readily scalable. Short educational videos can be incorporated into routine preoperative workflows using existing smartphones or tablets without exposing patients to additional medication-related adverse effects. This may be particularly valuable in resource-limited settings where staff time and pharmacological options are constrained.

Strengths of this study include its randomized controlled design, complete follow-up, and combined use of subjective and objective anxiety measures. Future multicenter studies should evaluate diverse obstetric populations, compare different video formats and digital delivery platforms, and integrate EEG with autonomic or hormonal biomarkers to better characterize perioperative anxiety. Emerging technologies such as interactive mobile applications and virtual-reality-based education may further enhance patient engagement and perioperative preparedness.[23] Such approaches may help refine personalized, non-pharmacological strategies to improve the perioperative experience for mothers undergoing cesarean delivery.

Study Limitation

This single-center study had a relatively modest sample size, which may limit generalizability. Participants could not be blinded to the intervention, which introduces the possibility that expectation bias influenced subjective outcomes. Additional interaction time in the intervention group may have contributed to a Hawthorne effect, which could have enhanced the observed benefit. The study population was limited to primigravida women undergoing elective cesarean section under spinal anaesthesia. Therefore, the findings may not be directly applicable to multiparous women, emergency procedures, or other surgical populations. Previous exposure to pregnancy-related online educational material or social media content was not assessed and may have influenced baseline perceptions and anxiety levels. QEEG recordings, although objective, are inherently susceptible to artifacts and environmental influences, and the use of an 8-channel system may not fully capture the complexity of neural activity associated with anxiety. Furthermore, other physiological markers of stress, such as heart rate variability and cortisol levels, were not assessed and could have provided complementary data. The study also focused on short-term perioperative outcomes, and longer-term effects on postoperative recovery, maternal satisfaction, or maternal-infant bonding were not evaluated.

Since this article is a literature review and neither of the authors included any new studies with human participants or animals, ethical approval was not required.

Conclusion

This study suggests that a structured, validated SPEV significantly reduces preoperative anxiety in women undergoing elective LSCS, as evidenced by subjective assessments (APAIS) and objective QEEG-derived TBR biomarkers. This reduction was associated with a lower intraoperative midazolam requirement. These findings support the incorporation of low-cost audiovisual educational tools into routine preoperative care as a practical, safe, and effective non-pharmacological strategy to improve patient preparedness and reduce perioperative anxiety.

Ethics

Ethics Committee Approval: The study was approved by the Institutional Ethics Committee of the All India Institute of Medical Sciences, Bhopal, New Delhi (approval no: IHEC-LOP/2023/IL0146, date: 02.01.2024).

Informed Consent: Written informed consent was obtained from all participants before enrollment.

Footnotes

Authorship Contributions: Surgical and Medical Practices - A.K., U.G.; Concept - A.K., T.M., A.J.; Design - A.K., T.M., A.J., U.G.; Data Collection and/or/Processing - S.J., L.P., U.G.; Analysis and/or/ Interpretation - A.K., S.J., U.G.; Literature Review - A.K., A.J., S.J., L.P., U.G.; Writing - A.K., L.P., U.G.

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Original Article

Regional Anaesthesia for Hernia Surgery

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Ilioinguinal-Iliohypogastric Block for Open Inguinal Hernia Repair: A Prospective Observational Study

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Abstract

Objective: This study aimed to evaluate the effectiveness of the ultrasound-guided ilioinguinal-iliohypogastric (II-IH) nerve block under mild intravenous sedation as a sole anaesthetic technique for open inguinal hernia repair and to identify factors independently associated with clinical inadequacy. The central research question was whether the II-IH block alone, when combined with intravenous sedation, could provide adequate anaesthesia for this procedure in a day-case setting.

Methods: In this prospective observational study conducted at a university hospital, 342 adult patients undergoing unilateral open inguinal hernia repair with II-IH block were enrolled. The primary outcome was a composite of the need for intraoperative opioid supplementation, additional local anaesthetic, or conversion to general anaesthesia. Logistic regression was used to assess predefined predictors of clinical inadequacy.

Results: Out of 342 patients, 233 (68.2%) successfully completed surgery with an II-IH block and mild intravenous sedation as the sole anaesthetic technique. In the remaining 109 patients (31.8%), only 9 (2.6%) required conversion to general anaesthesia. Logistic regression identified anaesthetic volume—but not dose—as significantly associated with clinical inadequacy ($P < 0.001$).

Conclusion: The II-IH block, when combined with sedation, is a feasible and effective anaesthetic approach for a substantial proportion of appropriately selected patients undergoing open inguinal hernia repair. This approach may represent a practical alternative to spinal or general anaesthesia.

Keywords: Ambulatory surgery, block failure predictors, ilioinguinal-iliohypogastric nerve block, inguinal hernia repair, regional anaesthesia, ultrasound-guided nerve block

Main Points

- Ultrasound-guided ilioinguinal-iliohypogastric (II-IH) nerve block combined with intravenous sedation provided adequate anaesthesia as the sole anaesthetic technique in more than two-thirds (68.2%) of patients undergoing open inguinal hernia repair and was associated with a low conversion rate to general anaesthesia (2.6%).
- In cases of clinical inadequacy, they were most often managed with minimal supplementation (additional local anaesthetic or opioids), supporting the feasibility of this approach in a day-case surgical setting.
- The volume of local anaesthetic—but not the total dose—was independently associated with clinical inadequacy, suggesting that excessive volume may reduce block effectiveness when the concentration of the local anaesthetic is lowered.
- Ultrasound-guided II-IH block may be an alternative to general or spinal anaesthesia for open inguinal hernia repair, but optimizing anaesthetic volume and sedation strategy is crucial to maximize procedural success and patient safety.

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Introduction

Inguinal hernia repair surgery is one of the most commonly performed surgeries worldwide.[1] This operation can be conducted under regional anaesthesia (namely spinal anaesthesia, epidural anaesthesia, nerve block or local anaesthesia) or general anaesthesia and the choice between these options largely depends on anaesthesiologist and surgeon habits, preference and expectations of the patients, reliability of the method, and ease and cost of the application.[2]

However, general anaesthesia and neuraxial anaesthesia options may not be the most appropriate choices for a surgery usually performed in a day-case setting due to possible consequences of these techniques as undesirable haemodynamic responses, urinary retention, postdural puncture headache, prolonged recovery and hospital stay.[3] Moreover, for this surgery patients undergoing neuraxial anaesthesia or general anaesthesia express a lower satisfaction than patients receiving other anaesthesia options.[3]

The ilioinguinal-iliohypogastric (II-IH) nerve block is a regional anaesthetic technique that targets the nerves arising from the L1 spinal nerve root. These nerves course between the internal oblique and transversus abdominis muscles, and can usually be visualized and blocked under ultrasound guidance near the anterior superior iliac spine. The ultrasound-guided II-IH block has been used in hernia surgery, either alongside general anaesthesia to reduce opioid and analgesic use,[4] or as a standalone technique with mild sedation.[5] However, its success rate as a sole anaesthetic for open hernia repair remains unclear, and predictors of clinical inadequacy are not well established.

The primary aim of this study was to assess the efficacy of the II-IH block as a standalone technique for open inguinal hernia repair. A secondary aim was to identify factors independently associated with the primary outcome.

Methods

This prospective observational study was conducted in the operating room of Padua University Hospital, Padua, Italy. Approved by the Clinical Research Ethics Committee of Azienda Ospedale University Hospital (approval no: 5804/AO/23, date: 05.09.2023). Registered prospectively on ClinicalTrials.gov (NCT06121726).

Patients aged 18 years or older undergoing unilateral open inguinal hernia repair with II-IH block as the main anaesthesia technique were evaluated for inclusion. Exclusion criteria included a documented allergy to local anaesthetics; cardiac, renal, or hepatic failure; central or peripheral neuropathies; abnormal coagulation tests; infection at the surgical site; and inability to understand or provide written informed consent, which was a mandatory requirement for participation in this study.

Given the observational nature of the study, participation did not alter standard patient management. Therefore, only a brief description of routine care at our hospital is provided in this manuscript. Patients are typically monitored using electrocardiography, pulse oximetry, and non-invasive blood pressure measurement. Following the establishment of peripheral venous access and premedication with midazolam (1-2 mg) and fentanyl 100 μg according to institutional protocol, the II-IH block is performed using ropivacaine, a long-acting local anaesthetic, under ultrasound guidance after proper skin disinfection. At our institution, volumes ranging from 4 to 20 mL and concentrations between 0.4% and 1% are typically used; however, the final dose and concentration are determined at the discretion of the attending anaesthesiologist. The II-IH nerves can be visualized in the transversus abdominis plane (TAP) using a high-frequency linear probe placed on the iliac crest and oriented obliquely between the iliac crest and the umbilicus. If the nerves are not visualizable despite accurate ultrasound scanning, the local anaesthetic is injected into the TAP in close proximity to the iliac crest. Mild sedation was performed with a target controlled infusion pump using the Eleved model;[6] the target concentration was determined at the discretion of the attending anaesthesiologist, typically guided by depth-of-anaesthesia monitoring using the SedLine® system (Masimo, Irvine, CA, USA), with the aim of achieving values consistent with mild sedation (Patient State Index target range: 50-70). All the anaesthesiologists performing the blocks had five or more years of experience in regional anaesthesia.

We collected the following patient-related variables: age (years), gender (male/female), weight (kg), height (cm), American Society of Anesthesiologists physical status (ASA-PS), ultrasound visualization of the II-IH nerves (yes/no), volume of local anaesthetic administered (mL), total dose of ropivacaine (mg), time from block to surgical incision (minutes), dose of propofol used (expressed as effect-site concentration, $\mu g\ kg^{-1}$), and any complications.

The time from block to surgical incision was defined as the interval between completion of the local anaesthetic injection and the skin incision. This variable was recorded to assess whether a shorter interval might be associated with incomplete block onset. The timing primarily depended on surgical workflow and was not modified by the attending anaesthesiologist for the purposes of this study.

We hypothesize that II-IH, when combined with mild intravenous sedation, can be used as the sole anaesthetic technique for open inguinal hernia surgery. For this reason the primary outcome was a composite endpoint defined as the occurrence of any of the following during surgery due to inadequate anaesthetic plan as determined by the attending

anaesthesiologist: (a) administration of additional local anaesthetic, (b) intraoperative opioid use, or (c) conversion to general anaesthesia. Pre-specified predictors of clinical inadequacy, which were defined and registered prior to the study, included age, body mass index, time from block to incision, local anaesthetic dose, local anaesthetic volume, and ultrasound visualization of the nerves.

As a secondary post hoc outcome, we evaluated the incidence of conversion to general anaesthesia.

A large language model (ChatGPT 5.2; OpenAI, San Francisco, CA, USA) was used solely to review and improve the manuscript's grammar and fluency. All content was critically reviewed and verified by the authors, who retain full responsibility and accountability for the final version of the manuscript.[7]

Statistical Analysis

Due to the observational nature of the study and the absence of prior data, a formal sample size calculation was not performed. Instead, we aimed to enroll as many patients as possible over a two-year period, up to a maximum of 400 patients, as approved by the Institutional Review Board.

The Shapiro-Wilk test was used to assess the normality of variable distributions. Continuous variables with normal distribution are presented as mean ± standard deviation, while non-normally distributed variables are reported as median with interquartile range (Q1, Q3). Categorical variables are expressed as absolute numbers and percentages.

Comparisons between groups were conducted using the Student's t-test for normally distributed continuous variables, the Mann-Whitney U test for non-normally distributed continuous variables, and the chi-square test or Fisher's exact test for categorical variables, as appropriate.

To identify predictors of the main outcome, a logistic regression analysis was performed, with the composite main outcome as the dependent binary variable and the pre-specified predictors as independent variables. Results are reported as odds ratios (OR) with 95% confidence intervals (CI).

Statistical significance was defined as a two-tailed P value < 0.05. All analyses were conducted using R software, version 4.0.2 (the R foundation for statistical computing).

Results

A total of 573 patients were evaluated for potential inclusion between October 13, 2023, and May 2, 2025. Of these, 236 patients were excluded: 216 because the attending anaesthesiologist selected an alternative anaesthetic technique (either general or spinal anaesthesia); 5 because they had abnormal coagulation tests; and 9 because they did not provide informed consent. This left 342 patients enrolled in the study (Figure 1). Patient characteristics for both groups—those with successful and failed blocks—are summarized in Table 1.

Among the included patients, 233 (68.2%) successfully underwent open inguinal hernia repair with an II-IH nerve block and mild intravenous sedation as the sole anaesthetic technique. The remaining 109 patients (31.8%) required additional local anaesthesia, administration of opioids, or conversion to general anaesthesia.

In particular, 85 patients required supplementary local anaesthetic administered by the surgeon; 36 received an additional 100 μg dose of fentanyl (interquartile range: 100-100); and nine patients (2.6%) required conversion to general anaesthesia. Of those converted, eight cases were attributable to inadequate anaesthesia despite the administration of both local anaesthetic and opioids, while one conversion was necessitated by intraoperative bronchospasm. Additionally, in five patients (1.5%), all of whom were in the success group, a femoral nerve block complicated the postoperative period, in all of these patients 20 mL of local anaesthetic were used. This complication necessitated overnight observation, resulting in a one-day prolongation of hospitalization. All affected patients had complete sensory and motor recovery by the first postoperative day and were discharged without further complications.

A scatter plot displaying the relationship among block clinical adequacy, volume, and concentration is shown in Figure 2.

In the logistic regression of the pre-specified predictors, only the volume—but not the dose—of local anaesthetic was statistically significant ($P < 0.001$), as shown in Table 2.

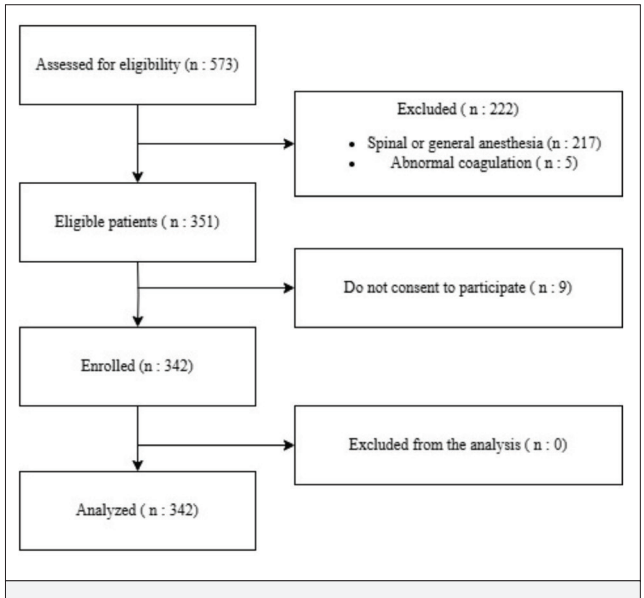

Figure 1. Enrollment flow-chart.

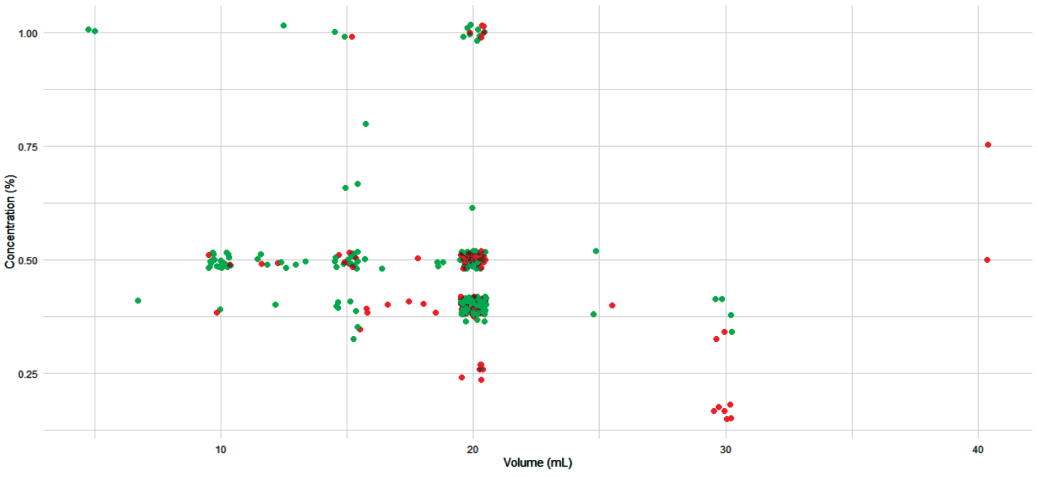

Figure 2. Scatter plot showing the association between injected volume and ropivacaine concentration, stratified by block outcome (failure in red, success in green). Each point corresponds to one patient. To minimize overplotting due to the limited number of concentration levels, a small vertical jitter was applied (±0.02%). Consequently, some points may appear marginally outside the true concentration values for visualization purposes only.

Table 1. Characteristics of Study Participants

Success	**Yes (233)**	**No (109)**	***P* value**
Gender (M)	210 (90.1%)	101 (92.7%)	0.447
Age (years)	60.18±14.64	60.77±12.26	0.694
ASA-PS	2 (1-2)	2 (1-2)	0.661
BMI (kg m^{2-1})	24.61±2.83	24.95±3.01	0.338
US optimal visualization (yes)	155 (66.5%)	80 (73.4%)	0.201
LA dose (mg)	80 (80-100)	80 (75-100)	0.978
LA volume (mL)	20 (15-20)	20 (20-20)	0.002*
Time to incision (min)	18.35±9.88	17.67±10.79	0.576
Propofol (cet)	1.5 (1.2-2.0)	1.8 (1.3-2.2)	0.009*

*: Statistically significant at *P* value < 0.050
ASA-PS, American Society of Anesthesiologists physical status; BMI, body mass index; Cet, target concentration at effect site; LA, local anaesthetic; M, male; US, ultrasound

Table 2. Logistic Regression (Binary Composite Main Outcome as Dependent Variable)

Variable	**OR (95% CI)**	***P* value**
Age (years)	1.01 (0.99- 1.03)	0.457
LA dose (mg)	1.00 (1.00-1.01)	0.388
LA volume (mL)	1.13 (1.06- 1.21)	<0.001*
Time to incision (min)	0.99 (0.96-1.01)	0.362
US optimal visualization (yes)	1.58 (0.93- 2.74)	0.098
BMI (kg m^{2-1})	1.04 (0.96- 1.13)	0.379

*: Statistically significant at *P* value < 0.050
BMI, body mass index; LA, local anaesthetic; US, ultrasound; OR, odds ratio; CI, confidence interval

Although the level of propofol sedation reached statistical significance in univariable analysis, it was not included in the multivariable logistic regression model for two reasons. First, according to our predefined statistical analysis plan, only variables identified a priori as clinically relevant were entered into the model. Second, the level of intraoperative propofol sedation may represent a consequence rather than an independent predictor of block inadequacy, since patients with insufficient block efficacy are more likely to receive higher levels of sedation. Including this variable in the model could, therefore, introduce reverse causality and bias the estimates. Table 3 compares patients who required conversion to general anaesthesia with those who did not.

Table 3. Group Characteristics for the Post-hoc Analysis Evaluating Conversion to General Anaesthesia

Conversion to GA	No (333)	Yes (9)
Gender (M)	303 (91.0%)	8 (88.9%)
Age (years)	60 (51-70.25)	66 (56-68)
ASA-PS	2 (1-2)	2 (1-2)
BMI (kg m^{2-1})	24.45 (22.86-26.57)	23.53 (22.78-26.99)
US optimal visualization (yes)	231 (69.4%)	4 (44.4%)
LA dose (mg)	80 (75-100)	80 (75-80)
LA volume (mL)	20 (20-20)	20 (15-20)
Time to incision (min)	15 (10-25)	15 (10-20)
Propofol (cet)	1.5 (1.2-2)	2 (1.8-3.5)

Given the exploratory nature of the analysis, we chose not to perform formal statistical comparisons between groups

ASA-PS, American Society of Anesthesiologists physical status; BMI, body mass index; Cet, target concentration at effect site; GA, general anaesthesia; LA, local anaesthetic; M, male; US, ultrasound

Discussion

The main finding of this study is that open inguinal hernia repair can be effectively performed using the II-IH nerve block under mild intravenous sedation as the sole anaesthetic technique in the majority of cases (68.2%). This finding suggests that the II-IH nerve block may be considered for selected patients undergoing inguinal hernia repair.

Even among the remaining 31.8% of patients who needed further intervention to achieve an adequate anaesthetic plane, most were managed with minimal supplementation, either with local anaesthetics or opioids. The rate of conversion to general anaesthesia remained low (2.6%), which further reinforces the clinical feasibility of this technique, especially in the context of ambulatory surgery. However, femoral nerve block occurred in 1.5% of the overall population, likely due to the anatomical proximity between the fascia iliaca compartment and the TAP.[8] This potential complication should always be considered, as it may have disproportionate implications for ambulatory surgery, where early mobilization and timely discharge are essential.

Pain during open inguinal hernia repair is not exclusively mediated by the II-IH nerves. The genital branch of the genitofemoral nerve may also contribute significantly to perioperative pain due to its anatomical course within the inguinal canal and its close association with the spermatic cord, although its trajectory and sensory distribution demonstrate considerable interindividual variability.[9,10] Surgical manipulation, hernia sac dissection, and mesh placement may stimulate this nerve, potentially leading to incomplete analgesia. Consequently, insufficient blockade of the genitofemoral nerve may partly account for cases of inadequate anaesthesia despite an apparently successful II-IH block; and the block of all of these nerve blocks have reported higher patient satisfaction than the II-IH alone.[11] However, a previous study compared the combined II-IH and genitofemoral nerve block with spinal anaesthesia in a similar surgical population. Although the authors reported reduced postoperative pain in patients receiving the II-IH block compared with spinal anaesthesia, 13.3% of patients in the II-IH group experienced block failure and were excluded from the final analysis. Moreover, the criteria used to define block failure were not clearly specified, which limits comparability with our reported failure rates.[12]

II-IH block has long been established as a preferred regional anaesthetic technique for pain control after open inguinal hernia repair. Its effectiveness has been shown to be superior to that of the TAP involve injections into a similar fascial plane, the II-IH block allows more targeted nerve blockade.[13]

However, this superiority has been demonstrated only when the II-IH block is performed under ultrasound guidance. When performed using a landmark-based (blind) technique, the II-IH block has been shown to be inferior to an ultrasound-guided TAP block.[14]

Although optimal nerve visualization under ultrasound was numerically higher in the failure group, this difference did not reach statistical significance. The lack of statistical significance suggests that the observed difference may be attributable to random variation rather than to a true underlying association, i.e., it likely reflects chance alone.

The II-IH block has been proposed for inguinal hernia repair because it offers several advantages over general and spinal anaesthesia. These include reduced opioid consumption,[4,15] higher satisfaction,[16] potential reductions in chronic postoperative pain—though findings remain conflicting—[1,17] and earlier hospital discharge.[15,18]

Of particular interest in our study is the relationship between clinical inadequacy and anaesthetic volume. While our institution has traditionally employed relatively

large volumes, our results suggest that larger volumes may not confer additional benefit and may, in fact, be counterproductive. When the total dose of anaesthetic is held constant, increasing volume necessarily decreases concentration, which could reduce the effectiveness of the block as a sole anaesthetic technique. Furthermore, variations in injectate volume may influence the spread within fascial planaes, alter local anaesthetic distribution, and increase the likelihood of unintended blockade of adjacent nerves. Notably, femoral nerve block occurred in a subset of patients and may have been facilitated by greater spread of injectate associated with larger volumes. Moreover, the existing literature indicates that the minimum effective volume for successful II-IH block is approximately 0.9 mL per nerve, and even with such small volumes, selective blockade of the ilioinguinal or of the iliohypogastric nerves individually is not reliably achievable suggesting that even with small volumes both nerves are blocked.[19,20] This suggests that precision in volume and concentration—rather than simply increasing total volume—may be more critical to the success and safety of the block.

An important consideration is the anatomical and surgical complexity of the inguinal region in open hernia repair. The II-IH block primarily targets the anterior branches of T12-L1; however, the surgical steps involved—including skin incision, spermatic cord manipulation, deep dissection, and mesh placement—may recruit nociceptive input beyond this territory. Specifically, the lateral cutaneous branches of T12-L1 and, critically, the genital branch of the genitofemoral nerve, which travels through the inguinal canal in close proximity to the spermatic cord, may contribute significantly to intraoperative nociception, particularly during cord manipulation and deep dissection. It follows that a subset of cases requiring analgesic supplementation may reflect incomplete anatomical coverage rather than a true technical failure of the block-a distinction with relevant clinical and methodological implications.

In this regard, our study should not be interpreted as an investigation of the practitioner's ability to successfully perform the II-IH block, but rather as an assessment of the extent to which the II-IH block provides adequate sensory coverage of the surgical field during open inguinal hernia repair. This distinction, while subtle, is substantial. Our findings indicate that the proportion of cases in which the II-IH block alone achieves complete intraoperative analgesia is appreciable but not absolute, suggesting that the anatomical territory of this block may be insufficient to cover the full nociceptive input of the surgical field in a non-negligible subset of patients.

For this reason, practitioners may consider adding complementary fascial-plane blocks to broaden sensory coverage of the inguinal region. The lateral and posterior TAP blocks may provide additional coverage of the lateral cutaneous contributions from T12-L1, while the transversalis fascia plane block has emerged as a promising approach to target the genitofemoral nerve genital branch within the preperitoneal space[21]-a territory not reliably reached by the II-IH block alone. Whether these complementary blocks should be systematically combined with the II-IH block or selectively employed based on intraoperative analgesic requirements remains an open and clinically relevant question. Prospective studies comparing the analgesic efficacy of the II-IH block alone versus that of combined fascial plane block strategies are warranted to optimize regional anaesthesia protocols for open inguinal hernia repair.

Study Limitations

Our study has several limitations that warrant consideration. First, its single-center observational design may limit the generalizability of the findings to other clinical settings. In addition, the lack of standardization of drug concentrations used for both the regional block and sedation and the absence of intraoperative data on pain or hemodynamics may have introduced confounding factors, thereby affecting the consistency of the results. Multicenter prospective studies with standardized protocols are needed to validate and expand upon these findings. Moreover, the absence of a control or comparison group represents an important methodological limitation. As a result, the findings reflect only observational outcomes, and no conclusions can be drawn regarding causality or the superiority or inferiority of the II-IH technique compared with other regional anaesthesia approaches.

Second, the study is subject to selection bias. Of the 573 patients who underwent open inguinal hernia repair at our institution during the study period, 231 were excluded, primarily because the attending anaesthesiologist chose an alternative anaesthetic technique. Unfortunately, we did not collect detailed data on the excluded patients, but it is reasonable to hypothesize that the anaesthetic approach may have been influenced by a variety of factors, including individual preferences of the anaesthesiologist, surgeon, or patient; hernia size; anticipated technical difficulty of the procedure; or the patient's underlying comorbidities. Consequently, more complex or higher-risk cases may have been disproportionately excluded, potentially limiting the generalizability of our findings. However, this type of bias is almost unavoidable in an observational study, as the conduct of the attending anaesthesiologist could not be modified by the researchers. For this reason, prospective and multicenter studies are deemed necessary, and while our findings offer an interesting perspective on the use of II-IH nerve block under mild intravenous sedation as a sole anaesthetic technique for inguinal hernia repair, they should be interpreted with caution.

Third, in addition to anaesthetic factors, surgical variables may have influenced block adequacy. The extent of surgical dissection can vary considerably depending on hernia characteristics, including size and complexity, incision length, degree of spermatic cord mobilization, and mesh size and plane of placement. More extensive tissue manipulation may increase nociceptive input from areas not consistently covered by an ilioinguinal-iliohypogastric block alone, potentially contributing to the inadequacy of the II-IH technique. Because these surgical factors were not systematically recorded in the present study, their impact on block success could not be evaluated. This inability to evaluate their impact should be considered a limitation of our analysis.

No a priori sample size calculation or power analysis was performed. Given the number of variables included in the logistic regression model, the study may have been underpowered to detect smaller but clinically relevant associations; consequently, the stability of the multivariable estimates should be interpreted with caution.

Conclusion

Our findings suggest that ultrasound-guided II-IH nerve block, combined with intravenous sedation, can provide adequate anaesthesia for open inguinal hernia repair in a substantial proportion of appropriately selected patients. This approach may represent a practical alternative to spinal or general anaesthesia, reducing exposure to more invasive anaesthetic techniques while maintaining satisfactory surgical conditions.

Ethics

Ethics Committee Approval: Approved by the Clinical Research Ethics Committee of Azienda Ospedale University Hospital (approval no: 5804/AO/23, date: 05.09.2023).

Informed Consent: Written informed consent was obtained from all participants included in the study.

Footnotes

Authorship Contributions: Surgical and Medical Practices - S.D.P., A.D.C., M.I., G.Z.; Concept - S.D.P., A.d.C.; Design - S.D.P., A.d.C.; Data Collection and/or/Processing - S.D.P., A.D.C., M.I., G.Z., A.B., G.S.; Analysis and/or/ Interpretation - S.D.P., A.D.C., M.I., G.Z., G.S., B.D., G.F., M.M.; Writing - S.D.P., A.D.C., M.I., G.Z., A.B., G.S., B.D., G.F., M.M.

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Effect of Multimodal Pre-emptive Analgesia with Pregabalin Versus Naproxen on Post-Thoracotomy Pain and Opioid Consumption: A Randomized Clinical Trial

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Abstract

Objective: Thoracotomy produces severe postoperative pain that limits deep breathing and coughing and may worsen recovery. Opioid-centred regimens can cause adverse effects; pre-emptive multimodal analgesia may reduce central sensitisation and opioid use.

Methods: In this randomized, active-controlled, assessor-blinded trial (CTRI/2022/07/043800), adults aged 18-70 years (American Society of Anesthesiologists I-II) undergoing thoracotomy were randomized (39 per group) to receive oral pregabalin 2.5 mg kg^{-1} or oral naproxen 7 mg kg^{-1} (maximum 500 mg) 2 hours preoperatively. All patients received standardized general anaesthesia combined with thoracic epidural analgesia. Numerical rating scale (NRS) pain at rest and during deep breathing and coughing were assessed at 2, 6, 12, and 24 hours. A rescue opioid was administered when NRS exceeded 3. Time to first rescue, total 24-hour opioid consumption, number of rescue doses, sleep interference, and adverse events were recorded.

Results: Baseline demographics and perioperative haemodynamics were comparable. Resting pain scores and sleep interference were similar between groups. Pregabalin reduced opioid requirement: fewer patients required rescue analgesia (46.2% vs. 69.2%; *P*=0.042), time to first rescue was longer (7.6±3.1 vs. 5.4±2.8 h; *P*=0.001), and 24-hour opioid consumption was lower (6.2±3.0 vs. 8.6±3.4 mg morphine equivalents; *P*=0.001). Dynamic pain during deep breathing and coughing was lower with pregabalin at early time points; sedation was slightly higher at 2 hours, without significant adverse neurocognitive events.

Conclusion: Pre-emptive pregabalin improved functional analgesia and produced an opioid-sparing effect compared with naproxen after thoracotomy, with acceptable short-term safety, thereby supporting enhanced recovery pathways.

Keywords: Analgesia, analgesics, epidural, naproxen, pain, pregabalin, thoracotomy

Main Points

- Pre-emptive pregabalin and naproxen provided effective control of postoperative pain at rest after thoracotomy when administered as part of a multimodal analgesic regimen that included thoracic epidural analgesia.
- Pregabalin demonstrated a significant opioid-sparing effect, with fewer patients requiring rescue analgesia, longer time to first rescue dose, lower total opioid consumption, and fewer rescue doses within the first 24 hours postoperatively.
- Functional analgesia was slightly better with pregabalin, as evidenced by significantly lower pain scores during deep breathing and coughing in the early postoperative period. This is clinically important for respiratory mechanics and pulmonary recovery. No major safety concerns were identified during the study period.

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Introduction

Thoracotomy was a commonly performed surgical approach that involved an incision through the intercostal space to access the thoracic cavity and was indicated for a wide range of cardiothoracic and pulmonary conditions, including distal aortic, cardiac, esophageal, and pulmonary diseases such as primary or metastatic lung malignancies, pleural tumors, pneumothorax, and empyema.[1-3] In the present study, the majority of patients who underwent thoracotomy had empyema thoracis. Despite advances in surgical and anaesthetic techniques, thoracotomy remains among the most painful surgical procedures, with significant implications for postoperative recovery and morbidity.

Acute pain functioned as a protective physiological response; however, postoperative pain represented a maladaptive phenomenon that conferred no benefit and adversely affected multiple organ systems.[4] Inadequately controlled postoperative pain has been associated with prolonged hospital stay, an increased risk of pulmonary and wound infections, delayed mobilisation, and impaired functional recovery. Moreover, acute postoperative pain was a strong predictor of chronic post-surgical pain, which is reported in 10-65% of patients, underscoring the importance of effective perioperative analgesic strategies.[5,6] Optimal pain control was therefore essential to enhance patient satisfaction, facilitate early ambulation and respiratory physiotherapy, reduce hospitalisation, and prevent immobility-related complications.[7]

Post-thoracotomy pain, reported in 20-80% of patients, exerts a profound negative impact on surgical outcomes by triggering sympathetic overactivity, resulting in tachycardia, hypertension, myocardial ischaemia, and reduced alveolar ventilation, and by impairing wound healing and causing significant patient discomfort. Although multimodal analgesia incorporating opioids and non-steroidal anti-inflammatory drugs (NSAIDs) was routinely practiced, opioid-based regimens were frequently limited by adverse effects such as nausea, vomiting, pruritus, and respiratory depression, and were often inadequate in achieving optimal analgesia.[8-10] These limitations provided a strong rationale for the use of pre-emptive analgesia, wherein analgesic agents were administered prior to the surgical insult to attenuate central sensitisation, hyperalgesia, and allodynia.

Surgical tissue injury led to the release of inflammatory mediators, including prostaglandins and bradykinin, which activated peripheral nociceptors and transmitted pain signals through the dorsal horn of the spinal cord, with N-methyl-D-aspartate receptor pathways playing a critical role in pain amplification and persistence.[11-13] Multimodal analgesia targeted multiple components of this pain pathway to achieve superior analgesic outcomes.[14] Pregabalin, by binding to the α2δ subunit of presynaptic voltage-gated calcium channels, reduced the release of excitatory neurotransmitters, while naproxen inhibited cyclooxygenase-1 and -2 enzymes, thereby decreasing prostaglandin synthesis and limiting both peripheral and central sensitisation.[15,16] Owing to limited direct comparative evidence between these agents as components of pre-emptive multimodal analgesia in thoracotomy, the present randomized study was undertaken to evaluate and compare the effects of pre-emptive pregabalin versus naproxen on postoperative pain intensity, functional pain, and opioid consumption in patients undergoing thoracotomy.

Methods

Study Design and Setting

This study was conducted as a prospective, randomized, active-controlled, assessor-blinded trial at a tertiary care centre in Northern India. The study was carried out in the Department of Anaesthesiology, in collaboration with the Department of General Surgery. The duration of the study was one year. Ethical approval was obtained from the Institutional Ethics Committee of King George's Medical University, U.P., (approval no: VI-PGTSC-IIA/P29, date: 27.10.2021). The study was registered in the Clinical Trials Registry of India (CTRI/2022/07/043800). Written informed consent was obtained from all participants prior to enrolment.

Study Participants

Adult patients of either sex who were scheduled to undergo thoracotomy were screened for eligibility. Surgical procedures included lobectomy, pneumonectomy, wedge resection, and decortication (specify the actual procedures and their numbers). Thoracoscopic (video-assisted thoracoscopic surgery) procedures were excluded. The thoracotomy incision was made in the fifth or sixth intercostal space, according to surgical indication. Inclusion criteria were patients aged 18-70 years, with American Society of Anesthesiologists (ASA) physical status I or II, and normal renal function (creatinine clearance >30 mL min^{-1}). Exclusion criteria were: use of opioids, antidepressants, or anticonvulsants prior to surgery; presence of serious, uncontrolled systemic illness (cardiac, pulmonary, hepatic, renal, or endocrine disorders); pregnancy or lactation; history of angioedema or drug hypersensitivity; and contraindications to epidural analgesia such as spinal deformity or anticoagulant therapy.

Sample size was calculated based on a previous study (Ethemoglu and Calik[17]), where the mean difference in postoperative day 1 numerical rating scale (NRS) between epidural analgesia and pregabalin groups was 1.17 (4.64 vs. 3.47), with variance (σ)=1.85. With α=0.05 ($Z\alpha/2$=1.96) and a power of 80% [$Z(1-\beta)$=0.84], the computed sample size was 39 patients per group.

Intervention Groups

Participants were divided into two groups:

• **Group I** (Pregabalin group): Patients received oral pregabalin at 2.5 mg kg^{-1}, administered 2 hours before surgery.

• **Group II** (Naproxen group): Patients received oral naproxen at 7 mg kg^{-1} (or a fixed dose of 500 mg as per protocol), administered 2 hours before surgery.

Both groups received standardized multimodal general anaesthesia and thoracic epidural analgesia.

Randomization, Allocation, Concealment, and Blinding

Randomization was performed using a computer-generated random-number sequence to allocate patients to either Group I or Group II. Allocation was performed prior to surgery. Outcome assessment was carried out by a trained investigator who was blinded to group allocation. Patients were instructed not to disclose the study medication to the assessor to maintain assessor blinding. Patient blinding was not performed because of the nature of the intervention; therefore, the study was conducted as an assessor-blinded trial.

Intervention and Data Collection Process

Eligible patients scheduled for thoracotomy were screened at the pre-anaesthetic evaluation clinic, and those fulfilling the inclusion criteria were enrolled after obtaining written informed consent. Enrolled patients were admitted to the surgical ward one day prior to surgery, where baseline demographic details, clinical history, ASA physical status, and routine preoperative investigations were recorded. On the day of surgery, patients received the allocated pre-emptive study medication orally with sips of water, approximately two hours before induction of anaesthesia; Group I received pregabalin at 2.5 mg kg^{-1}, while Group II received naproxen at 7 mg kg^{-1} or a fixed dose of 500 mg, as per protocol.

In the operating theatre, standard monitoring was established, following which a thoracic epidural catheter was inserted at the T7-T9 intervertebral level before induction of general anaesthesia. The epidural space was identified using the loss-of-resistance technique, and the catheter was advanced 6-8 cm into it. Correct placement was confirmed by assessment of sensory blockade using cold stimulation. Epidural analgesia was initiated at the start of surgery by administering 10 mL of 0.2% ropivacaine combined with dexmedetomidine (0.5 μg kg^{-1}) through the epidural catheter. Thereafter, all patients were induced and maintained under general anaesthesia with a standardized multimodal anaesthetic technique. Intraoperative hemodynamic parameters were recorded at predefined intervals. Total epidural local anaesthetic consumption and rescue epidural boluses were not recorded, which limits the interpretation of the independent analgesic contribution of pregabalin.

Postoperatively, patients were shifted to the recovery area and subsequently to the ward for continued monitoring. Pain intensity was assessed using the NRS at 2, 6, 12, and 24 hours after surgery, both at rest and during movement, including deep breathing and coughing. The sleep interference rate (SIR) was assessed on the morning of postoperative day one. Rescue analgesia was administered whenever the NRS score exceeded 3; the time to first rescue analgesic, total opioid consumption in the first 24 hours, and number of rescue doses required were documented. Patients were monitored throughout the postoperative period for adverse effects such as sedation, dizziness, somnolence, nausea, vomiting, confusion, and visual disturbances.

Follow-up continued for 24 hours postoperatively, during which all pain scores, sleep interference, analgesic requirements, and adverse events were systematically recorded and entered into the study pro forma for final analysis.

Statistical Analysis

Data were analysed using SPSS version 26.0. Data were checked for normality before analysis. Continuous variables were expressed as mean ± standard deviation for normally distributed data and as median with interquartile range for non-normally distributed data. Categorical variables were expressed as frequencies and percentages. Intergroup comparisons of baseline continuous variables were performed using the Student's t-test or the Mann-Whitney U test, as appropriate; categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate. Postoperative pain and sedation scores, measured repeatedly over time, were analysed using repeated-measures analysis of variance, with group as the between-subjects factor and time as the within-subjects factor. The group × time interaction was assessed to evaluate whether changes in scores over time differed between the study groups. Bonferroni-adjusted post hoc analyses were performed for multiple comparisons whenever significant main or interaction effects were observed. A P value of <0.05 was considered statistically significant.

Results

The baseline demographic and clinical characteristics were comparable between the two groups, with a similar mean age (37.72±13.92 years in Group I vs. 38.49±15.69 years in Group II), gender distribution, and ASA physical status, indicating adequate baseline comparability (Table 1). Perioperative hemodynamic parameters, including heart rate and diastolic blood pressure, remained comparable at all measured time points. A transient but statistically significant difference in systolic blood pressure was observed at 15

minutes (119.59±8.41 mmHg in Group I vs. 124.08±10.39 mmHg in Group II; *P*=0.039), which was not sustained at later intervals and was not clinically significant (Table 2).

Postoperative pain scores at rest were low and comparable between the two groups at all time points, with no statistically significant differences at 2, 6, 12, or 24 hours ($P > 0.05$ for all). SIR were also similar, with SIR-01 reported in 30.8% of patients in Group I and 35.9% of patients in Group II, SIR-02 in 46.2% of patients in Group I and 43.6% of patients in Group II, and SIR-03 in 23.1% of patients in Group I and 20.5% of patients in Group II, indicating comparable sleep quality in both groups (Table 3).

This enhanced analgesic efficacy translated into a significant opioid-sparing effect in Group I, with fewer patients requiring rescue analgesia (46.2% vs. 69.2%; *P*=0.042),a longer time to first rescue dose (7.6±3.1 vs. 5.4±2.8 hours; *P*=0.001),and lower total opioid consumption in the first 24 hours (6.2±3.0 mg vs. 8.6±3.4 mg morphine equivalents; *P*=0.001),along with fewer rescue doses [median 1 (0-2) vs. 2 (1-3); *P*=0.008] (Table 4).

In contrast, Group I demonstrated better control of movement-related pain. Pain scores on deep breathing were significantly lower in Group I at 2 hours (2.64±0.91 vs. 3.08±0.88; *P*=0.033) and 6 hours (2.18±0.84 vs. 2.62±0.79; *P*=0.019), while pain on coughing was significantly

Table 1. Baseline Demographic and Clinical Characteristics of Patients in Group I and Group II

Variables		Group I	Group II
Age		37.72±13.92	38.49±15.69
Gender	**Female**	14 (35.9%)	18 (46.2%)
	Male	25 (64.1%)	21 (53.8%)
ASA	**Grade I**	24 (61.5%)	26 (66.7%)
	Grade II	15 (38.5%)	13 (33.3%)

ASA, American Society of Anesthesiologists

Table 2. Comparison of Perioperative Hemodynamic Parameters Between Group I and Group II

Variables		Group I	Group II	t value	*P* value
Heart rate (beats per minute)	**Pre-op**	84.92±12.01	84.26±8.70	0.281	0.780
	15 min	86.13±11.00	84.59±7.82	0.712	0.479
	60 min	86.00±9.67	85.31±6.62	0.369	0.713
	150 min	86.00±8.34	85.10±5.98	0.546	0.587
Systolic BP (mmHg)	**Pre-op**	121.82±8.77	123.03±8.56	-0.614	0.541
	15 min	119.59±8.41	124.08±10.39	-2.096	0.039
	60 min	121.77±7.47	120.59±8.17	0.665	0.508
	150 min	120.33±7.88	122.38±7.90	-1.148	0.254
Diastolic BP (mmHg)	**Pre-op**	77.62±8.67	78.05±7.60	-0.236	0.814
	15 min	77.15±7.89	77.92±7.02	-0.455	0.650
	60 min	76.15±7.27	78.38±7.13	-1.368	0.175
	150 min	76.15±6.30	77.87±6.49	-1.186	0.239

BP, blood pressure

Table 3. Comparison of Postoperative Pain Intensity and Sleep Interference Between Group I and Group II

Variables		Group I	Group II	t value	*P* value
Level of pain (numerical rating scale)	**2 h**	1.79±0.89	1.64±0.78	0.037	0.970
	6 h	1.38±0.75	1.38±0.49	0.154	0.878
	12 h	1.28±0.60	1.08±0.62	1.454	0.146
	24 h	1.23±0.48	1.18±0.39	0.581	0.561
Sleep interference rate score	**SIR 01**	12 (30.8%)	14 (35.9%)	0.241	0.886
	SIR 02	18 (46.2%)	17 (43.6%)		
	SIR 03	9 (23.1%)	8 (20.5%)		

lower at 2 hours (3.10±0.96 vs. 3.74±0.93; *P*=0.004), 6 hours (2.72±0.89 vs. 3.26±0.90; *P*=0.010), and 12 hours (2.33±0.78 vs. 2.71±0.82; *P*=0.040), reflecting improved functional analgesia in Group I (Table 5).

Sedation scores were marginally higher in Group I at 2 hours postoperatively (2.38±0.54 vs. 2.10±0.45; *P*=0.015), but this difference was not observed at 6 hours. The incidence of excessive sedation, dizziness, somnolence, confusion, and visual disturbances was numerically higher in Group I, but the difference did not reach statistical significance, which indicates an acceptable safety and neurocognitive profile for both regimens (Table 6).

Table 4. Comparison of Rescue Analgesic Requirement and Opioid-sparing Effect (0-24 h)

Variable	Group I (n = 39)	Group II (n = 39)	Test value	*P* value
Patients requiring rescue analgesia, n (%)	18 (46.2%)	27 (69.2%)	χ^2=4.14	0.042
Time to first rescue analgesia (hours)	7.6±3.1	5.4±2.8	t=3.31	0.001
Total opioid consumption in first 24 h (morphine equivalents, mg)	6.2±3.0	8.6±3.4	t=-3.33	0.001
Number of rescue doses in 24 h [median (IQR)]	1 (0-2)	2 (1-3)		0.008

IQR, interquartile range

Table 5. Postoperative Pain Intensity at Rest vs. Movement (NRS)

Pain assessment	Time point	Group I (mean ± SD)	Group II (mean ± SD)	t value	*P* value
Pain at rest	2 h	1.79±0.89	1.80±0.78	0.06	0.95
	6 h	1.38±0.75	1.38±0.49	0.15	0.878
	12 h	1.28±0.60	1.08±0.62	1.45	0.146
	24 h	1.23±0.48	1.18±0.39	0.58	0.561
Pain on deep breathing	2 h	2.64±0.91	3.08±0.88	-2.17	0.033*
	6 h	2.18±0.84	2.62±0.79	-2.4	0.019*
	12 h	1.97±0.73	2.28±0.77	-1.82	0.073
	24 h	1.69±0.62	1.90±0.64	-1.48	0.143
Pain on coughing	2 h	3.10±0.96	3.74±0.93	-3	0.004*
	6 h	2.72±0.89	3.26±0.90	-2.64	0.010*
	12 h	2.33±0.78	2.71±0.82	-2.09	0.040*
	24 h	2.00±0.70	2.18±0.73	-1.12	0.265

test used- student's t test *: P value significant is less than 0.05
NRS, numerical rating scale; SD, standard deviation

Table 6. Sedation and Neurocognitive Adverse Effects (0-24 h)

Variable	Group I (n = 39)	Group II (n = 39)	Test value	*P* value
Sedation score (ramsay) at 2 h	2.38±0.54	2.10±0.45	t=2.50	0.015
Sedation score (ramsay) at 6 h	2.15±0.48	2.05±0.44	t=0.95	0.344
Excessive sedation requiring observation, n (%)	4 (10.3%)	1 (2.6%)	χ^2=1.90	0.168
Dizziness/vertigo, n (%)	9 (23.1%)	3 (7.7%)	χ^2=3.56	0.059
Somnolence, n (%)	7 (17.9%)	2 (5.1%)	χ^2=3.11	0.078
Confusion/disorientation, n (%)	2 (5.1%)	0 (0%)	χ^2=2.05	0.152
Visual disturbance, n (%)	1 (2.6%)	0 (0%)	χ^2=1.01	0.315

Discussion

Effective management of post-thoracotomy pain is essential, as inadequate analgesia adversely affects respiratory mechanics, delays mobilization, and increases the risk of pulmonary complications and chronic post-thoracotomy pain syndrome. Contemporary pain management strategies emphasize opioid-sparing multimodal analgesia to optimize recovery and reduce opioid-related adverse effects. In the present study, both pregabalin and naproxen provided satisfactory control of resting pain during the early postoperative period. However, clinically meaningful differences were observed with respect to opioid requirement, functional pain control, and overall analgesic quality.[18,19]

In our study, baseline demographic and perioperative variables were comparable between the pregabalin and naproxen groups, ensuring a valid comparison of analgesic outcomes. Postoperative pain scores at rest and rates of sleep interference were similar across groups at all assessed time points, indicating that both drugs effectively controlled baseline nociceptive pain. This finding is consistent with previous evidence supporting non-opioid agents as effective components of multimodal analgesia in thoracic surgery.

However, the pregabalin group demonstrated a significant opioid-sparing effect compared with the naproxen group. Fewer patients in the pregabalin group required rescue analgesia; the time to the first rescue dose was significantly longer; and total opioid consumption in the first 24 hours was substantially lower. These findings align with earlier studies by Matsutani et al.,[20] who reported reduced analgesic requirements and improved pain-related outcomes with pregabalin compared with epidural analgesia, and with meta-analytic evidence demonstrating reduced acute postoperative pain scores and opioid use following thoracic surgery when pregabalin is incorporated into the analgesic regimen.

Importantly, pregabalin was associated with better control of movement-related pain. Pain scores during deep breathing and coughing were significantly lower in the pregabalin group, particularly during the early postoperative hours. This observation is clinically relevant because effective analgesia during respiratory maneuvers is critical after thoracotomy for facilitating chest expansion, improving cough efficacy, and reducing pulmonary complications. Naproxen, while effective for inflammatory pain, primarily inhibits peripheral cyclooxygenase and may be less effective at modulating central sensitization and the neuropathic components of post-thoracotomy pain. In contrast, pregabalin acts centrally by binding to the α2δ subunit of voltage-gated calcium channels, reducing excitatory neurotransmitter release and attenuating central sensitization, which likely explains its better performance in functional pain control.[21]

Our findings are in agreement with Mishra et al.,[22] who demonstrated that pregabalin significantly reduced chronic post-thoracotomy pain at longer follow-up intervals, although acute pain scores were comparable initially. While our study did not extend into long-term follow-up, improved early functional analgesia and reduced opioid consumption may play a role in preventing central sensitization and the subsequent development of persistent pain syndromes.[22]

Contrasting evidence from non-thoracic surgical populations must also be considered. Choi et al.[23] reported no significant analgesic advantage of pregabalin over NSAIDs following ankle fracture fixation, with a higher incidence of dizziness and somnolence in the pregabalin group. This discrepancy highlights that the analgesic benefit of pregabalin is procedure-specific and may be more pronounced in surgeries such as thoracotomy, where neuropathic and centrally mediated pain components are prominent.[23]

Regarding safety, the pregabalin group in our study exhibited slightly higher sedation scores in the immediate postoperative period; however, this effect was transient and not associated with clinically significant adverse events such as confusion, excessive somnolence, or visual disturbances. Although dizziness and somnolence have been reported with pregabalin in other studies,[24,25] the incidence in our cohort did not differ significantly from that observed in the naproxen group, indicating an acceptable safety profile at the administered dose of 2.5 mg kg^{-1}.

The effectiveness of naproxen as part of multimodal analgesia is well supported, as highlighted by Weisman[26] who demonstrated its efficacy in reducing postoperative pain and opioid consumption without increasing bleeding risk. The comparable pain scores at rest observed in our naproxen group likely reflect this benefit. However, the more effective opioid-sparing effect and improved dynamic pain control with pregabalin suggest that centrally acting agents may provide additional advantages in thoracic surgical patients.

While both pregabalin and naproxen were effective in controlling postoperative pain at rest following thoracotomy, pregabalin was associated with better pain control during coughing and deep breathing and with reduced postoperative opioid consumption. These findings suggest that pregabalin may be a valuable component of a multimodal analgesic regimen for thoracic surgery; however, larger multicentre studies are warranted to confirm these observations.

A key strength of this study is its randomized design with comparable baseline characteristics, allowing a reliable comparison between pregabalin and naproxen as pre-emptive analgesic agents and a comprehensive assessment of pain at rest, functional pain, opioid consumption, and adverse effects. However, the study is limited by its relatively short follow-up duration, which precludes assessment of

chronic post-thoracotomy pain, and by a modest sample size, limiting generalizability; additionally, the absence of patient-reported quality-of-life measures and objective pulmonary outcomes represents a further limitation; by a modest sample size, which limits generalizability; and by the absence of patient-reported quality-of-life measures and objective pulmonary outcomes.

Study Limitations

This study was limited by its single-center design, relatively small sample size, and lack of long-term follow-up for chronic post-thoracotomy pain. Pain assessment was based on subjective scoring systems, and the lack of clearly defined blinding procedures may have introduced bias. Different doses of pregabalin were not evaluated. As all patients received thoracic epidural analgesia, the observed benefit of pregabalin should be interpreted as an additive effect within a multimodal analgesic regimen rather than as evidence of its independent superiority. Total epidural local anaesthetic consumption and rescue epidural boluses were not recorded, which limits interpretation of the independent analgesic contribution of pregabalin.

Conclusion

Both pregabalin and naproxen provided effective control of postoperative pain at rest following thoracotomy. Pre-emptive pregabalin was associated with improved functional analgesia during deep breathing and coughing, and with reduced postoperative opioid consumption, without a statistically significant increase in adverse events. These findings suggest that pregabalin may offer an additive benefit as part of a multimodal analgesic regimen for thoracic surgery. However, because all patients received thoracic epidural analgesia, and because total epidural local anaesthetic consumption and rescue epidural boluses were not recorded, the independent analgesic contribution of pregabalin cannot be fully determined. Therefore, the observed advantages should be interpreted with appropriate caution. Future multicentre studies with larger sample sizes, longer follow-up for chronic post-thoracotomy pain, standardized assessment of epidural analgesic requirements, and evaluation of optimal dosing strategies are warranted to better define the long-term efficacy and safety of pregabalin within enhanced recovery and multimodal analgesia protocols for thoracic surgery.

Ethics

Ethics Committee Approval: Ethical approval was obtained from the Institutional Ethics Committee of King George's Medical University, U.P., (approval no: VI-PGTSC-IIA/P29, date: 27.10.2021).

Informed Consent: Written informed consent was obtained from all participants prior to enrolment.

Footnotes

Authorship Contributions: Surgical and Medical Practices - P.D., R.G.; Concept - P.D., R.G.; Design - P.D., R.G.; Data Collection and/or/Processing - P.D.; Analysis and/or/ Interpretation - P.D., R.G.; Literature Review - P.D.; Writing - P.D.

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Case Report
Regional Anaesthesia and Acute Postoperative Pain

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The Role of Interfascial Plane Blocks in the Analgesia Management of High-risk Patients in Intensive Care Unit: M-TAPA and Pecto-intercostal Fascial Block after Simultaneous Liver Transplant Recipient and Coronary Artery Bypass Grafting Surgery

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Abstract

Liver transplantation is the gold standard treatment for end-stage liver failure, and early extubation in the postoperative period is recommended to improve graft function. Coronary artery bypass grafting (CABG) is a surgical procedure to restore normal blood flow to an obstructed coronary artery. Patients undergoing cardiac surgery are often heparinized, which increases the risk of hematoma associated with regional anaesthesia, particularly central neuraxial techniques. Effective analgesic management plays a crucial role in achieving early extubation in both surgical procedures. Opioid agents are often preferred for analgesia management. However, the use of opioids in these patients increases the risk of complications; therefore, regional anaesthesia techniques are preferred. In the intensive care unit, we performed a combination of modified thoracoabdominal nerve block and pecto-intercostal fascial plane block as rescue analgesia in a patient who had undergone simultaneous liver transplantation and CABG.

Keywords: Analgesia management, high-risk patient, intensive care unit, interfascial plane blocks, liver transplant recipient surgery, M-TAPA block, pecto-intercostal fascial block

Main Points

- Improving graft function and intensive care unit (ICU) outcomes requires early extubation following liver transplantation, yet opioid side effects and the limitations of regional anaesthesia in coagulopathic patients limit effective pain management.
- A patient undergoing simultaneous liver transplantation and coronary artery bypass grafting was successfully treated with a combination of pecto-intercostal fascial plane block and modified thoracoabdominal nerve block via perichondrial approach for rescue analgesia.
- Our regional anaesthetic approach enabled effective extubation within an hour after the block, stabilized vital signs, and markedly decreased the need for opioids.
- For both subcostal abdominal and median sternotomy incisions, interfascial plane blocks provide effective, targeted pain management, enhance respiratory mechanics, and reduce complications associated with inadequate ventilation.
- In critical care settings, ultrasound-guided interfascial plane blocks should be incorporated into multimodal analgesia protocols because they are safe and effective for ICU patients, including those receiving anticoagulation.

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Introduction

Liver transplantation is the gold standard treatment for end-stage liver failure.[1] Early extubation is recommended in the literature to improve graft function after transplantation, shorten intensive care unit (ICU) stay, and reduce costs.[2] Recent advances in surgical techniques and the adoption of early extubation have increased survival rates in these critically ill patients. However, problems in liver transplant recipients, such as impaired drug metabolism, coagulopathy, and thrombocytopenia, limit the use of regional anaesthesia.[3,4] The tendency towards opioids results in increased addiction rates and the emergence of side effects.[5] Furthermore, perioperative drains placed in the intercostal and subcostal regions may cause severe pain on inspiration and during coughing, leading patients to consciously restrict their breathing.[6] As a result of inadequate breathing, patients may experience hypoventilation and decreased excretion of secretions. This increases the incidence of atelectasis, predominantly at the bases of the lungs, and of recurrent pneumonia. This vicious circle that may occur in patients receiving postoperative mechanical ventilation support causes delays in the extubation process and may cause reintubation in extubated patients.[7] In addition to the challenges of liver transplantation, cardiac surgeries, such as coronary artery bypass grafting (CABG), present their own challenges in pain management.[8] Patients are often heparinized, which increases the risk of hematoma associated with central neuraxial procedures.

We aimed to present a case in which a combination of a modified thoracoabdominal nerve block via perichondrial approach (M-TAPA) and a pecto-intercostal fascial plane block (PIFPB) provided effective ICU analgesia following complex dual surgery. Written informed consent was obtained from the patient for the publication of this case report.

Case Presentation

A 50-year-old male weighing 75 kg with an American Society of Anesthesiologists physical status IV was scheduled for simultaneous liver transplantation and CABG surgery. He had end-stage liver disease due to hepatitis C, with a model for end-stage liver disease score of 28 and severe triple-vessel coronary artery disease (80% stenosis in the left anterior descending, circumflex, and right coronary arteries) requiring surgical revascularization. The total surgical duration was 12 hours, including 90 minutes of cardiopulmonary bypass.

Incisions and drains, surgical procedures:

• Median sternotomy + CABG x2

• Inverted T incision +2 bilateral subphrenic drains

There were no intraoperative complications. On postoperative day 1, the patient was in the ICU and was receiving continuous intravenous fentanyl via patient-controlled analgesia at a basal rate of 20 µg h-1, with 20 µg boluses and a 15-minute lockout. Despite this, he reported severe pain [numerical rating scale (NRS) 8/10] and exhibited tachycardia (heart rate of up to 125 bpm) and hypertension (blood pressure of 160/95 mmHg). The patient was responsive. When we asked him to rate his pain on a scale of 1 to 10 and to write it down on paper, he indicated 8. Initial evaluation excluded other causes such as hypovolemia, electrolyte imbalance, or myocardial ischemia. The patient was also on low-dose aspirin for his CABG, and his coagulation parameters were an international normalized ratio of 1.5, an activated partial thromboplastin time of 45 seconds, and a platelet count of 95,000 µL at the time of the block. Given the hemodynamic instability and inadequate analgesia, ultrasound (US)-guided interfascial plane blocks were performed as rescue analgesia after a thorough risk-benefit assessment.

Under aseptic conditions, a high-frequency linear transducer (11-12 MHz) was first placed at the level of the 9^{th}-10^{th} costal cartilages. Using an 80-mm needle, an M-TAPA block was performed by targeting the lower surface of the cartilage, with bilateral injections of 30 mL of 0.125% bupivacaine. The probe was then positioned parasagittally at the 3^{rd}-4^{th} rib level in the parasternal region, visualizing the ribs, costal cartilage, pectoralis major muscle, intercostal muscles, and pleura. The needle was advanced into the plane between the pectoralis major and intercostal muscles and 5 mL of saline was injected to confirm hydrodissection. A PIFPB was then performed bilaterally with 10 mL of 0.125% bupivacaine. A total of 80 mL of 0.125% bupivacaine solution was administered.

Within 30 minutes, the patient's tachycardia and hypertension resolved and his NRS score decreased to 2. He was extubated one hour later, fully oriented and cooperative, with adequate spontaneous breathing. Post-extubation sensory examination confirmed coverage of dermatomes corresponding to both median sternotomy and subcostal incisions. Routine analgesia consisted of paracetamol 1 g three times daily, with tramadol 1 mg kg^{-1} ordered as rescue analgesia. During the first 24 hours after extubation, his NRS score remained below 3/10, and no rescue analgesic was required (Table 1).

Table 1. 24-hour NRS and Need for Rescue Analgesia Monitoring

Time (hour)	NRS score (0-10)	Need for rescue analgesia
Extubation (0 hour)	2	No
2nd hour	3	No
4th hour	1	No
8th hour	2	No
12th hour	2	No
16th hour	3	No
20th hour	2	No
24th hour	1	No

NRS, numerical rating scale

Discussion

We performed a combination of M-TAPA and PIFPB as rescue analgesia on a patient in the ICU who had undergone liver transplantation and CABG. In our experience, this combination provided effective analgesic management during the extubation period in the ICU for a high-risk patient. To prevent complications and facilitate early mobilization, Enhanced Recovery After Surgery (ERAS) protocols recommend multimodal analgesia.[9,10] In order to minimize the opioid-related adverse events such as respiratory depression, nausea, and vomiting multimodal analgesia regimens are recommended including regional anaesthesia methods (epidural analgesia, nerve blocks and fascial plane blocks) and non-opioid agents (paracetamol, NSAIDs, gabapentin, local anaesthetic infiltrations).[3,4,10] Since patients undergoing cardiac surgery are heparinized, thoracic epidural analgesia and paravertebral nerve blocks are associated with risks, such as hematoma formation.[11] Since fascial plane blocks are superficial and performed under US guidance, the risk is minimal.[12] Because the M-TAPA block provides extensive abdominal dermatomal blockade and the PIFPB provides sternal analgesia, we combined these two blocks in our patient. PIFPB targets the anterior branches of the T2-T6 thoracic spinal nerves, therefore provides analgesia management of anterior chest wall caused by median sternotomy due to bypass surgery.[13] In cadaveric and clinical studies, it has been shown that M-TAPA provides analgesia in the medial and lateral abdomen with a wide abdominal spread.[14-16] Simultaneously, we performed the M-TAPA block and the PIFPB to provide analgesia for the sternotomy, thoracic and abdominal drains, and bilateral subcostal incisions arranged in an inverted T-shape for liver transplantation. The combination of M-TAPA and PIFPB targets the specific nerves innervating the surgical sites (sternotomy and subcostal incisions), providing highly focused regional analgesia that may be more targeted than systemic opioids in selected patients. Fentanyl, while potent, provides systemic analgesia and may not adequately address severe localized pain, especially when the patient is experiencing respiratory compromise due to pain-induced hypoventilation. The use of bupivacaine diluted to 0.125% is standard practice for fascial plane blocks, providing prolonged duration of action while minimizing the risk of local anaesthetic toxicity.

Paracetamol was prescribed as part of a multimodal analgesia protocol recommended by the ERAS guidelines.[9] Paracetamol is a non-opioid analgesic that works through a different mechanism than opioids, and when used in combination, it can provide an opioid-sparing effect. Its use in liver transplant patients is acceptable as long as liver function is carefully monitored and the dosage is adjusted to avoid toxicity. In this case, the patient's liver function was stable, and the standard dose was deemed appropriate for pain management. The combination of the regional blocks and paracetamol produced a synergistic effect, resulting in the patient's pain being well controlled without the need for rescue opioids. With this combined approach, the patient's postoperative pain from both the sternotomy and the subcostal incision was effectively managed. In addition to facilitating early extubation, the effective analgesia provided by the blocks supported respiratory function and, by improving respiratory mechanics, prevented the development of atelectasis and pneumonia. This also promoted early mobilization, reduced the need for opioids and sedatives, accelerated the overall recovery process, and shortened the length of stay in the ICU.

Although other fascial plane blocks, such as the Erector Spinae Plane (ESP), Serratus Anterior Plane (SAP), and subcostal Transversus Abdominis Plane (TAP), are valuable alternatives, we selected M-TAPA and PIFPB for specific anatomical reasons. The ESP block is performed posteriorly and, although effective, requires patient positioning that may be challenging in intubated ICU patients.[17] The SAP block primarily covers the lateral hemithorax and may not adequately address the medial sternotomy pain.[18] Although the subcostal TAP block is effective for upper abdominal incisions, the M-TAPA has been suggested to provide a wider dermatomal spread from a single injection site, effectively covering the large inverted-T incision used in liver transplantation.[19]

Thanks to the use of a combination of interfascial plane blocks, the need for opioids and sedation is reduced, spontaneous respiration is supported, and early extubation is facilitated.

Study Limitations

While a full dermatomal examination was not formally documented in this case, the patient's NRS of 2 and ability to move and respond to questions without experiencing pain

strongly suggest that the blocks provided effective coverage of the dermatomes associated with both the median sternotomy and the subcostal incisions. The clinical outcome, including stabilized vitals and successful extubation, served as the primary measure of the blocks' success.

Conclusion

Interfascial plane blocks provide several advantages in the ICU: an opioid-sparing effect, improved respiratory mechanics (facilitating early weaning), and feasibility in the ICU, as they can be safely performed under US guidance at the bedside. In conclusion, interfascial plane blocks should be considered part of a multimodal analgesia protocol for the analgesic management of critically ill patients in ICUs.

Ethics

Informed Consent: Written informed consent was obtained from the patient for the publication of this case report.

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Footnotes

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Case Report
Intensive Care

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Turkish Journal of Anaesthesiology & Reanimation

Successful Therapeutic Plasma Exchange in Refractory Anti-MDA5-Positive Dermatomyositis and Rapidly Progressive-Interstitial Lung Disease: A Case Report

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Abstract

Anti-MDA5-positive clinically amyopathic dermatomyositis (CADM) is closely linked to rapidly progressive-interstitial lung disease (RP-ILD) and is associated with high mortality rates. This report discusses a 60-year-old female patient diagnosed with anti-MDA5-positive CADM who developed RP-ILD that was resistant to pulse steroid therapy, tacrolimus, and intravenous immunoglobulin. As her respiratory condition worsened alongside rising inflammatory markers, therapeutic plasma exchange (TPE) was initiated. Following four sessions of TPE administered on alternate days, significant clinical and laboratory improvements were observed. This case underscores the potential life-saving impact of early TPE for patients with anti-MDA5-positive CADM and RP-ILD who do not respond to traditional immunosuppressive treatments.

Keywords: Anti-MDA5, dermatomyositis, RP-ILD, TPE

Main Points

- Anti-MDA5-positive dermatomyositis may present as an amyopathic condition, but poses a significant risk of developing rapidly progressive-interstitial lung disease, which carries a high mortality.
- Standard treatments, such as high-dose corticosteroids, calcineurin inhibitors, and intravenous immunoglobulin, often fail to halt neurological deterioration, as in this patient.
- Therapeutic plasma exchange (TPE) can effectively remove circulating anti-MDA5 antibodies and proinflammatory mediators, leading to substantial clinical and laboratory improvements.
- In this instance, TPE resulted in marked reductions in ferritin and C-reactive protein levels and in improved oxygenation and radiological outcomes shortly after the initial treatment.

Introduction

Anti-MDA5-positive clinically amyopathic dermatomyositis (CADM) is a rare variant of idiopathic inflammatory myopathies, distinguished by specific skin manifestations and minimal or absent muscle involvement. The principal clinical challenge arises from the development of rapidly progressive-interstitial lung disease (RP-ILD), which stands as the foremost cause of morbidity and mortality in affected individuals.[1,2] Reported mortality rates exceed 50% within six months post-diagnosis, highlighting the aggressive nature of this condition.[3,4] Current management approaches include administering high-dose corticosteroids along with calcineurin inhibitors or cyclophosphamide.[2-4] Nevertheless, many patients exhibit inadequate responses to aggressive immunosuppression and subsequently experience rapid clinical decline; thus, early identification of patients at high-risk is essential. Various laboratory indicators, including elevated serum ferritin levels, lactate dehydrogenase (LDH), and systemic inflammatory markers, have been correlated with disease severity and a poor prognosis.[5,6] These

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observations imply that ongoing inflammation and lung injury contribute significantly to the swift progression of RP-ILD in patients with anti-MDA5-positive CADM. Due to the limited effectiveness of standard therapies, alternative treatment strategies are being investigated. Early detection and intervention are critical for enhancing outcomes in this complex condition. This study documents a case of anti-MDA5-positive CADM complicated by RP-ILD that was resistant to conventional treatment but showed a marked response to therapeutic plasma exchange (TPE).

Case Report

A 60-year-old woman with a medical history of hypertension and an aneurysm presented with a three-week history of dry cough, worsening shortness of breath, and fatigue. Consent was obtained from the patient before reporting. She reported no muscle weakness or pain. Upon physical examination, findings included heliotrope rash, Gottron papules, periungual telangiectasia, and digital ulcers; muscle strength remained intact. Pre-TPE lab results indicated positive anti-MDA5 antibodies (other myositis-specific antibodies were negative), a creatine kinase (CK) level of 1,412 U L^{-1}, a LDH level of 361 U L^{-1}, a serum ferritin level of 1,450 ng mL^{-1}, and a C-reactive protein (CRP) level of 22 mg L^{-1}. Arterial blood gas analysis revealed hypoxemia (PaO_2: 45 mmHg). Her oxygen saturation ranged between 86% and 92% while using a high-flow nasal cannula (HFNC) at an FiO_2 of 80% delivered at a flow rate of 60 L min^{-1} (Figure 1). Initial therapy consisted of pulse methylprednisolone administered daily for three days, followed by oral prednisolone (1 mg kg^{-1}/day) combined with tacrolimus (3 mg/day) and intravenous immunoglobulin (IVIG) administered over five days (total dose 2 g kg^{-1}). Despite these efforts, her condition continued to deteriorate alongside increasing oxygen requirements; gastroscopy revealed subcutaneous emphysema, and thoracic computed tomography scans showed septal thickening in the lower lobes, bilateral ground-glass opacities indicating consolidations, and late-stage "honeycombing" suggestive of fibrosis. TPE commenced on day 17 of her intensive care unit (ICU) stay; five sessions were conducted on alternate days, with approximately two liters (40 mL kg^{-1}) exchanged per session, using fresh frozen plasma. Clinical improvement was observed following the second session when FiO_2 requirements decreased, leading up to HFNC discontinuation on day 19 in favor of nasal cannula oxygen support instead-ultimately ceasing all supplemental oxygen entirely by day 22 when she transitioned from ICU care back onto general ward status on day 27 without complications arising from the TPE procedure itself. Post-TPE lab values recorded ferritin reduced to 878 ng mL^{-1}, CRP down to 5 mg L^{-1}, LDH fell below 290 U/L, CK lowered significantly reaching 31 U/L (Figure 2).

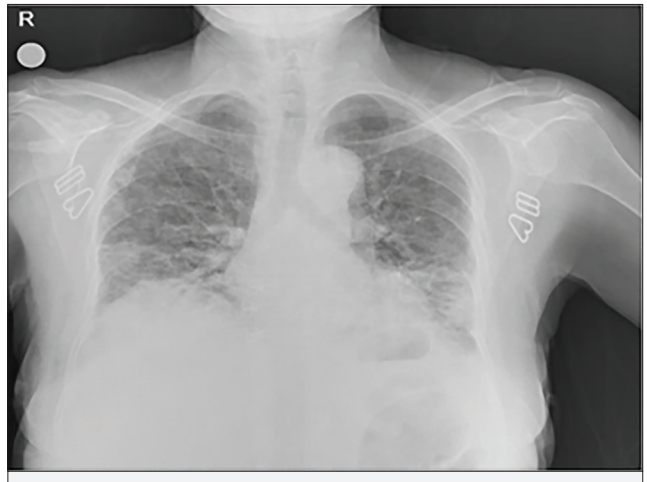

Figure 1. Chest X-ray before plasmapheresis.

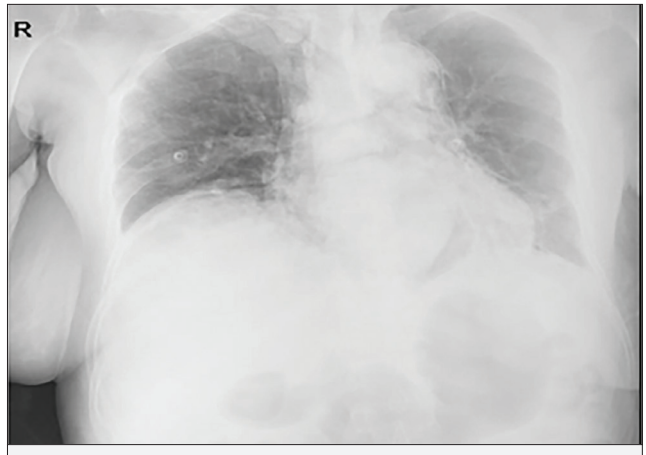

Figure 2. Chest X-ray after successful use of therapeutic plasma exchange.

Discussion

Anti-MDA5-positive dermatomyositis frequently correlates strongly with pulmonary involvement resulting in heightened mortality risks.[1,2] Notable prognostic biomarkers such as hyperferritinemia alongside elevated LDH levels, coupled with worsening respiratory metrics, serve as key indicators regarding overall severity faced throughout the course of the disease process.[5,6] In the context surrounding the current case represented here significant drops identified within both ferritin and CRP values coincided directly alongside observable clinical improvements, thereby reinforcing the therapeutic advantages yielded through application implementing TPE procedures undertaken upon patients exhibiting refractory responses towards established first-line therapies typically employed comprising primarily either corticosteroid options or else calcineurin-based agents plus possible adjunct use of IVIG if deemed necessary.[3,7] However, refractory RP-ILD remains a major therapeutic challenge. TPE facilitates the rapid removal of circulating

anti-MDA5 antibodies, immune complexes, and pro-inflammatory cytokines, which may explain the observed clinical stabilization in refractory cases.[8] Previous case series and reviews have reported improved outcomes when TPE is initiated early.[9,10] This case adds to the growing body of evidence suggesting that TPE may serve as a life-saving bridge therapy in patients unresponsive to conventional immunosuppression. Emerging therapies, including Janus kinase inhibitors such as tofacitinib and baricitinib, have shown promise in improving lung function and survival in patients with RP-ILD who have failed standard treatments.[11] Although these therapies remain under investigation, combining TPE with

Conclusion

TPE may represent an urgent, life-saving measure for individuals with anti-MDA5-positive CADM complicated by RP-ILD when conventional treatments, such as corticosteroids or IVIG, are insufficient alone. Prospective and controlled studies are warranted to define the role of TPE in standard treatment protocols for this patient population.

Ethics

Informed Consent: Consent was obtained from the patient before reporting.

Footnotes

Authorship Contributions: Surgical and Medical Practices - B.B., E.K.; Concept - B.B., E.K.; Design - B.B., E.K.; Data Collection and/or Processing - B.B., E.K.; Analysis and/or/Interpretation - B.B., E.K.; Literature Review - B.B., E.K.; Writing - B.B., E.K.

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Case Report
Paediatric Anaesthesia

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Anaesthetic Management of CHARGE Syndrome with Anorectal Malformation in an Infant: A Case Report

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Abstract

CHARGE syndrome is a rare congenital disorder with multisystem involvement, posing significant anaesthetic challenges. We report the perioperative management of an 11-month-old male who was diagnosed with anorectal malformation and CHARGE syndrome and who underwent posterior sagittal anorectoplasty. Key anaesthetic considerations included craniofacial asymmetry, facial nerve palsy, and anticipated airway difficulties. Inhalational induction with careful preoxygenation, video laryngoscopy, and caudal analgesia facilitated safe anaesthesia. Post-operative airway compromise was managed with continuous positive airway pressure, and the patient recovered without further complications or intervention. Ultrasound guidance may facilitate identification of relevant anatomy and real-time visualization of injectate spread during caudal block. This case highlights the importance of meticulous pre-anaesthetic planning and multidisciplinary evaluation in children with CHARGE syndrome.

Keywords: Airway management, anorectal malformation, CHARGE syndrome, paediatric anaesthesia, perioperative care, videolaryngoscopy

Main Points

- CHARGE syndrome presents unique anaesthetic challenges, especially airway management.
- Preoxygenation and confirmation of mask ventilation are crucial before intubation.
- Video laryngoscopy facilitates safe intubation in patients with craniofacial anomalies.
- Post-operative airway compromise can occur even after a smooth intra-operative course.
- Multidisciplinary evaluation (ear, nose and throat, ophthalmology, and cardiology) is essential.

Introduction

Anorectal malformation (ARM) refers to a range of conditions characterised primarily by an absent or abnormal anal opening. The incidence is 1 in 5000 live births and is more common in males.[1] The term "CHARGE" is an acronym for a group of clinical features, including Coloboma, heart defects, choanal atresia, retardation (of growth and/or development), Genitourinary malformations, and Ear abnormalities. The majority of patients have a single mutation in the *CHD7* gene.[2] CHARGE syndrome occurs in 1 in 10,000 live births and affects males and females equally.[3] From an anaesthetic perspective, these patients pose considerable perioperative challenges, including potential airway difficulty, congenital cardiac lesions, and neurological abnormalities.

We report the anaesthetic management of an 11-month-old infant with ARM and CHARGE syndrome, who was posted for anorectoplasty, emphasising its perioperative concerns.

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Case Report

An 11-month-old male infant weighing 5.1 kg and diagnosed with ARM and CHARGE syndrome was scheduled for posterior sagittal anorectoplasty.

The patient was born at term with a birth weight of 2.5 kg and was diagnosed with an imperforate anus. On day 1 of life, he underwent a sigmoid colostomy at another hospital. There was no significant antenatal or postnatal history. Currently, his developmental milestones are delayed. His weight was below the 3rd percentile, suggesting failure to thrive. The child exhibited multiple congenital anomalies consistent with CHARGE syndrome, including left iris coloboma, right facial nerve palsy, right anotia, right microphthalmos, right hanging thumb polydactyly, J-shaped palmar crease, and growth retardation (Figure 1). The presence of retrognathia, a short neck, and facial abnormalities led us to anticipate a difficult airway, particularly with regard to mask ventilation.

The examination revealed a heart rate of 120 beats/min, a respiratory rate of 20 breaths/min, and a blood pressure of 90/50 mmHg. Oxygen saturation was 98% on room air. Respiratory and cardiovascular examinations were normal. Routine laboratory investigations were within normal limits. Two-dimensional echocardiography and radiographs of the chest and lumbosacral spine revealed no abnormalities. Ophthalmology and ear, nose and throat evaluations were performed, and imaging of the brain and temporal bone was recommended for follow-up. Written informed consent for the planned anaesthesia and surgery, as well as for publication of the case details, was obtained from the patient's parents.

Anaesthetic Management

After the patient's fasting status was confirmed, the patient was taken to the operating theatre, and standard monitors were applied.

The difficult airway cart was kept ready for use. Inhalational induction of anaesthesia was performed using sevoflurane in 100% oxygen. A 22-G intravenous (IV) cannula was secured, and IV glycopyrrolate (5 μg kg^{-1}) and fentanyl (1 μg kg^{-1}) were given. Adequate mask ventilation was established with an oral airway. Nasal patency was confirmed by the gentle passage of a catheter. A smooth video laryngoscopy using a size 2 Macintosh blade on the C-MAC revealed a percentage of glottic opening of 50% (Figure 2). The video laryngoscopy showed normal supraglottic and glottic anatomy and no airway collapse. As tracheomalacia is an associated airway anomaly in CHARGE syndrome, dynamic bronchoscopy is the gold standard for diagnosis. In the absence of preoperative stridor, recurrent desaturation, persistent wheezing, or any history suggestive of significant airway compromise, we avoided further invasive airway evaluation. After administering IV atracurium (0.5 mg kg^{-1}) and ventilating for 3 minutes, an oral uncuffed endotracheal tube (ETT) of 4.5 mm internal diameter was secured. The Correct placement of the ETT was confirmed by bilateral auscultation and capnography. Anaesthesia was maintained with pressure-controlled ventilation using a 50:50 oxygen and air mixture at a minimal alveolar concentration of 1-1.5. For regional analgesia, an ultrasound-guided caudal

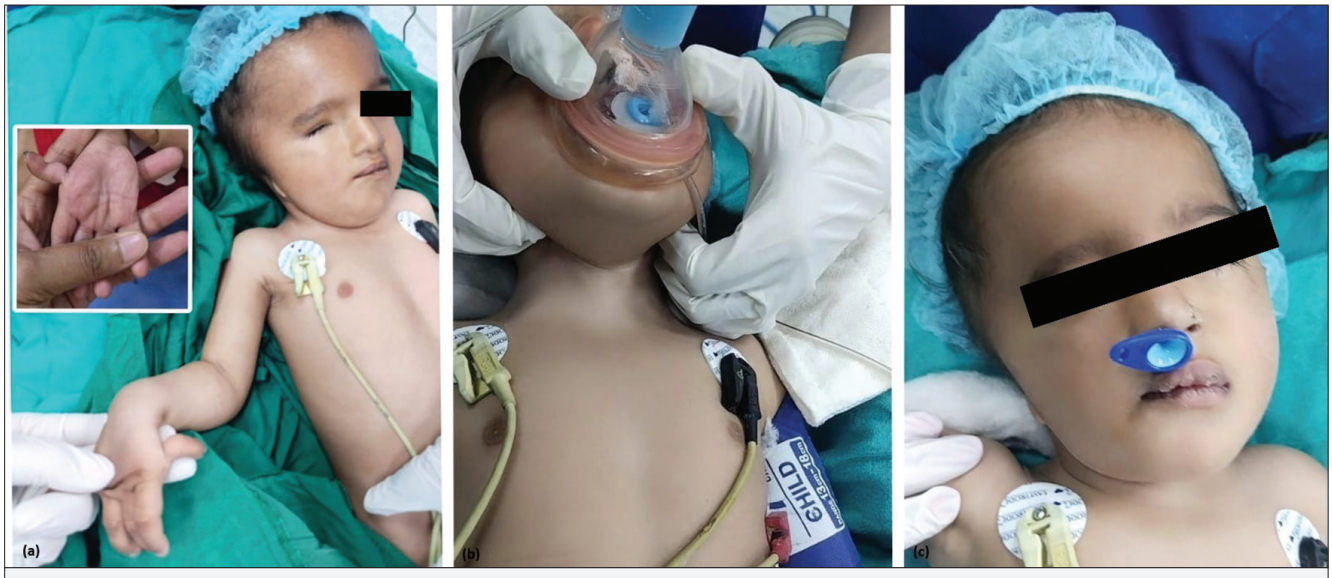

Figure 1. Clinical features of CHARGE syndrome. (a) Retrognathia, right-sided facial palsy, right anotia, right microphthalmos, right hanging thumb polydactyly, J-shaped palmar crease (sub-image). (b) Oral airway and jaw-thrust to ensure adequate mask ventilation. (c) The appropriately sized nasopharyngeal airway maintained a patent airway in the early post-operative period.

epidural block was administered in the left lateral position, using 5 mL of isobaric bupivacaine (0.25%) (Figure 3).

The patient was positioned in the prone jackknife position, with careful padding of the eyes and pressure points. Intraoperatively, a recto-bulbar (urethral) fistula was identified, with the preoperatively secured urinary catheter malpositioned within the fistulous tract. Later, a suprapubic urinary catheter was secured. The surgical time was 90 minutes. Intra-operative vital signs remained stable.

At the end of surgery, IV paracetamol 15 mg kg^{-1} was given, and neuromuscular blockade was reversed with neostigmine (50 µg kg^{-1}) and glycopyrrolate (10 µg kg^{-1}). After extubation, the patient developed suprasternal retraction and accessory muscle use. This was managed using a nasopharyngeal airway, continuous positive airway pressure at 5-10 cm H_2O, and 100% oxygen. The patient stabilised within minutes and was transferred to the recovery room. No further complications occurred.

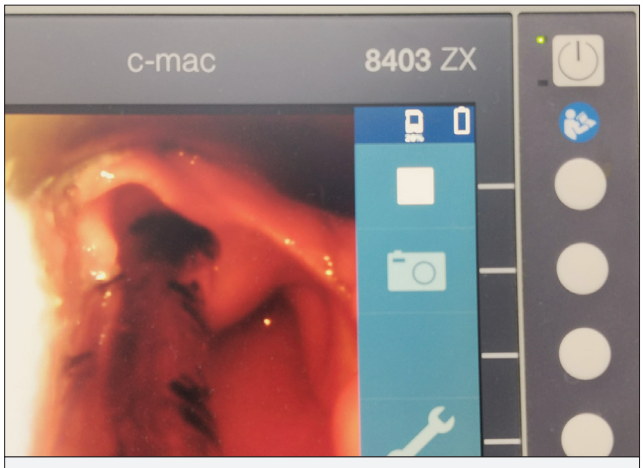

Figure 2. POGO score of 50% seen on C-MAC video laryngoscope with oral ETT secured.

POGO, percentage of glottic opening; ETT, endotracheal tube.

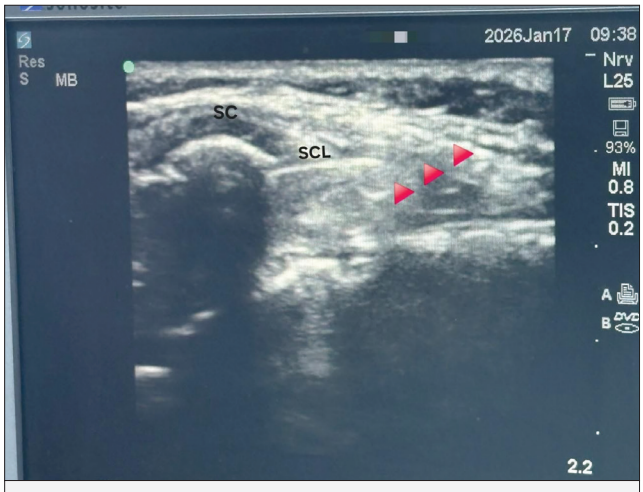

Figure 3. Ultrasonographic image of the caudal space depicting sacral cornu (SC) and sacrococcygeal ligament (SCL) with a needle in the caudal space (marked with red arrows).

Discussion

ARM result in an abnormal anal opening with a fistulous tract between the rectum and the urinary system (recto-urethral fistula in approximately 70% of cases) in males, or a fistulous connection with the reproductive system in females.[1]

The cause of ARM is unknown, but genetic factors play a significant role. Almost 60% of cases have associated vertebral, anorectal, cardiac, tracheoesophageal fistula/oesophageal atresia, renal, and limb (VACTERL) defects. ARM has been reported in association with trisomy 8 mosaicism, Down syndrome, and Fragile X syndrome.[4] The association between CHARGE syndrome and ARM is less commonly reported. Dworschak et al.[5] have reported CHARGE syndrome, resulting from de novo variants, as a rare monogenic cause of syndromic ARM.

The diagnosis of CHARGE syndrome is primarily clinical, as first described by Blake et al.[6] and later modified by Verloes[7]. According to Verloes'[7] criteria, our patient met one major criterion (coloboma) and two minor criteria (facial nerve palsy and right ear anotia). Notable phenotypic features include developmental delay, polydactyly, and a J-shaped palmar crease. The presence of recto-bulbar fistula is consistent among male patients with syndromic ARM.

The current guidelines for difficult airways in infants recommend video laryngoscopy as the first-line intubation technique. This approach reduces the number of intubation attempts and the consequent complications.[8]

Post-extubation respiratory distress may have been due to upper airway oedema caused by prone positioning. A similar event was reported by Kumar and Venkatesh[9] who suspected that the cause was glossoptosis and pharyngeal collapse due to underlying hypotonia or cranial nerve dysfunction.

The application of difficult-airway guidelines and regional analgesia provided safe anaesthesia for this syndromic infant. ARM is typically associated with VACTERL anomalies, but our case emphasises the anaesthetic challenges and considerations arising from its rare association with CHARGE syndrome.

Conclusion

This case report provides valuable insights into thorough preoperative evaluation, multidisciplinary management,

and structured perioperative strategies for a syndromic infant, particularly regarding difficult airway management.

Ethics

Informed Consent: Written informed consent for the planned anaesthesia and surgery, as well as for publication of the case details, was obtained from the patient's parents.

Footnotes

Authorship Contributions: Surgical and Medical Practices - N.S., C.C.; Design - G.K.; Literature Search - N.S., G.K., C.C.; Writing - N.S., C.C.

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Letter to the Editor

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Combined Ultrasound-Guided Rectointercostal and Transversalis Fascia Plane Blocks for Postoperative Analgesia in a Pediatric Renal Transplant Recipient

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Keywords

Paediatric anaesthesia, pain, pain management, postoperative pain, regional anaesthesia

The optimization of postoperative analgesia for pediatric patients remains a critical challenge, particularly in complex surgical cases where systemic analgesic options are limited. Ultrasound-guided regional anaesthesia techniques have increasingly been adopted in children due to their opioid-sparing effects, favorable safety profile, and ability to provide targeted analgesia.[1] Recently, the combination of multiple interfascial plane blocks has emerged as a promising strategy to enhance dermatomal coverage while minimizing systemic drug exposure.[2-4] However, clinical data describing combined block applications in pediatric patients, especially those with significant comorbidities, remain limited.

A 3-year-old child weighing 12 kg underwent a living-donor renal transplantation with a total operative duration of 5 hours. Owing to the complexity of the procedure and the need for close postoperative monitoring, the patient was transferred to the pediatric intensive care unit while intubated and was extubated in the early postoperative period. Given the presence of underlying cirrhotic liver disease, an opioid-sparing multimodal analgesic strategy was preferred. The surgical incision extended across the abdominal wall, involving both upper and lower abdominal dermatomal territories. Because this pediatric patient's renal transplantation required broad abdominal wall analgesia rather than analgesia limited to a single unilateral cutaneous distribution, a bilateral block strategy was selected. Bilateral rectointercostal plane blocks were intended to cover the upper anterior abdominal wall, whereas bilateral transversalis fascia plane blocks were intended to complement analgesia of the lower abdominal wall. This approach was chosen to provide broader, more continuous somatic analgesic coverage while maintaining an opioid-sparing strategy in a patient with limited systemic analgesic options. (Figure 1).

Written informed consent was obtained from the legal guardian of the patient for publication of the case details and images.

All blocks were performed under sterile conditions with the patient in the supine position. A high-frequency linear ultrasound transducer (6-13 MHz) was used.

For the rectointercostal plane block, the transducer was placed in a sagittal orientation just lateral to the midline at the level of the costal margin. The rectus abdominis muscle, costal cartilage, and underlying intercostal muscles were identified. Using an in-plane approach, a 22-gauge short-bevel needle was advanced cranial-to-caudal into the fascial plane between the posterior aspect of the rectus abdominis muscle and the costal cartilage and intercostal muscle complex.

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For the transversalis fascia plane block, the transducer was positioned transversely along the mid-axillary line between the iliac crest and the costal margin. The external oblique, internal oblique, and transversus abdominis muscles were identified, and the transversalis fascia deep to the transversus abdominis muscle was visualized. Using an in-plane technique, the needle was advanced in a lateral-to-medial direction into the fascial plane between the transversus abdominis muscle and the transversalis fascia. After careful aspiration, hydrodissection confirmed correct placement and the local anaesthetic was administered with visible spread along the plane.

For local anaesthetic administration, the dose was calculated according to the patient's body weight and distributed equally among the four injection sites. For each rectointercostal plane block, 1.25 mL of 0.5% bupivacaine, corresponding to 6.25 mg, was diluted with 4 mL of normal saline and then administered to each side. The same volume and concentration were used for each transversalis fascia plane block; therefore, 1.25 mL of 0.5% bupivacaine diluted with 4 mL of normal saline was administered on both the right and left sides. In total, four injections were performed: bilateral rectointercostal plane blocks and bilateral transversalis fascia plane blocks. The cumulative dose of bupivacaine was 25 mg, corresponding to approximately 2 mg kg^{-1}, which was within the recommended safe dosing limits for pediatric patients.

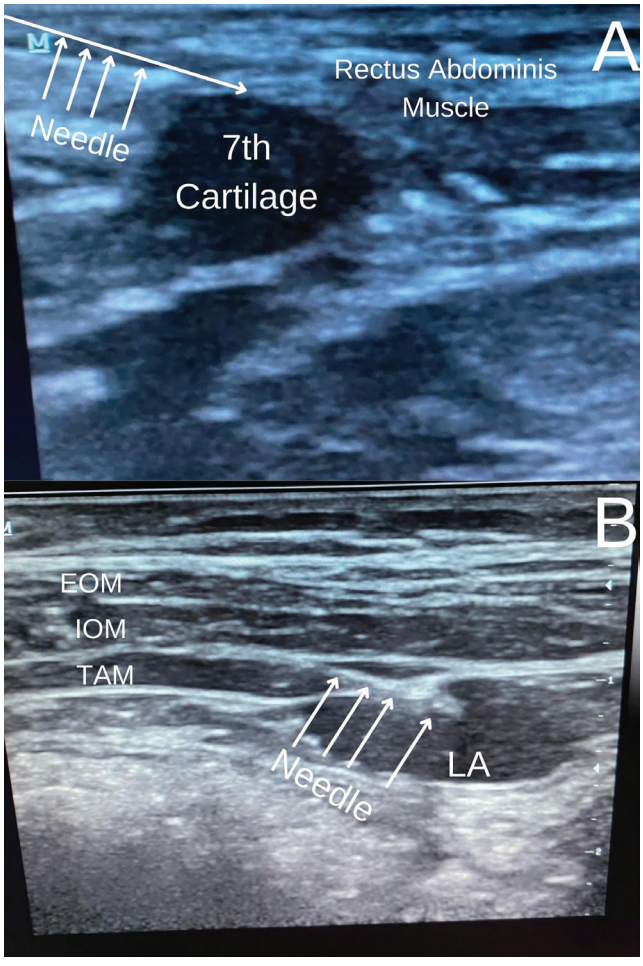

Figure 1. Applications of the blocks. A) Rectointercostal block. B) Transversalis fascia plane block.

LA, local anaesthetic; EOM, external oblique muscle; IOM, internal oblique muscle; TAM, transversus abdominis muscle.

Postoperative pain was assessed using the face, legs, activity, cry, consolability (FLACC) scale were performed by an anaesthesiologist experienced in pediatric pain evaluation, using a standardized assessment approach at predefined time points. Analgesia remained effective throughout the 24-hour follow-up period. The FLACC score was 0/10 at 30 minutes post-extubation, and remained low (1/10) during both the 1st and 2nd postoperative hours. At the 4th postoperative hour, the FLACC score increased modestly to 2/10, at which point intravenous paracetamol (10 mg kg^{-1}) was administered as rescue analgesia. Subsequent assessments demonstrated sustained pain control, with FLACC scores of 1/10 at the 6th and 12th postoperative hours. At 24 hours postoperatively, the FLACC score remained at 1/10. A second dose of intravenous paracetamol (10 mg kg^{-1}) was administered during the first postoperative day.

From an anatomical perspective, the combination of rectointercostal and transversalis fascia plane blocks may provide complementary dermatomal coverage. The rectointercostal plane block primarily targets the anterior cutaneous branches of the upper intercostal nerves (approximately T6-T9), contributing to analgesia of the upper anterior abdominal wall. In contrast, the transversalis fascia plane block targets the lower thoracic and upper lumbar nerves, particularly T12-L1 (iliohypogastric and ilioinguinal nerves), thereby providing sensory coverage of the lower abdominal region. This combined approach may therefore achieve broader and more continuous analgesic coverage than single interfascial plane techniques.

Recent case reports have suggested that the combination of different interfascial plane blocks may result in wider dermatomal spread and more comprehensive analgesic coverage than single-block techniques.[2-4] In line with these observations, the low and stable FLACC scores in our patient during both the early and late postoperative periods indicate that such a combined approach may provide effective postoperative analgesia, potentially covering both the anterior abdominal wall and deeper somatic pain components. However, these findings are limited to a single case and therefore remain hypothesis-generating. While our results support the feasibility and potential analgesic benefit of combined rectointercostal and transversalis fascia plane blocks, conclusions regarding efficacy, extent of spread, and clinical superiority cannot be drawn beyond the level of a case report.

Combined bilateral rectointercostal and transversalis fascia plane blocks may offer effective, opioid-sparing postoperative analgesia in pediatric patients with restricted systemic analgesic options and warrant further prospective evaluation.

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