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Make the Invisible Visible: Abandoning Comfortable Blindness in Anaesthesia

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Keywords: Anaesthesia, cardiovascular and thoracic anaesthesia, comfortable blindness, contemporary anesthetic, patient safety

Defining patient safety in anaesthesia solely by keeping vital signs within "acceptable" limits on a monitor is no longer a scientific strategy; it has become a form of comfortable blindness. Although strong evidence shows that both the duration and depth of perioperative hypotension are linked to cardiac, renal, and neurological complications, hemodynamic disturbances, particularly those occurring during regional anaesthesia or sedation, are still often tolerated. This paradox remains one of the most striking inconsistencies in contemporary anesthetic practice.[1]

A similar problem exists in brain monitoring. Depth-of-anaesthesia monitors and processed electroencephalography (EEG) are now widely available, yet the information they generate does not always translate into meaningful clinical decisions. In elderly and frail patients, the relationship between burst suppression and postoperative delirium or neurocognitive dysfunction is well established.[2] Even so, excessively deep anaesthesia may pass unnoticed behind screens that appear reassuringly stable.

The study by Çalışkan et al.,[3] published in this issue, reminds us that such passivity is not inevitable. Combining structured perioperative care based on Enhanced Recovery After Surgery principles with the Safe Brain Initiative was associated with shorter hospital stays, improved pain control, and reduced incidence of postoperative cognitive dysfunction. These results suggest that patient-centered care and advanced monitoring are not luxuries but active components of treatment that directly shape outcomes.

Yet, two national surveys published in the this issue show that advanced hemodynamic and neurophysiological monitoring is still used sparingly during high-risk surgery.[4,5] Cost, limited access to equipment, and insufficient training are often cited as barriers. However, these explanations do not justify choosing not to look when the risks are already known. The problem is not so much the absence of monitors as the reluctance to treat the information they provide as a clinical responsibility.

Ultimately, the value of monitoring in modern anaesthesia does not lie in the technology itself. It lies in the clinician's ability to interpret the data, place it in context, and translate it into individualized decisions. From this perspective, the limits of monitoring are conceptual rather than technical and are defined by clinical judgment.

Professional societies increasingly recommend tools such as processed EEG, cerebral oximetry, and goal-directed hemodynamic strategies for selected high-risk patients, yet consistent implementation remains limited. Protocols differ widely between institutions and practitioners, and the evidence regarding their effects on hard clinical outcomes continues to evolve.

Protection of the brain, the primary target organ of anaesthesia, cannot rely solely on hypnotic depth. Hemodynamic stability, cerebral perfusion, and neurophysiological integrity must be considered together. The question facing modern anaesthesia is whether we will choose to make the invisible visible or remain satisfied with what the screen shows and overlook what truly matters.

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Review Article
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Fluid-therapy for Brain Surgery: A Narrative Review

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Abstract

Brain surgery presents unique challenges to the anaesthesiology team in terms of complexity of patients and procedures. Managing fluid-therapy in this setting requires profound knowledge of different types of fluids and administration regimens. This review focuses on updated information about fluid therapy in elective and emergency brain surgery with specific insight on the clinical outcomes of patients.

Keywords: Blood products, brain surgery, colloids, crystalloids

Main Points

- Fluid-therapy in brain surgery affects the outcome.
- Specific hot points include: types of fluids and types of administration regimes.
- Fluid-therapy in neuro-anesthesia requires profound knowledge.

Introduction

Fluid therapy (FT) in neurosurgical patients significantly impacts the early and long-term clinical course.[1,2] Perioperative fluid management in brain procedures should optimize cerebral perfusion and haemodynamic stability, (both essential to guaranteeing neuronal homeostasis), maintain an adequate circulating blood volume, preserve cerebral perfusion pressure (CPP), mean arterial pressure (MAP), and intracranial pressure (ICP), and minimize cerebral oedema.[3,4] Excessive fluid volumes can result in acute cardiac failure, pulmonary oedema, or cerebral oedema, while a disproportionate restriction may lead to hypotension.[5] The clinical scenario is even more challenging in neurosurgery due to the use of osmotic diuretics, the long duration of surgeries, the major fluid shifts, the difficulty in assessing blood loss under the drapes, and the possibility of intraoperative central diabetes insipidus (CDI).[6,7] New clinical evidence related to periprocedural FT in neuro-anaesthesia makes it appropriate to summarize the most recent insights.

The aim of the present narrative review is to report clinical evidence related to periprocedural FT in patients undergoing brain surgery. FT can include crystalloids, colloids, blood-derived components, and several possible administration regimen infusion strategies: liberal, restrictive, goal-directed, etc.[8,9] Details on types of fluids and administration regimens, with specific insights on FT in elective and emergency brain surgery, will be provided in different sections. The supratentorial tumours and trans-sphenoidal surgery are considered paradigmatic of elective surgical procedures where FT plays a crucial role in clinical outcomes. Analogously, traumatic brain injury (TBI) and subarachnoid haemorrhage (aSAH) are discussed to review the impact of FT in emergency brain surgery.

Types of Fluids and Administration Regimes in Brain Surgery

Perioperatively, the principal aim of fluid administration is to restore and maintain intravascular volume, organ perfusion, and ultimately, substrate delivery such as oxygen, electrolytes, and glucose.[10] Furthermore, FT influences metabolite clearance,

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power of hydrogen homeostasis, medication supply, temperature control, and coagulation control.[11] Among different fluid types, the use of crystalloids, colloids, and blood products deserves discussion.

Crystalloid is the term commonly applied to solutions that contain water and low molecular weight (MW) <500 g mol^{-1}, solutes that may be charged (e.g. Na^+, Cl^-, Mg^{2+}, K^+) or uncharged (e.g. glucose or mannitol). Crystalloids are inexpensive, easy to store, with a long shelf life; they are readily available in a variety of formulations, require no special compatibility testing, and have a very low incidence of adverse reactions, with no religious objections to their use.[12] Crystalloids are categorized as hyperosmolar solutions by the inclusion of electrolytes [e.g., Na^+ and Cl^-, as in 3% hypertonic saline (3% HTS)] or low MW solutes, such as mannitol (MW 182) or glucose (MW 180). Hyperosmolar crystalloids (mannitol and HTS), in the presence of a normal blood-brain barrier (BBB), increase the osmotic gradient between the intravascular and cellular/interstitial compartments, leading to reductions in brain water content, brain volume, and ICP.[13]

Hypo-osmolar crystalloids [0.45% normal saline (0.45% NS) or dextrose 5% in water], when given in large amounts to neurosurgical patients, reduce plasma osmolality, drive water across the BBB, and increase cerebral water content, and ICP. Therefore, they should be avoided except in cases of CDI.[14] Iso-osmolar crystalloids such as 0.9% NS and Plasma-Lyte have an osmolarity of approximately 300 mOsm L^{-1}. These solutions neither change plasma osmolarity nor increase brain water content. However, caution should be exercised regarding large volumes of Ringer's lactate (RL) with an osmolarity ≈273 mOsm L^{-1}. Plasma-Lyte and the RL solutions contain bicarbonate precursors. These anions (e.g., lactate) are the conjugate base of the corresponding acid (e.g., lactic acid) and do not contribute to the development of acidosis, as they are administered with Na^+ rather than hydrogen. The metabolism of lactate in the liver results in the production of an equivalent amount of bicarbonate.[15]

Colloids are solutions with a MW above 30,000 g mol^{-1} and have an oncotic pressure similar to that of plasma (Table 1). Colloid solutions are categorized according to the naturally occurring human plasma derivatives (5% and 25% albumin solutions, plasma protein fraction, fresh frozen plasma, and immunoglobulin solutions) and semisynthetic colloids [gelatins, dextrans (MW 40 and 70), and hydroxyethyl starch (HESs)].[16] Colloids remain in the intravascular space for longer, and are used for volume expansion and to sustain blood pressure (BP) without associated complications from fluid overload. During active bleeding, more than 90% of the infused iso-oncotic colloids remain in the intravascular compartment. Possible negative effects, such as renal injury and coagulopathy, should be considered, and colloids should be used with caution in neurosurgical patients, in line with the do no harm principle. It is reasonable, therefore, to infuse colloids not before but when relative hypovolemia occurs. If a considerable amount of blood has been lost, replacement with blood products may be appropriate; however, increased organ dysfunction and poorer clinical outcomes are associated with "liberal" red blood cell (RBC) transfusion strategies. A "restrictive" strategy, intended to maintain haemoglobin at 7 to 9 g dL^{-1}, along with a normovolemic anaemia, reduces morbidity and the risk of vasospasm after aSAH.[3,17] In conclusion, in patients undergoing neurosurgery, hypotonic solutions such as RL should be avoided to minimize cerebral fluid accumulation. Colloids and RBCs should be used with caution, tolerating normovolemic anemia.[3,13-17]

Administration regimes (the amount and modality of administered fluids) also deserve a dedicated discussion; these include liberal, restrictive, goal-directed, and goal-directed haemodynamic FT. Several randomized controlled studies have compared restricted with liberal in patients undergoing major surgeries.[18-20] In a randomized assessor-blinded multi-centre trial held in 2003, two perioperative fluid regimens were compared.[18] Patients in the "liberal" group gained body weight and had more perioperative complications than the "restrictive" group. In that study, other evidence demonstrated that patients in the "restrictive" group had increased rates of surgical site infection and high risks of acute kidney injury.[19] Goal-directed fluid therapy (GDFT) is a fluid regimen that optimizes predefined targets based on directly measured haemodynamic parameters, such as cardiac output (CO), the cardiac index (CI), stroke volume (SV), stroke volume variation (SVV), pulse pressure variation (PPV), systolic pressure variation, and the pleth variability index (PVI).[20] SVV is a sensitive predictor of fluid responsiveness during brain surgery.[21] After the induction of anaesthesia and before the start of the surgical procedure, SVV more sensitively predicts an increase above 10% in SV compared to MAP, CO, heart rate (HR), or central venous pressure (CVP). In a comparison of two GDFT regimens (with threshold SVV values set at 10 for the "low SVV" group and at 18 for the "high SVV" group) for supratentorial tumour resection, the low SVV group had lower postoperative serum lactate levels, a shorter ICU stay, and a lower incidence of postoperative neurologic events.[22] PPV and PVI have also been reported to be good predictors of fluid reactivity during brain surgery.[23-35] According to a recent trial held in India in patients undergoing brain tumour surgery in supine position, between a "CVP group," which maintained a CVP of 5-10 cm H_2O, and a "PPV group," which maintained a PPV below 13%, the latter had better postoperative haemodynamic stability and less postoperative fluid requirements.[23]

Table 1. Fluid Characteristics: Crystalloids Versus Colloids				
Crystalloids	**Hypo-osmolar**	**Iso-osmolar**	**Hyperosmolar**	**Plasma expansion**
	<280 mOsm L^{-1}	280-300 mOsm L^{-1}	>300 mOsm L^{-1}	20%
Colloids	Low MW (<150,000 g mol^{-1})	Medium MW (>150,000 g mol^{-1})	High MW (>350,000 g mol^{-1})	80-200%
	69 to 150 kDa	Approx 150-350 kDa	>350 kDa	
MW, molecular weight; Da, dalton				

In a trial randomizing patients with supratentorial tumour resection, "PPV-guided" GDFT exhibited better haemodynamic stability, brain condition, and organ perfusion than the "standard care" group targeting a CVP over 8 cm H_2O.[24] Another trial held in 2023 analyzed 74 patients undergoing neurosurgery for supratentorial mass and compared the efficacy of PVI versus PPV in guiding GDFT.[25] Both groups received a baseline 2 mL kg^{-1} h^{-1} RL infusion, and additional fluid boluses of 250 mL of colloid if PVI >15% or PPV >13% for at least five minutes. The PVI- and PPV-guided GDFT strategies showed no significant difference in postoperative lactate values, with a *P* value of 0.18. Similarly, the mean total fluid administered, mean blood loss, length of ICU stay, and emetic and hypotension episodes showed no significant differences between the groups. More recently, an approach called "GDHT", guided by an algorithm based on non-invasive haemodynamic monitoring, has been investigated in major surgery.[26] The aim is to optimize haemodynamic parameters such as CO and CI, which are essential for oxygen delivery to tissues, and for organ perfusion.

The positive effects of GDHT on patient-oriented outcomes were demonstrated in neurosurgery by a single-centre randomized pilot study with an enrolment target of 34 adult patients scheduled for elective cerebral procedures.[27] The authors randomly assigned the patients to "control" and "GDHT" groups. The control group received standard therapy during surgery and aimed for a MAP above 65 mmHg, whereas the GDHT group received FT guided by an algorithm based on non-invasive haemodynamic monitoring. Specifically, after the determination of an optimal CI above 2.5 L·min·m^2, the authors aimed to maintain SVV below 15%. The GDHT protocol was safe, and no patients in either group required therapy during surgery or 24 h after surgery, for unsatisfactory brain tissue relaxation or brain oedema. Major complications occurred in two patients in the GDHT group and six patients in the control group. A larger randomized trial evaluating the effects of GDHT on the incidence of postoperative complications in elective neurosurgery should be safe and feasible.

In conclusion, while considering the administration regimens of FT, the parameters CI, SVV, PPV, and PVI seem to appropriately guide GDFT and GDHT, offering better tissue perfusion and lower perioperative complications than the standard of care, CVP or MAP-based approaches.[19-27]

Fluid Therapy in Elective Brain Surgery

Supratentorial Brain Tumours: In elective oncological procedures for supratentorial tumours, hypotonic solutions, such as the LR solution, should be avoided to minimize cerebral fluid accumulation.[15] In contrast, 0.9% NS, an isotonic crystalloid, is widely used because it is thought to reduce the risk of cerebral oedema.[28] However, since 0.9% NS has equal amounts of sodium and chloride (154 mEq L^{-1}), hyperchloremic metabolic acidosis may occur when a large amount is administered, as its chloride concentration is higher than the normal plasma chloride concentration (96-106 mEq L^{-1}). Based on the above, an isotonic balanced solution, such as Plasma-Lyte A, is preferred over 0.9% NS in neurosurgical oncological patients because of the lower risk of metabolic acidosis and renal injury.[28,29]

Intraoperatively, cerebral protection (related to the tumour debulking and dura incision) is provided with different strategies intended to reduce the impact and duration of high ICP: osmotherapy with either mannitol, a non-metabolized alcohol derivative of mannose, or 3% HTS, is the recommended first-line medical intervention to optimize cerebral perfusion through brain relaxation, thereby preventing neurological deterioration.[30] In a prospective randomized study, 74 patients with American Society of Anesthesiologists (ASA) I to III scheduled for intracranial tumour surgery were enrolled to compare the effects of equi-volume, equi-osmolar solutions of mannitol and HTS on brain relaxation and postoperative complications.[31] Patients received a 3.75 mL kg^{-1} intravenous infusion of either 3.2% HTS (n = 36) or 20% mannitol (n = 38). The surgeon assessed the condition of the brain using a 4-point scale after opening the dura. Patients who were administered 3.2% HTS had more brain relaxation compared with those who received mannitol (P <0.05). There were no significant differences between the groups in postoperative complications or in the length of ICU or hospital stay. The results suggest that HTS may provide better brain relaxation than mannitol during elective intracranial surgery for a tumour.

Preoperative anaemia management, such as with iron-deficiency correction or blood conservation strategies, is crucial in patients undergoing elective cerebral resection. In a recent retrospective analysis of patients who underwent primary glioblastoma resection between September 2009 and October 2019, complication rates were significantly higher among patients who received RBC transfusions than among those who did not-pneumonia (P <0.0001), sepsis (P=0.0013), pulmonary embolism (P=0.0061), and seizures (P <0.0001) - highlighting the importance of minimizing preoperative anaemia and intraoperative blood loss in elective neurosurgery.[17]

Infratentorial Surgery: Trans-sphenoidal surgery near the neurohypophysis for pituitary and sellar lesions can lead to salt and water disorders. Both CDI, a condition related to compromised arginine vasopressin synthesis that leads to hypernatremia and polyuria and was recently renamed arginine vasopressin deficiency, and the syndrome of inappropriate antidiuresis (SIAD), which leads to hyponatremia, may occur.[32] Intraoperatively, in case of CDI, if the patient presents persistent increased urine output, hypo-osmolar crystalloids can be administered to correct hypernatremia (serum Na^+ concentration >145 mmol L^{-1}) and large volumes of dilute urine (osmolarity <250 mmol kg^{-1}).[9,10] Also, in cases that warrant extended operative periods, pharmacological treatments for CDI can be considered, including vasopressin and analogues of vasopressin such as desmopressin (active on the same vasopressin receptors with a longer context-sensitive half-life), and hypo-osmolar crystalloids need to be discontinued to avoid subsequent hyponatremia.[14,33-35] In case of acute SIAD, if serum Na^+ concentration falls below 135 and large volumes of dilute urine are eliminated (osmolarity <110 mmol kg^{-1}), restrictive fluid regimes should be considered aiming to administer NS 1000 mL in 24 h (approximately 500 mL in theatre), and administration of 3% HTS in severely symptomatic cases, if presenting a serum Na^+ concentration <120 mmol L^{-1}, is recommended.[35]

Fluid Therapy in Emergency Brain Surgery

TBI: After trauma, when the BBB is mechanically damaged and the cerebral inflammatory response is activated, initial rapid infusion of large volumes of mannitol, and a hypertonic crystalloid solution is the current standard of care for people with combined haemorrhagic shock and TBI to restore BP and blood volume.[36] This approach is especially helpful in preventing subsequent ischemic brain damage by aiming for normovolemia and a haematocrit above 30%.[37] However, the role of colloids needs to be clarified. The Saline versus Albumin Fluid Evaluation (SAFE) study randomized critically ill patients to receive either 4% albumin or NS fluid resuscitation over 28 days.[38] Although there was no overall difference in 28-day mortality between the groups, there was a trend towards increased mortality in patients with trauma, randomized to albumin resuscitation. This increased mortality appeared to be driven by trauma patients with TBI compared with those with trauma without TBI. A post-hoc analysis of patients with TBI randomized in the SAFE trial confirmed that resuscitation with albumin, as compared with 0.9% NS, was associated with increased mortality at 24 months, as elevated albumin extravasation in the brain worsened cerebral oedema and increased interstitial oncotic pressure.[39]

Among plasma expanders, the role of gelatin and HES is extensively explored in the literature.[40,41] In several trials, haemodilution with gelatine and HES significantly impaired clot formation compared to crystalloid solutions; additionally, extravasation in the brain made cerebral oedema worse. Therefore, FT with crystalloid is more effective than FT with colloid in patients with TBI.[42] When osmotherapy with either mannitol or HTS is recommended to optimize CPP, a water shift from intracellular to extracellular (and thus intravascular) compartments is facilitated, leading to CO augmentation.[43,44] Moreover, HTS can directly improve myocardial performance through a reduction in myocyte oedema and an increase in myocardial uptake of Ca^{2+}.[45] Although available data suggest that both mannitol and HTS promote an augmentation of CO, this effect seems to be more pronounced after HTS than after mannitol administration.[46] Furthermore, mannitol increases diuresis, while HTS causes increases plasmatic Na^+ concentration. These effects might be responsible, in part, for the overall therapeutic effects associated with osmotic therapies.[47]

Endovascular procedures for aSAH: Maintenance of normovolemia, haemodilution (haematocrit at 30% to 35%), and cerebral perfusion are essential to avoid vasospasm after the procedure, and hypotonic solutions such as RL are usually avoided intraoperatively.[9] In a randomized controlled study held in Canada, 60% of enrolled patients with aSAH were dehydrated at the start of the endovascular coiling procedure.[48] The authors randomized patients to receive either standard liberal FT or GDFT; better haemodynamic optimization was observed in the second group. In another trial, the authors randomized patients undergoing a clipping procedure for aSAH to receive either NS or a balanced salt solution, namely, Plasma-Lyte A. The second group exhibited a better renal and acid-base profile (lower base deficit and higher bicarbonate levels).[49] According to a retrospective analysis on 54 patients with aSAH, mannitol or HTS is pivotal to ensure appropriate CPP when ICP spikes over 20 mmHg, especially during dura incision.[50] The authors recommended "CPP-guided FT" aiming for CPP above 70 mmHg through optimization of both ICP and MAP. If hyponatremia occurs from the release of atrial natriuretic factor (cerebral salt wasting), treatment includes hydration with either normal or HTS to improve CPP.[51]

Discussion

This narrative review demonstrates the impact of FT on neuro-anaesthesia in brain surgery. Crucial features of FT related to clinical outcomes have been reviewed and discussed.[1,2] In elective brain surgery, hypotonic solutions, such as RL, should be avoided to minimize cerebral fluid accumulation, except in infratentorial surgery if intraoperative CDI occurs.[35,36] An isotonic balanced solution such as Plasma-Lyte A is the best option for intraoperative maintenance in standard conditions.[47] In emergency brain surgery, after trauma or SAH, normovolemic anaemia should be tolerated; rapid infusion of large volumes of mannitol, and hypertonic crystalloid solution is the recommended first-line medical intervention to restore circulating volume.[48-51] Osmotherapy also optimizes cerebral perfusion through brain relaxation.[3]

A recent study reported the significant clinical impact of intra-operative over-hydration or excessive restriction on haemodynamic stability, serum lactate levels, urine output, and fluid retention. The study supported GDFT as the tailored optimal FT, guided by SVV, PPV, and PVI, rather than by CVP, MAP, HR, or inferior vena cava diameter.[19]

A limitation of the present review is the lack of a systematic methodology in the literature search; it may therefore be affected by uncertainty in study selection, which can potentially lead to bias. However, it presents some interesting and original insights. GDHT, based on non-invasive advanced haemodynamic monitoring, appears to be a promising approach in elective brain surgery. Specifically, after achieving a CI target above L·min·m^2, maintaining SVV below 15% helps preserve an optimal CI. Furthermore, the GDHT protocol is safe and effective, even though further randomized trials evaluating its role in elective neurosurgery should be conducted.[26,27]

Conclusion

While numerous studies on intraoperative FT in brain surgery have been performed, evidence is too scarce to draw definitive conclusions regarding specific transfusion thresholds, and more trials exploring the GDHT regimen are necessary.

Footnotes

Author Contributions: Concept - M.P.L., B.A., F.B.; Design - M.P.L., L.M., B.G.S.D.; Data Collection and/or Processing - M.P.L., L.M., B.G.S.D.; Analysis and/or/Interpretation - M.P.L., L.M., B.G.S.D., F.B.; Literature Review - M.P.L., B.G.S.D.; Writing - M.P.L., F.B.

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Base Excess and Beyond: Evolving Concepts in Acid-base Analysis

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Abstract

Base excess (BE), a marker used to detect metabolic acid-base disturbances, is also known to predict mortality in critically ill patients; the traditional concept, originally based on the Henderson-Hasselbalch model, has been further refined through integration with the Stewart approach, enabling a more comprehensive and mechanistic evaluation of acid-base disturbances. However, the increasingly complex mathematical formulations required for this integration demand extensive calculations, which can hinder bedside assessment. To address this, the BE formula has been simplified and integrated into the Stewart concept, resulting in a more reliable, detailed, and rapid bedside evaluation. Additionally, the term "alactic BE" was introduced to distinguish metabolic acidosis caused by retention of fixed acids from that caused by lactic acid accumulation, particularly in patients with renal failure. This review discusses the concept of BE and its evolution over the years.

Keywords: Acid-base equilibrium, alactic base excess, base excess, metabolic acidosis, metabolic alkalosis, Stewart approach

Main Points

- The original concept of base excess (BE) was later expanded upon by the Fencl-Stewart model, which reframed the idea in terms of physicochemical principles.
- The Fencl-Stewart equations were rather intricate and impractical for quick calculations. To adress this, a simplified variation of the equation that maintains the core physicochemical concepts was introduced.
- The recent concept of "alactic BE" helps clinicians differentiate metabolic acidosis due to lactate accumulation from metabolic acidosis caused by retained fixed acids in patients with renal impairment.
- While the modern BE framework is more effective at identifying mixed acid-base disturbances, its clinical relevance is still uncertain.The recent concept of "alactic BE" helps clinicians differentiate metabolic acidosis due to lactate accumulation from metabolic acidosis caused by retained fixed acids in patients with renal impairment.
- While the modern BE framework is more effective at identifying mixed acid-base disturbances, its clinical relevance is still uncertain.

Introduction

Base excess (BE) is a fundamental parameter used to quantify metabolic acid-base disturbances and has long been recognized for its clinical utility. Beyond its diagnostic role, accumulating evidence indicates that BE also carries prognostic significance in critically ill populations.[1-3] In patients with acute kidney injury (AKI), both markedly low and high BE values on admission have been associated with an increased risk of 30-day mortality.[1] Similarly, in critically ill patients with acute myocardial infarction, low BE has been identified as an independent predictor of short- and long-term mortality.[2] A recent study in patients with ischemic stroke further demonstrated that a BE value below -3 mmol L^{-1} at intensive care unit (ICU) admission may indicate elevated mortality risk.[3] Collectively, these findings highlight the potential of BE as a rapid and accessible early risk-stratification tool across a variety of acute and emergency conditions, including AKI, ischemic stroke, cardiac ischemia, and metabolic disturbances. Since its first description in 1948, the concept of BE has undergone substantial refinement and has been incorporated into contemporary approaches to acid-base interpretation, including the modern Stewart

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physicochemical framework. In this review, we examine the conceptual development of BE, its clinical applications, and its evolving role in modern acid-base evaluation.

Buffer Base Concept

Buffer base (BB), which was introduced by Singer and Hastings[4] in 1948, is the predecessor of the BE concept. According to this concept, plasma BB is practically equal to the sum of all buffer anions [total base (bicarbonate) and weak acid anions (e.g., albumin and phosphate)]. Therefore, BB increased either by an increase in base or by a decrease in plasma albumin concentration (Equation 1).

$$BB = HCO_3^- + A^- \quad (1)$$

The BB concept considers the non-carbonic buffers and is theoretically CO_2-independent. Unfortunately, inter-subject variability due to differences in non-carbonic buffer concentrations was observed. To overcome this limitation, Siggaard-Andersen introduced the BE concept, in which the "excess" may be positive or negative, and which defines the actual BB relative to the normal BB (i.e., the actual BB minus the BB at normal pH and pCO_2) as a measure of metabolic acid-base disturbance.[5,6]

Base Excess Concept

BE is the amount of acid or base (mmol L^{-1}) that must be added to a blood sample to reach a pH of 7.40 inunder standardized conditions (pCO_2 40 mmHg, 37 °C).[6] Affecters factors affecting of this semi-quantitative approach are pCO_2 and BB, and; standard BE is used as its marker. BE is a Handerson Hasselbalch based Henderson-Hasselbalch-based parameter. It is calculated from the Van Slyke equation, which accounts for pH, HCO_3 (mmol L^{-1}) and haemoglobin (Hb, mmol L^{-1}) (Equation 2).[7]

$$BE = (HCO_3^- - 24.4 + [(2.3 \times Hb + 7.7) \times (pH - 7.40)] + (1 - 0.023 \times Hb) \quad (2)$$

In this BE formula of Van Slyke, Hb can either be a constant value (16.2 mmol L^{-1}) or be computed as a function of Hb concentration (assuming a constant protein concentration of 70 g L^{-1}). The BE formula has also exhibits some inconsistencies due to changes in CO_2. As in vivo BE is less reliable than in vitro BE, Van Slyke modified the equation to standardize the effect of Hb on BE [standard base excess (SBE)] and considered a lower Hb value for the calculation (Equation 3).

$$SBE = 0.9287\ [HCO_3^- - 24.4 + 14.83 \times (pH - 7.40)] \quad (3)$$

However, the SBE equation assumes that the plasma albumin (g dL^{-1}) and phosphate (mg dL^{-1}) concentrations (Atot) are within the normal range. Therefore, Wooten described another formula for a multi-compartment model (Equation 4).[8,9] The normal value of SBE is between -2 and +2 mmol L^{-1}.

$$\text{Corrected SBE} = (HCO_3^- - 24.4) + [(8.3 \times \text{albumin} + 0.15) + (0.29 \times Pi \times 0.32)] \times (pH - 7.40) \quad (4)$$

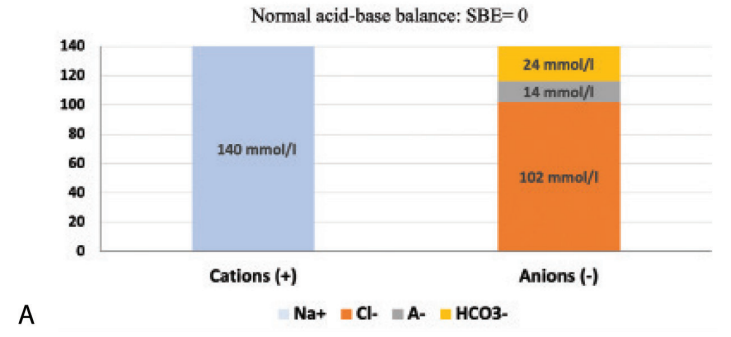
This multi-compartmental model has been shown to correlate well with the strong ion difference (SID) concept described by Stewart in that the change in SBE equals the change in SID across a vascular bed if there is no change in Atot.[8,10,11] The anionic contribution of the most important weak acid, albumin (Atot), is 10 mEq L^{-1}, whereas, unless phosphate levels are increased, their contribution to Atot is around 5%. If phosphate levels are elevated, then its contribution becomes more important. Because it is difficult to calculate Stewart's SID equation, BE can be used as a substitute for SID at the bedside. Standard BE is a powerful concept in defining the metabolic acid-base disorders; however, it is not helpful for diagnosing the underlying pathology.[12] Therefore, "mixed" acid-base disorders will go unnoticed without the use of detailed base-excess partitioning.[13,14] Furthermore, in some pathological situations, BE may be within the normal range and thus be misleading (Figure 1).[15]

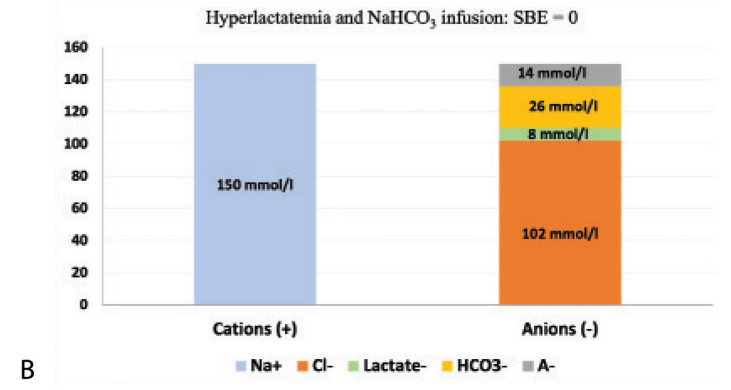
Gamblegram[8,16] is a graphic representation of SID (therefore BE) developed by James Gamble (Figure 1). Assuming electroneutrality, the Gamblegram demonstrates that the ions that occupy the SID between the strong cations and anions are primarily bicarbonate (a component dependent on the SID) and the total concentration of weak acids.

Ciabattoni et al.[16] compared Stewart's SID and SBE approaches for detecting metabolic disturbances in a group of ICU patients receiving mechanical ventilation and found that the correlation between the two parameters was poor. They explained the results by stating that the SBE was derived from a variety of parameters, showed the effect of a single independent variable in the Stewart approach.[16] Stewart's approach was superior to SBE in identifying metabolic alkalosis related to hypoalbuminemia and hypophosphatemia, and in identifying metabolic acidosis related to haemodilution following fluid resuscitation.

Stewart Approach and its integration to BE concept

Unlike the classical Henderson-Hasselbalch approach, Stewart demonstrated that the concentration of $[H^+]$ in a physiological fluid is determined by three independent variables: the SID (which is equal to the difference between positively and negatively charged ions that are fully dissociated in biological fluids, e.g., Na^+, K^+, Cl^-, lactate), the total concentration of weak acids (Atot), and the volatile acid CO_2. According to Stewart, $[H^+]$ and $[HCO_3^-]$ are dependent variables, and bicarbonate appears to be an indicator rather than a cause. Water becomes ionized under the influence of these independent variables, thereby regulating the pH. Stewart conducted his acid-base studies by applying the principles of electrical neutrality, the law of mass action, and conservation of mass. When expressed





Figures 1 A, B. Gamblegrams show the standard base excess values of two patients, both are within the normal range (0). Figure 1 A represents a patient with normal acid-base balance, whereas Figure 1 B represents a patient with hyperlactatemia receiving a bicarbonate infusion. SBE, standard base excess; A-, non-volatile weak acids.[12]

mathematically, apparent SID (SIDa) is equivalent to the "plasma BB" described by Singer and Hastings.[4]

Fencl-Stewart Approach

To overcome the weaknesses of the SBE concept, Balasubramanyan et al.[17] derived a new formula from the work of Fencl and defined it as the Fencl-Stewart approach. This derived formula combines BE with the Stewart approach. Gilfix et al.[18] derived an equation to estimate the BE effects of the SID and the Atot. However, this formula is complex and difficult to apply at the bedside (Equation 5). Therefore, another equation, a simplified form of the Fencl-Stewart formula, was described by Story et al.[19] (Equation 6).

$$BE = 0.3x\ [(Na^+) - 140] + 102 - [(Cl^-)\ x140 / (Na^+)] + (0.123x\ pH - 0.631)\ x\ [42 - albumin\ (g\ L^{-1})] \quad (5)$$

Story's Simplified Fencl-Stewart Approach

Rather than the complex formula of the aforementioned Fencl-Stewart approach, Story et al.[19] proposed a simplified form (Equation 6). They confirmed in a study of 300 blood samples taken from critically ill patients that this simplified formula was in good agreement with the more complex Fencl-Stewart approach. Using this formula, the effects of SID and albumin on BE can be estimated.

$$SBE\ NaCl = \{[Na^+] - [Cl^-]\} - 38\ (38\ is\ the\ average\ normal\ SID) \quad (6)$$

$$SBE\ Alb = 0.25\times\ (42 - measured\ albumin\ in\ blood)\ (42\ is\ the\ normal\ plasma\ albumin\ g\ L^{-1})$$

$$SBE\ NaCl + SBE\ Alb = SBE\ Correction$$

$$True\ SBE\ or\ BE\ gap = SBE - SBE\ Correction$$

The above equations require only basic mental arithmetic and are therefore easy to use at the bedside for evaluation, treatment, and follow-up of both simple and complex acid-base problems.

Alactic Base Excess

Alactic BE (ABE) was defined by Gattinoni et al.[20] to differentiate metabolic acidosis related to retention of non-lactate fixed acids (sulphates, phosphates) from that related to lactic acid in patients with renal failure (Equation 7).

$$ABE\ (mmol\ L^{-1}) = SBE\ (mmol\ L^{-1}) + Lactate\ (mmol\ L^{-1}) \quad (7)$$

Clinical and Research Consequences

Studies with Fencl-Stewart approach

Traditional BE and bicarbonate methods can miss complex metabolic disorders in critically ill patients. While the

Stewart and modified BE methods better identify multiple coexisting disturbances, their routine use may be more labor-intensive. The modified BE approach offers a practical balance between ease of use and clinical accuracy.[21] In liver transplant patients, the Fencl-Stewart approach helps identify complex acid-base changes immediately after transplantation.[22] Fencl-Stewart's method revealed frequent simultaneous metabolic acidosis and alkalosis missed by traditional analysis; both strong ion gap (SIG) and lactate independently predicted 28-day ICU mortality in critically ill.[23]

Balasubramanyan et al.[17] found that unmeasured anions measure with Fencl-Stewart's BE method correlates with mortality in pediatric intensive care unit patients, whereas Cusack et al.[24] did not observe this in adults. To address the small sample sizes of earlier studies, Rocktaeschel et al.[25] retrospectively analyzed 300 adult intensive care unit patients and found that unmeasured anions were the only acid-base variables with limited ability to predict mortality, while all calculation methods [anion gap (AG), corrected AG, SIG, and unmeasured anions measured by Fencl-Stewart BE] were strongly correlated with each other. Furthermore, of four methods for assessing chloride's effect on acid–base status, chloride-specific base excess (BECl) most closely correlates with standard BE and most accurately reflects its impact in critically ill patients.[26]

A clinical example of simplified Fencl-Stewart approach by Story et al.[19]

The patient underwent major gynaecological surgery with general anaesthesia. Isotonic sodium chloride was used as an intraoperative fluid. The metabolic acidosis, which developed 2 hours after induction of anaesthesia, is due to a decreased SID related to hyperchloremia. This effect was offset by a decrease in the concentration of albumin (a weak acid). There is no contribution from unmeasured ions in this case. This acidosis was observed after the infusion of 6 litres of isotonic sodium chloride (Table 1).

Table 1. Simplified Fencl-Stewart Approach[19]

Measured values	After anaesthesia induction	2 hours after anaesthesia induction
pH	7.41	7.28
CO_2 (mmHg)	39.7	39.7
Na^+	140	142
Cl^-	104	115
Base excess (mEq L^{-1})	-0.4	-6.7
Albumin (g dL^{-1})	4	2.8
Na-Cl effect (mEq L^{-1})	-2	-11
Albumin effect (mEq L^{-1})	0.5	3.5
Effect of unmeasured anions (mEq L^{-1})	1.1	0.8

Na - Cl effect on BE = (Na^+) - (Cl^-) -38

Albumin effect on BE = 0.25x [42 - (Albumin) - g L^{-1}]
Unmeasured ion effect on BE = SBE - $(Na^+$-$Cl^-)$ - Albumin effect

A clinical example comparing Fencl-Stewart, anion gap, and Stewart methods.[21]

Table 2 presents a patient with postoperative multiple organ failure. The patient has complex acid-base physiology. The pH of 7.33, pCO_2 of 30, and BE (-10) of -10 suggest metabolic acidosis and respiratory alkalosis; however, the etiology of the metabolic acidosis cannot be identified. By the AG method, the elevated corrected AG (ΔAGcorr =11 mEq L^{-1}) suggests metabolic acidosis due to unmeasured anions. The delta-delta calculation predicts a bicarbonate level of 13-17 mEq L^{-1}, and the observed bicarbonate of 15 mEq L^{-1} falls within this expected range. Based on this approach, no additional metabolic acid-base disorders are identified, even though a hypoalbuminemic alkalosis is intuitively suspected. In contrast, the Stewart approach reveals several abnormalities: an increased SIG, reduced sodium levels, elevated corrected chloride levels, and decreased albumin and phosphate levels. Together, these findings indicate a complex disturbance consisting of multiple metabolic acidoses (due to unmeasured anions, free-water excess, and hyperchloremia) and concurrent hypoalbuminemic and hypophosphatemic alkalosis. The modified BE method yields similar detail: a positive BEalb (+13 mEq L^{-1}), a negative BECl (-8 mEq L^{-1}), a negative BE for free water, and a negative BE for unmeasured anions (-8 mEq L^{-1}), reflecting coexisting hypoalbuminemic alkalosis, hyperchloremic acidosis, dilutional acidosis, and unmeasured-anion acidosis. In this case, only the Stewart and modified BE methods accurately characterize all metabolic acid-base disturbances, whereas the AG method fails to detect the hypoalbuminemic alkalosis, hyperchloremic acidosis, and dilutional acidosis. The clinical significance of these missed abnormalities, however, remains uncertain.

Table 2. Comparing Fencl-Stewart, Anion Gap, and Stewart Methods[21]

Measured values	Data
pH	7.33
CO_2 (mmHg)	30
Na^+ (mEq L^{-1})	117
Cl^- (mEq L^{-1})	104
Cl corrected (mEq L^{-1})	112
K^+ (mEq L^{-1})	3.9
BE lab (mEq L^{-1})	-10
Albumin (g dL^{-1})	6
Pi (mmol L^{-1})	0.6
HCO_3	15
ΔAgap corrected	11
Strong ion gap	18

Alactic base excess

Gattinoni et al.[20] studied ABE in septic patients and suggested that ABE may reflect the effects of renal dysfunction on plasma lactate concentration. Negative ABE values (<-3 mmol L^{-1}) are correlated with mortality in patients with sepsis. Neutral ABE values (≥-3 to <4 mmol L^{-1}) indicate that the kidneys effectively excrete fixed acids and maintain physiologic blood pH. Positive ABE values (≥4 mmol L^{-1}) suggest that lactate and standard base levels are within the normal range in the blood, reflecting the kidney's compensatory response to metabolic acidosis. In their study of intensive care patients with shock, Smuszkiewicz et al.[27] reported that an admission ABE below -3.63 mmol L^{-1} may be associated with an increased risk of 28-day all-cause mortality. Moreover, both BE and lactate levels—each contributing to ABE—offer independent and complementary predictive value.[27] The combined criteria of BE -9.5 mmol L^{-1} and lactate >4.5 mmol L^{-1} identify patients at the greatest risk of death more effectively than BE, lactate, or ABE alone. Importantly, the prognostic significance of these metabolic markers remains robust regardless of patients' age, sex, type of shock, or presence of severe renal failure. Negative ABE is also an independent predictor of in-hospital mortality among septic patients both with and without renal dysfunction, and among patients with acute myocardial infarction.[28,29]

Conclusion

In the mid-20th century, the concept of BB, which represents the sum of the concentrations of bicarbonate, albumin, and haemoglobin, evolved into the concept of delta BB, defined as the change in BB from the "normal" value. Since the blood volume is diluted by interstitial fluid, the extracellular fluid model was introduced; this model uses a standard haemoglobin concentration (5 g dL^{-1} or 3 mmol L^{-1}). Although it reflects only the non-respiratory (metabolic) component of acid-base disorders, the BE of the extracellular fluid remains valuable for etiological analysis, particularly when used alongside the Stewart approach in partitioning contributing factors. Clearly, the concept of BE continues to evolve, and ongoing refinements are likely. The Fencl-Stewart concept of BE has now been refined using the formula proposed by Story et al.[19] This enables straightforward bedside calculations and helps identify the underlying pathology of metabolic acid-base disturbances, which the BE value alone cannot provide. The novel ABE concept further enhances our understanding by shedding light on the kidney's role in metabolic acidosis.

Footnotes

Author Contributions: Concept – Ö.K., T.U., K.D., L.D.; Design - Ö.K., T.U., K.D., L.D.;Data Collection or Processing - Ö.K., T.U., K.D., L.D.; Analysis or Interpretation - Ö.K., T.U., K.D., L.D.; Literature Review - Ö.K., T.U.; Writing - Ö.K., T.U.

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Original Article
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Comparative Evaluation of Videolaryngoscopy and Direct Laryngoscopy Performed in Paediatric Patients Undergoing Elective Surgery

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Abstract

Objective: Paediatric airway management poses unique challenges due to anatomical and physiological differences compared to adults. Videolaryngoscopy (VL) has been proposed as a potential improvement over direct laryngoscopy (DL) for tracheal intubation. This study aimed to compare VL and DL in paediatric patients undergoing elective surgery.

Methods: A prospective, randomized study was conducted with 100 paediatric patients aged under 18 years, weighing 10-40 kg, and classified as American Society of Anesthesiologists physical status I-III. Patients were randomized into Group 1 (n = 50) that included patients who underwent laryngoscopic examination using Macintosh laryngoscope or Endolarenx videolaryngoscope (Group 2: n = 50). Data on intubation time, glottic view (Cormack-Lehane grades), first-attempt success rate, need for anterior laryngeal pressure, and complications were collected.

Results: VL was associated with longer intubation time than DL (29.1±5.7 s vs. 20.7±5.1 s, P=0.001). Glottic visualization was better in the VL group (Cormack-Lehane Grade 1: 78% vs. 66%), but first-attempt success rate was lower (74% vs. 98%, $P < 0.001$). The need for anterior laryngeal pressure was significantly reduced in VL (32% vs. 78%, P=0.01). No complications, such as trauma or hypoxaemia, were observed in either group.

Conclusion: VL improves glottic visualization and reduces the need for airway maneuvers but is associated with longer intubation times and lower first-attempt success. While DL may be more efficient for routine intubation, VL remains valuable in anticipated or emergent difficult airway situations.

Keywords: Airway management, direct laryngoscopy, elective surgery, paediatric intubatio, videolaryngoscopy

Main Points

- Videolaryngoscopy (VL) provided a clearer glottic view compared to direct laryngoscopy (DL), as evidenced by a higher rate of Cormack-Lehane Grade 1 views and reduced need for anterior laryngeal pressure during intubation.
- Despite improved visualization, VL had significantly lower first-attempt intubation success rates (74% vs. 98%) and longer intubation times than DL, indicating technical challenges especially in routine use.
- No complications, such as trauma or hypoxaemia, occurred in either group, demonstrating that both VL and DL are safe techniques for elective intubation in paediatric patients when performed by experienced providers.
- Although VL may not be superior for routine elective intubation, its ability to improve visualization makes it a valuable tool in emergency paediatric airway management, where rapid identification of airway structures is critical.

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Introduction

Airway management is essential for patients undergoing surgery or diagnostic procedures under anaesthesia, and it is crucial for emergencies, including cardiopulmonary resuscitation, that pose a threat to life.[1] Unlike adults, airway management in children may be more challenging. This difficulty may be attributed to various anatomical factors, particularly in infants, such as more anterior and cephalad larynx, a larger floppy epiglottis, a larger tongue, a shorter mandible, and a prominent occiput, all of which have the potential to hinder effective airway management. Moreover, the apnoea time in children is significantly reduced compared to adults, and awake intubation may not be feasible.[2]

As in adults, intubation in paediatric patients is typically performed via direct laryngoscopy (DL) using traditional laryngoscopes. Modern alternatives to traditional laryngoscopes utilize fiberoptic or digital technology to project images from the tip of laryngoscope onto an eyepiece or monitor for enhanced visualization by the practitioner. Videolaryngoscopes (VLs) have become integral part of the routine clinical practice, educational training, and a preferred option to be used following unsuccessful DL.[3]

It is unclear whether routine VL offers a clinical advantage in paediatric patients where difficult intubation is not anticipated. Paediatric data evaluating the effectiveness of VL compared to DL are somewhat limited and contradictory.[4] The Endolarenx VL (Endolarenx Video Laryngoscopes, İstanbul, Türkiye) used in this study features a distal camera and integrated screen, offering indirect laryngeal visualization in paediatric patients. The purpose of this study was to assess and compare intubation conditions provided with VLs and DLs, to identify the benefits and limitations of VL in paediatric patients.

Methods

This study was designed as a parallel-group randomized controlled trial with an equal 1:1 allocation ratio, and conducted following the approval obtained from the Clinical Research Ethics Committee of Gaziantep University on April 6, 2022 (approval number: 2022/100, date: 06.04.2022). Our protocol strictly adhered to the ethical principles outlined in the World Medical Association Helsinki Declaration and its recent amendments. The study was retrospectively registered in the ClinicalTrials.gov trial registry under the identifier NCT06644586 on October 15, 2024. Children scheduled for elective surgeries performed under general anaesthesia in the operating theatres were included in this prospective observational study.

The study included 100 paediatric patients, all under 18 years of age , weighing between 10 and 40 kilograms with physical status classified as American Society of Anesthesiologists (ASA) Class I-III, and underwent elective surgery between April 1, 2022, and August 1, 2022. Informed consent was obtained from the parents of all participants who received detailed information about the study. The patients were randomly allocated into two groups: Group 1 (n = 50), where intubation was performed using a Macintosh direct laryngoscope, and Group 2 (n = 50), where a VL (Endolarenx Video Laryngoscopes, İstanbul, Türkiye) was used for intubation. The groups were treated identically, except for the laryngoscopy method applied.

Paediatric patients weighing less than 10 kg or more than 40 kg, those with congenital airway abnormalities, patients with known or anticipated difficult airways and those undergoing emergency surgical procedures were not included in the study. The study was conducted with patients who received oral premedication with midazolam at a 0.3 mg kg^{-1} dose. Intubation was performed using appropriately sized endotracheal tubes (ETTs) purchased from a single manufacturer to ensure standardization. A malleable stylet was routinely inserted into the ETT in both groups to facilitate tube placement during intubation.

During preoperative assessment, age, gender, weight, height, and body mass index of each patient were documented. Special care was taken to allow the children to stay with their families in the preoperative waiting area until they were transferred to the operating room to ensure they felt secure.

Intubation attempts that lasted longer than 10 minutes or failed after three attempts were considered unsuccessful and were managed as difficult intubations according to the guidelines. If the peripheral oxygen saturation (SpO_2) dropped below 94% during the intubation procedure, then respiratory support was provided using 100% oxygen. Patients identified with suspected difficult airways were excluded from the study. Certain evaluations were made to predict difficult airways. In paediatric patients who could follow simple instructions, the Mallampati scores were assessed by asking them to open their mouths fully and protrude their tongues while seated. In patients who could not open their mouths, the Mallampati scores were assessed by opening their mouths with the help of a tongue depressor and evaluating the oropharyngeal structures. Scoring was done between one and four points.

After completing the airway assessment, the paediatric patients were transported to the operating room. Standard monitoring was initiated upon entering the operating room, and maintained throughout the procedure including a three-lead electrocardiogram monitoring, non-invasive blood pressure measurement, and oxygen saturation monitoring.

Following monitoring, anaesthesia induction was initiated. In children without an accessible intravenous route or who did not allow intravenous access, a suitable-sized intravenous cannula was placed after induction of inhalation with a mixture of 8% sevoflurane and 100% oxygen using a mask appropriate for the child's face. Anaesthesia induction was achieved by intravenous doses of lidocaine (1 mg kg^{-1}), propofol (2 mg kg^{-1}), and fentanyl (1 µg kg^{-1}). After ensuring effective ventilation, rocuronium (0.5 mg kg^{-1} IV) was administered to facilitate muscle relaxation. Two minutes following the administration of rocuronium, laryngoscopy was carried out. Half of the patients were intubated using a VL, and the other half were intubated using Macintosh laryngoscopes. All videolaryngoscopic intubations were performed using the same standard Macintosh-type curved blade compatible with the Endolarenx VL.

Vocal cord visibility and intubation difficulty were assessed using the Modified Cormack-Lehane scoring system. The size of ETT was calculated using the formula (age/4 + 4), and ETTs 0.5 mm larger and smaller than the calculated size were kept ready. All intubation procedures in both groups were performed by the same anaesthesiologist who had four years of experience in paediatric anaesthesia and had routinely performed both DL and VL in more than 300 paediatric intubations. The operator had completed structured training and was proficient in the use of the Endolarenx VL before the study. In the DL group, the intubation procedure was performed using the Macintosh blade. The laryngoscope blade was positioned and maneuvered by the non-dominant hand of the operator. The patient's mouth was gently opened with the dominant hand of the operator, and the blade was inserted into the oropharynx along the midline. The Cormack-Lehane scoring system was used to assess the glottic view.

In the group where VL was used, the light and screen images of the VL were checked. The VL was operated with the non-dominant hand while the patient's mouth was gently opened with the dominant hand. The blade of the laryngoscope was then advanced along the midline into the oropharynx, gliding over the tongue. The glottic view was evaluated using the Cormack-Lehane scoring system. The Cormack-Lehane grade was recorded before the application of any anterior laryngeal pressure in both groups to ensure consistency in assessing the initial glottic view. In the VL group, grading was based on the view displayed on the video screen. Anterior laryngeal pressure was applied when necessary to facilitate glottic visualization during intubation attempts in both groups. The need for this maneuver was recorded and compared as an outcome variable.

In both groups, the intubation time was recorded from the insertion of the laryngoscope into the oral cavity until the appearance of the end-tidal CO_2 waveform on the capnograph. Following intubation, lung auscultation was performed with a stethoscope to confirm equal ventilation on both sides, and then the cuff of the ETT was inflated.

The primary outcome was the requirement for anterior laryngeal pressure during the intubation procedure, which was evaluated as an indicator of the technical difficulty and efficacy of the intubation technique. Secondary outcomes encompassed the duration of endotracheal intubation, success rate of the intubation, and the total attempts necessary to achieve intubation. Failed intubation was defined as either an unsuccessful intubation after three attempts or any intubation attempt lasting longer than 10 minutes, after which a laryngeal mask airway was used as an alternative rescue strategy. Complications occurring during the intubation procedure, such as bleeding, lacerations, and tooth damage, were also recorded to assess the safety of the technique. The patient's haemodynamic parameters as heart rate (HR) and mean arterial pressure (MAP) values were recorded preoperatively and at the 1st minute after intubation.

An independent statistician generated a 1:1 random allocation sequence using computer software. Allocation was concealed using sealed, opaque, sequentially numbered envelopes, opened only after consent. Participants were enrolled by clinical staff, with assignments revealed just before the intervention. Study participants and outcome assessors were blinded to the study design. Care providers could not be blinded due to the intervention type but followed a standardized protocol to reduce bias.

Calculation of Sample Size

The necessary sample size to detect a clinically significant difference of 22% in anterior laryngeal pressure rates between the two groups was calculated using G*Power for Windows version 3.1.9.7. A two-sided test with a significance level of $\alpha=0.05$ and a statistical power of $1-\beta=0.80$ required a minimum of 43 participants per group.

Statistical Analyses

The data obtained was examined using the Shapiro-Wilk test to verify normality of distribution. For variables following a normal distribution, the comparison of two independent groups was performed using the Student's t-test, while the paired t-test assessed changes across two time points. Associations among categorical variables were evaluated using the chi-square test, with significant outcomes undergoing further exploration through Bonferroni-adjusted subgroup analyses. Numerical variables were summarized as mean ± standard deviation, and categorical data were expressed as numbers and percentages. All statistical computations were executed using SPSS software (Windows, version 22.0), and a threshold of $P < 0.05$ was applied to define statistical significance.

Results

The study included 100 participants, with 50 patients assigned to Group 1 (DL group) and 50 patients to Group 2 (VL group). The study flow, including patient enrollment, randomization, and group allocation, is illustrated in the CONSORT flow diagram (Figure 1).

No notable variations were observed between the groups in relation to demographic characteristics such as age, weight, height, gender, and Mallampati scores. Notably, the proportion of patients categorized as ASA grade III was significantly greater in the DL group (P=0.029) (Table 1). The mean intubation time was significantly longer in Group 2 compared to Group 1 (P=0.001). Conversely, Group 2 exhibited a markedly lower anterior laryngeal pressure rate compared to Group 1. Group 2 demonstrated a substantially reduced success rate for the first-attempt intubation when compared to Group 1. Cormack-Lehane scores presented in Table 2 reflect initial glottic views before the application of any external laryngeal pressure. Additionally, a fraction of patients exhibiting a Cormack-Lehane score of 3 was notably higher in the DL group (P=0.003). HR and MAP values before and after intubation were comparable between the groups (Table 2).

The distribution of surgical procedures showed no meaningful variation across groups (Table 3). No complications, including airway trauma or postoperative laryngeal oedema, were observed in either group.

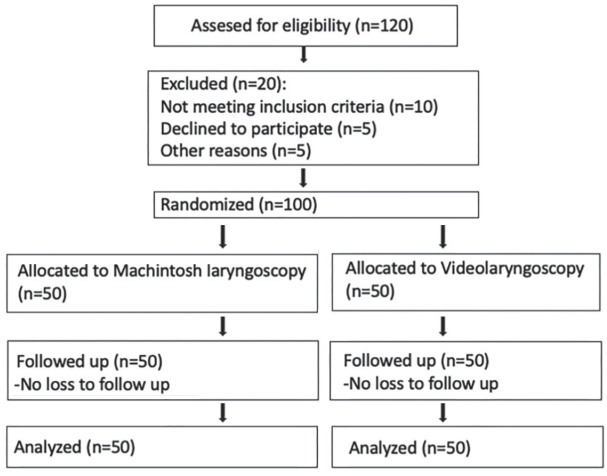

Figure 1. CONSORT 2010 flow diagram of the study participants.

Table 1. Demographic Data of the Patients

	Group 1 (n = 50)	Group 2 (n = 50)	*P* value
Age (years)	5.8±3.2	6.2±3.3	0.915
Weight (kg)	19.88±7.12	21.96±8.49	0.187
Height (cm)	114.52±20.69	113.56±21.46	0.820
Gender			
Female (n)	18	15	0.523
Male (n)	32	35	
ASA physical status			
1	35	43	
2	7	6	0.029*
3	8	1	
Mallampati scores			
1	37	44	
2	13	5	0.059
3	0	1	

Significant at $P < 0.05$.
ASA, American Society of Anesthesiologists

Table 2. Comparative data during tracheal intubation

	Group 1 (n = 50)	Group 2 (n = 50)	*P* value
Duration of intubation (sec)	20.7±5.1	29.1±5.7	0.001*
Anterior laryngeal pressure (n)			
Yes	39	16	
No	11	34	0.01*
Intubation attempts (%) (n)			
1	98% (49)	74% (37)	
2	2% (1)	26% (13)	0.001*
Cormack-Lehane grading system (%) (n)			
1	66% (33)	78% (39)	
2	18% (9)	22% (11)	
3	16% (8)	0% (0)	0.003*
Heart rates (mean ± SD/min)			
Before intubation	106.16±19.03	105.18±16.25	0.782
After intubation	114.3±17.99	122.52±15.9	0.017*
Mean arterial pressure, mmHg			
Before intubation	75.66±12.18	78.3±13.09	0.299
After intubation	81.74±15.02	90.82±15.8	0.004

$P < 0.05$; SD, standard deviation

Table 3. Comparison of Groups in Terms of Surgery Types

Type of surgery	Group 1 (n = 50)	Group 2 (n = 50)	*P* value
Paediatric surgery	19	15	0.803
Ear nose throat	20	25	
Urology	2	3	
Orthopedic surgery	6	4	
Eye surgery	3	3	

*Significant at $P < 0.05$

Discussion

Effective airway management is critical in paediatric anaesthesia due to the unique anatomical and physiological characteristics of children, which increase the complexity and risks associated with intubation. While DL has long been considered the standard technique for paediatric airway management, the advent of VL has introduced new possibilities, offering enhanced glottic visualization and potentially improving outcomes of intubation procedures. However, evidence regarding the routine use of VL in children remains controversial, with debates focusing on its efficiency, ease of use, and clinical benefits in scenarios where difficult airways are not anticipated.[5] In this study, we compared VL and DL in paediatric patients undergoing elective surgery to evaluate their respective advantages and limitations, providing insight into their practical applications and implications for routine paediatric anaesthesia.

Choudhary et al.[6] demonstrated that patients with higher Cormack-Lehane scores regarding DL had lower scores when compared to VL. In the same study, the intubation procedures of 85 patients were first performed using Macintosh and then VLs. The glottic view and Cormack-Lehane scores obtained with both laryngoscopes were recorded. According to Cormack-Lehane scoring system grades 2 (63%), 3 (17%), and 4 (5%) glottic views were observed in indicated percentages of patients undergoing DL, while grade 1 (54.1%), and 2 (45.9%) glottic views were observed in respective percenrages of patients undergoing VL. The findings of our study were consistent with those reported by Choudhary et al.[6] Our study revealed that intubation time was longer with VL compared to Macintosh laryngoscopy performed in paediatric patients. In the VL group, 74% of patients were successfully intubated on the first attempt, while 26% required a second attempt. In contrast, the DL group achieved a first-attempt success rate of 98%, while only 2% of the patients successfully intubated on the second attempt. No failed intubations were observed in either group. The DL group achieved a notably higher success rate on the first intubation attempt. Although VL provides a very clear glottic view, failures in the placement and advancement of the ETT may still occur. The lower first-attempt success rates observed in the VL group are likely attributed to challenges in coordinating eye-hand movements with the screen image, focusing prematurely on the vocal cords as they initially appear on the screen, and advancing the intubation tube blindly until it becomes visible on the screen.

Hu et al.[7] analyzed 27 studies involving 2,461 paediatric patients, and evaluated VL versus DL which revealed that intubation time was statistically significantly longer in patients intubated with VL. However, intubation times were comparable in the infant subgroup. Additionally, the study identified no notable distinctions between the two techniques regarding first-attempt success rates, Cormack-Lehane Grade 1 glottic view, intubation difficulty scores, and external laryngeal manipulation parameters.

Mutlak et al.[8] studied 65 children weighing less than 10 kg with normal airways undergoing elective surgery. In their study, 23 children were intubated using the C-MAC, 22 children with the TruView EVO2 VLs, and 20 children with the Macintosh blade. They found that intubation with the TruView EVO2 VL took a statistically significantly longer time (TruView 52 seconds, C-MAC Blade 28 seconds, Macintosh 26 seconds). Our study also demonstrated longer intubation times in the VL group.

Our findings are broadly in line with those of Klabusayová et al.[9], who evaluated 501 paediatric patients undergoing elective airway management and reported a lower first-attempt success rate and longer intubation times with VL compared to DL, while overall intubation success was similar between the groups. However, our study differs in several methodological aspects. First, we used the Endolarenx VL, a device that has not been previously assessed in paediatric patients. Second, we employed a consistent design in which all intubations were performed by the same operator using the same blade type across both groups, minimizing confounders related to device variability and user skill.

Hu et al.[7] also evaluated complication rates related to videolaryngoscopic versus direct laryngoscopic procedures. They found that traumatic complications were statistically significantly less frequent in the VL group. Similarly, Klabusayová et al.[9], evaluated 76 paediatric patients, and reported that the incidence of complications was comparable between videolaryngoscopic and direct laryngoscopic interventions.

de Carvalho et al.[10] evaluated the outcomes of various laryngoscopy techniques employed in paediatric patients younger than 18 years, focusing on the first and the second attempt success rates, glottic view, intubation time, and complications. Their analysis, which reviewed 46 meta-analyses, found that in children aged 0-1 year, the VL group

had statistically significantly higher success rates for both the first and the second intubation attempts. However, when all age groups were taken into consideration, the success rates for the first and the second attempts were statistically similar among VL and DL groups. VL was associated with a markedly reduced incidence of major complications in patients aged 0-18 years. Additionally, no significant differences were observed between the two techniques in terms of intubation time, overall intubation success, or glottic exposure.

Hajiyeva et al.[3] conducted a study on paediatric patients aged 5-10 years (weighing 10-40 kg) undergoing elective operation. Participants were allocated to two groups at random: one group underwent intubation with DL, while the other was intubated using the C-MAC D-Blade VL. Among patients with expected normal airways, intubation was completed in significantly less time with VL than with DL. The glottic view results were statistically similar between the groups. In our study, the requirement for anterior laryngeal pressure was markedly reduced in the VL group relative to the DL group. Hoshijima et al.[11] conducted a meta-analysis, reviewing 16 articles that consisted of a total of 18 studies. In these studies, 1012 patients were intubated using a Macintosh blade, while 1007 patients were intubated using C-MAC VLs. In 4 of these studies, the patients were expected to have a normal airway, while in the remaining studies, the patients were predicted to have a difficult airway. In 16 of 18 studies, it was shown that C-MAC VLs provided a better glottic view compared to Macintosh laryngoscopes. There was a lower need for external laryngeal manipulation in intubations performed with C-MAC VLs compared to Macintosh laryngoscopes. C-MAC VL provided greater success, particularly in patients with suspected difficult airways, compared to Macintosh laryngoscopy. Consistent with the results of this meta-analysis, our study also demonstrated that C-MAC VL offered improved glottic visualization and required less external laryngeal manipulation than Macintosh laryngoscopy.

Jagannathan et al.[12] compared King Vision aBlade VL with Miller DLin 200 paediatric patients undergoing intubation under two years of age. Their study did not observe any notable variations in the number of intubation attempts or in achieving an optimal glottic view. However, they reported that the intubation time was statistically significantly longer with King Vision aBlade VL. The need for airway manipulation and anterior laryngeal pressure was statistically significantly less with King Vision aBlade VL.

Kim et al.[13] conducted a study involving 84 paediatric patients, distributed across two groups. Group 1 patients were intubated using McGrath laryngoscopes, and for Group 2, Macintosh laryngoscopes were used. Both groups were evaluated concerning intubation time, glottic view, external laryngeal manipulation, intubation difficulty score, complications, and haemodynamic values. Grade 1 glottic view was achieved in a significantly higher number of patients in Group 1. In addition, external laryngeal manipulation was less frequently required, and intubation difficulty scores were significantly lower. Intubation times and procedural success rates were comparable in both groups. In Group 1, one patient experienced a lip injury, however, complications did not differ significantly between the groups. Consistent with our findings, Kim et al.[13] reported that VL was associated with significant haemodynamic changes, although these did not differ in clinical significance between groups. In our study, the VL group exhibited significantly greater changes in HR, systolic and diastolic blood pressures (SBP and DBP), while changes in MAP were comparable between groups. Similarly, Hajiyeva et al.[3] found a notable rise in HR after intubation in both groups where DL and C-Mac D-Blade VL were applied. However, this change was determined to be comparable between the groups.

Küçükosman et al.[14] conducted a study on ASA class 1-2 patients (n = 90) aged 18-65 years, who were scheduled to undergo elective surgery and intubation. Allocation of patients into three groups was carried out via a concealed envelope system. Equal number of patients (n = 30) were intubated with a McCoy laryngoscope, a Macintosh laryngoscope, or a C-MAC VL. No discernible statistical differences were detected among the groups concerning haemodynamic parameters. Although HR and MAP exhibited an upward trend within the first minute after intubation across all groups, this rise remained below the threshold of statistical significance.

Rajan et al.[15] evaluated the haemodynamic responses during nasotracheal intubation using the Macintosh blade and C-MAC D Blade VLs and reported no postoperative complications or significant trauma in either group. Similarly, in our study, no complications such as laryngeal oedema, trauma, or hypoxia were observed in either group, suggesting that both techniques can be safely employed in elective paediatric airway management. For paediatric patients, VLs offer better laryngeal vision. They can be used in educational settings as well. A longer learning curve is necessary for inexperienced users, particularly because non-standard blades demand more strict hand-eye coordination. In younger children, standard straight laryngoscope blades, such as the Propper Miller fiberoptic blade, are generally preferred because they offer better visualization of the glottis and are increasingly used in clinical practice. Since both midline and paraglossal approaches have been effectively used in paediatric patients, it is crucial to master both techniques. In paediatric patients, elevating the base of the tongue or the epiglottis facilitates the implementation of laryngoscopic procedures.[16]

Several studies have reported that as operator experience with VL increases, both intubation time and first-attempt success rates improve, even surpassing those of DL. This is particularly relevant in settings such as neonatal intensive care units, emergency departments, and in children with syndromic or anatomically difficult airways. Accordingly, elective surgical cases may serve as a valuable training ground for gaining proficiency in VL use, ultimately improving performance in more critical or challenging situations.[17-19]

Unlike previous studies that often involved multiple operators, various VL blade types, or highly experienced anaesthesiologists, our study was intentionally designed to reflect real-world clinical conditions. All intubations were performed by a single anaesthesiologist with structured training and substantial experience in paediatric VL, having performed with sufficient experience in VL before the study. A single operator with moderate experience in paediatric anaesthesia but limited prior exposure to VL performed all intubations. Both VL and DL were performed using the same Macintosh-type blade, thereby eliminating confounding related to blade geometry. In particular, such devices could support skill development among trainees during routine paediatric cases, especially in institutions gradually introducing VL into standard practice.

Study Limitations

Importantly, all patients included in this study were paediatric cases scheduled for elective surgery and were not anticipated to have difficult airways. Therefore, our findings may not be generalizable to emergency settings or to children with known or suspected airway anomalies.

One constraint of this study is that it focuses exclusively on elective paediatric patients, and excluded patients with abnormal airways. There is a need to study greater number of patients with difficult airways or in emergency conditions so as to assess the effectiveness of VL. Another key drawback of the study is its dependence on a single operator with four years of experience, potentially narrowing its applicability. Moreover, the outcomes may not translate to other VL designs, such as the C-MAC D-blade or Glidescope, restricting the generalizability of the findings.

Conclusion

This study highlights that while VL provides superior glottic visualization in paediatric patients undergoing elective surgery, it does not offer significant advantages over DL in terms of intubation success or efficiency. The extended intubation times and reduced first-attempt success rates associated with VL suggest that it may not be an ideal laryngoscopy procedure to be used for routine paediatric intubations. However, given its ability to improve glottic visualization, VL may act as an essential component in emergency paediatric cases by potentially reducing the duration of hypoxic episodes, underscoring its value as an essential tool in urgent airway management. Further research is warranted to explore its utility in complex airway scenarios and to evaluate its outcomes when performed by experienced operators and using diverse VL devices. These conclusions apply specifically to paediatric patients undergoing elective surgery without anticipated difficult airways. Extrapolation of the findings to emergency situations or children with anatomical airway anomalies should be made with caution.

Ethics

Ethics Committee Approval: Ethical approval was obtained from Clinical Research Ethics Committee of Gaziantep University on April 6, 2022 (approval number: 2022/100, date: 06.04.2022).

Informed Consent: Written informed consent was obtained from parents of the paediatric patients.

Footnotes

Author Contributions: Surgical and Medical Practices - T.Y.; Concept - L.P., E.Ş., A.M.; Design - L.P., A. M.; Data Collection or Processing - T.Y., L.P.; Analysis or Interpretation - T.Y., L.P.; Literature Search - T.Y., E.Ş.; Writing - T.Y., L.P., E.Ş., A.M.

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Craniotomy in Semi-sitting Position: A 4-year Single Institution Experience

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Abstract

Objective: We aimed to determine patient outcomes after craniotomies performed in semi-sitting position in our institution from 2019-2023. Primarily, we examined surgical and anaesthetic (clinical) outcomes. Secondarily, we evaluated any major complications that may have occurred.

Methods: Hospital records from 2019-2023 were retrospectively reviewed for adult patients who underwent craniotomy in the sitting position. Individual charts were examined for intra- and postoperative events. The demographic and clinically important findings were tabulated using Excel spreadsheet. The dataset was descriptively analyzed, with quantitative data represented as mean ± standard deviation, and qualitative data as valid percentages from the total cohort. Parametric comparisons of sex vs. (length of intensive care unit and hospital stay) and anaesthesia duration (in minutes) were performed using Student's t-test. A 95% confidence level was used to determine statistical significance. Analyses were performed using IBM SPSS® Edition 22.

Results: From 2019-2023, 10 patients underwent craniotomy in a sitting position. General anaesthesia was induced and maintained using an intravenous target-controlled infusion of remifentanil and propofol. Nine patients developed pneumocephalus, with one developing increased intracranial pressure. One patient had a significant venous air embolism with severe manifestations, including massive pleural effusion. All patients except one were extubated at the end of the surgery.

Conclusion: Of the 10 craniotomies performed in the sitting position from 2019-2023, 90% were managed without major long-term sequelae. Although the sitting position for craniotomies is not without challenges, a dedicated and experienced team can manage complications and improve patient outcomes.

Keywords: Craniotomy, neuroanaesthesia, perioperative care, pneumocephalus, sitting position, venous air embolis

Main Points

- Craniotomy is rarely performed in the sitting position to facilitate surgical exposure and drainage of cerebrospinal fluid and blood.
- Patients aged 50 years and younger were primarily candidates for cerebellopontine angle tumor resection or pineal gland lesion surgeries in the semi-sitting position, whereas older patients typically underwent the procedure for posterior fossa metastatic tumors.
- Pneumocephalus and venous air embolism are two potentially significant complications that may arise when performing craniotomy in the sitting position.
- A dedicated and experienced neuroanaesthesia team can manage possible complications and improve patient outcomes.

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Introduction

The semi-sitting position facilitates the drainage of the cerebrospinal fluid and blood by gravity and provides improved surgical exposure and a wide and clean surgical field.[1] Anatomical orientation and early decompression of the cisterna magna are additional advantages.[2] This position has been used for years in surgeries using the supracerebellar approach. Moreover, better neurosurgical outcomes have also been reported. However, there is an ongoing debate on whether these benefits outweigh the risks to patients.[3] Maintaining the patient's head above heart level during surgery causes the intracranial venous pressure to reach a negative value. Air entry into the venous system can develop due to pressure changes and can lead to air embolism. Air can infiltrate the circulation through any open vein or dural sinus in the surgical region.[4] The semi-sitting position poses a higher risk of venous air embolism (VAE) than the prone position.[5] The frequency of air embolism is as high as 38.6% and has been reported to be more common in posterior fossa surgeries than in cervical spinal procedures.[6]

The neurosurgery team at our institution successfully performs more than 1000 surgeries annually while seeking to maintain high-quality care. As an academic center, we also have a neurosurgical residency program and a neuroanaesthesia fellowship program. Together with faculty-level physicians, experienced neurophysiologists and nurses, our institution provides a multidisciplinary team approach to deliver safe patient care. In a systematic manner, our neurosurgical and anaesthesia teams reassess their practice every few years as part of their self-appraisal. Therefore, we retrospectively studied all cases of neurosurgery performed in the sitting position. This study aimed to determine patient outcomes in a semi-sitting position over the past 4 years. Our primary aim was to quantify our experience in terms of surgical and anaesthetic (clinical) outcomes. Our secondary aim was to evaluate the major complications in the semi-sitting position.

Methods

Following ethical approval from the Medical Research Committee of Hamad Medical Corporation (approval no.: MRC-04-23-578; date: 21 Aug 2023), an electronic medical record database was used to retrospectively examine the patient records. Adult patients who underwent craniotomies in the sitting position between January 2019 and June 2023 were included. Individual patient charts were used to evaluate significant intra- and postoperative events. All the critical and adverse events were recorded.

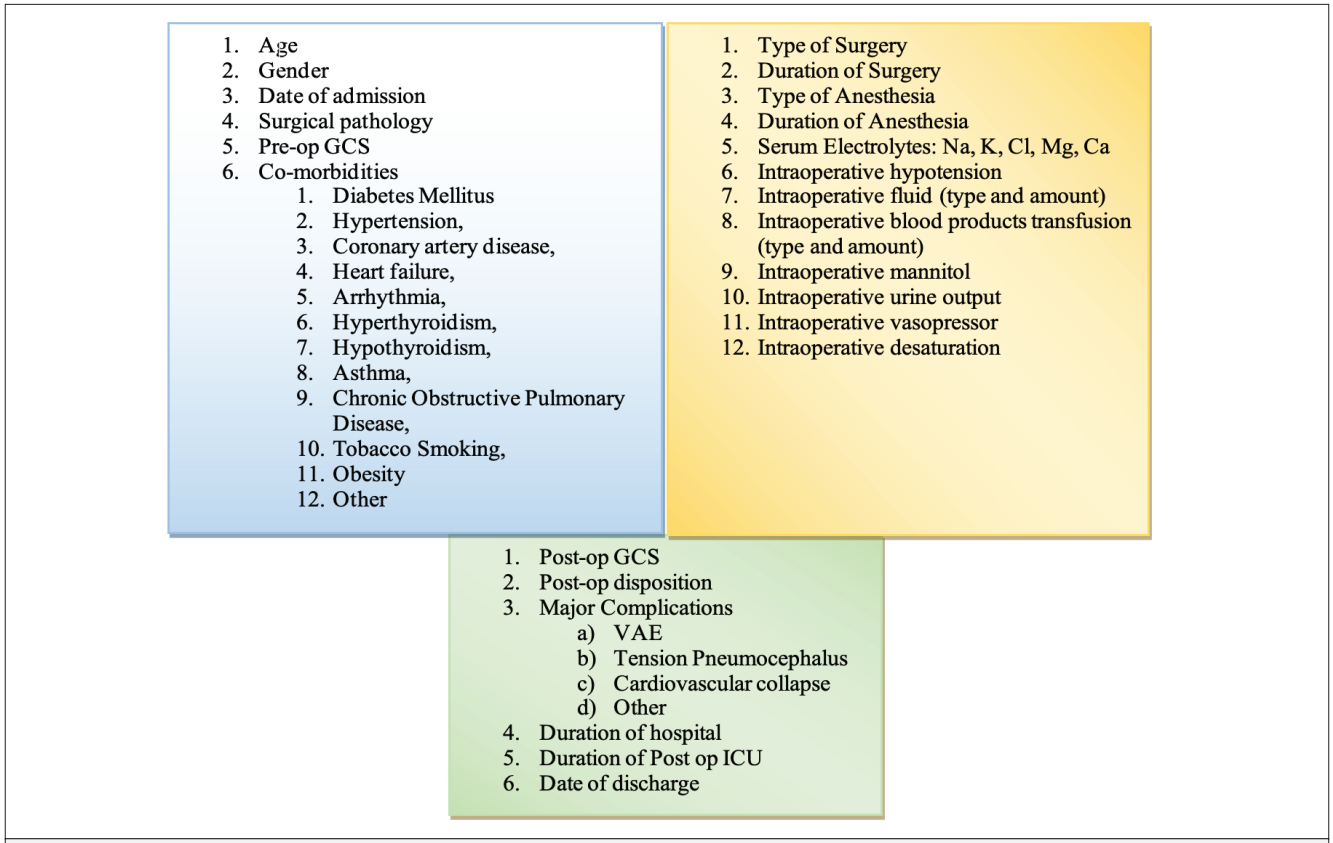


Figure 1. Data collection template.

GCS, Glasgow Coma Scale; VAE, venous air embolism; ICU, intensive care unit.

The data collection template is shown in Figure 1. The data collected were de-identified and coded for the statistical analyses.

The study dataset was descriptively analyzed using quantitative data represented as mean ± standard deviation and qualitative data represented as valid percentages from the total cohort. A possible parametric comparison involving sex, length of intensive care unit (ICU) stay, hospital stay, and duration of anaesthesia (in minutes) was performed using Student's t-test. A 95% confidence level was used to determine statistical significance. All analyses were performed using the IBM SPSS® Edition 22.

Results

Ten patients underwent craniotomies in the sitting position at our institution from January 2019 to June 2023. The patient demographics are presented in Table 1. No patients were excluded from the analysis.

Baseline Characteristics

All patients had a preoperative Glasgow Coma Scale (GCS) score of 15 and normal preoperative echocardiography. Intraoperatively, all patients were administered target-controlled infusions of propofol and remifentanil intravenously. All patients also had an arterial line and a central venous catheter inserted along with a Foley catheter to monitor urine output.

The sex ratio was 1:1, with five males and five females. All patients were between 33 and 60 years of age. Of note, patients 50 years and younger underwent surgery for cerebellopontine angle (CPA) tumor resections or for lesions in the pineal gland. Two patients older than 50 years underwent surgery for metastatic tumors in the posterior fossa.

Types of Surgeries

CPA tumor resection was the most common surgery (n = 5). Three surgeries were performed for lesions in the pineal region, and two for metastatic tumors in the posterior fossa. All surgeries lasted for an average of >7 hours (363-512 min; mean, 443 min; standard deviation, 49.6 min). All procedures were performed in a semi-sitting position, using Mayfield pins to fix the skull. All patients received general anaesthesia with endotracheal intubation using propofol and remifentanil target-controlled infusion modes for total intravenous anaesthesia and muscle relaxation. Almost all patients had post-induction hypotension and required intravenous vasopressors. Seven of 10 patients received a phenylephrine (PE) bolus or infusion; while all 10 received norepinephrine (NE) to maintain blood pressure. Nine patients had pneumocephalus, and one patient developed severe manifestations. One patient developed a clinically significant VAE with severe manifestations, including massive pleural effusion and adult respiratory distress syndrome. Except for this one patient, all patients were extubated at the end of surgery. A summary of the major complications is presented in Table 2.

The detrended normal Q-Q plot depicted the differences between the observed and predicted hospital and ICU stays (Figure 2).

Case Presentations

The distribution of case presentations is summarized in Figure 3.

Case 1

A thirty-three-year-old male presented with pineal gland pilocytic astrocytoma and underwent left occipital craniotomy. The preoperative GCS score was 15. Known medical risks and comorbidities included hyponatremia. Preoperative echocardiography was normal. The duration of anaesthesia was 7 h and 55 min. Intraoperatively, he received 2100 mL of normal saline (NS), 500 mL of colloids, and 100 µg of PE, along with 35 g of mannitol. His urine output was 1500 mL, and blood loss was estimated at 250 mL. No VAE was detected during surgery, and pneumocephalus occurred without complications. Postoperatively, the patient experienced hyponatremia, possibly related to inappropriate antidiuretic hormone secretion or adrenal insufficiency. The patient also exhibited unequal pupils and upward-gaze palsy, which gradually improved over time.

Case 2

A thirty-nine-year-old male patient was diagnosed with right cerebellopontine (CP) angle acoustic schwannoma and underwent surgical intervention. The preoperative GCS score was 15. Known medical risks or comorbidities included hypertension, obesity, gastric ulcer, and lumbar spondylosis. Preoperative echocardiography was normal. The duration of anaesthesia for this complex procedure was 8 h and 32

Table 1. Demographics of Patients in a Semi-Sitting Position

Demographics	Range	Mean	Standard deviation
Age (years)	33-60	43.30	10.27
Weight (kg)	60-137	85.26	23.17
BMI (kg m²)	24.2-49.6	30.31	8.47

BMI, body mass index

Table 2. Major Complications and Their Frequency in Patients Who Underwent Craniotomy in the Semi-Sitting Position

Major hypotensive event				
	Frequency	Percent	Valid percent	Cumulative percent
Yes	9	90.0	90.0	90.0
No	1	10.0	10.0	100.0
Total	10	100.0	100.0	
Venous air embolism				
	Frequency	Percent	Valid percent	Cumulative percent
No	9	90.0	90.0	90.0
Yes	1	10.0	10.0	100.0
Total	10	100.0	100.0	
Pneumocephalus				
	Frequency	Percent	Valid percent	Cumulative percent
No	9	90.0	90.0	90.0
Yes	1	10.0	10.0	100.0
Total	10	100.0	100.0	
Delayed extubation				
	Frequency	Percent	Valid percent	Cumulative percent
No	9	90.0	90.0	90.0
Yes	1	10.0	10.0	100.0
Total	10	100.0	100.0	
Post-operative nausea and vomiting				
	Frequency	Percent	Valid percent	Cumulative percent
No	7	70.0	70.0	70.0
Yes	3	30.0	30.0	100.0
Total	10	100.0	100.0	

min. Intraoperatively, the patient received 2300 mL of NS and 500 mL of colloids, while 292 µg of NE was given to maintain hemodynamic stability. Additionally, 50 g mannitol was administered, and the patient exhibited a urine output of 3000 mL. The estimated intraoperative blood loss was 300 mL. Notably, VAE was detected during the procedure but was managed successfully. Pneumocephalus occurred but resulted in no complications. Postoperatively, the patient experienced postoperative nausea and vomiting (PONV) and was extubated in the operating room. However, he developed hypertension immediately after surgery. He also exhibited lower motor neuron palsy in the right facial nerve.

Case 3

A fifty-seven-year-old female patient with a history of invasive breast ductal carcinoma developed cerebellar metastasis to the left posterior fossa. The preoperative GCS score was 15. Known medical risks or comorbidities included hypertension, diabetes mellitus, obesity, and metastatic breast cancer. Preoperative echocardiography was normal. The surgery lasted for 6 h and 35 min. During the surgery, the patient received 1000 mL of NS, 500 mL of plasma protein fraction (PPF), 900 µg of PE, and 840 µg of NE to maintain hemodynamic stability. Additionally, 80 g of mannitol was administered, and the patient exhibited a urine output of 1500 mL, with an estimated blood loss of 250 mL. No VAE was detected during the procedure, and the patient recovered uneventfully in the operating room.

No immediate postoperative complications occurred. However, cranial pathology progressed, and the patient succumbed to the condition.

Case 4

A sixty-year-old female patient was diagnosed with metastatic cervical cancer that had spread to the left superior cerebellar peduncle. The preoperative GCS score was 15. Known medical risks or comorbidities included smoking tobacco, hypertension, and metastatic cervical cancer (metastases to the lungs and brain). Preoperative

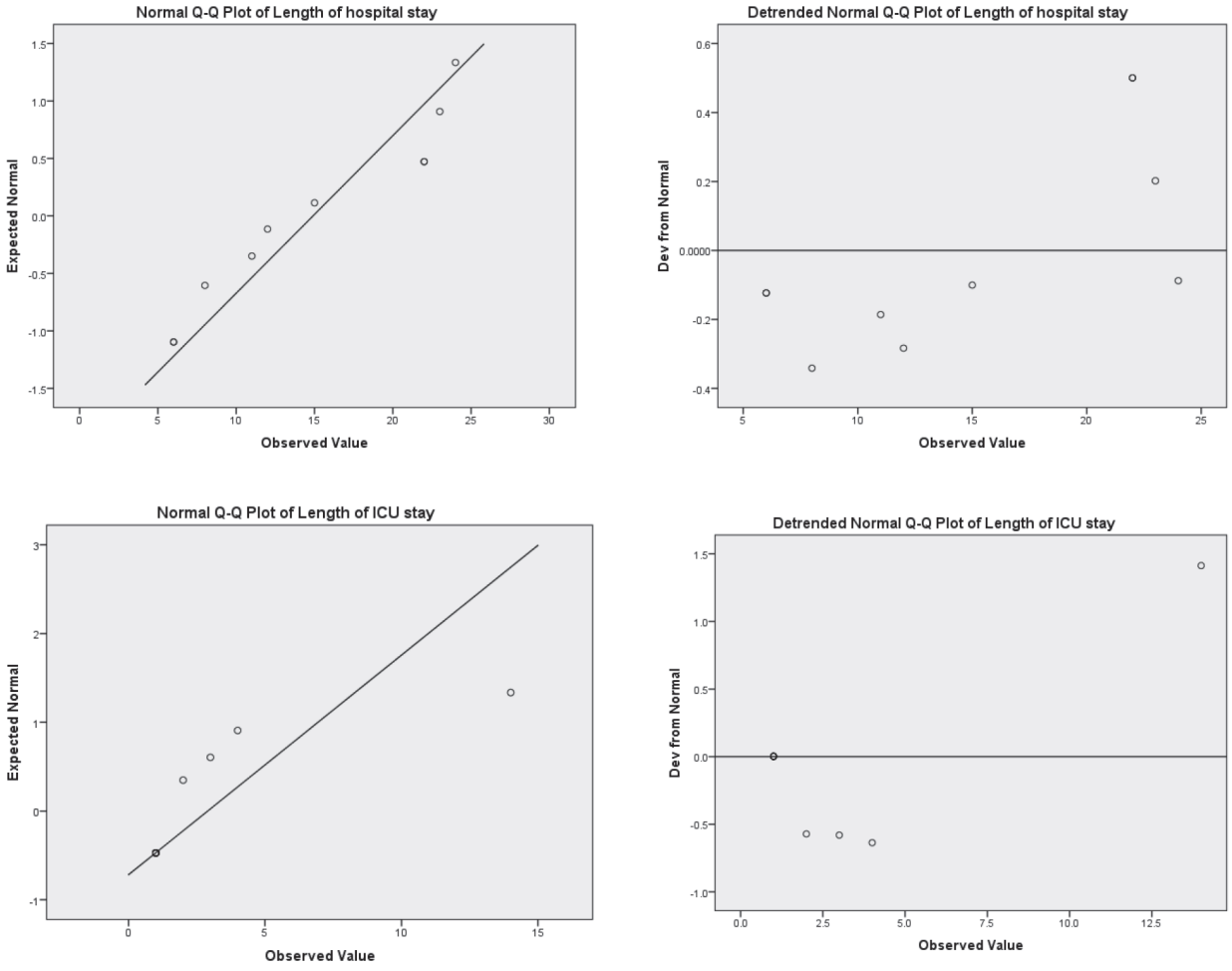


Figure 2. Normal and detrended normal Q-Q plots of the length of hospital and intensive care unit stay.

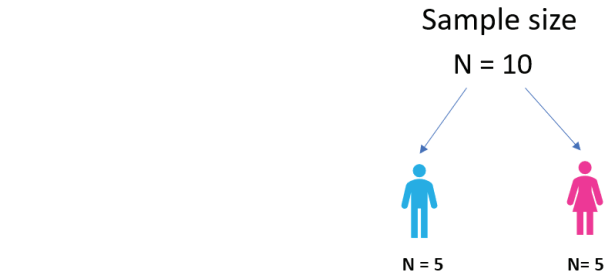
echocardiography was normal. The surgery lasted 6 h and 46 min. Intraoperative bradycardia episodes occurred during surgical manipulation. During the procedure, the patient received 1500 mL of NS, 500 µg of PE, and 0.3817 mg of NE to manage hemodynamic parameters. Specific details regarding plasma proteins or other administered substances were not provided. The estimated blood loss was 250 mL.

Significant postoperative complications were observed. The patient developed pneumocephalus in the subdural space of the left temporal and both frontal lobes, resulting in mass effect and increased intracranial pressure (ICP), which was associated with hypertension and bradycardia. Postoperatively, multiple episodes of nausea and vomiting were observed. Although the patient showed some improvement in preoperative cerebellar signs, she still exhibited an ataxic gait.

Case 5

A thirty-three-year-old male patient was diagnosed with right acoustic schwannoma. The preoperative GCS score was 15. Known medical risks or comorbidities included hypertension. Preoperative echocardiography was normal. The surgery lasted for 6 hours and 3 minutes. During the procedure, the patient received 500 mL of NS, 500 mL of PPF, and 1000 mL of plasmalyte. Hemodynamic stability was maintained with the administration of 466.6 µg of PE, 1291.66 µg of NE, and 12 mg of ephedrine. The estimated intraoperative blood loss was 250 mL.

Postoperatively, the patient did not experience any immediate complications, such as VAE or pneumocephalus. He reported only PONV. The patient did not require prolonged respiratory support. The absence of immediate complications and successful intraoperative management suggested a favorable outcome for this patient in the early postoperative period.



Sl. No.	1	2	3	4	5	6	7	8	9	10
Dx	PG	Rt. Ac. Schw	Met Tumour	Met Tumour	Rt. CP	PG	Lt. CP	Rt. CP	PG	Rt. CP
Age/Gender	33 M	39 M	57 F	60 F	35 M	33 M	33 F	50 M	44 F	49 F
Major Complications	Transient Neuro Sg	Neuro Sg	Headache, PONV, Mortality	Ten. Pneu	Headache, PONV	Pneu, Hydrocep, Transient N Sg.	VAE, Massive Pleural Eff.	Cough, Neuro Sg.	Neuro Sg	Transient Neuro Sg

Figure 3. The distribution of case presentations.

Dx, diagnosis; Rt, right; Lt, left; PG, pineal gland tumor; Ac. Schw, acoustic schwannoma; Met, metastatic; CP, cerebellopontine angle; Ten. Pneu, tension pneumocephalus; Pneu, pneumoncephalus; Hydrocep, hydrocephalus; N. Sg/Neuro Sg, neurological symptoms/signs; VAE, venous air embolism; PONV, postoperative nausea and vomiting; Eff., effusion.

Case 6

A thirty-three-year-old male patient was diagnosed with a meningothelial meningioma, typically found in the meninges, which was detected near the pineal glands.

The preoperative GCS score was 15. The patient had no known medical comorbidities. Preoperative echocardiography was normal. The surgery lasted for 6 h and 56 min. During the procedure, the patient received 2000 mL of NS and 1000 mL of PPF. Hemodynamic stability was maintained with the administration of 513.3 µg of NE. Mannitol (40 g) was administered to manage ICP, and the patient exhibited a urine output of 2800 mL, with an estimated blood loss of 300 mL.

Postoperatively, the patient's recovery was initially uneventful, with no immediate complications such as VAE or pneumocephalus. However, the patient developed dilation of the lateral and third ventricles and a right temporal subgaleal hematoma. This was associated with staring episodes; an external ventricular drain was inserted to manage increased ICP. The patient improved; however, he also experienced diplopia, left foot numbness, and later developed headaches.

Case 7

A thirty-three-year-old female patient was diagnosed with left CP angle vestibular schwannoma. The preoperative GCS score was 15. She had a history of obesity, obstructive sleep apnea, and hypertension. Preoperative echocardiography was normal. The surgery lasted for 7 h and 40 min. Intraoperatively, to manage fluid balance and hemodynamic stability, the patient received 2100 mL of NS, 500 mL of PPF, and 500 mL of Ringer's lactate (RL). Additionally, 2.48 mg of NE was administered to maintain blood pressure. Mannitol (45 g) was administered during surgery, and the patient exhibited a urine output of 3000 mL, with an estimated blood loss of 100 mL.

However, the postoperative course was marked by significant complications related to VAE. VAE manifested during the surgery, leading to its diagnosis, with intraoperative episodes of desaturation and a decrease in end-tidal carbon dioxide ($EtCO_2$). Postoperatively, the patient exhibited signs of VAE-induced pulmonary complications, including pulmonary congestion and high oxygen requirements. To manage these complications, furosemide was administered, and the patient was intubated for respiratory support. Subsequently, 100 mg of hydrocortisone was administered.

Despite these challenges, the immediate surgical recovery was uneventful. However, the patient's postoperative stay in the surgical ICU (SICU) was characterized by two additional episodes of VAE. These episodes were accompanied by persistent high oxygen requirements and the development of multiple complications, including acute respiratory distress syndrome, massive pleural effusion, acute kidney injury, and sepsis. The patient also experienced sick euthyroid syndrome, which was attributed to the VAE.

Upon further follow-up at the neurosurgery clinic, the patient presented with left-sided facial weakness that required continued evaluation and management.

Case 8

A fifty-year-old male patient was diagnosed with right CP angle schwannoma. The preoperative GCS score was 15. She also had a history of hypertension. The surgery lasted for 8 h and 31 min. Preoperative echocardiography was normal. During the procedure, the patient received 3500 mL of NS and 1250 mL of PPF to maintain fluid balance. Hemodynamic stability was maintained with the administration of 417 µg of PE and 1.44 mg of NE. Mannitol (50 g) was administered, and the patient exhibited a urine output of 1800 mL, with an estimated blood loss of 400 mL.

Postoperatively, the patient's immediate surgical recovery was uneventful, with no complications during the intraoperative phase. However, during his hospital stay, the patient developed nosocomial meningitis, which required treatment. Fortunately, he responded well to the treatment and showed improvement. During long-term follow-up, the patient reported right-sided facial numbness, which may be a neurological consequence of the surgery or related complications.

Case 9

A forty-four-year-old female patient was diagnosed with a large pineal parenchymal tumor with intermediate differentiation. The preoperative GCS score was 15. She was COVID-19 positive. Preoperative echocardiography was normal. The surgery lasted for 7 h and 45 min. During the procedure, the patient received 1200 mL of NS and 1000 mL of PPF for fluid management. Hemodynamic stability was maintained with the administration of 1000 µg of PE, 240 µg of NE, and 40 mg of labetalol (used to control one episode of surge in blood pressure exceeding 170 mmHg). Mannitol (30 g) was administered and the patient exhibited a urine output of 1600 mL, with an estimated blood loss of 250 mL.

The patient's immediate postoperative surgical recovery was uneventful, with no complications noted during the intraoperative phase. However, during the postoperative period, the patient experienced occasional polyuria, horizontal nystagmus, on-and-off diplopia, and blurred vision in the left eye.

Case 10

A forty-nine-year-old female patient was diagnosed with a right vestibular schwannoma. She had a history of migraines. Preoperative echocardiography was normal. The surgery lasted for 7 h and 10 min. During the procedure, the patient received 500 mL of NS, 750 mL of PPF, and 500 mL of RL for fluid management. Hemodynamic stability was maintained with the administration of 660 µg of PE and 800 µg of NE. Additionally, mannitol (20 g) was administered, and the patient exhibited a urine output of 1800 mL, with an estimated blood loss of 200 mL.

The patient's immediate postoperative surgical recovery was uneventful, with no complications noted during the intraoperative phase. However, during the neurosurgical follow-up, right-sided Bell's palsy was observed.

Discussion

In this case series, we analyzed the outcomes of 10 patients who underwent intracranial surgery in the semi-sitting position. Owing to the serious risks of VAE, hemodynamic instability, tension pneumocephalus, and quadriplegia, the semi-sitting position in craniotomy has long been a topic of debate in the fields of neurosurgery and neuroanaesthesia.

Our results indicated that patients aged 50 years and younger were primarily candidates for CP angle tumor resection or pineal gland lesion surgeries in the semi-sitting position, whereas older patients typically underwent the procedure for posterior fossa metastatic tumors. These findings align with the literature's understanding that the choice of position often depends on specific surgical indications and patient characteristics.

Anaesthetic management is a critical factor in the success of craniotomies in a semi-sitting position. Our study highlights the need for vigilant hemodynamic control, as most patients require vasopressor support owing to post-induction hypotension. The incidence of hypotension in the sitting position ranges from 5% to 32%.[7] This is theorized to be due to venous pooling in the legs caused by gravity, which leads to a reduced cardiac preload. This effect is further compounded by anaesthesia-mediated vasodilation and myocardial depression. Preloading patients with crystalloid solution before assuming a sitting position has been shown to reduce the incidence of hypotension.[8] Our institution does not mandate preloading, although some practitioners do. Our patients were maintained on vasopressor therapy, commonly PE infusion or occasionally NE infusion, to regulate blood pressure, and received fluid therapy only to ensure euvolemia.

Pneumocephalus is a potential complication of semi-sitting craniotomy. This was a common occurrence in our cohort, with one patient experiencing severe manifestations. Importantly, we documented a case of clinically significant VAE, which is a rare but potentially life-threatening complication.

The existing literature on VAE presents a variety of data. Different monitoring techniques have been employed to diagnose VAE, and severity classifications have been used to categorize its varying levels. Additionally, it's worth noting that most of these studies were retrospective in nature.[9] Previous studies have reported varying $EtCO_2$ thresholds for diagnosing clinically significant VAE.[10] For example, Durmuş et al.[11] established a limit of 5 mmHg. In contrast,

Feigl et al.[12] determined this limit to be 3 mmHg, whereas Ammirati et al.[13] settled at 5 mmHg. In the present study, we did not set a specific $EtCO_2$ threshold. Instead, we considered an unexplained reduction, accompanied by tachycardia and desaturation, in patients undergoing procedures in the sitting position to be indicative of a clinically significant VAE.

The incidence of VAE has also been reported in different publications. In a systematic review of 977 patients undergoing cervical spine or posterior fossa surgery in the semi-sitting position, air embolism occurred in 40.2% of the patients.[6] In a case series reported by Kurihara and Nishimura,[14] 26% of 23 patients, operated in the semi-sitting position, experienced VAE, with an $EtCO_2$ reduction by more than 5 mmHg. A retrospective study by Ammirati et al.[13] found that 26.8% of 41 patients had a decrease of >5 mmHg. In another study evaluating the risk of paradoxical VAE in patients with a patent foramen ovale, 9.6% exhibited an $EtCO_2$ increase >3 mmHg.[12] Finally, in a prospective study, the reported incidence rate was 4%.[15]

Head elevation is closely associated with the incidence of complications. Durmuş et al.[11] employed a 40° head elevation and did not observe any clinically significant air embolism leading to $EtCO_2$ reductions >5 mmHg or hemodynamic changes. In this case series, 11 patients underwent craniotomy in the dynamic lateral semi-sitting position between 2020 and 2022. Notably, none of these patients experienced clinically significant VAEs or major complications during surgery, and all were successfully extubated postoperatively. Postoperative imaging confirmed the total removal of the tumors and cavernomas, reflecting the efficacy of the surgical procedures. In contrast, our study involving 10 patients over 4 years of age revealed that while most patients were safely extubated, one patient suffered from a clinically significant VAE with severe manifestations. The use of medical anti-shock trousers or anti-gravity, to reduce the incidence of VAE has been described in the literature.[16,17,18] Inflation of the trousers to 40 mmHg in the leg compartment and 30 mmHg in the abdominal compartment led to an increased right atrial pressure, which, in turn, linearly increased the pressure on the venous sinuses and thereby reduced the risk of VAE. However, this is not a widely accepted practice, and practitioners must consider peripheral vessel and nerve compression, as well as abdominal compression. This was not part of our institution's routine practice.

These findings emphasize the complexity and potential risks associated with craniotomies in the sitting position and the importance of careful patient selection and anaesthesia management to ensure safe outcomes. In a prospective study, clinically significant air embolisms occurred in 8% of patients with 30° head elevation and 50% of patients with 45° head elevation.[4] In our study, the incidence was 10% with 35° head elevation.

Study Limitations

Our study was retrospective in nature and had a small sample size of ten patients. The critical findings reported in our study may not necessarily translate into other centers with dissimilar case volumes of craniotomy performed in the semi-sitting position. Nevertheless, we believe that the findings are relevant for reflecting standards and quality of management adopted for each individual case.

Conclusion

In conclusion, our study contributes to the ongoing discussion on the use of the semi-sitting position for craniotomies. It emphasizes the complexity and potential risks associated with this position. It highlights the critical role of careful patient selection, anaesthesia management, and adherence to safety protocols to ensure optimal outcomes in neurosurgical procedures. It is essential to continue evaluating positioning techniques and monitoring methods to enhance patient safety and the quality of care in neurosurgical procedures.

Ethics

Ethics Committee Approval: Following ethical approval from the Medical Research Committee of Hamad Medical Corporation (approval no.: MRC-04-23-578; date: 21 Aug 2023).

Informed Consent: An electronic medical record database was used to retrospectively examine the patient records.

Footnotes

Author Contributions: Surgical and Medical Practices - A.K., M.J.K., A.S., M.I.H.H., K.K.G., N.K.; Concept - A.K., M.J.K., A.S., M.E.; Design - A.K., M.J.K., A.S., M.E.; Data Collection and/or/ Processing - A.K., M.J.K., A.S., M.J.O., K.K.G., Analysis and/or/ Interpretation - A.K., M.J.K., A.S., M.E., M.I.H.H., M.J.O., K.T.S., P.R., K.K.G., N.K.; Literature Review - S A.K., M.J.K., A.S., M.E., M.I.H.H.; Writing - A.K., M.J.K., A.S., M.E., M.I.H.H., K.T.S., P.R., K.K.G., N.K.

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Attitudes of Anaesthesiology Specialists and Residents Toward Hemodynamic Monitoring: A National Survey Study

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Abstract

Objective: This descriptive survey study aims to evaluate the knowledge, attitudes, and practices of anaesthesiology specialists and residents in Türkiye regarding advanced hemodynamic monitoring in high-risk surgical patients.

Methods: The survey, comprising 25 questions, was distributed to 960 anaesthesia professionals, with 713 completing the questionnaire.

Results: The study reveals that while invasive blood pressure monitoring is widely used (96.3%), the adoption of advanced hemodynamic monitoring techniques, such as cardiac output monitoring, remains limited (12.6%). For awake high-risk surgical patients under regional anaesthesia, a significant proportion of respondents (15.1% and 37.1%) considered non-invasive blood pressure monitoring to be insufficient. Additionally, 41.1% of participants believed that stroke volume variation, pulse pressure variation, and systolic pressure variation parameters could be used to assess fluid deficits in awake patients.

Conclusion: High costs, technical complexity, and lack of training are identified as major barriers. The findings highlight the need for enhanced educational programs and practical training to improve the utilization of advanced hemodynamic monitoring, ultimately aiming to reduce perioperative morbidity and mortality. The study underscores the importance of integrating advanced hemodynamic monitoring into routine clinical practice and suggests the development of nationwide algorithms to standardize practices.

Keywords: Advanced hemodynamic monitoring, fluid responsiveness, goal-directed therapy, high-risk surgical patients, survey

Main Points

- The use of advanced hemodynamic monitoring techniques among anaesthesiologists in Türkiye is limited in high-risk surgical patients.
- High costs, technical complexity, and lack of experience are significant barriers to the widespread adoption of these techniques.
- Dynamic fluid responsiveness parameters and cardiac output monitoring preferences have fallen behind conventional monitoring methods in terms of usage rates in high-risk surgeries.

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Introduction

With advancements in medical technology and perioperative care, the number of patients undergoing high-risk or major surgeries has been increasing. Although high-risk surgeries constitute only 12.5% of all surgical procedures, they account for more than 80% of postoperative mortality.[1] Hemodynamic instability is common during these procedures, making the optimization of hemodynamic management a crucial factor directly associated with patient outcomes. Effective hemodynamic monitoring helps detect physiological changes, diagnose underlying causes, and optimize oxygen delivery to tissues. Additionally, it is essential for assessing the adequacy of therapeutic interventions such as fluid resuscitation or vasoactive drug administration. Studies have shown that hemodynamic optimization in high-risk surgical patients reduces postoperative complications and improves overall outcomes.[2]

Beyond routine hemodynamic parameters such as blood pressure, urine output, and blood gas values, cardiac output (CO) monitoring and dynamic fluid responsiveness assessment can be utilized for intraoperative hemodynamic optimization. Various hemodynamic monitoring devices exist with different levels of invasiveness and accuracy. However, challenges such as high costs, technical complexity, and a lack of knowledge or experience hinder the widespread adoption of hemodynamic monitoring techniques. Surveys conducted among anaesthesiologists in North America, Europe, Korea, Italy, and China have revealed significant gaps in the clinical application of hemodynamic monitoring and management in high-risk surgeries.[3-6] Similarly, a study among anaesthesiologists in Japan indicated that while CO and dynamic fluid monitoring parameters were recommended for high-risk surgical patients, their actual use in clinical practice remained low.[7]

To date, no study has been conducted to investigate the frequency and details of hemodynamic monitoring among anaesthesiologists in Türkiye. This study aims to evaluate the monitoring methods used to ensure hemodynamic stability during and after surgery, analyze the knowledge, experience, and perspectives of anaesthesiologists regarding hemodynamic monitoring, determine the factors influencing device and technique preferences, assess critical thresholds considered in hemodynamic parameter monitoring, and identify potential educational or developmental needs in this field.

Methods

This descriptive survey study was designed to evaluate the knowledge and attitudes of anaesthesiology specialists and residents in Türkiye regarding advanced hemodynamic monitoring in high-risk surgical patients. The study received approval from the Ankara Bilkent City Hospital, Scientific and Ethical Evaluation Board for Medical Research No. 2 (TABED) (approval no.: TABED 2-24-635, date: 13.11.2024). The survey was conducted using web-based software (SurveyMonkey, San Mateo, CA) and was available for participation between November 15-21, 2024. Informed consent was received from all participants.

The target population consisted of anaesthesiology specialists and residents working in Türkiye. According to the *Turkish Society of Anesthesiology and Reanimation*-TARD website, there are 4,438 anaesthesiology specialists and 5,110 residents. A web link to the survey (SurveyMonkey, Palo Alto, CA, USA) was sent to 960 participants (10% of the total population). Retired physicians were excluded from the study.

Survey Structure

The survey comprised 25 questions divided into three main sections:

Descriptive and Socio-demographic Questions: This section collected basic demographic and professional data, including participants' age, gender, years of professional experience, level of education, and workplace information.

Knowledge Assessment Questions: These questions aimed to evaluate participants' knowledge of advanced hemodynamic monitoring practices in high-risk surgical patients.

Attitude Assessment Questions: This section assessed participants' perspectives and attitudes toward advanced hemodynamic monitoring using statements rated on a five-point Likert scale (1: strongly disagree - 5: strongly agree) ((Supplementary Form 1).

Definition of High-Risk Surgical Patients

For this study, high-risk surgical patients were defined as adults (≥18 years) undergoing surgeries expected to last more than two hours and meeting at least two of the following criteria:

- Presence of functional limitation due to cardiac or respiratory disease.
- Extensive surgery planned for cancer requiring bowel anastomosis.
- Expected acute massive blood loss (>2 liters) during surgery.
- Age ≥65 years with functional impairment in one or more organ systems.
- Septicemia (positive blood cultures or septic focus).
- Open-heart surgery or complex cardiac procedures.
- Acute abdomen (e.g., pancreatitis, perforation, gastrointestinal bleeding).

- Acute kidney injury (creatinine >2 mg dL^{-1}).
- Aortic surgery.
- Extensive malignancy surgery.

The criteria for patient and surgical classification were adapted from similar surveys conducted among North American and European anaesthesiologists.[3] To ensure content appropriateness and clarity, the full questionnaire was reviewed by an expert.

Statistical Analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences software, version 23.0 (IBM Corp., Armonk, NY, USA). The collected data were analyzed using descriptive statistical methods. Categorical variables were presented as counts and percentages.

Table 1. Demographic and Descriptive Data of Participants

All participants (n = 713)	Respond rate number (%)
Age (years)	
24-35	532 (74.6%)
36-45	84 (11.8%)
46-55	77 (10.8%)
>56	20 (2.8%)
Gender	
Female/Male	402/311 (56.3/43.7%)
Work experience in anaesthesia (years)	
0-5	486 (68.1%)
6-10	71 (10%)
11-20	99 (13.9%)
21-30	42 (5.9%)
>30	15 (2.1%)
Number of operating rooms	
<5	21 (2.9%)
5-10	45 (6.3%)
11-20	137 (19.2%)
21-30	198 (27.8%)
31-40	86 (12.1%)
>40	226 (31.7%)
Type of the institution	
State Hospital	45 (6.3%)
Training and Research Hospital	359 (50.4%)
University Hospital	293 (41.1%)
Private Hospital	16 (2.2%)
Job title	
Resident	503 (70.6%)
Specialist	122 (17.1%)
Faculty member	88 (12.3%)
Frequency of anaesthesia management in high-risk surgeries	
I do not directly manage anaesthesia	58 (8.1%)
1-5 times a week	364 (51.1%)
6-10 times a week	169 (23.7%)
>10 times a week	122 (17.1%)
Timing of hemodynamic monitoring	
Before anaesthesia induction	541 (75.9%)
After anaesthesia induction	456 (63.9%)
During surgery	191 (26.8%)
Postoperative	91 (12.7%)
Distribution of high-risk surgeries	
General Surgery	70.4%
Cardio-thoracic Surgery	69.7%
Neurosurgery	62.5%
Orthopedics and Traumatology	59.8%
Gastrointestinal and Hepatobiliary Surgery	58.2%
Obstetrics and Gynecology	31.9%
Urology	27.2%
Ear, Nose, Throat	14.3%
Others	3.9%

Results

A total of 960 anaesthesia specialists and residents were invited to participate in the survey, of whom 713 completed the questionnaire. The demographic characteristics of the participants are presented in Table 1. The most commonly reported high-risk surgeries were general surgery (70.4%), cardiothoracic surgery (69.7%), and neurosurgery (62.5%), followed by orthopedic surgery (59.8%), gastrointestinal-hepatobiliary surgery (58.2%), obstetrics and gynecology (31.9%), and urology (27.2%) (Table 1).

The most frequently monitored parameters in high-risk surgeries were invasive blood pressure (96.3%), fluid balance (88.1%), and lactate levels (86.5%). Central venous pressure monitoring was used by 55.9% of respondents, while non-invasive blood pressure monitoring was reported by 53.1%. Among dynamic fluid management parameters, stroke volume variation (SVV), pulse pressure variation (PPV), and systolic pressure variation (SPV) were utilized by 32.1% of

participants. CO monitoring was reported by only 12.6% of respondents (Table 2). Notably, 69% of respondents indicated that they never used CO monitoring in high-risk surgical patients.

Among those using CO monitoring, the PRAM-Mostcare monitor was the most commonly used device (62.2%), followed by PICCO (51.3%), Massimo LIDCO (28%), and transesophageal echocardiography (27%). The primary barrier to the use of CO monitoring was the high cost of the devices (68.8%), followed by the invasive nature of the available monitors (19.4%), difficulties in learning new monitoring techniques (18.9%), and increased workload (18.6%).

Table 3 summarizes the parameters used to assess fluid needs and evaluate volume replacement adequacy in high-risk surgical patients.

When all monitoring options were available, the preferred parameters for fluid deficit assessment and volume optimization are presented in Table 4.

More than half of the participants (59.3%, n = 331) reported never attending any training program on hemodynamic management or the use of advanced hemodynamic monitors. The most frequently reported challenge in applying advanced hemodynamic monitoring was difficulty in interpreting the monitored parameters (60.5%). Other significant challenges included difficulties in equipment use or placement (58.9%), concerns regarding device accuracy and reliability (58.2%), and the complexity of device interfaces (42.8%).

In cases of critical hemodynamic deterioration, the most

Table 2. Routinely Used Hemodynamic Parameters in High-Risk Surgical Patients

Parameter (multiple choice available)	Respond rate number (%)
Invasive blood pressure	96.3%
Fluid intake/uriner output	88.1%
Lactate	86.5%
Central venous pressure	55.9%
Non-invasive blood pressure	53.1%
Stroke volume variation, pulse pressure variation, systolic pressure variation	32.1%
P(a-v) CO_2	21.7%
Near-infrared spectroscopy	21.1%
Central venous oxygen saturation	19.2%
Cardiac output	12.1%
Plethysmographic waveform variation	10.9%
Transesophageal echocardiography	10.5%
Mixed venous oxygen saturation ($ScvO_2$)	7.0%
Oxygen delivery (DO_2)	6.1%
Pulmonary capillary wedge pressure	1.6%
Esophageal Doppler (flow time corrected, FTc)	0.28%

Table 3. Parameters Used to Determine Fluid Deficit and Fluid Adequacy

Fluid deficit (multiple choice available)	(%)	Fluid adequacy (multiple choice available)	(%)
Urine output	95.0%	Increase in urine output	91.2%
Lactate	84.0%	Decrease in lactate	83.9%
Blood pressure	80.4%	Increase in blood pressure	82.3%
Clinical experience	78.3%	Decrease in heart rate	72.9%
Other blood gas parameters (base excess, pH)	70.8%	Decrease in SVV, PPV, SPV	50.8%
SVV, PPV, SPV	60.9%	Other blood gas parameters (base excess, pH)	49.5%
CVP	53.0%	Increase in cardiac output	30.2%
Passive leg raise and fluid challenge	51.9%	Decrease in SVR	20.7%
Cardiac output	25.6%	Decrease in PVI	17.8%
Ultrasound/echocardiography	22.1%	Increase in $ScvO_2$	12.2%
Pleth variable index	15.4%	Decrease in P(a-v) CO_2	10.8%
P(a-v) CO_2	12.2%	Increase in SvO_2	10%
$ScvO_2$	9.3%		
SvO_2	6.8%		
Total number of respondents: 628			

CVP, central venous pressure; SVV, stroke volume variation; PPV, pulse pressure variation; SPV, systolic pressure variation; SvO_2, central venous oxygen saturation; $ScvO_2$, mixed venous oxygen saturation; SVR, systemic vascular resistance

frequently chosen intervention was the administration of cardiovascular drugs (74.5%). Other common responses included informing the surgical team (67.9%), applying additional monitoring methods (64.7%), adjusting the depth of anaesthesia (59.5%), and modifying the patient's positioning (54.8%).

The general attitudes and behaviors of participants in extreme situations are summarized in Table 5. For awake high-risk surgical patients under regional anaesthesia, a significant proportion of respondents (15.1% and 37.1%) considered non-invasive blood pressure monitoring to be insufficient. Additionally, 41.1% of participants believed that SVV, PPV, and SPV parameters could be used to assess fluid deficits in awake patients. The vast majority (95.7%) agreed that hemodynamic monitors should be used for goal-directed therapy in pediatric patients. Furthermore, 60.1% of respondents believed that hemodynamic monitoring was

Table 4. Preferred Parameters for Fluid Deficit and Optimization in the Presence of All Available Resources

Parameter (multiple choice available)	%
Urine output	84.0%
Clinical experience	78.8%
SVV, PPV, SPV	76.3%
Cardiac output	72.9%
Blood pressure	71.8%
Transesophageal echocardiography	52.8%
Central venous pressure	52.8%
Plethysmographic waveform variation	37.1%
Near-infrared spectroscopy	35.8%
Central venous oxygen saturation	32.6%
Mixed venous oxygen saturation	31.0%
Pulmonary capillary wedge pressure	22.2%
Total number of respondents: 558	
SVV, stroke volume variation; PPV, pulse pressure variation; SPV, systolic pressure variation	

Table 5. General Attitudes and Behaviors of Participants

Statement	Strongly disagree	Disagree	Somewhat agree	Agree	Strongly agree	Total
Non-invasive arterial blood pressure monitoring is sufficient for hemodynamic monitoring in high-risk surgical patients under regional anaesthesia.	15.1% 84	37.1% 206	37.9% 210	8.3% 46	1.6% 9	555
Stroke volume monitoring with invasive arterial blood pressure in high-risk patients under regional anaesthesia guides fluid and vasoactive drug therapy.	1.9% 11	5.1% 29	28.1% 156	54.9% 306	10% 55	557
SVV, PPV, and SPV can be used to assess fluid responsiveness in awake patients.	9.7% 54	13.3% 74	30.4% 168	41.2% 228	5.4% 30	554
Hemodynamic monitoring devices can be used for goal-directed therapy in critically ill pediatric patients.	0.4% 2	3.9% 22	25.6% 142	53.5% 297	16.6% 92	555
Hemodynamic monitors are useful in deciding erythrocyte suspension replacement in high-risk patients.	1.1% 6	5.7% 32	23.5% 131	55.7% 311	14% 78	558
Advanced hemodynamic monitoring also provides an advantage in the management of patients with fluid overload.	0.4% 2	1.4% 8	14.4% 80	60.1% 335	23.7% 132	557
SVV, stroke volume variation; PPV, pulse pressure variation; SPV, systolic pressure variation						

valuable in guiding management even in patients with fluid overload (Table 5).

Discussion

The results of this trial have revealed the limited usage of CO monitors among Turkish anaesthesiologists. The conventional parameters hold the majority of routine clinical practice, despite having the necessary knowledge regarding the indications of advanced hemodynamic monitorization. Such parameters like blood pressure, urine output, and lactate levels are still preferred over dynamic indices. Nevertheless, invasive blood pressure monitoring is the most frequently used method for close hemodynamic follow-up.

When this attitude is investigated within the world perspective, it can be seen more members of American Society of Anesthesiologists (35.4%) and European Society of Anaesthesiology and Intensive Care (34.9%) actively practice CO monitors than Turkish (12.6%) and Chinese (13.3%) communities, and this may be interpreted as technological advancements are more embraced in Western countries.[3,4] As CO guided goal-directed fluid therapy drops the incidence of intraoperative hypotension and perioperative complication rates, this massive gap in practice needs clarification.[8] The long-term benefits of advanced hemodynamic monitorization is not observed intraoperatively, and one may argue that the physicians who are not included in the postoperative care may overlook the anticipated benefits of such monitorization.[9] On the other hand, there is not a "sole" parameter that enhances the perioperative outcomes. Combination of several parameters is suggested to optimize CO, and in order to interpret those parameters correctly, a profound theoretical and physiological knowledge is required.[10] Besides, the high costs and practical difficulties of these devices still stand as a handicap. Although hemodynamic principles are introduced during basic medical education, integrating this knowledge into clinical practice, interpreting relevant parameters, and applying them effectively can be challenging for many practitioners. This gap underscores the need for dedicated training programs aimed at enhancing the understanding of hemodynamics and the application of advanced monitoring techniques. In our study, a majority of participants reported that they had not received formal training in this area.

Abovementioned details might be accepted as an explanation for why advanced hemodynamic monitorization is not adapted to routine clinical practice, especially considering the busy environment of operating rooms. At this point, pulse contour analysis seem to be a solid option for hemodynamic follow-up since our results have validated broad use of invasive arterial blood pressure. SVV, SPV, and PPV are well-understood parameters by the majority of physicians (61%), yet very few use them routinely (32%) in order to distinguish volume responsiveness. Dynamic parameters are considered among the most reliable indicators for predicting fluid responsiveness, particularly in the context of goal-directed fluid therapy. However, their validity is highly dependent on specific physiological and mechanical ventilation conditions, such as regular rhythm, controlled mechanical ventilation, and absence of spontaneous breathing.[3,5] Although our findings indicate that participants generally understand the purpose of dynamic parameters, the notable rate of reported use under regional anaesthesia suggests a significant gap in knowledge regarding their limitations and the conditions required for accurate interpretation. This highlights the importance of targeted training programs that not only introduce these parameters but also emphasize the clinical scenarios in which they are appropriately applied.

Using advanced hemodynamic monitorization in goal-directed fluid therapy has been shown to be cost-effective for both hospital and communal economics.[11,12] Providing trainings and improving the basic knowledge regarding the principles of CO monitors would help administrators to gain a better insight on expected benefits which may consequently result in supplying these devices for physicians taking care of critical operations. Almost 75% of our participants were residents which explicitly indicates that advanced hemodynamics is not possibly embedded within the regular anaesthesiology training. Adapting such trainings into the curriculum might be one solid long-term solution with the aim of reducing perioperative morbidity and mortality. Anaesthesiologists should be able to interpret advanced parameters along with the mainstream ones. Another survey study from Italy has shown interesting results. Despite the high rates of CO monitor usage (41%), the physicians who do not use those have claimed they prefer to evaluate CO via central venous oxygen saturation (SvO_2) and mixed venous oxygen saturation ($ScvO_2$).[6] However, our results have revealed a very sparse use of SvO_2 (19%) and $ScvO_2$ (7%) among the Turkish anaesthesiologists which also supports the idea regarding the insufficient training on advanced hemodynamics.[13-15]

In high-risk patients undergoing awake surgery with regional anaesthesia, the use of CO monitoring may play a crucial role in guiding hemodynamic management. Studies have demonstrated that such advanced monitoring improves patient outcomes by optimizing fluid status, reducing the incidence of intraoperative hypotension, and ensuring more effective vasoactive drug administration.[16,17] Hemodynamic monitoring devices can be used for goal-directed therapy in critically ill pediatric patients. These devices provide real-time insights into cardiovascular parameters, such as CO, stroke volume, and systemic vascular resistance, which are essential for guiding fluid management, vasoactive drug administration, and other therapeutic interventions. In critically ill children, particularly those with complex or

unstable conditions, advanced monitoring can help tailor individualized treatments, improving the likelihood of positive outcomes. Studies have demonstrated the potential benefits of using these devices in pediatric intensive care units, where early detection of hemodynamic changes and timely intervention are critical to improving survival rates and reducing morbidity.[18,19]

Current study reflects a snapshot of routine clinical practice in Türkiye. Most survey trials that were referred above were performed at least one decade ago, and apparently, our clinical tendency is still away from the expected amendment, even though the reported outcomes are mainly from training hospitals (total 91%). Providing translational education via adapting basic sciences into routine training, and ensuring this teaching with hands-on practices would increase the general understanding of advanced hemodynamics. More importantly, as the existing literature mainly focus on the superiority of one parameter over another, simple diagrams and teaching materials that explain the hierarchy of such parameters are needed.[20] The implementation of targeted educational interventions or specialized training programs in this area is expected to enhance both the conceptual understanding and clinical recognition of the critical role of hemodynamic monitoring.

Study Limitations

This study has several limitations that should be considered when interpreting the findings. First, it is based on self-reported data, which may be subject to various biases, including overestimation or underestimation of actual practices and knowledge. Respondents may have provided socially desirable answers or may not have accurately recalled their routine clinical behaviors. Furthermore, the survey may not have captured all factors influencing hemodynamic monitoring practices, such as institutional policies, availability of resources, or individual clinician preferences. The cross-sectional nature of the study presents another limitation, as it offers a single time-point snapshot of current practices without capturing potential changes or trends over time. Additionally, while the survey achieved a relatively high response rate from anaesthesiologists working in university hospitals and training and research institutions, participation from other healthcare settings was limited. This may reflect a lower level of interest or engagement with the topic of hemodynamic monitoring in those populations, potentially leading to sampling bias. Given these limitations, the generalizability of our results to the entire population of anaesthesiologists in Türkiye is restricted. Nevertheless, the data provide valuable insights into prevailing attitudes and clinical tendencies regarding hemodynamic monitoring among a substantial segment of the anaesthesiology community.

Conclusion

This study highlights the limited use of advanced hemodynamic monitoring techniques among anaesthesiologists in Türkiye, despite their recognized benefits in high-risk surgical patients. The predominant reliance on conventional parameters such as invasive blood pressure monitoring underscores the need for enhanced education and training in advanced hemodynamic monitoring. High costs, technical complexity, and lack of experience are significant barriers to the widespread adoption of these techniques. Addressing these challenges through targeted educational programs and practical training could improve the utilization of advanced hemodynamic monitoring, ultimately enhancing patient outcomes and reducing perioperative morbidity and mortality. The development of standardized protocols and nationwide algorithms may further support the integration of advanced hemodynamic monitoring into routine clinical practice.

Ethics

Ethics Committee Approval: The study received approval from the Ankara Bilkent City Hospital, Scientific and Ethical Evaluation Board for Medical Research No. 2 (TABED) (approval no.: TABED 2-24-635, date: 13.11.2024).

Informed Consent: Informed consent was received from all participants.

Footnotes

Author Contributions: Surgical and Medical Practices - A.A., B.D., B.A., M.E.A., Ü.K., A.F.E.; Concept - A.A., B.A., M.E.A., Ü.K., A.F.E.; Design - G.T., B.D., M.E.A., Z.A.D., Ü.K., A.F.E.; Data Collection and/or/Processing - G.T., B.D., Z.A.D.; Analysis and/or/Interpretation - A.A., B.D.; Literature Search - G.T., E.S.B., Z.A.D.; Writing - G.T., A.A., E.S.B., Z.A.D.

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Comparison of the Effects of Target-Controlled Versus Conventional Infusion Sedation on Recovery in Geriatric Patients Undergoing Diagnostic Cystoscopy

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Abstract

Objective: Procedural sedation management in geriatric patients undergoing cystoscopy requires careful monitoring due to age-related physiological changes and increased sensitivity to anaesthetic agents. Although both target-controlled infusion (TCI) and conventional total intravenous anaesthesia (TIVA) techniques with propofol are commonly used methods for sedation, their comparative effectiveness and safety in this population remain subjects of ongoing investigation. This study aims to compare the effectiveness of the two techniques in terms of time to induction, recovery time, hemodynamic stability, airway intervention requirements, and propofol consumption.

Methods: This prospective, randomized study enrolled 60 male patients aged 65 years and older who were scheduled to undergo elective cystoscopy. Participants were randomly assigned to either the TCI group (n = 30) or the TIVA group (n = 30). The two groups were compared in terms of induction time, recovery time, hemodynamic parameters, airway interventions, and total propofol consumption.

Results: Compared with the TCI group, the TIVA group presented significantly shorter induction-to-surgery initiation and recovery times (P=0.009 and P=0.016, respectively). However, systolic blood pressure was more stable in the TCI group compared to the TIVA group (P=0.014). Propofol consumption per unit time was greater in the TIVA group (P=0.048), although total propofol usage did not differ significantly. Airway intervention was more common in the TIVA group, particularly in the early phase; however, this difference was not significant.

Conclusion: Both TCI and TIVA are effective sedation techniques for geriatric cystoscopy. While TIVA provides faster induction and recovery, TCI offers better hemodynamic stability and may reduce propofol requirements. Further studies are recommended to confirm these findings in broader patient populations.

Keywords: Geriatric anaesthesia, propofol, sedation, target-controlled infusion, total intravenous anaesthesia

Main Points

- Sedation with total intravenous anaesthesia (TIVA) results in shorter induction and recovery times than does target-controlled infusion (TCI) in geriatric patients undergoing diagnostic cystoscopy.
- TCI provides more stable systolic blood pressure throughout the procedure.
- Although total propofol consumption was similar in both groups, propofol usage per unit of time was significantly greater in the TIVA group.
- Airway interventions were more frequently needed in the TIVA group, particularly during the early procedural period.
- The findings indicate that both TCI and TIVA are safe and effective anaesthetic approaches, as neither group experienced major postoperative complications.

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Introduction

Sedation management in the geriatric population is crucial for maintaining perioperative hemodynamic stability, ensuring a rapid recovery, and preserving cognitive function. Due to the increased sensitivity of geriatric patients to anaesthetic agents, they should be monitored more closely; furthermore, appropriate dose adjustments must be made accordingly.

Propofol is a widely used anaesthetic agent, commonly preferred for both induction and maintenance phases of anaesthesia. For maintenance, propofol may be administered via a conventional manually controlled total intravenous anaesthesia (TIVA) method or through target-controlled infusion (TCI) systems. In the conventional approach, clinicians manually adjust infusion rates using pharmacokinetic data obtained from prior clinical studies to reach the desired depth of anaesthesia. Conversely, TCI devices employ pharmacokinetic models that calculate and deliver specific infusion rates to achieve a predetermined drug concentration either in plasma or at the effect site, tailored to individual patient characteristics.[1] These advanced infusion systems rely on three-compartment pharmacokinetic models, taking into account variables such as age, weight, sex, body height, tissue perfusion, and clearance rates. Once the target concentration is achieved, the TCI system maintains that level by adjusting the infusion rate automatically.[2] TCI can be effectively applied in both sedation and general anaesthesia practices. Although several studies have investigated the use of TCI in gastrointestinal (GI) endoscopic procedures such as colonoscopy and upper GI endoscopy, limited data exist regarding its application in elderly patients undergoing cystoscopy.[3,4] Considering the growing elderly population and the frequency of such urologic diagnostic procedures, evaluating optimal sedation strategies is crucial. This prospective study aimed to compare the clinical performance of TCI and TIVA techniques in geriatric patients undergoing cystoscopy under sedation. Our primary focus was to assess and compare both methods in terms of induction time, recovery profile, hemodynamic stability, overall propofol usage, and airway support requirements.

Methods

This study was conducted between December 1, 2022, and September 1, 2023, in the operating rooms of Ankara University Faculty of Medicine İbni Sina Hospital. The Human Research Ethics Committee of Ankara University Faculty of Medicine approved this study (approval no.: İ-10 22-611, date: 10.11.2022). Sixty male patients aged >65 years, with American Society of Anesthesiologists (ASA) Physical Status I-III, scheduled for elective cystoscopy or urethrocystoscopy under sedoanalgesia, were included in the study. Patients were informed about participation in the study before the procedure, and written informed consent was obtained from all participants. Patients with ASA IV, those undergoing emergency surgery, female and pediatric patients scheduled for cystoscopy, patients aged <65 years, those requiring general anaesthesia due to procedural necessity, and those who did not provide informed consent were excluded. Additionally, patients whose procedure times were shorter than 7 minutes or longer than 12 minutes were excluded. The exclusion of cases with procedure durations shorter than 7 minutes or longer than 12 minutes was intended to minimize variability in propofol consumption and recovery time attributable to extreme procedural lengths. This approach was intended to obtain a more homogeneous sample and to enhance comparability between the groups.

Demographic characteristics such as age, body weight, height, sex, ASA classification, comorbid medical conditions, chronic medication use, and prior surgical history were systematically recorded for all participants. Standard ASA-recommended monitoring—comprising electrocardiography, pulse oximetry, and non-invasive blood pressure measurement (NIBP)—was initiated for all patients upon arrival in the operating room. Additionally, bispectral index (BIS) monitoring (Covidien, Ireland) was performed, and the baseline values were recorded. Intravenous access was established in all patients, and a crystalloid infusion was initiated. All patients received intravenous fentanyl at a dose of 0.5 micrograms per kilogram. Additionally, 1 mg kg^{-1} lidocaine was administered intravenously before the initiation of the propofol infusion. Following oxygen supplementation at 5 L min^{-1} via facemask, patients were randomly assigned to one of two groups: target-controlled infusion (TCI; n = 30) or TIVA (TIVA; n = 30).

In the TCI group, remifentanil was initiated at an infusion rate of 0.05 µg kg^{-1} min^{-1}. Two minutes later, propofol infusion was initiated via a TCI device with the Schnider pharmacokinetic model, which targeted an effect-site concentration of 2 micrograms per milliliter. The time of infusion initiation was recorded for all patients. If necessary, the effect-site target concentration was increased in increments of 0.5 micrograms per milliliter until the Ramsay Sedation Scale reached level 6. Following the attainment of level 6 sedation, patients were placed in the lithotomy position and the surgical intervention was subsequently commenced. The time of surgical procedure initiation was recorded. After the procedure began oxygen saturation, heart rate, NIBP and BIS values were documented every two minutes. Episodes of desaturation and airway intervention requirements were also noted.

The TIVA group received an identical remifentanil infusion protocol (0.05 µg kg^{-1} min^{-1}). Two minutes later, propofol was administered as a 0.5 mg kg^{-1} intravenous bolus, followed by

continuous infusion at a rate of 50 μg kg^{-1} per minute via a perfusion pump. The initiation time of propofol infusion was noted. If required, additional intravenous boluses of 10 mg propofol were administered. Following the attainment of level 6 sedation, patients were placed in the lithotomy position, and the surgical intervention was subsequently commenced. The surgical procedure initiation time was documented. Following the commencement of surgery oxygen saturation, NIBP, heart rate and BIS values were measured and recorded every two minutes.

In both groups, sedation depth was titrated to achieve Ramsay Sedation Scale level 6. BIS monitoring was used as an adjunct to avoid oversedation, but BIS was not used as the primary target parameter. BIS values were recorded every 2 minutes during the procedure. Titration in propofol dosage was planned in the event that BIS values remained below 40 for more than 2 consecutive minutes. Throughout the procedure in both groups, if peripheral oxygen saturation levels dropped below 90%, the flow was increased, and airway maneuvers such as chin lifts were employed as needed. If desaturation persisted, an oropharyngeal airway was inserted. A mechanical ventilator was retained on standby for assisted ventilation with a facemask if needed. Atropine (0.5-1 mg) was prepared for administration in cases of bradycardia (heart rate <50 beats per minute), and a crystalloid infusion was initiated when the mean arterial pressure dropped below 60 mmHg. Ephedrine was prepared at a concentration of 5 mg mL^{-1} and kept readily available on the table. Additionally, the presence of desaturation and the need for airway intervention were noted for all patients.

Infusions were stopped at the end of the surgical procedure in both groups. The total volume of propofol consumed during the procedure, the duration of surgery completion, and the final vital signs and BIS values at the end of surgery were recorded. The modified Aldrete recovery score was used to assess postoperative recovery. Patients who achieved a score of 9-10 were transferred from the operating room to the post-anaesthesia care unit. The time elapsed from the end of the surgical procedure to transfer to the recovery room was recorded. In the recovery room, patients were evaluated for postoperative nausea, vomiting, and delirium, and the findings were documented. All patients were closely monitored for the occurrence of major postoperative complications within the first 24 hours following surgery.

Statistical Analysis

All statistical procedures were conducted using SPSS software version 11.5. Numerical data were described using both mean ± standard deviation and median with range (minimum-maximum), while categorical variables were expressed as frequencies and proportions. To compare a continuous variable between two independent categorical groups, the Student's t-test was applied under the assumption of normality; if this assumption was not met, the non-parametric Mann-Whitney U test was used instead. Relationships between categorical variables were analyzed using either the chi-square test or Fisher's exact test, depending on expected cell counts. For evaluating changes over time within and between groups for continuous outcomes, a two-way repeated measures ANOVA was utilized. Statistical significance was defined as a p-value less than 0.05. The sample size calculation determined that enrolling a total of 96 participants (48 per group for TIVA and TCI) would provide 80% statistical power to detect a medium effect size (Cohen's d = 0.5). During the course of the study, several participants were excluded due to predefined exclusion criteria and unforeseen clinical circumstances, resulting in a smaller sample size than initially planned (48 participants per group). Therefore, the sample size was recalculated based on the final number of participants. In line with similar studies in the literature, the estimation was performed assuming a large effect size (Cohen's d = 0.8) for the difference in emergence time between the TIVA and TCI groups, with a significance level of 0.05, a statistical power of 0.80, and using the Mann-Whitney U test.[5] This recalculation demonstrated that a minimum of 27 participants per group (total n = 54) would be sufficient, confirming that the study retained adequate statistical power despite the reduced sample size.

Results

A total of 96 patients were initially enrolled in the study. However, patients whose procedure duration was shorter than 7 minutes or longer than 12 minutes were excluded from the analysis. Statistical analyses were performed on a total of 60 patients, with 30 in the TIVA group and 30 in the TCI group (Figure 1).

When the demographic data were compared between the TIVA and TCI groups, a significant difference was found only in terms of hypertension diagnosis (*P*=0.018). Hypertension was observed in 73.3% of patients in the conventional TIVA group and in 43.3% of those in the TCI group (Table 1).

A statistically significant difference was observed between the TIVA and TCI groups regarding the time-dependent trend of systolic blood pressure (SBP) (*P*=0.014). At each time point, the mean SBP value in the TIVA group was 0.964 units higher than that in the TCI group (Figure 2).

When the differences in blood pressure over time were evaluated between the TIVA and TCI groups, significant differences in SBP were observed at the 6^{th} and 8^{th} minutes and at the end of surgery and time of transfer from the operating table (*P*=0.027, *P*=0.011, *P*=0.011, and *P*=0.015, respectively). The measured SBP values at these time points were greater in the TIVA group than in the TCI group.

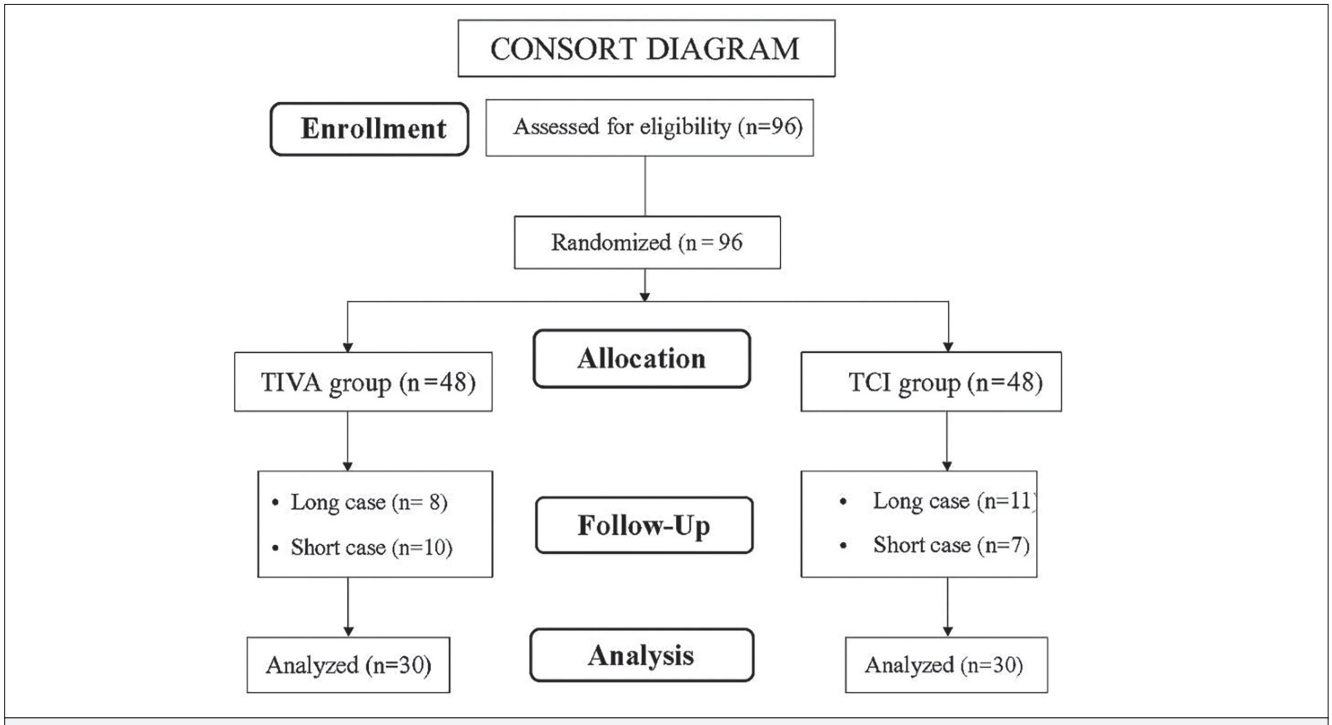

Figure 1. CONSORT flow diagram of patient distribution.
CONSORT, Consolidated Standards of Reporting Trials; TCI, target-controlled infusion; TIVA, total intravenous anaesthesia.

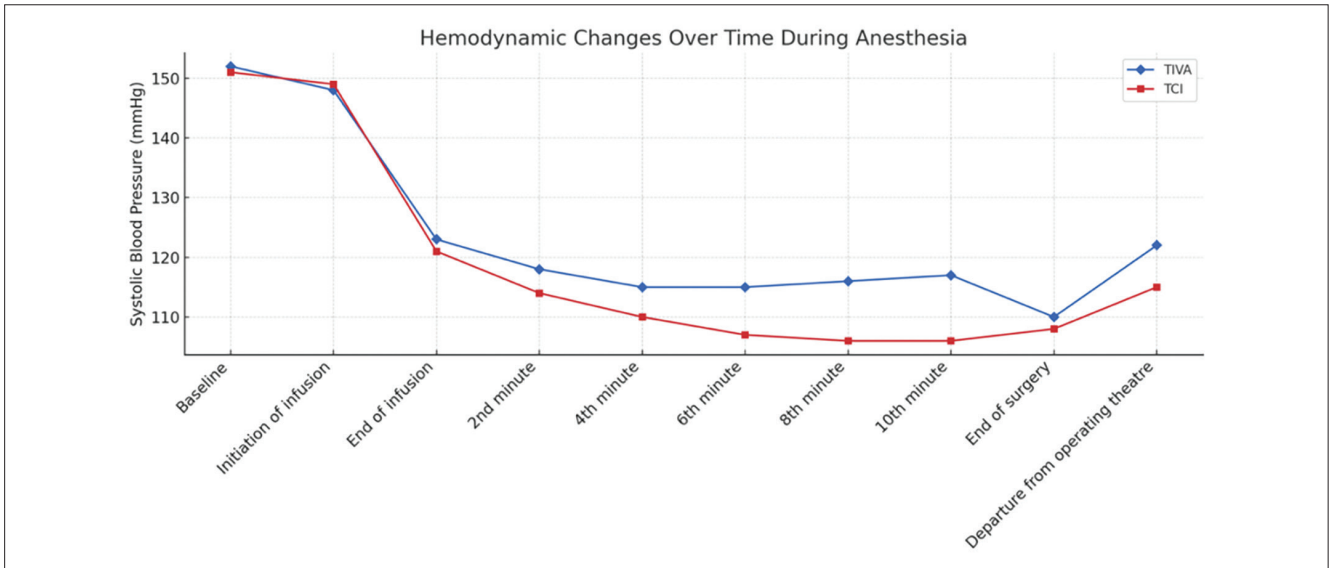

Figure 2. Graphical representation of the time-dependent changes in systolic blood pressure between the two groups.
TCI, target-controlled infusion; TIVA, total intravenous anaesthesia.

The temporal patterns of oxygen saturation, heart rate, and BIS values did not differ significantly between the TCI and TIVA groups (P=0.090, P=0.416, and P=0.716, respectively). However, the mean BIS value at each time point was 1.417 units greater in the TIVA group than in the TCI group (Table 2).

When comparing the time intervals, the duration between infusion initiation and the start of surgery (6 minutes in the TIVA group and 8 in the TCI group; P=0.009) and that between the end of surgery and the time of transfer from the operating room demonstrated significant differences (7 minutes in the TIVA group and 10 in the TCI group;

P=0.016; *P*=0.048, *P*=0.009, and *P*=0.016, respectively). The mean propofol consumption per unit time was 23.67±6.57 mg in the TIVA group. The TCI group demonstrated a significantly lower value at 20.69±4.52 mg. Although the total propofol consumption was slightly greater in the TIVA group than in the TCI group, the difference was not statistically significant (Table 2). The TIVA group demonstrated shorter intervals for both the onset of surgery and postoperative recovery in comparison to the TCI group (Table 2).

At the beginning of the surgical procedure, additional airway intervention was required in 15 patients in the TCI group and 19 in the TIVA group (no statistically significant difference). Following the intervention, oxygen saturation levels rose above 90% in all patients. Airway placement requirements did not differ significantly between the TIVA and TCI groups throughout the procedure. However, at the 10th minute, 71.4% of patients in the TIVA group and 55.6% in the TCI group required airway support (Table 3). No significant difference was found between the TIVA and TCI groups in terms of the time-dependent trends of oxygen saturation, heart rate, or BIS values (*P*=0.090, *P*=0.416, and *P*=0.716, respectively). Although the mean BIS value at each time point was 1.417 units greater in the TIVA group than in the TCI group, this difference was not significant (Table 4).

Throughout the follow-up period, none of the patients experienced postoperative vomiting, delirium, or any major complications (Table 4).

Table 1. Baseline Demographic and Clinical Characteristics of Patients in the TIVA and TCI Groups

Variables		TIVA (n = 30)	TCI (n = 30)	Total (n = 60)	*P* value
Age	Median (min-max)	70.50 (65.00-87.00)	69.00 (65.00-81.00)	69.00 (65.00-87.00)	0.229[b]
BMI	Mean ± SD	26.67±3.44	26.30±3.08	26.49±3.25	0.663[a]
ASA score, n (%)	I	1 (3.3)	2 (6.7)	3 (5.0)	0.677[d]
	II	18 (60.0)	20 (66.7)	38 (63.3)	
	III	11 (36.7)	8 (26.6)	19 (31.7)	
DM, n (%)		14 (46.7)	10 (33.3)	24 (40.0)	0.292[c]
Hypertension, n (%)		22 (73.3)	13 (43.3)	35 (58.3)	**0.018[c]**
ASHD, n (%)		12 (40.0)	11 (36.7)	23 (38.3)	0.791[c]
Asthma, COPD n (%)		2 (6.7)	2 (6.7)	4 (6.7)	1.000[d]
CVD, n (%)		2 (6.7)	1 (3.3)	3 (5.0)	1.000[d]
Cancer, n (%)		13 (43.3)	10 (33.3)	23 (38.3)	0.426[c]

[a]Student's t-test; [b]Mann-Whitney U test; [c]Chi-square test; [d]Fisher's exact test

TCI, target-controlled infusion; TIVA, total intravenous anaesthesia; SD, standard deviation; min, minimum; max, maximum; BMI, body mass index; ASA, American Society of Anesthesiologists; DM, diabetes mellitus; ASHD, arteriosclerotic heart disease; COPD, chronic obstructive pulmonary disease; CVD, cerebrovascular disease

Table 2. Procedural Parametres During Sedation TIVA and TCI Groups

Variables		TIVA (n = 30)	TCI (n = 30)	Total (n = 30)	*P* value
Total surgery time (minute)	Median (min-max)	8.50 (6.00-12.00)	10.00 (7.00-13.00)	10.00 (6.00-13.00)	0.131[b]
Time between infusion start/ surgery start (minute)	Median (min-max)	6.00 (3.00-15.00)	8.00 (5.00-14.00)	7.00 (3.00-15.00)	**0.009[b]**
Time between end of surgery/ exit from OR (minute)	Median (min-max)	7.00 (3.00-13.00)	10.00 (4.00-14.00)	8.00 (3.00-14.00)	**0.016[b]**
Propofol consumption (mg)	Mean ± SD	219.14±58.97	205.45±42.22	212.30±51.32	0.511[a]
Propofol consumption per unit of time (mg)	Median (min-max)	23.50 (14.20-46.25)	21.33 (14.04-31.71)	22.33 (14.04-46.25)	**0.048[b]**
Time to stay under BIS 60 (minute)	Median (min-max)	2.00 (0.00-8.00)	0.00 (0.00-13.00)	2.00 (0.00-13.00)	0.710[b]
BIS value	Mean ± SD	66.19±7.48	65.38±6.53	65.79±6.97	0.656[a]

[a]Student's t-test; [b]Mann-Whitney U test

TCI, target-controlled infusion; TIVA, total intravenous anaesthesia; SD, standard deviation; min, minimum; max, maximum; OR, operating room; mg, miligram

Table 3. Frequency of Airway Interventions at Different Procedural Time Points in TIVA and TCI Groups

Times	TIVA		TCI		*P* value
	n	%	n	%	
Surgery start	19	63.3	15	50.0	0.297[a]
2 min	20	66.7	15	50.0	0.190[a]
4 min	21	70.0	15	50.0	0.114[a]
6 min	21	70.0	15	50.0	0.114[a]
8 min	21	72.4	14	48.3	0.060[a]
10 min	10	71.4	10	55.6	0.358[a]
Surgical end	22	73.3	15	50.0	0.063[a]

[a], chi-square test; [b], Fisher's exact test; TCI, target-controlled infusion; TIVA, total intravenous anaesthesia; min, minimum

Table 4. Postoperative Outcomes in TIVA and TCI Groups

Variables	TIVA (n = 30)	TCI (n = 30)	Total (n = 30)	*P* value
Nausea, n (%)	3 (10.0)	1 (3.3)	4 (6.7)	0.612[b]
Vomiting, n (%)	0	0	0	-
Delirium, n (%)	0	0	0	-
Major postoperative complication (%)	0	0	0	-

[b]Fisher's exact test; TCI, target-controlled infusion; TIVA, total intravenous anaesthesia

Discussion

This study revealed that in patients over 65 years of age, the time to surgical readiness and the post-procedure recovery times were significantly shorter in the TIVA group versus the TCI group. While the propofol consumption per unit time was lower in the TCI group, the total propofol consumption was similar between the groups. Although the need for airway placement (improvement in desaturation after airway placement) was greater in patients in the TIVA group, this difference was not significant.

Furthermore, patients receiving TIVA demonstrated a faster recovery following the discontinuation of propofol compared to those receiving TCI. Similarly, Mazanikov et al.[6] reported longer recovery times in patients aged between 18 and 65 years using who underwent endoscopic retrograde cholangiopancreatography via TCI than in those who underwent patient-controlled sedation. In their study, recovery was 10±13 minutes with TCI and 6±5 minutes with patient-controlled methods.[6] Similarly, Lehmann et al.[7] observed shorter extubation times with manual infusion (11.9±2.4 minutes) versus TCI (15.6±6.8 minutes) in patients undergoing defibrillator implantation with low cardiac output. Conversely, in another study evaluating ERCP performed with laryngeal mask airway, TCI was associated with significantly faster recovery than TIVA (11.60±2.27 minutes vs. 15.4±3.25 minutes; $P < 0.001$).[8] Passot et al.[9] also demonstrated that although both groups had similar propofol consumption, TCI allowed for quicker recovery.

When we evaluated our results in terms of propofol consumption, the volume of propofol administered per unit of time was greater in the TIVA group (23.5 mg, P=0.048). Although the total dose of propofol administered did not differ significantly between the groups, it was numerically higher in the TIVA group (219.14±58.97 mg) compared to the TCI group (205.45±42.22 mg). The existing literature presents variable results on this topic. For instance, Mu et al.[10] reported that pediatric patients in the TCI group received a larger propofol dose without any improvement in recovery time. In other studies conducted on adult patients, although propofol consumption was found to be slightly greater in the TCI group, the difference was not significant.[8,9] However, additional studies have demonstrated that propofol consumption decreases with increasing age.[3,4] Although the TCI method has been associated with increased propofol consumption in some studies, it has generally been linked to better-controlled sedation and shorter recovery times. Our findings showing lower total and per-minute propofol consumption in the TCI group are in line with prior observational studies focusing on elderly patients undergoing procedural sedation. For instance, a prospective study evaluating TCI sedation during gastrointestinal endoscopy in geriatric patients reported adequate sedation with favorable recovery and safety profiles, suggesting that TCI may offer a more efficient drug delivery tailored to patient needs, thereby avoiding over-sedation and minimizing propofol usage.[4] Similarly, in a recent study evaluating propofol administration via TCI

during gastrointestinal endoscopic procedures, Sarraj et al.[11] reported that the propofol consumption per unit time was significantly lower in the TCI group compared to the nurse-administered intermittent bolus group (8.2±2.7 mg min^{-1} vs. 9.3±3.4 mg min^{-1}; *P*=0.046). This observation is in line with the pharmacokinetic nature of TCI, where the infusion algorithm maintains a stable target effect-site concentration throughout the procedure, often resulting in slightly elevated per-minute infusion rates without increasing the total drug dose. This finding suggests that TCI systems may achieve the desired depth of sedation with more precise dosing and reduced drug requirements. The same study also reported a trend toward lower total propofol usage in the TCI group, which is consistent with the results observed in our study.

Apart from the higher prevalence of hypertension in the TIVA group (22 patients) compared to the TCI group (13 patients), the demographic and clinical profiles of patients were similar between groups. Moreover, at all recorded time points, the mean SBP was higher in the TIVA group compared to the TCI group. This observation may be attributed to the higher prevalence of hypertension among patients receiving TIVA. Moreover, fluctuations in blood pressure and transient hypertensive episodes occurred more frequently among patients receiving TIVA. In our study, both groups demonstrated a reduction in SBP compared with baseline values during the procedure. However, when analyzing the time-dependent trends, SBP values in the TCI group showed less fluctuation and remained closer to baseline levels compared to the TIVA group. This pattern supports the statement that SBP was "more stable" in the TCI group. The improved stability in the TCI group is likely attributable to the pharmacokinetic delivery algorithm of TCI, which maintains a consistent target effect-site concentration and avoids sudden peaks in plasma propofol levels. This contrasts with manually controlled infusion in TIVA, where bolus dosing may cause transient hemodynamic changes. While some studies have shown no clear hemodynamic advantage with TCI despite faster induction and recovery times,[8] others support our findings. Similar to our findings, Wang et al.[12] conducted a prospective randomized crossover trial in anaesthesiology residents performing colonoscopy sedation and reported that TCI of propofol provided greater hemodynamic stability, higher endoscopist satisfaction, and a shorter recovery time compared with manually controlled infusion, without increasing adverse events. These results support our observation that the modest advantages of TCI over conventional infusion may be particularly relevant in short-duration endoscopic procedures, especially when performed by less experienced anaesthesia providers.

Oxygen supplementation was provided to all patients through a facemask at a rate of 5 liters per minute. At the onset of surgery, airway adjuncts were required in 15 patients from the TCI group and 19 from the TIVA group—though this difference was not statistical significance. Following the intervention, oxygen saturation levels rose above 90% in all patients. Comparison of airway placement requirements at all time intervals revealed no significant differences between the TIVA and TCI groups. However, at the 10th minute, airway placement was performed in 71.4% of patients in the conventional TIVA group and 55.6% in the TCI group. Although this difference was not significant, we considered that airway patency was better maintained in the TCI group. The fact that the rate of airway placement at the 10th minute was higher than at other time points in both groups may have resulted from a decrease in the need for propofol due to a decrease in stimuli such as cystoscopy placement and positioning. Interestingly, another study reported lower SpO_2 values in patients sedated with TCI compared to TIVA.[12] During anaesthesia induction, the administration of intravenous agents as a bolus leads to a more rapid achievement of peak plasma drug concentrations and faster attainment of threshold effect site concentrations. However, rapid anaesthesia induction may increase the risk of complications such as hemodynamic instability and apnea. Although no significant hemodynamic differences were observed in our study, the need for airway intervention was greater in the conventional TIVA group. This finding may be attributed to the rapid rise in the effect-site concentration of propofol in the conventional TIVA group, likely resulting from the use of bolus dosing.

The interval between anaesthesia induction and surgical initiation was found to be significantly shorter in the TIVA group. A similar observation was made by Hunt-Smith et al.,[13] who compared TCI and manual infusion in 123 surgical patients and reported prolonged induction with TCI. Although the difference in total propofol consumption was not statistically significant, it tended to be lower in the TCI group. Furthermore, no significant variation in recovery times was noted between the two groups in that study.[13] The rapid rise in the effect-site concentration of propofol observed in the conventional TIVA group was likely attributable to the use of bolus dosing.

In our study, the number of airway interventions was lower in the TCI group; however, this difference was not found to be statistically significant. Consistent with our observations, the literature also suggests that airway patency is maintained more effectively in the TCI group. In a study conducted by Struys et al.,[14] which included 90 female patients and compared the use of propofol administered via TCI and manual infusion, the number of patients who experienced apnea lasting longer than 20 seconds was significantly lower in the TCI group than in the manual infusion group. Additionally, Clouzeau et al.[15] demonstrated that during fiberoptic bronchoscopy performed on patients with non-invasive ventilation, TCI not only preserved

spontaneous breathing but also induced minimal alterations in hemodynamic status. While these observations suggest a potential advantage of TCI in maintaining airway patency, this finding in our study should be interpreted with caution and confirmed by larger-scale investigations.

In our study, BIS monitoring was used in both groups, and the duration spent below the lower sedation threshold value of 60 was minimal in both groups, with no significant difference. The lowest BIS recorded was 40. Liu et al.[16] demonstrated that closed-loop infusion systems provide better control of BIS values than open-loop control systems do. In a study involving 200 patients undergoing upper gastrointestinal endoscopy, participants were divided into two groups based on whether BIS monitoring was utilized. The mean propofol infusion rate was significantly greater in the group without BIS monitoring. BIS monitoring not only reduced propofol consumption but also allowed the procedure to be performed safely.[3] These findings highlight the importance of BIS monitoring as a valuable adjunct to optimizing propofol administration, enhancing patient safety, and potentially improving pharmacoeconomic effectiveness during sedation, particularly in elderly patients.

No major postoperative complications were observed in any of the patients during the initial 24-hour postoperative period. When evaluating minor complications, postoperative nausea was documented in three patients from the TIVA group and in one patient from the TCI group; this difference was not statistically significant. Moreover, none of the patients exhibited vomiting or postoperative delirium during the observation period.

Study Limitations

Several limitations should be acknowledged. First, although the sample size was adequate for the primary outcomes, a larger cohort could enhance the statistical power and allow for more robust subgroup analyses. Second, the single-center design of the study may restrict the applicability of the results to broader clinical contexts or other healthcare institutions. Third, the procedural duration was narrowly defined between 7 and 12 minutes, which precludes assessment of sedation techniques in longer or more complex procedures. Lastly, while BIS monitoring was employed to ensure adequate sedation depth, additional parameters such as cognitive recovery scales or patient satisfaction scores were not evaluated.

Conclusion

In this study comparing TCI and conventional TIVA for sedation in geriatric patients undergoing cystoscopy, both techniques were found to be safe and effective. Although the time from anaesthesia induction to surgical initiation and the recovery time were shorter in the TIVA group, the TCI group exhibited more stable hemodynamic parameters and lower propofol consumption. While airway interventions were less frequent in the TCI group, this finding needs to be supported by larger-scale, multicenter studies. BIS monitoring enabled adequate sedation depth in both groups; however, no significant reduction in propofol consumption was observed. No major postoperative complications, delirium, or significant differences in nausea and vomiting were observed between the groups. Given these findings, both sedation techniques appear to be clinically viable in geriatric patients; however, the choice of method may be guided by patient-specific factors such as cardiovascular stability and airway sensitivity. Further research involving longer surgical durations and larger, diverse patient populations is needed to validate and expand upon these results.

Ethics

Ethics Committee Approval: The Human Research Ethics Committee of Ankara University Faculty of Medicine approved this study (approval no.: İ10-611-22, date: 10.11.2022).

Informed Consent: Patients were informed about participation in the study before the procedure, and written informed consent was obtained from all participants.

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Footnotes

Author Contributions: Surgical and Medical Practices - N.S.B., F.N.D.E., A.G.; Concept - N.S.B., N.A.; Design - N.S.B., F.N.D.E., N.A.; Data Collection and/or/Processing - N.S.B., A.G.; Analysis and/or/Interpretation - N.S.B., N.A.; Literature Review - N.S.B., F.N.D.E., Writing - N.S.B., F.N.D.E., N.A.

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Current Trends in Anaesthesia Monitoring: A Survey Study

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Abstract

Objective: This study aims to evaluate the use of anaesthesia depth, nociception, and neuromuscular blockade monitoring among Turkish anaesthesiologists, exploring the frequency of their use, the devices employed, and the barriers to their routine adoption in clinical practice.

Methods: A cross-sectional survey was conducted among 62 anaesthesiologists attending a symposium in İstanbul, Türkiye. Participants were asked about their monitoring practices, devices used, and reasons for not consistently using these technologies. Data were analysed using descriptive statistics and subgroup comparisons based on professional title and hospital type.

Results: Anaesthesia depth monitoring was frequently used by only 37.1% of participants, with cost and availability as major barriers. Nociception monitoring was more commonly used (72.1% frequently) but still faced challenges such as cost and device unavailability. Neuromuscular blockade monitoring was the least used; with 24.2% of respondents never using it. There were no significant differences in responses based on professional title or hospital type.

Conclusion: The study highlights significant variability in the use of advanced monitoring technologies. Barriers such as cost, device unavailability, and reliance on alternative methods hinder their widespread adoption. Addressing these barriers could enhance patient safety and improve perioperative outcomes through more consistent use of monitoring tools.

Keywords: Anaesthesia depth, monitoring in anaesthesia, neuromuscular blockade, nociception monitoring, perioperative care

Main Points

- **Inconsistent use of Anaesthesia Depth Monitoring:** Only 37.1% of anaesthesiologists frequently use anaesthesia depth monitoring, with cost and availability being significant barriers. This inconsistency may increase the risk of intraoperative awareness or excessive anaesthetic use.
- **Wider Adoption of Nociception Monitoring:** Nociception monitoring was frequently used by 72.1% of participants, although barriers such as cost and device availability limit its widespread implementation.
- **Low Utilization of Neuromuscular Blockade Monitoring:** Despite its importance in preventing postoperative complications, only 9.7% of anaesthesiologists frequently monitor neuromuscular blockade, with many relying on clinical signs or alternative methods.
- **Barriers to Routine Monitoring:** Cost, device availability, and reliance on traditional methods are the main factors hindering the routine use of advanced monitoring technologies in anaesthesia practice. Addressing these barriers could improve perioperative patient outcomes.

Introduction

The use of physiological monitoring in anaesthesia has significantly evolved, providing anaesthesiologists with valuable tools to enhance patient safety, optimize anaesthetic dosing, and improve perioperative outcomes. Among these, monitoring technologies for anaesthesia depth, nociception, and neuromuscular blockade have been developed to offer objective assessments that guide intraoperative management. However, despite their potential benefits, adoption and utilization remain inconsistent across different clinical settings.

Anaesthesia depth monitoring aims to reduce the risk of intraoperative awareness, prevent excessive anaesthetic administration, and improve postoperative recovery.[1] Devices such as Bispectral Index® (BIS), SedLine®, Entropy®, and NeuroSense® provide

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quantitative assessments of anaesthetic depth, but their routine use is inconsistent due to concerns regarding cost, accuracy, and clinical necessity.[2,3]

Nociception monitoring has emerged as a promising tool for individualized analgesia, potentially reducing opioid overuse and postoperative pain. Monitors such as Nociception Level Index® (NOL), Analgesia Nociception Index® (ANI), Surgical Pleth Index® (SPI), and the Response Entropy® monitor aim to provide real-time assessments of intraoperative nociceptive responses.[4-7] Their implementation remains limited due to device availability and unclear clinical impact.[2,3]

Neuromuscular blockade monitoring is recommended to ensure complete recovery from neuromuscular blocking agents, reducing the risk of postoperative residual paralysis, and respiratory complications.[8] However, studies indicate that many anaesthesiologists continue to rely on clinical signs rather than objective quantitative monitoring, potentially increasing the likelihood of incomplete neuromuscular recovery.

Study Rationale

Despite the availability of these monitoring technologies, real-world usage patterns, barriers to adoption, and factors influencing anaesthesiologists' decisions remain poorly understood. While previous studies have assessed specific monitoring modalities, comparative data on all three—anaesthesia depth, nociception, and neuromuscular blockade—are limited. Understanding anaesthesiologists' monitoring habits and the obstacles they face can help identify strategies to optimize perioperative monitoring and improve patient outcomes.

Objective

This study aims to evaluate the frequency and patterns of use of anaesthesia depth, nociception, and neuromuscular blockade monitoring among anaesthesiologists. Furthermore, it seeks to identify barriers to routine use and explore whether monitoring practices differ based on institutional setting or professional experience.

Methods

Study Design and Setting

This cross-sectional survey study was conducted among Turkish anaesthesiologists working in various hospital settings. Data were collected in İstanbul, Türkiye, on January 25th, 2025, during a symposium on regional anaesthesia. The study was conducted in accordance with the Declaration of Helsinki and approved by the Koç University Ethics Committee (approval no.: 2025.037. IRB3.004, date: 23.01.2025).

Participants

Participants were eligible if they were actively practicing anaesthesiology. No additional exclusion criteria were applied. Informed consent was obtained from the participants.

Survey Instrument and Data Collection

The survey included questions regarding demographic characteristics (age, gender, professional title, and years of experience), workplace setting, and monitoring practices for anaesthesia depth, nociception, and neuromuscular blockade. Respondents were asked about the frequency of use, the specific monitoring devices employed, and barriers to regular use. The questionnaire was administered in written format and designed to allow multiple-choice selections where applicable. Responses were collected anonymously to reduce response bias.

Variables and Outcomes

The primary outcomes were the frequency of monitoring anaesthesia depth, nociception, and neuromuscular blockade; the devices used; and the reasons for not consistently using these monitors. Responses for monitoring practices were categorized as frequently, usually, rarely, or never. Barriers to use were assessed using a multiple-choice format, allowing participants to select all relevant reasons.

Statistical Analysis

Descriptive statistics were used to summarize participant characteristics, monitoring practices, and barriers to use. Categorical variables were presented as frequencies and percentages. Subgroup analyses were performed to compare responses based on professional title (resident vs. specialist) and hospital type (public teaching hospital, public hospital, university hospital). Statistical comparisons were conducted using chi-square tests or Fisher's exact tests, as appropriate. Results of the statistical test were corrected using the Benjamini-Hochberg method to control the type-one error rate. All statistical analyses were performed using R version 4.4.1 software. An adjusted P value <0.05 was considered statistically significant.

Results

Participant Characteristics

A total of 70 anaesthesiologists were invited to participate, and 62 completed the survey. The median age of participants was 33.5 years [interquartile range (IQR): 28.5-40.5; range: 28-60], and the median professional experience was 8 years (IQR: 3-13; range: 1-38). Age data were available for 60 participants and all provided their years of experience.

Among those who reported their gender (n = 51), 47.1% (n = 24) were male, and 52.9% (n = 27) were female. In terms of professional title, 37.1% (n = 23) were anaesthesia residents, while 62.9% (n = 39) were specialists. Most participants worked in public teaching hospitals (77.4%, n = 48), followed by public hospitals (17.7%, n = 11) and university hospitals (4.8%, n = 3).

Monitoring the Depth of Anaesthesia

All participants responded to the questions regarding anaesthesia depth monitoring. Among the respondents, 37.1% (n = 23) reported that they frequently monitor the depth of anaesthesia, 35.5% (n = 22) usually monitor, and 27.4% (n = 17) rarely use depth monitoring (Figure 1). The most used method was SedLine® (50.0%, n = 31), followed by NeuroSense® (27.4%, n = 17), Entropy (14.5%, n = 9), and BIS® (8.1%, n = 5) (Figure 2).

Monitoring Nociception

All participants provided responses regarding nociception monitoring. Most participants (72.1%, n = 44) reported frequently using nociception monitoring, while 3.3% (n = 2) usually did, 19.7% (n = 12) rarely used it, and 4.9% (n = 3) never used it (Figure 1). The most reported nociception monitoring methods were response entropy (34.5%, n = 19), NOL® (30.9%, n = 17), ANI® (18.2%, n = 10), SPI® (10.9%, n = 6), and frontal EEG variations (5.5%, n = 3). Seven participants did not report the method they use (Figure 3).

Monitoring Neuromuscular Blockade

All participants answered the questions on neuromuscular blockade monitoring. Neuromuscular blockade monitoring was frequently performed by 9.7% (n = 6) of respondents, while 29.0% (n = 18) reported usually using it, 37.1% (n = 23) rarely used it; and 24.2% (n = 15) never monitored neuromuscular function (Figure 1).

Reasons for Not Always Using Anaesthesia Depth Monitoring

All participants responded to this multiple-choice question. Only 32.3% (n = 20) of respondents reported that they always use anaesthesia depth monitoring, while 67.7% (n = 42) do not. The most frequently cited barriers were cost (27.4%, n = 17) and lack of availability (21.0%, n = 13). Additionally, 32.3% (n = 20) of respondents reported that they use other parameters instead of a depth monitor. Only 1.6% (n = 1) believed anaesthesia depth monitors were ineffective, and another 1.6% were unfamiliar with their function (Figure 4).

Reasons for Not Always Using Nociception Monitoring

All participants answered this question. A minority of respondents (6.5%, n = 4) reported always using nociception monitoring, while the majority (93.5%, n = 58) did not. The most common reasons for not using nociception monitoring were cost (35.5%, n = 22) and lack of availability (46.8%, n = 29). Additionally, 6.5% (n = 4) expressed doubt about its efficacy, 3.2% (n = 2) stated they did not know how it worked, and 17.7% (n = 11) reported relying on other parameters (Figure 4).

Reasons for Not Always Using Neuromuscular Blockade Monitoring

All participants answered this question. Among participants, 24.2% (n = 15) reported always using neuromuscular

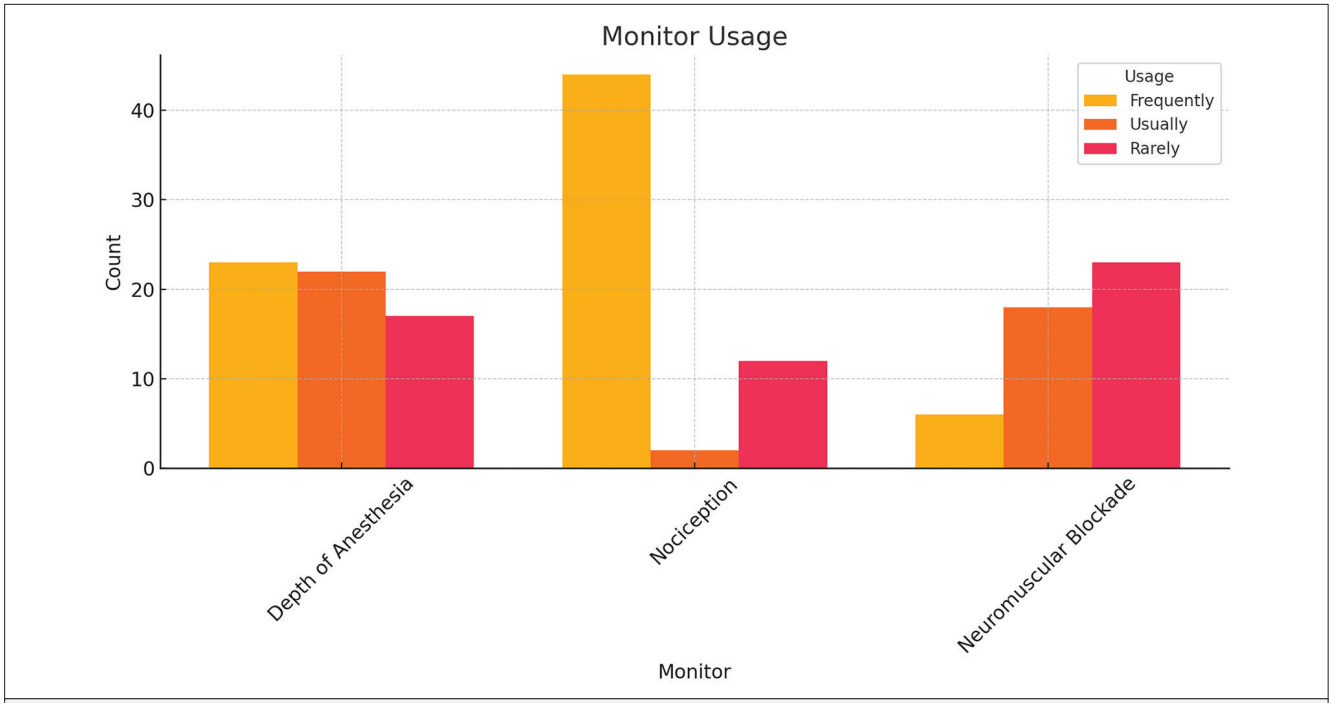

Figure 1. Rates of monitor usage for the depth of anaesthesia, nociception and neuromuscular blockade.

blockade monitoring, while 75.8% (n = 47) did not. The most cited reason was reliance on other parameters (51.6%, n = 32), followed by lack of knowledge (8.1%, n = 5) and cost concerns (14.5%, n = 9). Only 1.6% (n = 1) cited unavailability, and another 1.6% (n = 1) doubted its effectiveness (Figure 4).

Subgroup Analysis

Subgroup analyses were performed to assess whether responses varied based on the participants' professional title (resident vs. specialist) and hospital type (public teaching hospital, university hospital, or public hospital). No statistically significant differences were observed between these groups in terms of the frequency of monitoring anaesthesia depth, nociception, and neuromuscular blockade, the methods used for monitoring, or the reasons for not always using these monitors (Figure 1).

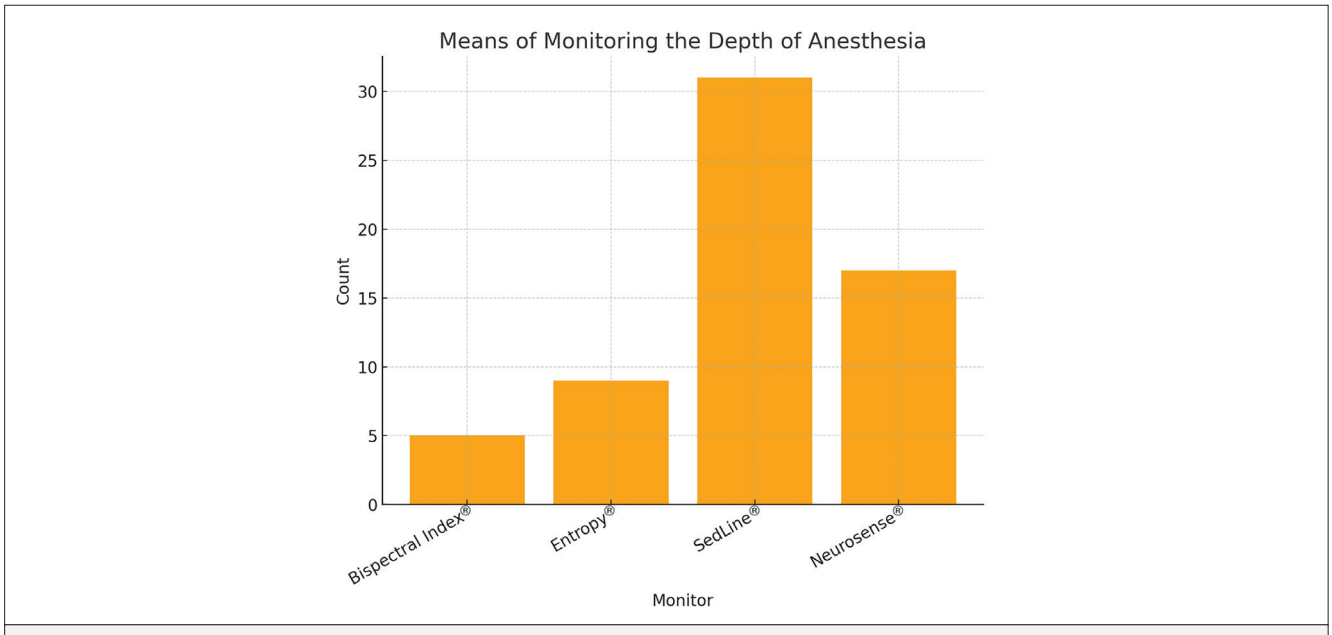

Figure 2. Means of monitoring the depth of anaesthesia.

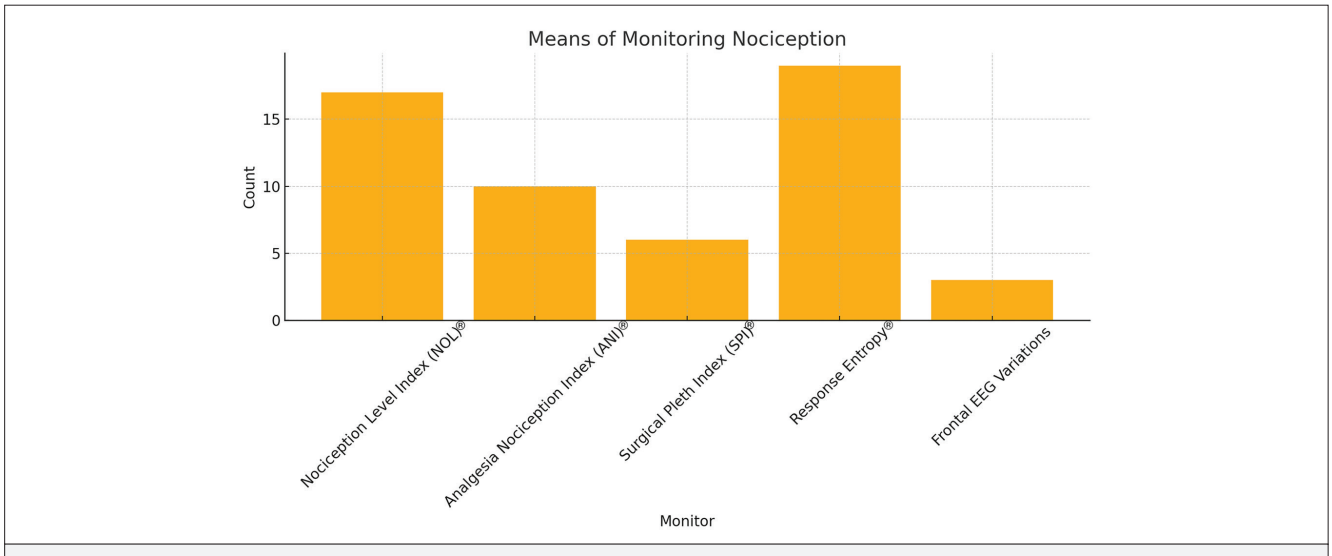

Figure 3. Means of monitoring nociception.

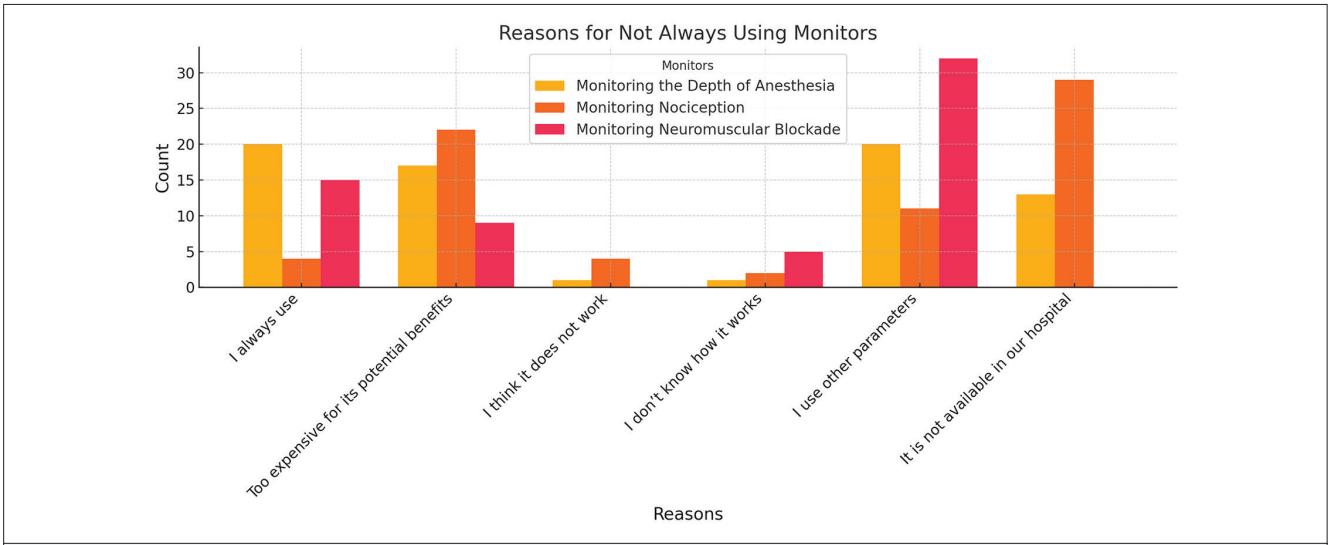

Figure 4. Reasons for not always using monitors for the depth of anaesthesia, nociception, and neuromuscular blockade.

Discussion

This cross-sectional survey provides insights into the monitoring practices of anaesthesiologists regarding anaesthesia depth, nociception, and neuromuscular blockade. The findings demonstrate significant variability in the use of monitoring technologies, with barriers such as cost, availability, and reliance on alternative methods influencing their adoption.

Among the surveyed anaesthesiologists, anaesthesia depth monitoring was not universally practiced, with only 37.1% reporting frequent use. Despite growing evidence supporting its role in reducing intraoperative awareness and optimizing anaesthetic dosing, its use remains inconsistent, possibly due to concerns about reliability, cost, or necessity in routine cases.[1-3,9,10] The lack of consistent monitoring may lead to inadequate anaesthetic depth, increasing the risk of intraoperative awareness or excessive anaesthetic administration, which can contribute to delayed recovery and hemodynamic instability.[11,12]

Nociception monitoring was more widely practiced than anaesthesia depth monitoring, with 72.1% of respondents reporting frequent use. Interestingly, the most commonly used nociception monitor was response entropy, a feature of anaesthesia depth monitors, rather than a dedicated nociception monitor. This suggests that many anaesthesiologists may be relying on anaesthesia depth monitors for nociception assessment, potentially due to familiarity or availability. While numerous studies highlight the potential of nociception monitoring in optimizing opioid administration and improving postoperative pain outcomes. Limited adoption of dedicated nociception monitors could result in suboptimal intraoperative analgesia, leading to either excessive opioid use and its associated side effects or insufficient analgesia, increasing postoperative pain and opioid requirements.[4-7]

Despite being the oldest monitoring modality, neuromuscular blockade monitoring was the least frequently used modality, with only 9.7% of participants frequently monitoring neuromuscular function and 24.2% never using it.[13] While some anaesthesiologists may rely on clinical assessments or qualitative nerve stimulators, objective monitoring with quantitative train-of-four or electromyography is strongly recommended to ensure complete recovery from neuromuscular blockade. The lack of routine neuromuscular monitoring increases the risk of residual paralysis, which has been linked to postoperative respiratory complications, including hypoxia, airway obstruction, and an increased need for postoperative ventilatory support.[14,15]

The most frequently cited barriers to routine monitoring were cost and device unavailability, particularly for nociception and anaesthesia depth monitoring. Cost was a reported limitation for 27.4% of respondents in anaesthesia depth monitoring and 35.5% in nociception monitoring, while device unavailability was a significant concern for 46.8% of respondents regarding nociception monitors. These findings align with previous research highlighting economic constraints as a major factor in the underutilization of advanced monitoring technologies, particularly in resource-limited settings.[2,3]

A considerable proportion of anaesthesiologists reported relying on alternative parameters rather than dedicated monitors. This suggests that practitioners may favor traditional hemodynamic responses, clinical signs, or

subjective assessments over objective monitoring, potentially due to familiarity, skepticism, or concerns about monitor accuracy. While these alternative approaches may provide some clinical guidance, they are less reliable than objective monitoring, increasing the likelihood of imprecise anaesthetic and analgesic management, which may negatively impact patient outcomes.[15,16]

Study Limitations

This study has several limitations. First, the survey was conducted among anaesthesiologists attending a regional anaesthesia symposium, which may introduce selection bias, as participants may have a particular interest in advanced monitoring techniques. Second, the study relied on self-reported data, which may be subject to recall bias or social desirability bias. Third, the sample size was relatively small, and findings may not be generalizable to all anaesthesiologists.

Conclusion

The underutilization of neuromuscular blockade monitoring despite its well-documented benefits in preventing postoperative respiratory complications suggests a need for increased awareness and institutional protocols to promote its routine use. Similarly, expanding access to nociception and anaesthesia depth monitoring could enhance personalized anaesthetic management, but cost considerations must be addressed.

Future studies should explore interventions to improve monitoring adoption, including cost-effectiveness analyses, training programs, and policy-driven implementation strategies. Additionally, investigation into the clinical impact of nociception monitoring on postoperative pain outcomes and the comparative efficacy of different anaesthesia depth monitoring modalities could help define their optimal role in anaesthetic practice.

Ethics

Ethics Committee Approval: The study was conducted in accordance with the Declaration of Helsinki and approved by the Koç University Ethics Committee (approval no.: 2025.037.IRB3.004, date: 23.01.2025).

Informed Consent: Informed consent was obtained from the participants.

Footnotes

Author Contributions: Surgical and Medical Practices - M.S.S., Y.S., E.M., Y.G.; Concept - M.S.S., Y.S., E.M., Y.G.; Design - M.S.S., Y.S., E.M., Y.G.; Data Collection and/or/Processing - M.S.S., Y.S., E.M., Y.G.; Analysis and/or/Interpretation - M.S.S., Y.S., E.M., Y.G.; Literature Review - M.S.S., Y.S., E.M., Y.G.; Writing - M.S.S., Y.S., E.M., Y.G.

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

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Ultrasound-guided Deep Iliacus Plane Block (DIPB): Cadaveric Evaluation and Pilot Retrospective Evaluation of Another Novel Fascial Plane Block for Hip Analgesia

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Abstract

Objective: Regional anaesthesia for hip surgery aims to cover both articular and cutaneous nerves. Current techniques often miss components or require multiple injections. We hypothesized that the deep iliacus plane block (DIPB)—which involves injection deep to the iliacus muscle at the anterior inferior iliac spine—could simultaneously target both lumbar plexus branches and articular nerves.

Methods: We conducted a cadaveric investigation and a retrospective clinical pilot. Bilateral DIPB was performed on a fresh cadaver (50 mL dye) using 50 mL of dye to assess dye spread. Clinically, 20 hip fracture patients received a single-injection DIPB (30-40 mL of 0.25% bupivacaine). Blocks were performed postoperatively (n = 13) or preoperatively for positioning (n = 7). Primary outcomes included dye spread and opioid consumption. Pain scores were evaluated before and after the block in the positioning subset.

Results: Cadaveric dye stained the lateral femoral cutaneous nerve (LFCN), the femoral nerve (FN), and the pericapsular branches. In the clinical cohort (n = 20), the median postoperative numeric rating scale (NRS) score was 1; only one patient required rescue analgesia within 24 hours. In the positioning subset (n = 7), median NRS dropped from 9.0 (7-10) to 1.0 (0-2) 30 minutes post-block ($P < 0.001$).

Conclusion: Preliminary findings suggest that DIPB may provide simultaneous coverage of the LFCN, FN, and pericapsular branches with a single injection. Further prospective studies are required to confirm the safety and efficacy.

Keywords: Cadaveric study, deep iliacus plane block, hip analgesia, hip fracture, PENG block

Main Points

- This study introduces the deep iliacus plane block (DIPB), a novel single-injection technique hypothesized to provide simultaneous blockade of the pericapsular nerves that supply the hip capsule and of the major cutaneous nerves arising from the lumbar plexus.
- Anatomical evaluation in a cadaveric dissection demonstrated that the injectate stained the lateral femoral cutaneous nerve, the femoral nerve, and the articular branches supplying the hip capsule, thereby supporting the technique's proposed mechanism.
- In the retrospective pilot study of 20 patients undergoing hip fracture repair, the DIPB showed a significant analgesic effect, reducing the median numeric rating scale pain score from 9.0 before the block to 1.0 thirty minutes after the block.
- The block provided sustained analgesia, with only one of the 20 patients requiring rescue analgesia within the first 24 hours postoperatively.

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Introduction

Hip surgeries require effective regional anaesthesia to optimize perioperative analgesia and facilitate patient positioning. Over the past few decades, clinical research has increasingly focused on refining these techniques.[1] The lumbar plexus plays a crucial role in providing anaesthesia and analgesia for hip and knee procedures. It consists of the obturator nerve, lateral femoral cutaneous nerve, and femoral nerve. Together with the sacral plexus, it provides innervation to the lower limb.[2]

The suprainguinal fascia iliaca block (SIFIB) is a regional technique designed to block the anterior components of the lumbar plexus.[3] However, it requires a relatively high volume of local anaesthetic,[4] which increases the risk of direct quadriceps weakness. Recently, the Pericapsular Nerve Group (PENG) block has emerged to selectively block the articular branches of the femoral, obturator, and accessory obturator nerves supplying the hip capsule.[5] While the PENG block may provide superior analgesia compared to a femoral nerve block alone,[6] high volumes (>30 mL) can lead to motor weakness due to spread into the psoas compartment.[7,8] Another proposed technique is the iliopsoas plane block (IPPB); however, this approach requires the identification of a deep fascial plane that can be technically demanding.[9]

Current literature indicates that while the SIFIB provides a broad cutaneous blockade, it may spare the deep articular branches and the obturator nerve.[1,4] Conversely, PENG and IPPB target these deep branches but often fail to block the lateral femoral cutaneous nerve and the femoral nerve, which provide cutaneous innervation to the incision site.

We hypothesized that by injecting a sufficient volume of local anaesthetic deep to the iliacus muscle at the level of the anterior inferior iliac spine, we could achieve simultaneous blockade of both the cutaneous branches of the lumbar plexus and the PENG. We aimed to present this novel technique, deep iliacus plane block (DIPB), via a cadaveric evaluation of injectate spread and a pilot retrospective study assessing its potential analgesic effect.

Methods

The İstanbul Medipol University Ethics and Research Committee approved (approval no.: 965, date: 31.07.2025) the retrospective evaluation of 20 patients who underwent DIPB. The cadaveric examination was conducted with the approval of the same Institutional Review Board (IRB) (approval no.: 65, date: 18.01.2024). The IRB waived the requirement for written informed consent.

One fresh-frozen cadaver specimen (female, 63 years of age) was included. The specimen demonstrated normal anatomy and showed no evidence of previous surgical procedures, trauma, or pathological changes involving the inguinal or lower abdominal regions.

Description of DIPB

With the cadaver in the supine position, blocks were performed. The convex transducer (Clarius, Canada), in trapezoid imaging mode, was positioned obliquely from superolateral to inferomedial, just above the femoral crest, similar to the PENG block technique. Anatomical structures, including the AIIS, iliopubic eminence (IPE), sartorius muscle (SM), iliopsoas muscle (IPM), psoas tendon, femoral nerve, femoral artery, femoral vein, and iliac fascia, were identified sono-anatomically. The anterior inferior iliac spine was centered in the transducer image. To determine the insertion point of the rectus femoris tendon (RFT) on the anterior inferior iliac spine, the transducer was rotated sagittally, and the level where the RFT ends cephalically was identified. After identifying the target (the most cephalic level between anterior inferior iliac spine and IPM without tendon-bursa), the transducer was obliquated again to visualize the IPE. The 22G x 100 mm block needle (Stimuplex Ultra 360, B-Braun, USA) was advanced in-plane from lateral to inferomedial towards the potential space between the IPM and the anterior inferior iliac spine. After confirming the target plane with a few mL of saline, 50 mL of 0.5% methylene blue solution was applied to the area (Figure 1). We used 50 mL of dye in the cadaveric model to clearly delineate the maximum anatomical spread of the injectate, a standard volume for cadaveric dye studies.

Unfortunately, although identification of the insertion point and tendon of the rectus femoris muscle (RFM) on the left side was successful, the insertion of the RFM and its tendon could not be identified on the right side; therefore, the anterior inferior iliac spine was targeted directly. The spread could not be clearly determined.

Cadaveric Dissection

Approximately one hour after block performance, two experienced anatomists initiated bilateral dissections. The dissection line was drawn from the anterior inferior iliac spine to the tuberculum pubicum, and from the midpoint of that line to the midpoint of the patella. Dissection of the skin and fascia started at the midline and proceeded laterally. The SM and lateral femoral cutaneous nerve were examined for staining. After the femoral nerve was identified in the femoral triangle, the muscular branches of the femoral nerve and the subsartorial canal were exposed by dissecting the SM from its insertion. Afterward, the tendon of the IPM was dissected from the insertion point, the hip joint capsule was exposed, and the presence of staining in the articular branches of the obturator and femoral nerves was evaluated.

Pilot Study Assessing the Potential Analgesic Effect of DIPB

This cadaver study was performed on a single model; subsequently, the authors obtained informed consent from willing patients for this block. Patients who underwent DIPB between February 2024 and August 2025 were evaluated for opioid consumption and pain scores. Written informed consent, which specifically included consent for administration of the novel interfascial plane block technique, was obtained from all patients. All operations were performed by the same surgical team. All blocks were performed by the same anaesthesiologists (the authors) to minimize technical variability. Pain assessments were performed by a nurse anaesthetist not affiliated with the study team. For spinal anaesthesia, a standardized dose of 10-12.5 mg of hyperbaric bupivacaine was administered, in accordance with our institution's protocol for hip fracture surgery. As this was a retrospective analysis of clinical cases, the injectate volume was not fixed but ranged from 30 to 40 mL. This volume was determined by the attending clinician, based on the patient's body weight, to ensure safety with respect to local anaesthetic systemic toxicity.

Based on the cadaveric findings, DIPB was chosen for eligible patients who were likely to benefit from this novel technique. Patients were included in this retrospective analysis if they were adults (≥18 years old) undergoing hip fracture repair surgery, were classified as American Society of Anesthesiologists (ASA) physical status II or III, and had received a single-injection DIPB for postoperative analgesia. Patients were excluded if they had pre-existing neurological deficits affecting the lower limbs, a known allergy to local anaesthetics, or severe coagulopathy. Figure 2 shows the CONSORT flow chart used for patient enrollment.

The block was performed in the supine position under sterile conditions. All DIPBs were performed using a low-frequency convex transducer with an in-plane approach. After sterile preparation and local infiltration of the skin, the needle tip was advanced under real-time ultrasound guidance to the fascial plane deep to the iliacus muscle at the level of the anterior inferior iliac spine. After confirmation of the proper block area with 5 mL saline, 30-40 mL of 0.25% bupivacaine was administered. The Spread of local anaesthetic was visualized within the target plane. The clinical technique mirrored the cadaveric approach. However, for patient safety, the attending anaesthesiologist reduced the volume to 30-40 mL of 0.25% bupivacaine based on each patient's weight and safety profile.

Eight patients underwent general anaesthesia, and 12 underwent spinal anaesthesia. Patients receiving general anaesthesia received the standard general anaesthesia protocol. After monitoring (ECG, arterial pressure, SpO_2),

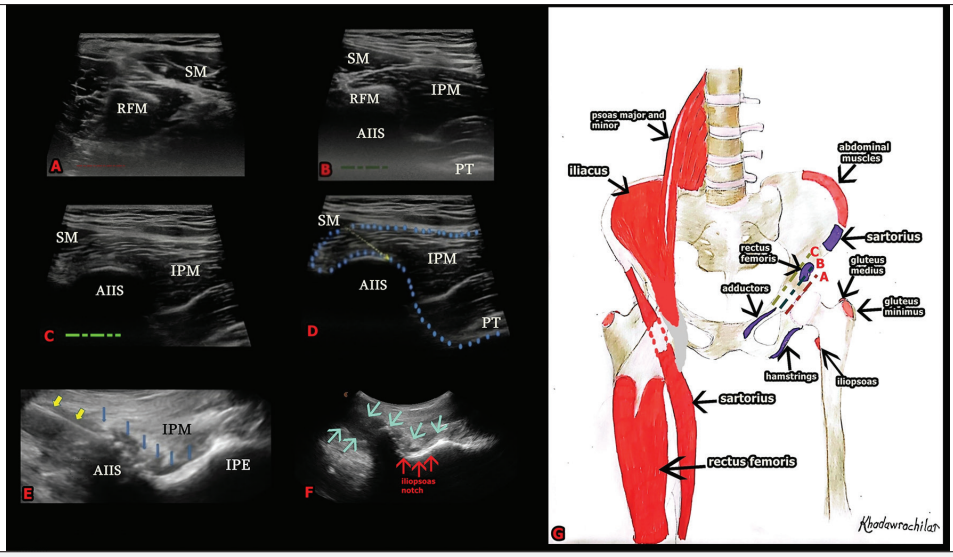

Figure 1. Sonographic anatomy and anatomic illustration of deep iliacus plane block.

A: Sartorius and rectus femoris muscles are seen in the caudal direction. B: As the probe moves cranially, the sartorius, rectus femoris, iliopsoas muscle, iliopsoas tendon, and anterior inferior iliac spine are visualized. C: Rectus femoris is out of view. Sartorius and iliopsoas muscles, iliopsoas tendon, and AIIS are seen D: The yellow arrow indicates the direction of the needle toward the AIIS. The area enclosed by blue dots denotes the block's target area. E: The Spread of local anaesthetic is evident. The yellow arrows indicate the needle. The blue arrows indicate the spread of lo-cal anaesthetic. F: The spread of local anaesthetic is seen along the iliopsoas notch. The blue arrows indicate the spread of local anaes-thetic.G: Anatomic illustration of the muscles and attachment points in the block area. The sartorius muscle is cut to reveal the attachment point of the rectus femoris muscle.

SM, sartorius muscle; RFM, rectus femoris muscle; IPM, iliopsoas muscle; AIIS, anterior inferior iliac spine; PT, psoas tendon.

induction was performed with IV propofol (1-2 mg kg^{-1}), fentanyl (2-5 µg kg^{-1}), and followed by rocuronium (0.6-0.8 mg kg^{-1}) for intubation. Spinal anaesthesia was administered under sterile conditions with the patient in the lateral decubitus position with the fractured side on top. A 25 G spinal needle was inserted into the L3-L4 or L4-L5 interspinous space and 10-12.5 mg of bupivacaine heavy was injected. The surgery was started after successful spinal anaesthesia is con-firmed by a dermatome test.

All of the blocks were unilateral. We performed DIPB in seven patients for positional pain before spinal anaesthesia. We recorded the pain scores before and 30 min after the block, and during positionbefore the block, during positioning, and 30 min after the block. We ordered 400 mg of intravenous ibuprofen for the patients every 8 hours during the postoperative period. We planned to administer 100 mg of tramadol as a rescue analgesic if the patient's NRS score was above 4. We observed all patients for 24 hours postoperatively.

Statistical Analysis

Statistical analyses were performed using IBM SPSS for Windows, version 20.0 (SPSS, Chicago, IL, USA). To evaluate the assumption of normality, the Shapiro-Wilk test was employed. Numerical variables were presented as mean ± standard deviation or as median (25^{th}-75^{th} percentiles), depending on data normality. A t-test and a signed-rank test were performed to evaluate the differences between the measurements. $P < 0.05$ was considered statistically significant.

Results

Cadaveric Findings

On the right side, the injectate stained only the RFM. No dye was detected outside the fascia surrounding the RFM. Dissection of the skin and subcutaneous tissue on the left revealed conspicuous staining of the lateral femoral cutaneous nerve adjacent to the SM. The deep fascia of the SM and the branches of the femoral nerve supplying this area were also stained. The spread of injectate was observed beneath the IPM, below the psoas tendon, and around the iliacus muscle within the iliac fascia. Upon lifting the SM and the fascia iliaca, the surface of the IPM and both the posterior and anterior divisions of the femoral nerve were stained. This staining was prominent in the femoral nerve, which runs deep to the RFM and in its branches within the femoral triangle. Extensive staining was also noted between the IPE and the iliacus muscle, deep to the psoas tendon, and caudally in the area where the IPPB was applied. The articular branches of the femoral nerve were observed to be stained within the iliopsoas notch. Cadaveric images and areas of intense methylene blue staining are presented in Figure 3.

Clinical Patient Results

While all 20 patients were monitored for 24-hour postoperative opioid consumption, a subset of seven patients received the DIPB preoperatively to manage severe pain during positioning for spinal anaesthesia. For these seven patients, NRS pain scores were recorded immediately before the block and 30 minutes post-block. Among the 20 patients, 8 received general anaesthesia and 12 received spinal anaesthesia. We observed no discernible difference in postoperative pain scores or rescue analgesia requirements between these two subgroups.

Patient demographic and block characteristics are presented in Table 1. The study included 20 patients with a median age of 71.0 years (64.5-77.0), a median height of 161.5 cm (158.2-172.2), and a median weight of 73.5 kg (67.8-78.5). Of these patients, nine were male and eleven were female; ASA classifications were II (n = 14) and III (n = 6). The

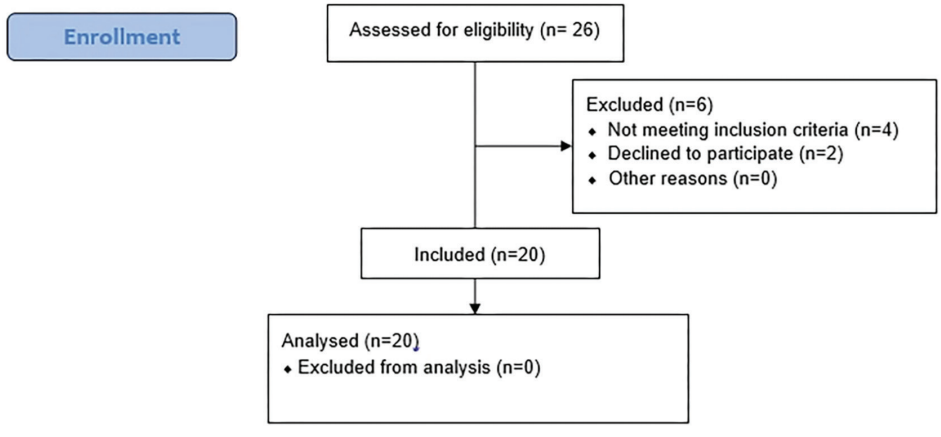

Figure 2. CONSORT flow diagram of the retrospective evaluation.

Table 1. Demographic Data of the Patients	
Gender (M/F)	9/11
Age	71.0 (64.5-77.0)
Height (cm)	161.5 (158.2-172.2)
Weight (kg)	73.5 (67.8-78.5)
ASA I/II/III	0/14/6
Duration of surgery (min)	113.5 (107.2-118.0)
Duration of anaesthesia (min)	133.0 (128.8-137.5)
Operation type	Total hip prosthesis: 13 (65.0%); partial hip replacement: 7 (35.0%)
Incision type	Posterolateral incision: 14 (70.0%); lateral incision: 5 (25.0%); anterior incision: 1 (5.0%)
Anaesthesia type	Spinal anaesthesia: 12 (60.0%); general anaesthesia: 8 (40.0%)

Values are expressed as median (percentiles 25-75) or number
ASA, American Society of Anesthesiologist; cm, centimeter; F, female; kg, kilogram; M, male; min, minutes

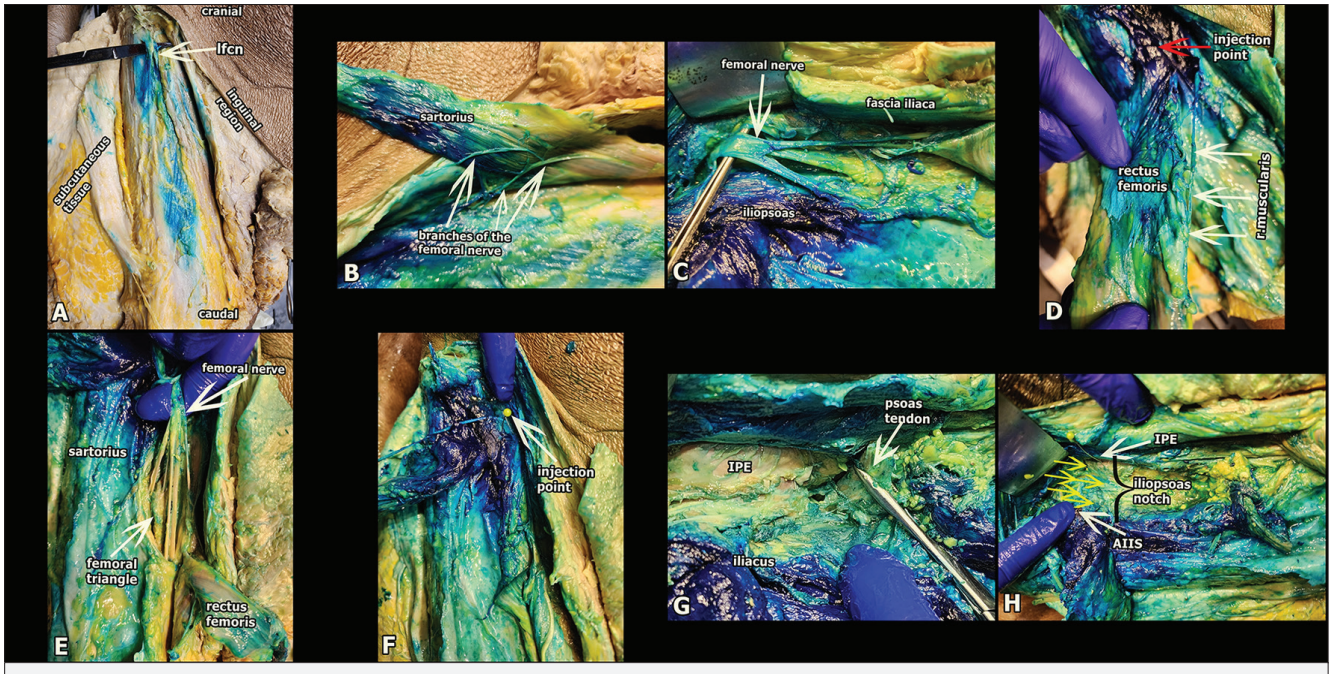

Figure 3. Dye spread of the deep iliacus plane block.

A: The staining of the lateral femoral cutaneous nerve was observed. The white arrow indicates the LFCN. B: The sartorius muscle was removed. Just below the sartorius, stained branches of the femoral nerve are visible. The white arrows indicate branches of the femoral nerve. C: Below the fascia iliaca, the stained iliopsoas muscle and the posterior and anterior divisions of the femoral nerve are seen. The white arrow indicates the femoral nerve. D: The rectus femoris muscle is manually lifted. Dye spread is seen in the nervus rectus femoris and its branches, deep to the rectus femoris muscle in the femoral triangle. The white arrows indicate the r. muscularis of the femoral nerve. The red arrow indicates the injection point of the block. E: The femoral nerve is seen in the femoral triangle. There is intense staining on the femoral nerve and adjacent anatomical structures. F: This image demonstrates intense staining in the block area. The white arrow indicates the injec-tion point. E: Extensive dye spread is seen between the IPE and the iliacus muscle, deep to the psoas tendon. This region corresponds to the area where the iliopsoas plane block is performed. The white arrow indicates the psoas tendon. F: Dye spread was observed in the area corresponding to the iliopsoas notch between the IPE and AIIS. Yellow arrows indicate the articular branches of the femoral nerve.

LFCN, lateral femoral cutaneous nerve; IPE, iliopubic eminence; AIIS, anterior inferior iliac spine.

mean duration of surgery was 113.5 minutes (107.2-118.0). The mean duration of anaesthesia was 133.0 minutes (128.8-137.5). Eight patients underwent surgery under general anaesthesia, while 12 received spinal anaesthesia. Surgical procedures included total hip prosthesis in 13 patients (65.0%) and partial hip replacement in 7 patients (35.0%). The post-NRS scores are shown in Table 2.

Only one patient required rescue analgesia, specifically, 100 mg tramadol, at the 16th postoperative hour. The remaining 19 patients did not require any additional analgesics within 24 hours post-block. No adverse effects, such as local anaesthetic systemic toxicity, nerve injury, or hematoma, were observed in any of the patients included in this pilot case series. The type of anaesthesia (general vs. spinal) did not appear to be a primary determinant of rescue analgesic needs, as patients in both anaesthesia groups experienced significant pain reduction and minimal need for rescue analgesics.

In seven patients, the median NRS score before the block was 9 (7-10), and the median NRS score 30 minutes after the block was 1 (0-2) (Table 3). A paired t-test showed a statistically significant difference between the two measurements ($P < 0.001$). No adverse effects, such as local anaesthetic systemic toxicity, nerve injury, or hematoma, were observed in any patient. Furthermore, no block failures were observed among the included patients, as evidenced by a significant reduction in pain scores after block placement.

Table 2. NRS Scores at 1, 4, 8, 16, and 24 h Postoperatively

Hours	Median values (min-max)	Mean
1st hour	0 (0-2)	0.45
4th hour	0 (1-2)	0.7
8th hour	0 (1-2)	1.2
16th hour	0 (1-3)	1.15
24th hour	0 (1-1)	0.7
1st hour	1 (1-3)	1.4
4th hour	1 (2-3)	1.8
8th hour	1 (2-3)	2.1
16th hour	1 (1-5)	1.8
24th hour	0 (1-2)	1.2

Data are expressed as median (percentiles 25-75)
NRS, numeric rating pain scale; min-max, minimum-maximum

Table 3. Comparison of the Before Block and After Block NRS Scores and Evaluation of NRS Values During Position

	Median values (min-max)	Mean
NRS before block (n = 7)	9 (7-10)	8.7
NRS after block (n = 7)	1 (0-2)	1
NRS during position (n = 7)	2 (1-3)	2.2

P value for the comparison of the scores between "before" and "after" block =0.0000034
P value is obtained with paired t-test (n)
NRS, numeric rating scale; min-max, minimum-maximum

Discussion

We identified that "DIPB", despite the absence of an anatomical plane in that region, suggests simultaneous coverage of the lateral femoral cutaneous nerve, the femoral nerve, and the PENG with a single injection. We were unable to advance to the obturator canal to visualize the obturator nerve, and no dye was observed beneath the pectineus muscle.

Regional anaesthesia techniques are frequently used in lower-extremity surgeries for both analgesia and anaesthesia. However, the only method to achieve complete blockade of all components of the lumbar plexus is through a lumbar plexus block performed in either the lateral or prone position.[2] Positioning, particularly in trauma patients, can be challenging. Additionally, clinicians may avoid this deep and relatively complex technique in patients on anticoagulants or those with coagulation disorders.

Anterior techniques have limitations, and no technique guarantees blockade of both the articular and cutaneous branches of the nerves of the lumbar plexus. For this purpose, a combination of PENG block and the lateral femoral cutaneous nerve block can be used10, or a high-volume SIFIB (60 mL) may be employed.[3,11] A study hypothesized that combining SIFIB and PENG blocks could achieve extensive spread. Cadaveric evaluations demonstrated that this combination could block major components and terminal branches of the lumbar plexus, except for the obturator nerve.[12] In our cadaveric evaluation, we determined that we could achieve such widespread distribution, with the same volume, using a single injection.

The SIFIB successfully targets the articular branches of the femoral, obturator, and accessory obturator nerves that innervate the anterolateral hip joint and are often missed by the infra-inguinal approach because of their cephalad separation.[1] However, achieving adequate blockade of the obturator nerve's articular branch within the hip capsule may necessitate significantly higher volumes of local anaesthetic, which could cause direct weakness of the quadriceps muscle. The PENG block is not effective at providing cutaneous innervation of the surgical incision line in hip surgery. It has been argued that when the injected volume in the PENG block exceeds 30 mL, it may result in anteromedial spread to the psoas, producing effects similar to a fascia iliaca block and potentially causing motor weakness.[7,8] We are aware that the SIFIB, while providing a broad cutaneous blockade of the hip, it may miss deep branches to the hip capsule and

the obturator nerve. PENG and IPPB target deep branches, but fail to block the lateral femoral cutaneous nerve and the femoral nerve, which are involved in cutaneous innervation.

The DIPB aims to address a specific clinical gap: the need for comprehensive hip analgesia via a single injection. Currently, the PENG block effectively targets the deep articular branches but often spares the superficial cutaneous nerves (LFCN and FN), potentially resulting in pain at the incision site. Conversely, the SIFIB provides excellent cutaneous coverage, but may not consistently reach the deep and accessory obturator articular branches. The DIPB is anatomically positioned to function as a hybrid, utilizing a high-volume injection deposited deep to the iliacus muscle to spread cephalad (targeting lumbar plexus roots, similar to SIFIB) and caudally (targeting articular branches, similar to PENG).

Study Limitations

This study has several significant limitations. First, the anatomical evaluation was limited to a single cadaver. Notably, the block failed on the cadaver's right side due to poor visualization of the rectus femoris tendon, highlighting a learning curve and the risk of sono-anatomical misinterpretation. Second, our clinical data are retrospective, have a small sample size (n = 20), and lack a control group. Third, we did not systematically evaluate quadriceps motor strength. The use of 30-40 mL of local anaesthetic carries a risk of motor blockade (quadriceps weakness) due to femoral nerve involvement, which we observed during dissection. This necessitates caution in patients requiring early ambulation. Finally, variation in anaesthesia type (spinal vs. general) may have influenced perception of postoperative pain.

Conclusion

The DIPB is a novel technique that may offer simultaneous blockade of the lumbar plexus cutaneous branches and hip articular nerves. While our pilot data indicate effective analgesia for hip fracture patients, the risk of motor block and the technical difficulty of the injection require further investigation. Randomized controlled trials are needed to validate these preliminary findings.

Ethics

Ethics Committee Approval: The İstanbul Medipol University Ethics and Research Committee approved (approval no.: 965, date: 31.07.2025) the retrospective evaluation of 20 patients who underwent DIPB. The cadaveric examination was conducted with the approval of the same Institutional Review Board (approval no.: 65, date: 18.01.2024).

Informed Consent: Retrospective study.

Footnotes

Author Contributions

Surgical and Medical Practices - S.T., B.Ç., B.K., A.A., S.A., B.B., B.U.S., E.O., M.N., H.A.A.; Concept - S.T., B.Ç., B.K., A.A., S.A., B.B., B.U.S., E.O., M.N., H.A.A.; Design - S.T., B.Ç., B.K., A.A., S.A., B.B., B.U.S., E.O., M.N., H.A.A.; Data Collection and/or/ Processing - S.T., B.Ç., A.A., B.B., B.U.S., M.N.; Analysis and/or/ Interpretation - S.T., B.Ç., A.A., B.U.S.; Literature Review - S.T., B.Ç., M.N., H.A.A.; Writing - S.T., B.Ç., A.A., S.A., B.B., B.U.S., M.N., H.A.A.

Declaration of Interests: Two authors of this article, Serkan Tulgar and Ali Ahıskalıoğlu, are members of the Editorial Board of the Turkish Journal of Anaesthesiology and Reanimation. However, they did not involved in any stage of the editorial decision of the manuscript. The other authors declared no conflict of interest.

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A Retrospective Cohort Study on The Impact of the Enhanced Recovery After Surgery with Safe Brain Initiative on Total Knee Arthroplasty Outcomes in Türkiye

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Abstract

Objective: Enhanced recovery after surgery (ERAS) protocols are recognised for improving postoperative outcomes. Integrating structured prehabilitation with the safe brain initiative (SBI) may further enhance these benefits. This study evaluated the impact of an ERAS-SBI programme on postoperative recovery and analgesic requirements in patients undergoing total knee arthroplasty (TKA).

Methods: This retrospective single-centre cohort study included adults classified as American Society of Anesthesiologists I-III who underwent elective TKA at a tertiary-care teaching hospital. Outcomes of patients managed with the ERAS-SBI programme (n = 138; December 2023-2024) were compared with those of patients treated prior to programme implementation (n = 66; December 2022-2023). The primary outcome was the length of hospital stay. Secondary outcomes included timing of postoperative discharge and cumulative rescue opioid analgesia at 24 and 48 hours.

Results: The ERAS-SBI group had a significantly shorter hospital stay than the pre-ERAS-SBI group ($P < 0.001$). The time to postoperative discharge was also reduced ($P < 0.001$). Rescue opioid analgesia consumption at 24 and 48 hours was significantly lower in the ERAS-SBI group ($P < 0.001$ for both comparisons). Perioperative anaemia and blood transfusion rates were reduced in the ERAS-SBI group ($P=0.007$ and $P=0.003$, respectively).

Conclusion: Implementing an ERAS-SBI pathway, incorporating a dedicated prehabilitation-focused ERAS outpatient clinic, is associated with shorter hospitalisation and reduced postoperative analgesic requirements following TKA. These findings support the role of enhanced multidisciplinary perioperative optimisation in improving clinical outcomes.

Keywords: Enhanced recovery after surgery, safe brain initiative, pain management, length of stay, total knee arthroplasty

Main Points

- Enhanced recovery after surgery (ERAS) programs improve surgical outcomes by standardising multimodal, evidence-based perioperative care.
- Patient-centred prehabilitation and multidisciplinary coordination are considered important; however, their implementation is inconsistent across many institutions.
- This study is among the first to evaluate an integrated ERAS and safe brain initiative (SBI) protocol, which begins in a dedicated preoperative ERAS outpatient clinic and continues in a postoperative ERAS recovery room.
- The implementation of the ERAS-SBI protocol in total knee arthroplasty resulted in optimised patient recovery, enhanced pain management, and improved resource utilisation.

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Introduction

Initially designed to enhance perioperative patient care in colorectal surgery, enhanced recovery after surgery (ERAS) protocols have also been successfully applied to orthopaedic surgery.[1] Studies examining the adaptation of ERAS protocols for total joint arthroplasty have demonstrated significant reductions in hospital length of stay (LOS), mortality rates, complications, and the need for blood transfusions.[2] However, there is an ongoing interest in improving the steps defined by the ERAS Society and implementing multidisciplinary coordination in practice.[1] ERAS results are improved more effectively through better organisation of prehabilitation strategies than by altering intraoperative techniques or analgesia methods.[3] To achieve this goal, a specially designed outpatient clinic that coordinates predefined, multidisciplinary steps could be transformative.

Previous ERAS literature regarded short LOS and early postoperative rehabilitation as desirable outcomes. However, to accelerate recovery, the practitioner should minimise the patient's physical and psychological stress, primarily by ensuring effective pain management.[4] However, the same anaesthesia and analgesia plan may not result in the same pain perception or the same rehabilitation success.[5] Personalised care could be the missing piece that completes the entire puzzle, making personalised care suitable for implementation in ERAS protocols such as the safe brain initiative (SBI), which aims to improve perceptions of brain health by reducing anxiety and mental stress.[6]

In this study, we investigated the impact of implementing an ERAS-SBI programme on postoperative outcomes following total knee arthroplasty (TKA), while maintaining consistency in surgical technique and anaesthesia management. The primary outcome was length of hospital stay (LOS). Secondary outcomes included postoperative discharge time, requirements for rescue opioid analgesia within 48 hours, perioperative anaemia and blood transfusion rates, and postoperative cognitive recovery parameters, assessed using ERAS-SBI tools.

Methods

Study Design and Patient Selection

This retrospective single-centre cohort study was conducted at a tertiary-care teaching hospital following approval from the University of Health Sciences Türkiye, İstanbul Haseki Training and Research Hospital, Clinical Research Ethics Committee (approval no.: 50-2025, date: 09.04.2025). We studied American Society of Anesthesiologists (ASA) I-III patients who underwent TKA in the orthopaedic operating room. Patients were excluded if they withdrew from surgery, were unable to complete the ERAS outpatient clinic protocols, or were unable to cooperate with medical staff during rehabilitation. Two consecutive time-defined patient cohorts were evaluated: the ERAS-SBI group (patients treated after implementation of the ERAS and SBI; December 2023-December 2024; n = 138) and the pre-ERAS-SBI group (patients treated prior to programme implementation; December 2022-December 2023; n = 66). Data from both groups were collected from the hospital system and from follow-up interviews conducted in the wards. Additional prehabilitation information for the ERAS-SBI cohort was available from the ERAS outpatient clinic system. Finally, we obtained data for all 138 patients in the ERAS-SBI-treated period and for all 66 patients in the pre-ERAS-SBI period.

ERAS Outpatient Clinic and Orthopaedic Ward

From December 2023 onward, patients at the orthopaedic outpatient clinic with an indication for TKA who were scheduled for surgery were referred to the ERAS outpatient clinic. Patients requiring treatment for anaemia were directed to the anaemia outpatient clinic, where, based on the timing of their surgery and the severity of their anaemia, they initiated intravenous (IV) iron therapy or oral iron replacement therapy. Sarcopenia was evaluated using the hand-grip test, and, if necessary, patients were referred to the nutrition unit for nutritional planning or supplementation. Smokers were referred to a smoking cessation support unit at least four weeks prior to their surgery to assist them in quitting.

Finally, all patients were referred preoperatively to the physiotherapy unit, where they were instructed in range-of-motion and muscle-strengthening exercises for three weeks.

Patients admitted to the surgical ward were placed in a dedicated ERAS room under the supervision of a trained ERAS nurse. At 22:00 on the night before surgery, patients were provided with a light, high-protein snack (such as yoghurt and eggs) in accordance with ERAS nutritional principles to maintain perioperative energy and protein balance. On the morning of surgery, clear fluids (up to 400 mL water or tea) were permitted at 06:00. ERAS surgical care principles included no routine use of tourniquets or drains and administration of tranexamic acid (1 g IV).

ERAS-SBI Protocol

All patients in the ERAS-SBI group were managed using the SBI patient-centred precision care approach. Patient-reported outcomes — including pain, anxiety, stress, thirst, nausea, vomiting, and overall well-being — were evaluated using the standard SBI questionnaire. These parameters were re-assessed both upon arrival in the post-anesthesia care unit and at discharge.[6]

Additionally, cognitive status and delirium were assessed using the Nursing Delirium Screening Scale (NU-DESC), a validated tool scored 0-10, where a score of ≥2 indicates delirium. If the patient opted for general anaesthesia, we

administered total intravenous anaesthesia (TIVA) under electroencephalographic (EEG) guidance. For those who consented to regional anaesthesia, we administered spinal anaesthesia (17.5 mg of heavy Marcaine and 10 mcg of fentanyl) and a postoperative adductor canal block (20 mL of 0.375% bupivacaine) for pain relief in both scenarios. The multimodal analgesia plan, started intraoperatively in the surgical ward, included dexamethasone 8 mg (IV), the nonsteroidal anti-inflammatory drug (tenoxicam 1x1), paracetamol (1 g 3x1), and tramadol (1 mg kg^{-1}, maximum 400 mg/day) as rescue therapy. Rescue opioids were administered if the numerical rating scale score was ≥4 at rest or ≥6 during mobilisation. Ondansetron (4 mg) was used for prophylaxis against postoperative nausea and vomiting (PONV). In the recovery room, a physician supervised the administration of 200 mL of water and assessed pain control and delirium scores. The ERAS nurse and anaesthesiologist jointly monitored patients for 48 hours postoperatively (Figure 1).

Non-ERAS-SBI Protocol

The non-ERAS-SBI group differs from the ERAS-SBI group in its affiliation with the ERAS outpatient clinic and in the preoperative preparation it receives. In this group, the general anaesthesia protocol used sevoflurane rather than EEG-guided TIVA and other applications of SBI because early oral hydration was not available. However, the multimodal analgesia plan, which included a postoperative adductor canal block, remained the same for both time periods.

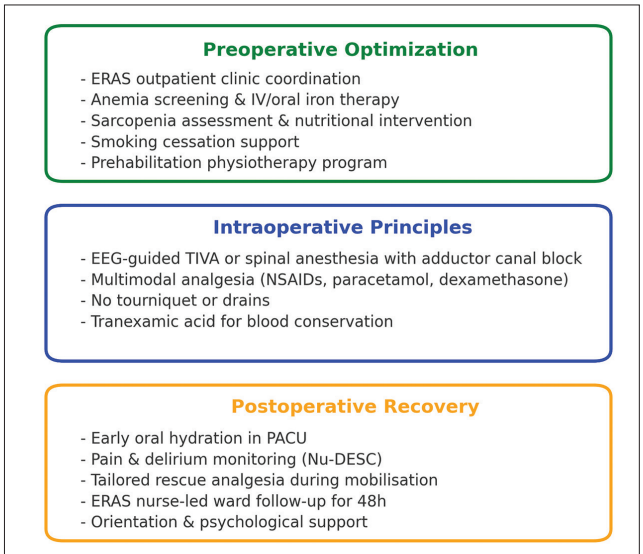

Figure 1. ERAS-SBI protocol key components.

NU-DESC, nursing delirium screening scale; ERAS, enhanced recovery after surgery; SBI, safe brain initiative; IV, intravenous; EEG, electroencephalography; TIVA, total intravenous anesthesia; NSAIDs, non-steroidal anti-inflammatory drugs; PACU, post-anesthesia care unit.

Because the same senior anaesthesiologist managed all perioperative care, the analgesia protocol used after ERAS-SBI adoption was identical to that routinely applied before ERAS-SBI implementation. All procedures were performed by the same senior orthopaedic surgical team using a medial parapatellar approach with a cemented prosthesis.

Clinical Data and Outcome Variables

For both groups, the following were recorded: demographic variables [age, gender, body mass index (BMI), ASA score], the presence of preoperative anaemia (defined as Hb 12 g dL^{-1} on the day of surgery), and the amount of perioperative blood transfusion.

The primary outcome was LOS, defined as the number of days from admission to discharge. Secondary outcomes included postoperative discharge time, defined as hours from arrival in the ward after surgery until criteria-based discharge home, and total rescue opioid analgesia at 24 and 48 hours.

Moreover, for the ERAS-SBI group, we documented additional variables, including sarcopenia, frailty, anxiety score, smoking status, preoperative sleep time (on the day before surgery), and the presence of preoperative and postoperative delirium (screened by NU-DESC).

Statistical Analysis

The descriptive statistics for the data included the mean, standard deviation, median, minimum, maximum, frequencies, and ratios. The distribution of the variables was assessed using the Shapiro-Wilk test. The Mann-Whitney U test was employed to analyse independent quantitative data that were not normally distributed. For the analysis of independent qualitative data, the chi-square test was used. The analyses were conducted using IBM SPSS Statistics for Windows, version 28.0 (IBM Corp., Armonk, NY, USA).

Results

The age and sex distributions did not differ significantly between the ERAS-SBI and non-ERAS-SBI groups (Table 1). BMI was significantly higher in the ERAS-SBI cohort (35.8±6.2 kg m^{2-1} vs. 32.2±5.6 kg m^{2-1}, $P < 0.001$, r = 0.28). Most patients in both groups were classified as ASA II; however, the pre-ERAS-SBI group did not include any ASA I patients ($P < 0.001$, Table 1).

The LOS was significantly shorter in the ERAS-SBI group [median 3 (3-4) days] than in the non-ERAS-SBI group [median 5 (4-6) days; $P < 0.001$, r = 0.63] (Figure 2). Likewise, postoperative discharge time was reduced [median 28 (24-36) hours vs 45 (36-54) hours; $P < 0.001$, r = 0.58].

Total rescue opioid analgesic use was significantly lower in the ERAS-SBI group at both postoperative time points ($P <$

0.001; Table 2). In the first 24 hours, 81.2% of ERAS-SBI patients required no rescue opioids, compared with 25.8% of non-ERAS-SBI patients. A similar pattern was observed between 24 and 48 hours (81.2% and 21.2%, respectively).

The distribution of anaesthetic techniques differed significantly between groups (Table 2). General anaesthesia combined with a peripheral nerve block was used more frequently in the ERAS-SBI group than in the non-ERAS-SBI group (61.8% vs. 31.9%; $P < 0.001$). In contrast, spinal

Table 1. Demographic Variables

	Non-ERAS-SBI (n = 66)	ERAS-SBI (n = 138)	*P* value
Age (years)	65.8±8.2 (66.0)	65.1±8.4 (66.0)	0.760[m]
Sex			0.255[χ²]
Female	54 (81.8%)	103 (74.6%)	
Male	12 (18.2%)	35 (25.4%)	
BMI (kg m$^{2-1}$)	32.2±5.6 (32.2)	35.8±6.2 (35.2)	<0.001[m]
ASA physical status			<0.001[χ²]
I	0 (0.0%)	29 (21.0%)	
II	38 (57.6%)	81 (58.7%)	
III	28 (42.4%)	28 (20.3%)	

Data are presented as mean ± standard deviation (median) or n (%)
[m]: Mann-Whitney U test, [χ²]: Chi-square test (Fisher's exact test where appropriate)
BMI, body mass index; ASA, American Society of Anesthesiologists; ERAS, enhanced recovery after surgery; SBI, safe brain initiative

Table 2. Perioperative Anesthesia and Analgesia Management of the Study Groups

Postoperative rescue analgesia (0-24 h)	Non-ERAS-SBI (n = 66)	ERAS-SBI (n = 138)	*P* value
0 doses	17 (25.8%)	112 (81.2%)	<0.001[χ²]
1 dose	2 (3.0%)	3 (2.2%)	0.721[χ²]
2 doses	23 (34.8%)	4 (2.9%)	<0.001[χ²]
3 doses	24 (36.4%)	19 (13.8%)	<0.001[χ²]
Postoperative rescue analgesia (24-48 h)			
0 doses	14 (21.2%)	112 (81.2%)	<0.001[χ²]
1 dose	2 (3.0%)	1 (0.7%)	0.276[χ²]
2 doses	27 (40.9%)	3 (2.2%)	<0.001[χ²]
3 doses	23 (34.8%)	22 (15.9%)	<0.001[χ²]
Type of anaesthesia			
General anaesthesia + PNB	21 (31.9%)	86 (61.8%)	<0.001[χ²]
Spinal anaesthesia + PNB	31 (46.9%)	26 (18.7%)	<0.001[χ²]
Combined spinal-epidural	13 (19.6%)	14 (10.1%)	0.067[χ²]
General anaesthesia + epidural	1 (1.5%)	13 (9.4%)	0.031[χ²]
Postoperative ICU admission			
No	64 (97.0%)	138 (100%)	0.104[χ²]
Yes	2 (3.0%)	0 (0.0%)	
Postoperative complications			
No	59 (89.4%)	125 (90.6%)	0.790[χ²]
Yes	7 (10.6%)	13 (9.4%)	

Data are presented as n (%)
[χ²]: Chi-square test (Fisher's exact test applied where appropriate)
ICU, intensive care unit; ERAS, enhanced recovery after surgery; SBI, safe brain initiative; PNB, peripheral nerve block (adductor canal block)

anaesthesia combined with peripheral nerve block was more common in the non-ERAS-SBI group (46.9% vs. 18.7%; *P* < 0.001). Rates of postoperative adductor canal block were similar between groups (80.5% vs. 78.8; *P*=0.76), as were rates of epidural analgesia (27.0% vs. 21.1; *P*=0.43) (Table 2).

Preoperative anaemia was significantly less frequent in the ERAS-SBI group compared with the non-ERAS-SBI group (25.4% vs. 43.9%, *P*=0.007, odds ratio: 0.43; 95% confidence interval: 0.23-0.81). Perioperative blood transfusions occurred in 7.6% of patients in the non-ERAS-SBI group, whereas none were recorded in the ERAS-SBI group; Figure 3). Postoperative complication rates were comparable between groups (9.4% vs. 10.6; *P*=0.790), and there was no statistically significant difference in intensive care unit admission rates.

Prehabilitation-related variables (frailty, sarcopenia, anxiety, smoking status, and sleep duration) were comprehensively recorded only in the ERAS-SBI cohort (Table 3), revealing prevalences of sarcopenia (34.8%) and median frailty and anxiety scores of 5 and 3, respectively prior to surgery.

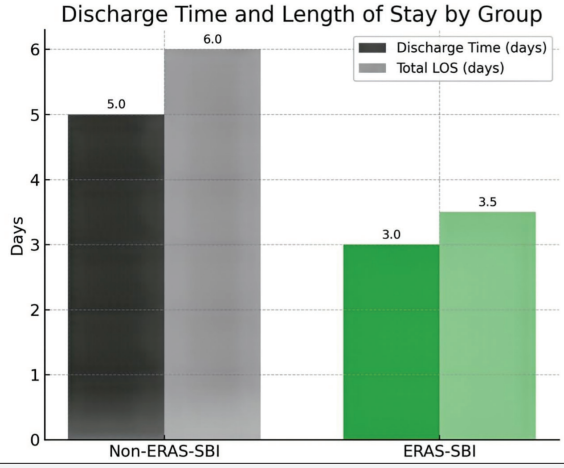

Figure 2. Comparison of discharge time and total length of hospital stay.

ERAS, enhanced recovery after surgery; SBI, safe brain initiative; LOS, length of stay.

Table 3. Additional Variables Specific to ERAS-SBI Group

	Mean ± SD / n-% median (range)
Smoking status	
No use	123-89.1%
Quit (3 weeks before surgery)	7-5.1%
Resume smoking	8-5.8 %
Anemia outpatient clinic	27-19.57 %
IV iron therapy	3-2.17 %
Oral iron theraphy	5-3.67 %
Frailty score (1-9)	5.0±0.1, 5.0 (4.0-6.0)
Sarcopenia (handgrip test positive) (nutrition outpatient clinic supplement)	48-34.8 %
Preoperative anxiety score (0-10)	2.9±0.9, 3.0 (1.0-6.0)
Preoperative delirium (NU-DESC +)	0.0 %
Postoperative delirium (NU-DESC +)	0.0 %
Sleep time, the day before surgery (h)	6.0±0.9, 6 (5.0-10.0)
PONV at the first 24h	
(+)	7-5.07 %
(-)	131-94.9 %

ERAS, enhanced recovery after surgery; SBI, safe brain initiative; PONV, postoperative nausea and vomiting; SD, standard deviation

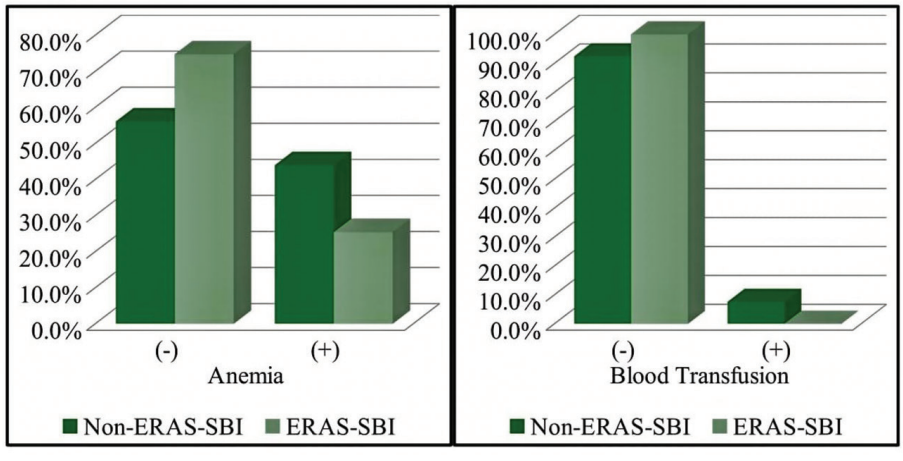

Figure 3. Comparison of anemia and perioperative blood transfusion of the same study population.

ERAS, enhanced recovery after surgery; SBI, safe brain initiative.

Discussion

This study is the first to report the clinical consequences of the ERAS-SBI protocol, achieved by organising an ERAS outpatient clinic and implementing the SBI approach. A key finding of this study is the marked reductions in both discharge time and total LOS following the implementation of the ERAS-SBI protocol. These outcomes are consistent with published ERAS literature showing that coordinated perioperative pathways improve postoperative outcomes following arthroplasty.

The primary objective of ERAS protocols is to establish a system that reduces both the LOS and overall healthcare costs.[7] To achieve this, the individual components of ERAS have been evaluated with a focus on promoting early mobilisation and reducing postoperative complications.[8] Although our shorter hospital stay aligns with ERAS literature, addressing variations in the application of accepted ERAS protocols can help adapt protocols to clinical differences.[1] While ERAS programs are widely recognised for their potential to accelerate recovery, the strategic integration of prehabilitation, personalised care via the SBI, and multidisciplinary coordination can further enhance these benefits. Shortening the LOS is not merely a metric of efficiency — it is a direct indicator of enhanced patient recovery, reduced risk of complications associated with prolonged hospitalisation, and more efficient use of healthcare resources. From a health economics standpoint, our LOS reduction translates into substantial savings. Adding secondary benefits — such as reduced transfusions, lower opioid consumption, and increased surgical throughput — raises the potential of these systems without compromising safety. Importantly, our data showed that complication rates and intensive care unit admissions did not increase despite earlier discharge, indicating that the gains in efficiency were accompanied by maintained safety standards. In our cohort, the median LOS decreased significantly compared with the non-ERAS-SBI period, despite surgical techniques and multimodal analgesia regimens remaining unchanged because the same surgeon and anaesthesiologists managed both cohorts. This underlines that the organisational and patient-centred modifications — not procedural innovations — were the drivers of improvement. The ERAS outpatient clinic structure facilitated the early detection and targeted management of modifiable preoperative risks such as anaemia, sarcopenia, smoking, and preoperative anxiety, all of which are known to delay mobilisation and discharge. Moreover, personalised counselling and expectation-setting primed patients psychologically for early discharge, amplifying the protocol's effect. However, interpretation requires caution because the ERAS-SBI cohort had fewer ASA III patients and exhibited differences in BMI, which may partially explain faster recovery and lower transfusion requirements. Studies on ERAS have shown that postoperative opioid use remains high, even among ERAS patients.[9] Thus, the effectiveness of our analgesic management could be due to the implementation of SBI as a patient-centred precision-care approach. It led us to revisit a lesser-discussed aspect of ERAS: the role of patient-dependent variables, including physical and mental prehabilitation, in redefining personalized pain perception. Furthermore, the presence of a dedicated nurse for ERAS-SBI patients may have significantly influenced this outcome. This ERAS-SBI nurse was trained to minimise unnecessary opioid use and to actively assess the patients' pain levels. This assessment included not only subjective evaluations using a visual analogue scale (VAS) but also observational assessments during postoperative mobilisation, which may have further contributed to a reduced need for analgesics. Although intraoperative anaesthetic techniques differed between groups, postoperative analgesia was standardised throughout both study periods, using the same multimodal regimen of IV paracetamol, tenoxicam, dexamethasone, and a single-shot adductor canal block with identical local anaesthetic volumes and concentrations. Furthermore, administration of rescue analgesia was protocol-driven and based on predefined VAS thresholds, thereby reducing the likelihood that lower opioid use reflected altered prescribing behaviour rather than pain-related need. Despite this consistency, the ERAS-SBI group required less postoperative rescue analgesia, suggesting that non-pharmacological factors inherent to the SBI framework—such as structured communication, expectation management, and continuous patient-centred assessment—may have influenced pain outcomes.

Recommended interventions by the ERAS Society for perioperative care in knee replacement surgery begin with preoperative information and counselling to the patient.[1] In our ERAS protocol, the outpatient clinic educates patients and implements these strategies to foster expectations of early discharge. Although the initial part of the ERAS recommendations is supported by a low level of evidence, the literature suggests that setting patient expectations can positively impact LOS.[10] While this finding highlights the influence of psychological strategies for which evidence is limited, incorporating the SBI approach into the ERAS protocol may amplify its positive impact on patient expectations. The preoperative recommendations from the SBI project emphasise the importance of preventing oral dehydration and minimising prolonged fasting periods, such as those in ERAS protocols. Instead, we encouraged oral liquid intake in the recovery room, regardless of anaesthesia type, to ensure early resumption of oral intake.

Additionally, SBI focuses on enhancing patient orientation and maintaining a regular day-night rhythm.[6] Therefore, we assess these patients in the recovery room for pain and delirium; during this assessment we tell them the time of

day and remind them of the therapeutic benefits of early mobilisation when pain is absent and of early discharge from the hospital. These measures are designed to reduce perioperative anxiety and delirium and, ultimately, to facilitate earlier patient discharge, as demonstrated by decreased LOS and shorter discharge times after our ERAS-SBI protocol.

As pain-free early mobilisation is the most critical factor for early discharge, perioperative analgesia management is the most influential factor in these protocols. Peripheral nerve blocks are generally preferred to epidural or IV patient-controlled analgesia (PCA) for managing postoperative pain after primary arthroplasty.[11] This preference arises from a lower incidence of neurological side effects, reduced nausea and vomiting, and earlier mobilisation. Given the innervation of the knee joint, either a femoral nerve block or an adductor canal block can be used; however, the adductor canal block is recommended to minimise motor block associated with a femoral nerve block, which is undesirable for early mobilisation.[12] In line with these recommendations, we implemented an adductor canal block as the peripheral nerve block for patients in our ERAS-SBI protocol. Epidural PCA was usually considered when complete pain relief was necessary for 48 hours because of patient-specific considerations, such as anatomical or psychological factors. We did not use an adductor canal catheter because it had limited cost-effectiveness.[13] In postoperative pain management following TKA, different nerve blocks and their combinations are increasingly utilised, with protocols prioritising early mobilisation.[14] Thus, future studies may identify a more effective block strategy that aligns better with ERAS protocols than the currently used adductor canal block.

The correction of anaemia during the preoperative optimisation phase is increasingly regarded as a crucial strategic change. Preoperative anaemia is linked to higher transfusion requirements and associated with various perioperative complications and health issues, such as an increased risk of cardiac events and cancer recurrence.[15,16] IV iron therapy is particularly effective during the perioperative period due to its rapid onset of action. Therapeutic approaches in this field are continually evolving, particularly with respect to dosing strategies and administration methods.[17] Establishing a dedicated anaemia clinic that focuses on the diagnosis, treatment, and follow-up of patients with anaemia could significantly improve the quality of perioperative care. Our institution benefits from such a clinic, which has become a key component of our ERAS protocol. In our cohort, in which the mean patient age exceeds 65 years, the prevalence of preoperative anaemia on the day of surgery decreased from 45% to 25%. Importantly, none of the patients in the ERAS-SBI group required a perioperative blood transfusion. The remaining 25% of anaemia cases were likely due to factors such as patient noncompliance or challenges coordinating treatment at the anaemia clinic with surgical scheduling. As the protocol continues to develop, eliminating preoperative anaemia remains a primary objective for future phases.

Sarcopenia is commonly identified in the geriatric population and is known to adversely affect early postoperative mobilisation following major joint surgeries, thereby contributing to prolonged hospital stays.[18] For this reason, patients identified with sarcopenia during ERAS clinic evaluations were referred to a separate outpatient nutrition clinic for further assessment and follow-up. As a result, nutritional support was planned for 34.8% of these patients. However, no reassessment was performed prior to surgery, and the effectiveness of prehabilitation interventions for anaemia and sarcopenia could not be measured quantitatively, except for those reflected in the overall results.

When examining our PONV rates, we considered the 5.1% incidence a favourable outcome, particularly given that our population primarily consisted of elderly female patients undergoing arthroplasty, groups traditionally associated with a higher risk of PONV.[19] Several factors likely contributed to this low incidence, including the routine administration of dexamethasone (8 mg) and ondansetron, as recommended, and a reduced postoperative opioid requirement.[20] Additionally, shortening fasting durations and facilitating oral fluid intake within the first hour postoperatively, as part of the SBI approach, may have further supported this outcome.[21]

While certain intraoperative elements consistent with ERAS recommendations were already standard practice, the ERAS-SBI programme introduced structured prehabilitation, multidisciplinary coordination, and the SBI framework as new components. To further enhance the ERAS-SBI protocol, future efforts may explore additional intraoperative modifications, such as avoiding the use of bone cement.[2] Despite recent literature examining the key components of ERAS protocols and demonstrating success in their primary objectives, there may nonetheless be a need to redefine those objectives beyond strategies that merely optimise known outcomes.[22,23] Future studies could place greater emphasis on prehabilitation and patient-centred care by developing a multidisciplinary approach and organisation similar to initiatives such as the Safe Brain Project.[24]

Although our ERAS-SBI protocol showed improvement over our standard care protocol, we must recognise that further enhancements are possible, particularly through the adaptation of hospital facilities to accommodate this system. Although postoperative discharge time was significantly shorter in the ERAS-SBI group, we found that

LOS nevertheless remained longer than three days owing to one key reason. Specifically, hospital facilities—such as the number of beds, availability of operating rooms, and access to prosthetic materials—may significantly influence the ability to achieve rapid discharge, rather than this ability depending solely on patient recovery protocols. For surgical specialities that rely on equipment, such as orthopaedics, streamlining these processes could enable even greater gains from ERAS-SBI implementation.

Study Limitations

This study represents the initial evaluation of the ERAS-SBI protocol within our institution; therefore, several limitations should be considered. The retrospective, single-centre design introduces an inherent risk of selection bias and limits generalisability. Additionally, although the surgical and anaesthetic techniques remained consistent between groups, baseline differences in the ERAS-SBI cohort, such as higher BMI and variations in ASA classification, may have influenced outcomes independently of the protocol implementation. Because multivariate or propensity-based adjustment was not performed, the potential confounding effects of these variables cannot be excluded, and causal inferences must be interpreted cautiously. Furthermore, institutional workflow constraints and incomplete data in the non-ERAS-SBI group precluded one-to-one matching across all variables, which may have introduced additional bias.

Another limitation relates to the incomplete assessment of postoperative functional recovery. For example, the exact time to first mobilisation could not be recorded, although it is an essential marker of ERAS success, particularly in TKA. Likewise, long-term cognitive trajectories were not captured. Although the SBI framework emphasizes perioperative brain health, postoperative cognitive dysfunction beyond the acute period remains to be studied. Patient-reported outcome measures (PROMs) were not incorporated into this preliminary implementation phase, despite their value in capturing patient-centred recovery.

Future research should build on these findings using prospective, preferably multicentre, study designs with multivariable adjustment to better assess confounding. We plan to incorporate routine PROMs, early mobilisation metrics, and long-term cognitive outcomes into the ERAS-SBI outpatient pathway to obtain a more comprehensive assessment of functional and patient-centred outcomes.

Conclusion

The implementation of the ERAS-SBI protocol represents an important step towards optimising perioperative care in TKA, particularly in elderly populations, who are vulnerable to perioperative cognitive dysfunction. Enhanced prehabilitation, guided by a single ERAS clinic across multiple specialised outpatient clinics, could lead to further improvement in postoperative care within the ERAS-SBI protocol, thereby resembling a system of gears that functions through distinct yet harmoniously integrated mechanisms. Although accelerated recovery is often reflected in outcomes such as a shortened LOS, our ultimate goal extends beyond this. Rather than focusing solely on the joint, we aim for comprehensive physical and psychological recovery of the patient as a whole. When recovery is conceptualised in this broader, patient-centred manner, future studies, guided by more nuanced and multidimensional assessments, may achieve even more meaningful outcomes.

Ethics

Ethics Committee Approval: This retrospective single-centre cohort study was conducted at a tertiary-care teaching hospital following approval from the University of Health Sciences Türkiye, İstanbul Haseki Training and Research Hospital, Clinical Research Ethics Committee (approval no.: 50-2025, date: 09.04.2025).

Informed Consent: Retrospective study.

Footnotes

Author Contributions: Surgical and Medical Practices - B.Ç., Ş.D.; Concept - B.Ç., M.G.Ç., B.C.M., F.M.R.; Design - B.Ç., M.G.Ç., B.C.M., F.M.R.; Data Collection and/or/Processing - B.Ç., Ş.D., M.G.Ç.; Analysis and/or/Interpretation - B.Ç., B.C.M., F.M.R.; Literature Review - B.Ç.; Writing - B.Ç.

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Case Report
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Anaesthetic Management and Multidisciplinary Approach in a Case of Aortic Foreign Body Impalement Following Thoracolumbar Instrumentation

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Abstract

Iatrogenic thoracic aortic injury caused by misplaced spinal instrumentation is a rare but potentially fatal complication of posterior spinal fusion and fixation procedures. The close anatomical relationship between the vertebral column and descending thoracic aorta puts the aortic wall at risk, especially when pedicle screws are malpositioned. While such injuries may remain asymptomatic initially, progressive erosion of the aortic wall can lead to catastrophic rupture. This case report highlights a 72-year-old woman with a history of diabetes, hypertension, and Takotsubo cardiomyopathy who developed a thoracic aortic injury following thoracolumbar instrumentation. Imaging revealed a pedicle screw at the T5 level, directly impinging on the aortic wall. A multidisciplinary approach involving cardiovascular, neurosurgery, and anaesthesiology teams was utilized, and thoracic endovascular aortic repair (TEVAR) was performed to stabilize the aorta before hardware removal. Despite successful surgical intervention, the patient later developed a right-sided middle cerebral artery infarction, possibly due to thromboembolism from the TEVAR site. This case underscores the importance of a staged surgical approach with TEVAR in managing aortic injury during spinal instrumentation, especially in high-risk patients with comorbidities such as Takotsubo cardiomyopathy. Careful anaesthesia management and multidisciplinary collaboration are essential to optimize outcomes in such complex cases.

Keywords: Cardiovascular and thoracic anaesthesia, neuroanaesthesia, spinal instrumentation, TEVAR, thoracic aortic injury

Main Points

- Iatrogenic thoracic aortic injury from misplaced spinal instrumentation requires urgent intervention.
- Thoracic endovascular aortic repair is effective for stabilizing the aorta before hardware removal in high-risk patients.
- A multidisciplinary approach is essential for managing complex cases with multiple comorbidities.
- Postoperative neurological risks, like thromboembolic events, must be carefully monitored.

Introduction

Thoracic aortic injuries caused by misplaced spinal instrumentation are rare but potentially fatal complications of posterior spinal fusion and fixation procedures. The close anatomical relationship between the vertebral column and descending thoracic aorta places the aortic wall at risk during instrumentation, particularly when posterior pedicle screws are malpositioned. Although such injuries may remain clinically silent for a period of time, progressive erosion of the aortic wall by hardware can ultimately result in life-threatening rupture. The diagnosis and management of these injuries are further complicated by variability in clinical presentation, ranging from incidental radiological findings to acute hemorrhage. In recent years, thoracic endovascular aortic repair (TEVAR) has emerged as a less invasive and effective strategy for stabilizing the aorta before

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hardware removal, thereby reducing the risk of catastrophic bleeding.[1]

Here, we present a case of iatrogenic aortic impingement caused by a pedicle screw, emphasizing anaesthetic challenges and perioperative decision-making in the context of multiple comorbidities, including Takotsubo cardiomyopathy with severely reduced myocardial function.

Case Report

A 72-year-old female with a history of diabetes mellitus and hypertension was immobilized for 1.5 years due to paraplegia, which developed postoperatively following scoliosis correction and lumbar decompression surgery. She subsequently underwent thoracolumbar instrumentation after which she was admitted to the intensive care unit with ST-segment elevations and elevated troponin levels, raising the suspicion of inferolateral myocardial infarction. Coronary angiography revealed normal coronary arteries, while echocardiography demonstrated global hypokinesis with a left ventricular ejection fraction of 30-35%. It also showed apical segment hypokinesis and hypercontractility of the basal segments, leading to a diagnosis of Takotsubo cardiomyopathy. Routine postoperative imaging, including thoracic computed tomography, revealed a pedicle screw at the T5 level, penetrating the left lateral aspect of the vertebral body, with direct contact and indentation of the adjacent aortic wall (Figure 1). Given the high-risk of aortic rupture, a multidisciplinary approach involving cardiovascular surgery, neurosurgery, and anaesthesiology teams is required. Despite the absence of hematoma, pseudoaneurysm formation, or pleural effusion, it was evident that the misplaced pedicle screw resulted in aortic injury. Nevertheless, based on radiological findings alone, it was challenging to determine whether the screw tip had breached the posterior thoracic wall and entered the lumen or merely compressed the aortic wall. The team agreed to proceed with TEVAR to strengthen the affected section of the aorta.

Under general anaesthesia, radial artery catheterization and right internal jugular central venous catheter placement were performed. Induction and tracheal intubation were conducted cautiously to avoid hemodynamic instability, which could increase shear stress on the aortic wall. Anaesthesia was induced using propofol (0.5-2 mg kg^{-1}), remifentanil (0.5 µg kg^{-1} IV bolus and 0.3 µg kg^{-1} min^{-1} infusion), and rocuronium (1 mg kg^{-1} IV) for endotracheal intubation. Neuromuscular blockade was maintained intraoperatively with additional rocuronium boluses, targeting a Train-of-Four count of 1-2. Anaesthetic maintenance included sevoflurane in an oxygen and air mixture (60% O_2) at age-adjusted 1.0 minimum alveolar concentration, along with a continuous remifentanil infusion, both titrated to maintain mean arterial pressure (MAP) and heart rate within 20% of baseline values. The depth of anaesthesia was guided using bispectral index monitoring, with values maintained between 40 and 60. Volume-controlled ventilation was implemented with a tidal volume of 7-8 mL kg^{-1}, an I:E ratio of 1:2, and respiratory rate adjustments to achieve an end-tidal CO_2 of 30-35 mmHg. Central venous access via the right internal jugular vein enabled additional hemodynamic monitoring and guided fluid management. Glycemic levels and fluid therapy were also carefully titrated according to intraoperative needs. Intraoperative hemodynamics remained stable, with no episodes of hypotension or arrhythmia observed, and no need for vasopressor or inotropic agents. In the preoperative period, thromboembolism prophylaxis was initiated with subcutaneous low molecular weight heparin and compression stockings, considering the patient's prolonged immobility and elevated risk profile. A massive transfusion protocol was prepared in anticipation of potential catastrophic hemorrhage after screw removal. The surgical plan was staged to optimize patient safety and minimize the risk of aortic rupture. Immediately after anaesthesia induction

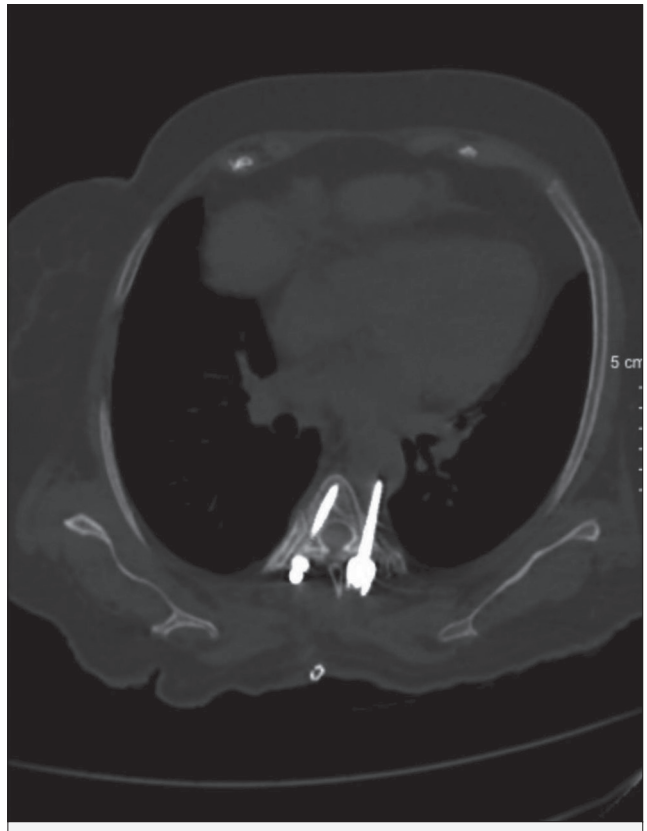

Figure 1. Axial computed tomography scan of the thorax demonstrating a malpositioned left-sided pedicle screw at the T5 level in close proximity to the descending thoracic aorta. The screw is seen penetrating the left lateral aspect of the vertebral body, creating an indentation on the adjacent aortic wall, indicating direct contact and risk of vascular injury.

and intubation, the cardiovascular surgery team deployed a TEVAR sheath through the common femoral artery to provide immediate endovascular control in cases of rupture during screw extraction. The patient was then turned to the prone position, allowing the neurosurgical team to safely extract the screw without applying excessive traction force that could destabilize the aortic wall. The screw was successfully removed, without bleeding. The patient was then carefully repositioned supine to facilitate the placement of a straight thoracic endovascular covered Ankura TAA stent graft (Lifetech Scientific, Shenzhen, China), reinforcing the structurally compromised aortic segment and preventing a delayed rupture. The patient was administered 5000 IU of low molecular weight heparin intravenously. The reason the TEVAR stent graft was not deployed before turning prone is related to the necessity to safely extract the pedicle screw and minimize the risk of destabilizing the aorta. It was crucial to ensure that the screw extraction process did not cause aortic rupture before the stent graft could be placed. This is why we did not deploy the graft beforehand. Throughout all stages of the procedure, the patient's hemodynamic profile remained stable without the need for vasopressor or inotropic support. MAP was maintained between 65 and 80 mmHg, and heart rate remained within 70-85 beats per minute. Intraoperative fluid therapy included 1500 mL of balanced crystalloid solution, with no significant blood loss or need for transfusion.

The immediate postoperative course was uneventful, and the patient was extubated in the intensive care unit with stable hemodynamics. However, on postoperative day 2, she developed right-sided hemiparesis, and brain magnetic resonance imaging revealed an acute middle cerebral artery infarction. No atrial fibrillation was detected on continuous electrocardiography (ECG) monitoring, and echocardiography revealed no cardiac embolic sources. Given the timing and vascular distribution, we hypothesized that the infarct resulted from thromboembolism originating from the TEVAR deployment site. This highlights the under-recognized neurological risks associated with endovascular repair.

As a result of this acute neurological event, the patient was closely monitored and subsequently transferred to the neurosurgery ward after a two-week stay in the intensive care unit. Neurological examination revealed complete plegia of the right upper extremity, spontaneous movement in the left upper extremity, and symmetric but limited motor responses to painful stimuli in both lower extremities. After approximately one month of inpatient follow-up, the patient was discharged home in stable clinical condition.

Discussion

The risk of iatrogenic aortic injury from spinal instrumentation is well documented; however, its management remains complex because of variability in the timing of diagnosis, presence of symptoms, and patient-specific risk factors.[2] TEVAR is a rational approach for preventing catastrophic rupture during screw extraction in patients with instrumentation-related aortic involvement.[3,4] Although pre-removal TEVAR deployment is advocated in the literature as a means to ensure immediate control in case of rupture,[5] our team opted for a staged approach after thorough multidisciplinary discussion. The graft was not deployed prior to screw removal to minimize the risk of endograft malposition or dislodgement during patient repositioning to the prone position. Furthermore, the exact depth of aortic penetration could not be confirmed radiologically, and deploying the stent without visual confirmation of screw mobility carried additional risk. To mitigate both scenarios, a TEVAR sheath was placed in advance for rapid deployment if rupture occurred during screw removal, which was performed under tightly controlled hemodynamic conditions. This approach was tailored to the patient's specific anatomical and cardiovascular status. The presence of Takotsubo cardiomyopathy further complicates the perioperative course,[6] as these patients are at high-risk for hemodynamic instability, arrhythmias, and low cardiac output, particularly during major vascular interventions. Anaesthetic management must balance pressor use to maintain coronary perfusion with strategies that prevent excessive afterload, which can exacerbate heart failure.

On postoperative day 2, the patient developed a right-sided middle cerebral artery infarction, which we attributed to a thromboembolic complication of the TEVAR procedure. Intraoperatively, 5000 IU of intravenous low molecular weight heparin was administered following stent graft placement as prophylaxis. Continuous ECG monitoring revealed no atrial fibrillation, and echocardiography excluded intracardiac thrombi. Given the infarct timing and distribution, distal embolization originating from the endovascular graft or its manipulation was considered the most likely source. Although rare, such neurological events following TEVAR are increasingly recognized and highlight the importance of optimized antithrombotic protocols and vigilant postoperative neurological assessment.[7]

Conclusion

This case highlights the importance of vascular intervention in patients with instrumentation-related aortic involvement, particularly when a direct impingement is identified. A staged surgical approach with TEVAR before screw removal minimizes the risk of catastrophic hemorrhage. The presence of Takotsubo cardiomyopathy further complicates anaesthetic management, necessitating careful perioperative monitoring, goal-directed hemodynamic support, and multidisciplinary collaboration.

Ethics

Informed Consent: Informed consent was obtained.

Footnotes

Author Contributions: Concept - B.D., Y.E.D., M.K.D.; Design - B.D., E.T.; Data Collection and/or/Processing - B.D., E.T.; Analysis and/or/Interpretation - Y.E.D., M.K.D.; Literature Search - B.E.Ç.; Writing - B.D., E.T., B.E.Ç., Y.E.D., M.K.D.

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Declaration of Generative AI and AI-assisted Technologies in the Writing Process: During the preparation of this work, the author(s) used ChatGPT (OpenAI) to improve language, structure, and readability. After using this tool, the author(s) reviewed and edited the content as needed and took full responsibility for the content of the publication.

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Case Report
Obstetric Anaesthesia

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Turkish Journal of Anaesthesiology & Reanimation

Perioperative Diagnosis of Acute Pulmonary Embolism Following Laparoscopic Hysterectomy Under General Anaesthesia: A Rare Case Report

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Abstract

Perioperative pulmonary embolism (PE) is rare but potentially fatal and often difficult to diagnose under general anaesthesia. A fifty-one-year-old woman with hypertension and type II diabetes underwent laparoscopic hysterectomy. After pneumoperitoneum and Trendelenburg positioning, she developed hypoxemia, decreased $EtCO_2$, and hypotension. Hemodynamics improved after de-sufflation, but hypoxemia persisted post-extubation. Echocardiogram showed right heart strain, and computed tomography pulmonary angiography confirmed acute PE from lower extremity deep vein thrombosis. She was treated with anticoagulation therapy, vasopressor support, and inferior vena cava filter placement and discharged from intensive care unit on postoperative day 5. This case highlights the importance of early suspicion and prompt diagnostic evaluation of intraoperative PE. A multidisciplinary approach and timely anticoagulation with or without interventional therapy are critical to improve outcomes.

Keywords: Laparoscopic hysterectomy, multidisciplinary approach, perioperative care, pulmonary embolism

Main Points

- Suspect pulmonary embolism with sudden hypoxemia and decreased $EtCO_2$ after pneumoperitoneum and Trendelenburg positioning in high-risk patients.
- Early echocardiogram and computed tomography pulmonary angiography are key to rapid diagnosis and guiding treatment.
- Early detection perioperative acute pulmonary embolism and a multidisciplinary approach improves survival.

Introduction

Perioperative acute pulmonary embolism (PE) is relatively rare, but potentially fatal. The development of PE during surgery under general anaesthesia is difficult to recognize, leading to a delay in diagnosis and subsequent treatment. We describe a case of suspected unstable PE diagnosed by clinical characteristics, transthoracic echocardiography, computed tomography (CT) pulmonary angiography (CTPA), and CT venography of the lower extremities. The patient was treated with anticoagulation therapy and inferior vena cava filter insertion. The patient was discharged from the intensive care unit (ICU) on postoperative day (POD) five. Although laparoscopic surgery-related PE is uncommon, early detection and a multidisciplinary approach are important in the management of this life-threatening complication to improve patient outcomes.

Case Report

Written consent has been obtained from the patient indicating his approval for publication. A fifty-one-year-old female, body max index 26 kg m^{2-1}, with a history of hypertension and newly diagnosed diabetes type II presented with a chief complaint of menorrhagia secondary to uterine adenomyosis. The patient was taking medically prescribed oral contraceptives

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(Desogestrel) and tranexamic acid, as well as self-prescribed herbal medication (Panax notoginseng), 3 months prior to the operation. She was scheduled for a laparoscopic total hysterectomy under general anaesthesia due to failure of medical management to resolve her symptoms. Preoperative workup included a transthoracic echocardiogram that was unremarkable, with normal biventricular systolic function and a left ventricular ejection fraction of 72%. Chest X-ray was also unremarkable. Baseline vital signs were within normal ranges, including a heart rate (HR) of 88 bpm, blood pressure (BP) 135/80 mmHg, SpO_2 99% on room air. Airway and cardiopulmonary examination was normal.

The patient was induced with intravenous fentanyl (2 µg kg^{-1}), propofol (3 mg kg^{-1}), and rocuronium (0.6 mg kg^{-1}). Direct endotracheal intubation was atraumatic, and the patient was maintained under general anaesthesia with sevoflurane. The patient's abdomen was insufflated with CO_2 gas to 12 mmHg, was placed in Trendelenburg position, and the surgery progressed uneventfully. Twenty minutes into the case, the SpO_2 suddenly dropped from 99% to 94%. Vitals were BP 110/70 mmHg, HR 86 bpm, $EtCO_2$ 35 mmHg, and Ppeak 22 cmH_2O. On a clinical exam, the endotracheal tube remained in appropriate position, lung sounds were clear without rales, and the SpO_2 remained between 94% and 96%. However, after 5 minutes, the SpO_2 dropped to 84%, and the $EtCO_2$ decreased to 32 mmHg with a BP of 120/70 mmHg. Airway pressures remained normal: (Ppeak 22 cmH_2O), and a expiratory tidal volume (VTe) of 7 mL kg^{-1} was maintained. The surgery team was notified; the abdomen was desufflated and the patient was repositioned to the zero degree supine position. The ventilator was checked, minimal sputum was aspirated from the endotracheal tube, and the patient was ventilated manually with an ambu bag. After 5 minutes, SpO_2 improved to 97% and BP improved to 115/70 mmHg.

At this point, it was decided to resume the procedure laparoscopically. However, upon abdominal insufflation and positioning the patient in Trendelenburg, the SpO_2 dropped rapidly to 89-90%, $EtCO_2$ decreased from 38 mmHg to 30 mmHg, and BP dropped to 95/50 mmHg. Due to the hemodynamic changes with insufflation, the surgical team decided to convert to open surgery. Following abdominal desufflation and opening of the abdomen, the patient's vitals remained stable with an SpO_2 of 97-98%, HR of 86-95 bpm, BP of 110/80-130/80 mmHg, and $EtCO_2$ of 32-35 mmHg. The patient was extubated without difficulty when the procedure was completed 1 hour later. However, shortly after extubation, the SpO_2 decreased to 90-92% on room air, and an arterial blood gas (ABG) was indicated. Supplemental O_2 was administered via nasal cannula at 5 L min^{-1} and she was transferred to the recovery room with SpO_2 94% and BP 105/60 mmHg. After excluding possible surgical causes, we had a high suspicion of PE due to air or thrombi, with an simplified Pulmonary Embolism Severity Index score of 3 points. A transthoracic echocardiogram was performed showing right heart dilatation, mild tricuspid regurgitation, and pulmonary artery systolic pressure of 60 mmHg (Figure 1). The electrocardiogram showed sinus rhythm and S1Q3 sign (Figure 2). A chest X-ray showed evidence of cardiomegaly (Figure 3). The remarkable laboratory tests showed elevated D-dimer 4213 ng mL^{-1}, lactate 2.1 mmol L^{-1}, hs-troponin T 0.021 ng mL^{-1}, Pro BNP 1601 pg mL^{-1}, and ABG results with pH 7.36, PaO_2 90 mmHg, $PaCO_2$ 35 mmHg. Acute PE was strongly suspected. A CTPA was obtained to confirm the presence of a PE (Figure 4), which also showed evidence of pulmonary hypertension (Figure 5). Deep vein thrombosis was also evident under ultrasound and CTPA (Figure 6).

Multidisciplinary consultations, including cardiology, interventional radiology, obstetrics and gynecology, cardiothoracic surgery, and critical care, confirmed acute PE secondary to deep vein thrombosis. The patient was treated with intravenous heparin bolus 5000 IU followed by a 500 IU/hour infusion. The patient was admitted to the ICU for hemodynamic monitoring requiring a noradrenaline infusion up to 0.1 mcg kg^{-1} min^{-1} for 24 hours. Deep venous thrombosis ultrasound and CT venography

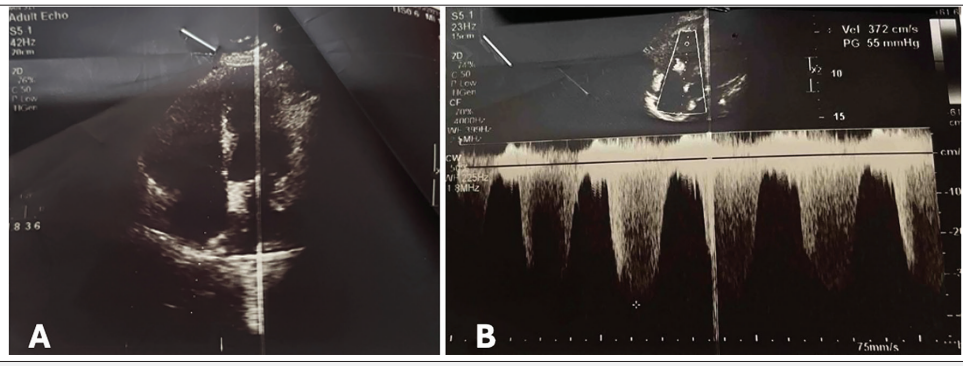

Figure 1. Transthoracic echocardiogram shows right ventricular strain (A) and evidence of pulmonary hypertension with tricuspid regurgitation pressure grafient 55 mmHg (B).

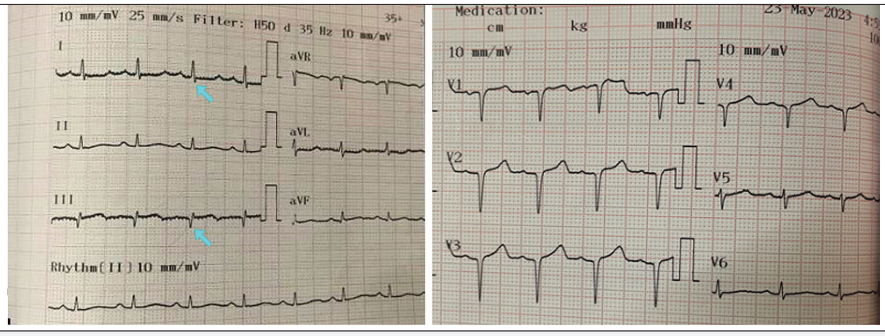

Figure 2. S1Q3 in electrocardiogram.

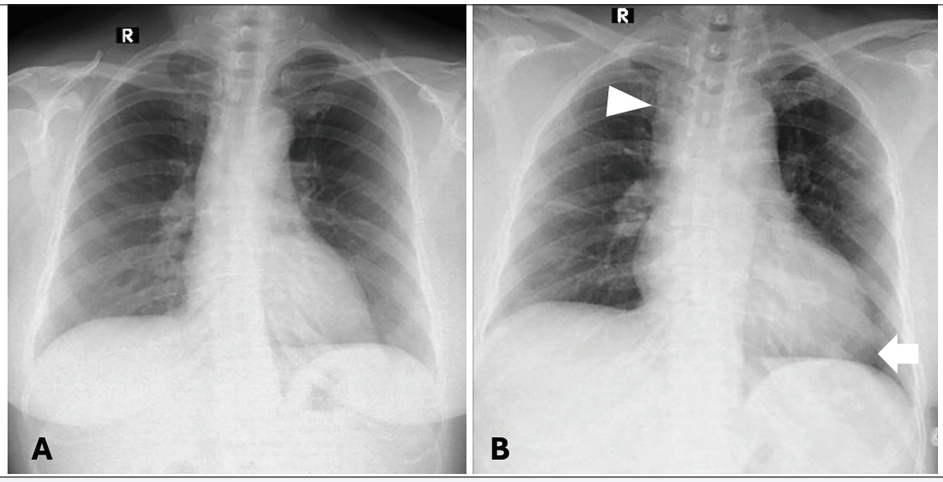

Figure 3. Comparison of chest X-ray before and after operation. Preoperavite chest X-ray (A) was normal. On postoperative X-ray, cardiomegaly with rounded left heart border and uplifted cardiac apex was appreciated, compatible with right ventricle dilatation (arrow). Widening of the right paratracheal stripe was also noted, suggesting an enlargement of the superior vena cava (arrowhead).

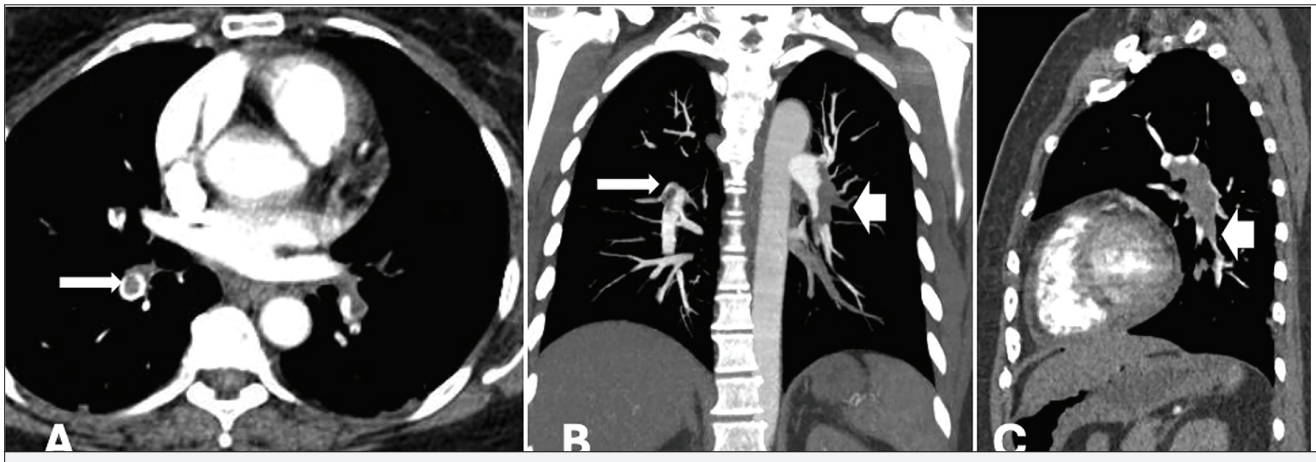

Figure 4. Acute pulmonary embolism was confirmed on computed tomography pulmonary angiogram (CTPA). Axial CTPA image (A) shows rim sign in the right middle lobe pulmonary artery (long arrow), corresponding to a focal thrombi seen on coronal view (B). Massive acute thrombosis of the left pulmonary artery extending to the interlobal artery and the anterior branch (short arrow) was appreciated (B, C).

of the lower extremities were performed, showing the left popliteal vein and acute thrombosis localized to the right common iliac vein, respectively. An inferior vena cava filter was subsequently inserted by interventional radiology via a transjugular approach (Figure 6). On POD 3, the heparin infusion was discontinued, and the patient was transitioned to oral rivaroxaban, 30 mg day^{-1}. The patient was discharged from the ICU on POD 5.

Discussion

Unstable acute PE is a medical emergency with a high mortality rate, reaching up to 30% if untreated.[1] Risk factors for PE include conditions that impair venous elasticity, vascular disorders that damage or disrupt endothelial function, and a hypercoagulable state.[2] Non-specific symptoms of PE may include dyspnea, pleuritic chest pain, headache, fatigue, syncope, and may lead to cardiac arrest.[3,4] However, diagnosing PE in patients under general anaesthesia may be challenging.[5] The incidence of PE during surgical procedures is a rare complication associated with a perioperative mortality rate of approximately 12.5%.[6]

In this case, the female patient presented with two groups of risk factors:

1. Factors Promoting Thrombus Formation: The patient had a history of cardiovascular disease (hypertension and diabetes) and was taking oral contraception, tranexamic acid, and Panax notoginseng for the treatment of menorrhagia. Some traditional herbs commonly used in Vietnam to treat menorrhagia include Panax notoginseng, Typha angustifolia, Eclipta prostrata, Styphnolobium japonicum, and Glycyrrhiza uralensis.[7] Panax notoginseng contains active compounds, including dencichin and flavonoids, that promote blood coagulation in the body.[8] Using tranexamic acid and Panax notoginseng

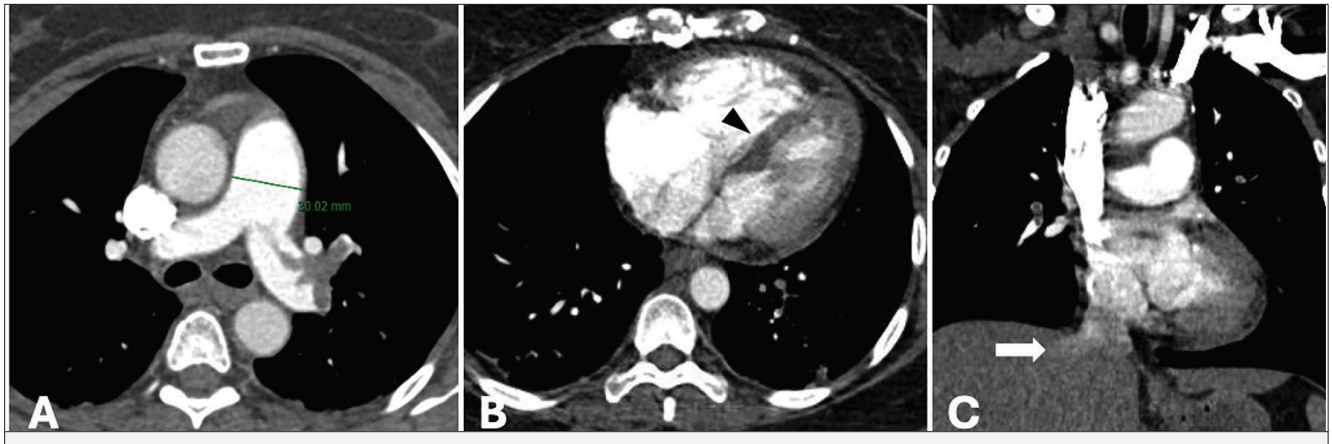

Figure 5. Pulmonary hypertension was suggestive on computed tomography pulmonary angiography with (A) enlargement of the pulmonary artery trunk, (B) dilatation of the right ventricle and flattening of the interventricular septum (arrowhead), and (C) reflux of the contrast media to the right hepatic vein (arrow).

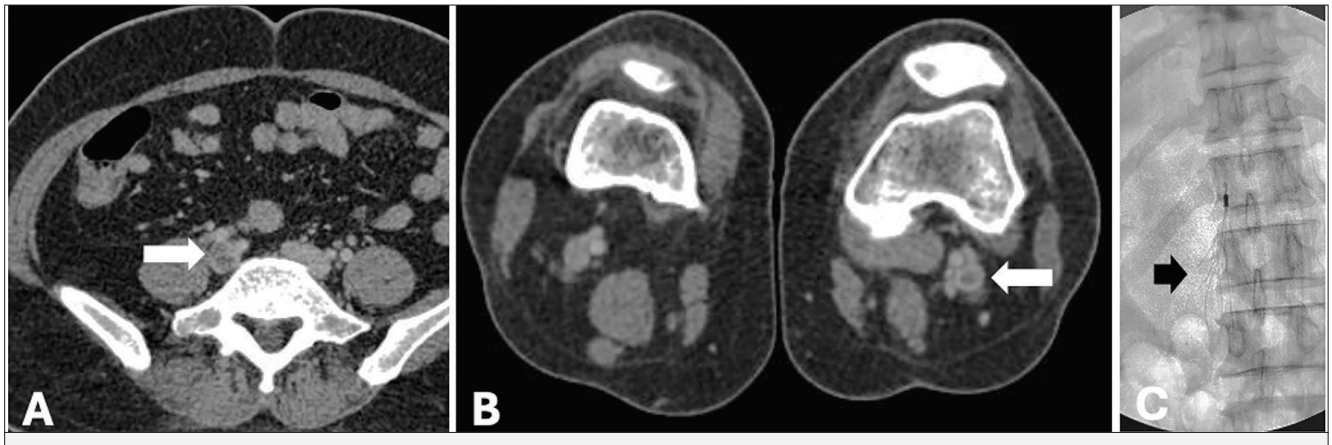

Figure 6. Deep vein thrombosis was seen at (A) the right common iliac vein and (B) the left popliteal vein (arrow) noted the vessel wall thickening and enhancement indicating an acute phase of thrombosis. (C) An inferior vena cava filter was inserted (short arrow).

concomitantly is a high-risk factor for acute deep vein thrombosis.

2. Factors Promoting Thrombus Displacement: Laparoscopic pneumoperitoneum and the Trendelenburg position may enhance thrombus movement from the lower extremities to other organs, specifically pulmonary circulation. The combination of elevated intra-abdominal pressure during laparoscopic surgery and reverse Trendelenburg positioning increases the risk of venous thromboembolism by the combination of elevated intra-abdominal pressure during laparoscopic surgery and reverse Trendelenburg positioning because of their additive effects on venous stasis and impaired venous return. Current evidence suggests that laparoscopic surgery is associated with a reduced risk of postoperative PE compared to open surgical approaches. This observed benefit is largely attributed to enhanced postoperative recovery, including pain control and earlier mobilization, both of which are critical factors in mitigating venous thromboembolic risk.[9]

During the laparoscopic hysterectomy, the patient suddenly experienced a decrease in SpO_2, $EtCO_2$, and hypotension following the establishment of pneumoperitoneum and positioning. Potential causes for these changes could include bronchospasm, pulmonary edema, pneumothorax, cardiogenic shock, hypovolemic shock, or obstructive shock. However, the patient exhibited no evidence of elevated airway pressures; the endotracheal tube was correctly positioned, VTe was adequate, and there was minimal blood loss during surgery. Given the identified patient risk factors, we raised suspicion for PE. Since open hysterectomy has less respiratory and hemodynamic effects compared to laparoscopy, the decision was made to convert to an open procedure after multidisciplinary discussion. According to the European Society of Cardiology guidelines, bedside echocardiography and if feasible, CTPA, should be performed promptly when PE is suspected in a patient with hemodynamic instability.[3] In this case, the patient, with a ten-year history of hypertension, was suspected of having hemodynamically unstable PE due to hypotension requiring vasopressor support, despite ruling out iatrogenic causes, hemorrhagic and distributive shock. Following the procedure, a CTPA, D-dimer, transthoracic echocardiography, assessment of right ventricular function, and ABG analysis were obtained to establish an early diagnosis of PE and guide management.

The CTPA results confirmed a diagnosis of PE likely secondary to lower extremity DVT. Currently, the American Heart Association and the American College of Chest Physicians recommend systemic thrombolysis as first-line therapy for patients with massive PE and suggest considering thrombolysis for patients with submassive PE. For high-risk patients with absolute contraindications to thrombolytic therapy, catheter-directed therapy, or surgical thrombectomy is recommended.[10,11] The patient was admitted to the ICU presenting with mild hypoxemia, HR 115 bpm, BP 95/60 mmHg no altered mental status, and no shock symptoms. Post-hysterectomy, the risk of postoperative bleeding was classified as moderate, placing her in a group contraindicated for systemic thrombolytic therapy. This necessitated careful consideration of the benefits and risks associated with anticoagulation therapy.

Following a multidisciplinary consultation, including cardiology, interventional radiology, obstetrics and gynecology, cardiothoracic surgery, anaesthesia, and intensivists, the patient was started on unfractionated heparin with close hemodynamic monitoring. If hemodynamic instability occurred, intravascular thrombectomy and placement of an IVC filter in the catheterization lab would be considered. According to recommendations, the choice of intervention in cases of PE should be individualized and depend on the available resources.[5] Invasive methods such as surgical intervention, catheter-directed thrombectomy, or percutaneous thrombectomy; as well as less invasive options thrombolysis or anticoagulation therapy, may be considered. For this clinical case, important considerations in management included a thorough assessment of the patient's tissue hypoxia status, selection of less invasive treatment, close monitoring of treatment response, and contingency planning for potential complications. Minimally invasive interventions to achieve maximum efficacy are a current trend in treatment.

This patient presented with multiple risk factors for PE including a history of diabetes, oral contraceptive use, tranexamic acid, Panax notoginseng use, and prolonged immobilization post-surgery. Given the significant acute thrombosis in the common iliac and popliteal veins, the placement of an IVC filter was indicated to prevent further progression, following the recommendations of the Society of Interventional Radiology Clinical Practice Guideline.[12]

Conclusion

Unstable intraoperative PE can be difficult to diagnose in patients under general anaesthesia. PE can be suspected based on the presence of sudden hypoxia, decreased $EtCO_2$, and hemodynamic instability after CO_2 inflation and Trendelenburg positioning, in patients with known PE risk factors. The clinical outcome of our patients who experience intraoperative PE depends on timely diagnosis, multi-specialty coordination, minimally invasive treatment, and interventional resources of the hospital facility.

Ethics

Informed Consent: Written consent has been obtained from the patient indicating his approval for publication.

Footnotes

Author Contributions: Surgical and Medical Practices - T.P., T.B.L., B.B., M.N.V.; Concept - T.P., L.T.T.T., T.B.L., M.N.V.; Design - T.P., B.B., M.N.V.; Data Collection and/or/Processing - T.P., L.T.T.T., T.B.L., B.B., M.N.V.; Analysis and/or/Interpretation - T.P., L.T.T.T., B.B., M.N.V.; Literature Review - L.T.T.T., T.B.L., M.N.V.; Writing - T.P., L.T.T.T., T.B.L., B.B., M.N.V.

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

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Letter to the Editor

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Triple Nerve Analgesia Block for Facial Dog-bite Laceration in a Child

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Keywords

Child, face surgery, nerve block, postoperative analgesia

Dear Editor,

Multiple superficial nerves supply the face, and peripheral nerve blocks play an essential role in multimodal analgesia. Infraorbital nerve blocks are valuable for upper lip and nose surgeries, such as cleft lip repair, septoplasty, and nasal endoscopy.[1,2] The mental nerve provides sensory supply to the lower lip, skin, and buccal mucosa ventral to the mental foramen. Maxillary nerve blocks allow for anaesthesia over cosmetically significant areas of the cheek without causing local wound oedema, facilitating repair.[3] However, multiple nerve blocks in paediatric facial surgeries, especially in a single patient and given the highly vascularised nature of face, are rarely practised and reported. Nevertheless, combining these three blocks may be necessary in unique cases. We performed a triple nerve block on a 2-years-old, 12 kg boy with facial lacerations caused

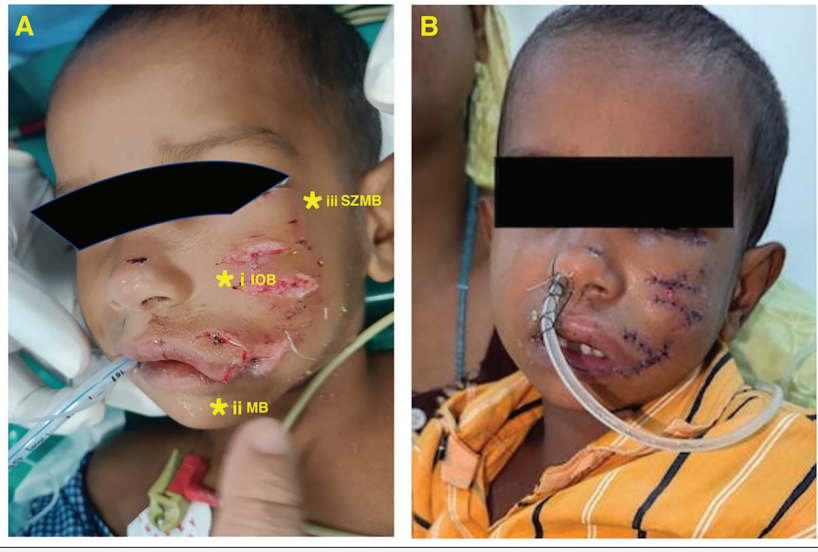

Figure 1. Dog-bite lacerations of the left cheek and lip in a 2-year-old boy. A (Pre-repair): Wounds before surgical debridement and closure, with planned regional anaesthetic sites marked by yellow asterisks—i: infra-orbital nerve block, ii: mental nerve block, iii: supra-zygomatic maxillary block—. B (Post-repair): Immediate postoperative appearance showing layered suturing and a nasotracheal tube in situ.

IOB, infra-orbital nerve block; MB, mental nerve block; SZMB, supra-zygomatic maxillary block.

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by a dog-bite affecting the left mouth angle, philtrum, infraorbital, and maxillary areas (Figure 1).

Following parental counselling and informed consent, the case was operated under general anaesthesia, and each block was performed using the following landmark-based techniques: i) Infraorbital nerve block: A 25-gauge needle was advanced at the infraorbital foramen, limiting advancement by palpating the foramen, and 2 mL of local anaesthetic (LA) was injected after negative aspiration. ii) Mental nerve block: A 25-gauge needle was inserted near the mental foramen, directed laterally to medially, and 2 mL of LA was injected after confirming no blood return. iii) Supra-zygomatic maxillary nerve block: The needle entry was located at the angle of the zygomatic arch and posterior orbital rim. A 25-gauge needle was inserted perpendicularly to reach the greater wing of the sphenoid at a depth of 10 mm, then reoriented caudally and posteriorly, advancing 20 mm to reach the pterygopalatine fossa, where 2 mL of LA was injected after negative aspiration. A total of 6 mL of LA was used, comprising 3 mL of 0.25% bupivacaine, 3 mL of 1% lidocaine with 1:200,000 epinephrine, and 1 mg of dexamethasone. Intraoperatively, intravenous paracetamol was administered at a dose of 15 mg kg^{-1} as part of a multimodal analgesia regimen. Postoperatively, paracetamol was continued at 15 mg kg^{-1} every 8 hours for 2 days. Postoperatively, the child remained calm, cooperative, and non-agitated in the post anaesthesia care unit, pain-free for 48 hours without requiring any further rescue analgesia and resumed oral intake within a day.

A recent study suggests that these blocks may be especially beneficial in paediatric patients, offering pain relief without systemic opioid-related side effects.[4] Nonetheless, meta-analysis also indicates that the benefits of these blocks go beyond pain control and provide benefits against agitation.[2]

The practice of multiple nerve blocks for facial trauma and lacerations is rare, and the reported median (interquartile range; Q3-Q1 of a number of regional nerve blocks is shown to be 1 (1-1).[5] The present case hints that the triple nerve block approach may be considered for perioperative pain management in cases with multiple facial lacerations. We will require more cases in the future to ascertain the safety and efficiency.

Footnotes

Author Contributions: Surgical and Medical Practices - B.B.A., M.A.A., D.K.B., H.M.R.K.; Concept - B.B.A., M.A.A., D.K.B., H.M.R.K.; Design - B.B.A., M.A.A., D.K.B., H.M.R.K.; Data Collection and/or Processing - B.B.A., M.A.A., D.K.B.; Literature Search - B.B.A., M.A.A., D.K.B., H.M.R.K.; Writing - B.B.A., M.A.A., D.K.B., H.M.R.K.

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