EISSN 2667-6370

Turkish Journal of Anaesthesiology & Reanimation

Volume 52 • Issue 3 • June 2024

Official journal of the TURKISH SOCIETY OF ANAESTHESIOLOGY AND REANIMATION

galenos Publishing House

turkjanaesthesiolreanim.org

Turkish Journal of Anaesthesiology & Reanimation

Turkish Journal of Anaesthesiology & Reanimation

Publisher Contact
Address: Molla Gürani Mah. Kaçamak Sk. No: 21/1
34093 İstanbul, Turkey
Phone: +90 (530) 177 30 97
E-mail: info@galenos.com.tr/yayin@galenos.com.tr
Web: www.galenos.com.tr **Publisher Certificate Number:** 14521

Publishing Date: June 2024
E-ISSN: 2667-6370
International scientific journal published bimonthly.

Turkish Journal of Anaesthesiology & Reanimation

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The journal is published online.

Owner: Ali Fuat Erdem on behalf of the Turkish Anesthesiology and Reanimation Association

Responsible Manager: Zekeriyya Alanoğlu

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Perioperative Fluid Management in Paediatric Liver Transplantation: A Systematic Review

Raihanita Zahra, Andi Ade Wijaya Ramlan, Christopher Kapuangan, Rahendra Rahendra, Komang Ayu Ferdiana, Arif Hari Martono Marsaban, Aries Perdana, Nathasha Brigitta Selene

Universitas Indonesia Faculty of Medicine, Department of Anaesthesiology and Intensive Care, Central Jakarta, Indonesia

Cite this article as: Zahra R, Ramlan AAW, Kapuangan C, et al. Perioperative Fluid Management in Paediatric Liver Transplantation: A Systematic Review. *Turk J Anaesthesiol Reanim.* 2024;52(3):83-92.

Abstract

Perioperative fluid management remains a challenging aspect of paediatric liver transplantation (LT) because of the risk of postoperative complications and haemodynamic instability. Limited research has specifically investigated the impact of fluid management and transfusion on mortality and morbidity in pediatric LT patients. This systematic review summarizes the evidence regarding perioperative fluid management and its clinical outcomes in paediatric LT patients. All primary studies published in English evaluating perioperative fluid management in paediatric LT patients were eligible. PubMed, EBSCOHost, Embase, Proquest, and Google Scholar databases were searched from inception to December 19, 2023. Risks of bias were assessed using the Joanna-Briggs Institute checklist. The results were synthesized narratively. Five retrospective cohort studies of good-excellent quality were included in this review. Two studies evaluated intraoperative fluid administration, one study compared postoperative fluid balance (FB) with outcomes, and two studies compared massive versus non-massive transfusion. A higher mortality rate was associated with intravenous lactated ringer's (LR) than with normal saline, but not with massive transfusion (MT). Longer hospital stays were correlated with MT, >20% positive FB in the first 72 hours, and greater total intraoperative blood product administration. Higher intraoperative fluid administration was associated with a greater thrombotic risk. Additionally, intraoperative MT and lR infusion were associated with an increased risk of 30-day graft loss and graft dysfunction, respectively. Fluid management may impact the outcomes of paediatric LT recipients. These findings underscore the need for more studies to explore the best fluid management and evaluation strategies for children undergoing LT.

Keywords: Children, fluid management, liver transplantation, mortality

Main Points

- Perioperative fluid management may affect the clinical outcomes of paediatric liver transplant recipients, such as mortality rate, hospital length of stay, postoperative complications, and graft health. A higher mortality rate was found in those receiving intravenous lactated ringer compared with normal saline.
- Higher intraoperative fluid administration is associated with longer hospital stays and a higher risk of thrombosis. More studies are required to determine the best fluid management and postoperative monitoring for children undergoing liver transplantation.

Introduction

Liver transplantation (LT) in children is indicated for patients with end-stage liver disease (acute or chronic), hepatic tumors, genetic metabolic diseases, or viral infections. Paediatric LT increases life expectancy and quality of life.[1,2] There is almost no perioperative mortality in paediatric LT patients, and they have excellent long-term survival rates.[3] Scientific advancements have made LT feasible for infants, with a survival rate of 85% at 1 year post-transplantation.[4]

During surgery, periods of haemodynamic instability may occur with significant blood loss and a risk of a systemic inflammatory response leading to endothelial leakage and the shifting of extravascular fluids.[1] Perioperative fluid

Corresponding author: Andi Ade Wijaya Ramlan, e-mail: andi.ade@ui.ac.id

Received: March 04, 2024 Accepted: April 11, 2024

management aims to optimize intravascular volume and ensure adequate tissue perfusion, which may reduce the risk of complications and aid rapid recovery.[5]

After undergoing LT, paediatric patients are admitted to the paediatric intensive care unit (PICU) to receive ongoing resuscitation and close monitoring of their intravascular and haemodynamic status, as well as careful titration of medications.[6] Posttransplantation complications include vascular complications (hepatic artery and portal vein thrombosis), retransplantation, biliary complications, renal complications [acute kidney injury (AKI)], pulmonary complications, and infections.[4]

Several studies have investigated the risks of patient mortality and morbidity in the intraoperative period; however, there are limited data evaluating such risks in the immediate postoperative period and their effect on patient outcomes.[7,8] In adult LT recipients, perioperative variables such as haemodynamic variations and transfusion volume have been associated with the postoperative complications mentioned above.[9,10] A high intraoperative fluid volume (>260 mL kg^{-1}) during paediatric LT is associated with a longer hospital length of stay (LOS), longer mechanical ventilation days, and increased likelihood of requiring red blood cell (RBC) transfusion during the postoperative period (first 72 hours post-operation).[11] However, Winters et al.[6] concluded that during the postoperative period, a positive fluid balance (FB) in paediatric LT recipients in the first 3 days postoperatively is associated with poor in-hospital clinical outcomes. In addition, children who undergo LT may experience haemodynamic derangements in diseased livers and are at increased risk of thrombotic complications and hemorrhage. There are limited data on intraoperative blood loss and its association with postoperative mortality and morbidity in adult LT patients.[12,13]

Moreover, to date, no systematic review has evaluated fluid management and blood transfusion during both intraoperative and postoperative periods in paediatric LT recipients.

Therefore, this study aimed to evaluate the effect of perioperative fluid management (fluid replacement and blood transfusion) during the postoperative period in paediatric LT recipients. Our primary outcomes were mortality rate, length of hospital and PICU stay, and number of mechanical ventilation days. Moreover, the secondary outcomes of our study were clinical outcomes such as readmission, the need for postoperative blood transfusion, the occurrence of postoperative complications, and graft health.

Methods

A systematic review was conducted to identify articles that discussed the outcomes of perioperative fluid management in paediatric LT patients. This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[14] The PROSPERO registration number for this systematic review is CRD42023423224.

Eligibility Criteria

The inclusion criteria for this review were (1) studies that addressed fluid management in paediatric (<18 years old) liver transplant recipients during the perioperative and postoperative periods; (2) studies involving perioperative fluid management, including fluid replacement using isotonic and colloid agents, perioperative FB, blood transfusion, and blood component transfusion; (3) randomized controlled trials and observational analytical studies (cohort studies, case studies, cross-sectional studies); (4) studies with the main outcomes of mortality rate, mechanical ventilation days, PICU LOS, and hospital LOS; (5) studies on clinical outcomes such as readmission, the requirement for postoperative blood transfusion, and postoperative complications (AKI, acute lung edema, pneumonia, acidosis); and (6) studies on additional outcomes such as pulmonary complications (pulmonary edema, acute respiratory distress syndrome, pneumonia), graft complications (graft failure, posttransplant cholangiopathy, stricture), cardiovascular complications (arrhythmia, shock, thromboembolic events), hepatic arterial thrombosis, relaparotomy, acidosis, acute lung edema, leakage anastomosis, and coagulopathy.

The exclusion criteria were (1) combined liver-kidney transplantation; (2) death prior to postoperative day 3; (4) liver failure; (5) preoperative liver supportive therapy [Molecular Absorbents Recirculating System (MARS)]; (5) studies assessing surgical techniques; (6) systematic reviews, case reports, or case series; and (7) studies for which the full text was not available.

Search Strategy

A systematic search was conducted using the following bibliographic electronic databases: PubMed, EBSCOhost, Embase, ProQuest, and Google Scholar, as well as a manual search to identify literature discussing perioperative fluid management in paediatric LT by a medical librarian as a collaborator. The search using electronic databases was performed between 19th May and 21st June 2023. A manual search was performed on 12th December 2023. The search terms used were liver transplant, paediatric, children, fluid management, fluid resuscitation, FB, blood transfusion, mortality rate, and length of hospital stay. In some cases, due to difficulty in retrieving articles regarding the topic, keywords concerning only the population and intervention were used to find as many articles as possible

(Supplementary Tables 1-5). The search was limited to 33 years (1990–2023) from the publication date. Excluded studies were not published in English.

Data Collection and Analysis

Three authors independently analyzed the titles, abstracts and full texts retrieved from the databases. The information extracted from the selected studies was shared among the three authors, and discrepancies were resolved through discussion.

Several data points were extracted from the included studies for analysis:

- Study design and methodology
- Participant demographics, such as age, sex, baseline characteristics, and indications for LT.
- Intervention: type of fluid management, infusion rate/ FB, and transfusion dose
- Outcomes: mortality rate, mechanical ventilation days, PICU LOS, hospital LOS, readmission, posttransplant transfusion requirement, postoperative complications, and graft health.

Risk of Bias Assessment

The strength of evidence of the included studies was assessed using the Joanna Briggs Institute (JBI) critical appraisal tool.[15] Assessment of the study quality consisted of 11 points and was performed by two independent reviewers. Any discrepancies between the assessment points were discussed with a third- party until a consensus was reached.

Results

Study Selection

The search strategy involving five electronic databases (PubMed, EBESCOhost, Embase, Proquest, and Google Scholar) yielded 103 potentially relevant records. After eliminating duplicates, 101 records were assessed based on titles and abstracts, resulting in the identification of 95 potentially relevant publications. Through a comprehensive review of the complete texts of the remaining articles and subsequent exclusions for reasons such as inappropriate populations, interventions, outcomes, study designs such as case reports and reviews, and content related to surgical intervention and anaesthetic techniques, five studies were deemed suitable for inclusion in this systematic review. The flowchart in Figure 1 outlines the screening and selection process.

Study Characteristics

All included studies were retrospective cohort studies. The sample size ranged from 129-333 paediatric LT recipients. We identified three different interventions or factors studied: intraoperative fluid administration (n = 2 studies),[16,17] massive transfusion (MT) versus non-massive transfusion (n = 2 studies),[18,19] and positive FB within 72 h of surgery (n = 1 study).[6] The outcomes studied varied greatly and included mortality (n = 2 studies),[16,18] risk factors for MT (n = 2 studies),[17,19] ventilator-free days (n = 1 study),[6] duration of mechanical ventilation (n = 1),[17] LOS (n = 3 studies),[6,17,19] PICU LOS (n = 2 studies),[6,17] postoperative complications (n = 3 studies),[6,16,17] and graft health (n = 3 studies).[16,18,19] The complete characteristics of the five

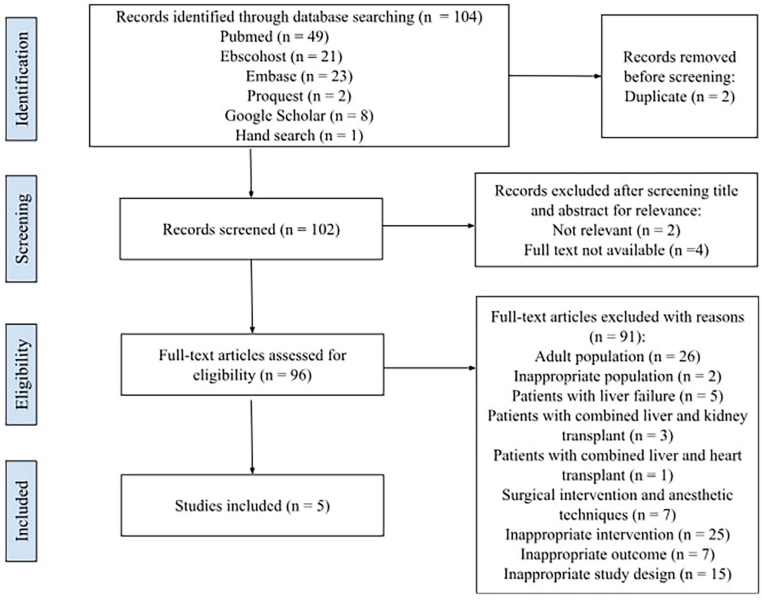

Figure 1. PRISMA flowchart for the selection of included studies

included studies, including population demographics, details of the fluid therapy intervention (whether it was performed preoperatively or postoperatively), presence of a control group, and outcomes of the studies, are listed in Table 1.

The included studies used various approaches to examine the effects of fluid management and blood transfusions for paediatric liver transplants. Most of the included studies examined risk factors for blood transfusions.[17-19] Elevated white blood cell counts, low platelet counts, and the use of cadaveric donors have emerged as robust predictors of MT during paediatric LT.[18] Moreover, technical graft variants, prolonged operative time, and specific transfusions were identified as risk factors for MT and estimated blood loss.[19] Notably, patient weight emerged as a significant risk factor for MT, which posed a substantial risk of 30-day graft loss.[19] A noticeable pattern indicated a tendency for increased volume transfusions in infants, particularly in instances of total parenteral nutrition-related liver failure, as well as in third transplants when compared with second and primary transplants.[17]

Quality Appraisal Analysis

As determined by the JBI checklist evaluation, most the included studies achieved an "excellent" quality rating, attesting to their robust methodological standards. The quality appraisals of all studies using the JBI tool are listed in Table 2.

Study Results

In terms of mortality, Dai et al.[16] reported that 30-day, 90-day, 1-year, and 2-year mortality rates were greater among children receiving lactated ringer's (LR) solution than among those receiving normal saline (NS) during surgery. Jin et al.[18] reported that the 6-month mortality rate was not significantly different between the MT group and the non-massive transfusion group (7.3% vs. 7.1%, P=0.964).

Two included studies examined risk factors for blood transfusions.[18,19] Elevated white blood cell counts, low platelet counts, and the use of cadaveric donors emerged as robust predictors of MT during paediatric LT.[18] Moreover, technical graft variants, prolonged operative time, and specific transfusions were identified as risk factors for both MT and estimated blood loss.[19]

Two studies evaluated the association between FB and mechanical ventilation. A cumulative FB of >20% in the first 72 h following LT reduced the likelihood of ventilator-free days at 28 days (the number of days patients are free from ventilators and alive within the first 28 days after LT).[6] Another study focusing only on intraoperative fluid management during paediatric LT concluded that there was an association between intraoperative FB and the duration of postoperative mechanical ventilation in which every 10 mL kg^{-1} h^{-1} of intraoperative fluid administration increased the duration of postoperative ventilation by more than 12 hours.[19]

Three studies assessed the association between blood transfusion and fluid administration and length of hospital stay. Villarreal et al.[19] reported that MT and massive estimated blood loss were associated with significantly longer lengths of stay (31.5 days in patients receiving a MT compared to 11 days in patients who did not receive a MT). Similarly, Efune et al.[17] concluded that hospital LOS was independently correlated with total intraoperative blood product administration (sum volume of all blood products administered during surgery). The study revealed that for every 1 mL kg^{-1} of total blood product administered intraoperatively, LOS increased by 0.1 days. Additionally, a study by Winters et al.[6] demonstrated that a cumulative FB of more than 20% within 72 h following LT operation led to an additional hospital day [adjusted incidence rate ratio: 1.39, 95% confidence interval (CI): 1.10-1.77].

In the context of PICU hospital days, Winters et al.[6] emphasized the impact of FB and suggested that a FB exceeding 20% at 72 h postoperatively is associated with an increased length of PICU and hospital stay. Another study by Efune et al.[17] reported a median ICU LOS of 4.3 days (interquartile range: 2.7, 6.8). In addition, the ICU LOS was independently correlated with the intraoperative time of hypotension (r2 = 00318).[17]

Although Winters et al.[6] did not identify any differences between the groups in terms of the likelihood of postoperative complications. Efune et al.[17] reported that for every 1 mL kg^{-1} h^{-1} of intraoperative fluid administered, paediatric patients receiving LT had an increased risk of developing either hepatic artery or portal vein thrombosis in the postoperative period (odds ratio: 1.053, 95% CI: 1.001, 1.107). However, they did not find any association between postoperative AKI and intraoperative fluid administration.[17] Additionally, Dai et al.[16] reported that AKI occurred within 7 days postoperatively in 6.6% of recipients in the LR group and 4.9% of recipients in the NS group.

In terms of graft health, Jin et al.[18] examined the association between MT and graft failure. Higher graft failure rates within 6 months were observed in the MT group than in the control group.[18] However, Villarreal et al.[19] reported that while MT is not statistically linked to overall graft survival, it does pose a substantial risk for 30-day graft loss, although the result is not statistically significant. Intraoperative fluid management using LR yielded higher incidence rates of early allograft dysfunction (EAD) and primary non-function (PNF) than did the use of NS in paediatric LT patients.[16] Notably, patient weight emerged as a significant risk factor for MT, which posed a substantial risk of 30-day graft loss.

Table 1. Characteristics of the Included Studies

Author	Year	Country	Population	Intervention	Control	Outcomes(s)	Results
Intraoperative period of the intervention							
Dai et al.[16]	2021	China	333 paediatric living donor LT recipients	Intraoperative fluid management using the LR	Intraoperative fluid management using the NS	The primary outcome was the mortality rate at 90 days, whereas additional measures encompassed early allograft dysfunction, primary non-function, acute renal injury, and the number of days without hospitalization (days alive after discharge within the first 30 days following liver transplantation)	- The average volumes per body weight were 234±67 and 223±76 mL kg^{-1}, respectively, with no significant difference ($P > 0.05$). - The 90-day mortality rate was higher in the group receiving the LR solution than in the NS group (11.5% vs. 0.0%). - The LR group showed higher incidences of early allograft dysfunction (19.7% vs. 3.3%) and primary nonfunction (11.5% vs. 0.0%) than the NS group. - Within 7 days postoperatively, acute renal injury occurred in 6.6% of recipients in the LR Group and 4.9% in the NS group. - Hospital-free days and PICU-free days were not significantly different between the two groups.
Efune et al.[17]	2023	USA	286 paediatric LT recipients	Intraoperative fluid administration using a formula for total fluids = crystalloid (mL) + (5% albumin in mL x 1.5) and indexed it to weight (kg) and duration of anaesthesia (hours)		Duration of mechanical ventilation postoperatively, ICU LOS, hospital LOS, vascular thrombosis (hepatic artery or portal vein), and AKI in the postoperative period	- The median intraoperative fluid administration was 12.5 mL kg^{-1} h^{-1} (IQR: 8.7, 16.9). - The median intraoperative blood product administered was 20.1 mL kg^{-1} (IQR: 8.9, 45.2). - The median duration of postoperative mechanical ventilation was 10.8 h (IQR: 0.0, 35.4). - The median ICU LOS was 4.3 days (IQR: 2.7, 6.8). - The median hospital LOS was 13.6 days (9.8, 21.1). - There was a weak correlation between intraoperative fluid administration and the duration of postoperative mechanical ventilation in paediatric patients receiving LT ($r^2 = 0.037$, P=0.001). - Hospital LOS was independently correlated with total intraoperative blood product administration ($r^2 = 0.229$, P=0.001). - For every 1 mL kg^{-1} h^{-1} of intraoperative fluid administered, paediatric patients receiving LT had an increased risk of developing either hepatic artery or portal vein thrombosis in the postoperative period (OR: 1.053, 95% CI: 1.001, 1.107). No association between postoperative AKI and intraoperative fluid administration was observed.
Jin et al.[18]	2016	Korea	249 paediatric LT recipients	Massive intraoperative transfusion	No MT	Risk factors for massive intraoperative transfusion, graft failure rate, and mortality at 6 months	- The overall amount of red blood cell transfusion administered to all patients averaged 126.7±175.4 mL kg^{-1}. - Elevated white blood cell count, reduced platelet count, and the use of cadaveric donors were significant predictors of massive transfusion during paediatric liver transplantation. - In the MT group, there was a higher graft failure rate within 6 months than that in the control group (6.6% vs. 1.8%, P=0.068). - There was no significant difference in patient mortality rates within 6 months between the intervention and control groups (7.3% vs. 7.1%, P=0.964).

Table 1. Continued

Author	Year	Country	Population	Intervention	Control	Outcomes(s)	Results
Intraoperative period of the intervention							
Villarreal et al.[19]	2019	USA	250 paediatric LT recipients	MT and massive EBL	No MT or massive EBL	Risk factors contributing to massive intraoperative blood loss/transfusion, LOS, and graft loss in 30 days.	- The median estimated EBL was 9.8 (5.5-21.5) mL kg^{-1}, and the median amount of blood transfused during surgery was 16 (6.9-28.8) mL kg^{-1}. - The average LOS in the groups with MT and massive EBL was significantly longer than that in the groups without (31.5 days vs. 11 days) (P=0.001). - Technical graft variants, extended operative time, and transfusion of FFP, platelets, and/or cryoprecipitate were found to be significant independent risk factors for both MT and EBL, whereas admission from home was considered a protective factor. - The weight of the patients was found to be a significant risk factor for MT alone. - Although MT was not statistically linked to overall graft survival, it posed a significant risk of 30-day graft loss.
Postoperative period of intervention (72 hours postop)							
Winters et al.[6]	2022	USA	129 paediatric LT recipients	FB assessment in the first 72 h after surgery	Three groups based on FB (<10%, 10-20%, and >20%)	PICU and hospital length of stay, VFD at 28 days, Day 3 severe kidney injury, and postoperative complications (infections, biliary and vascular complication).	- Thirty-seven patients (28.7%) had a FB of 1020%, and 26 patients (20.2%) had >20% FB. - Having >20% FB was linked to a higher probability of an additional day in the paediatric intensive care unit (aIRR: 1.62, 95% CI: 1.18-2.24), an extra day in the hospital (aIRR: 1.39, 95% CI: 1.10-1.77), and a reduced likelihood of ventilator-free days at 28 days (aIRR: 0.85, 95% CI: 0.74-0.97). - There were no differences between the groups in the likelihood of postoperative complications.

LT, liver transplantation; LR, lactated ringer; NS, normal saline; PICU, paediatric intensive care unit; LOS, length of stay; AKI, acute kidney injury; MT, massive transfusion; EBL, estimated blood loss; VFD, ventilator-free days; FFP, fresh frozen plasma; FB, fluid balance, aIRR, adjusted incidence rate ratio; CI, confidence interval.

Table 2. Quality Appraisal of the Included Studies

JBI Checklist	Dai et al.[16]	Efune et al.[17]	Jin et al.[18]	Villareal et al.[19]	Winters et al.[6]
Were the two groups similar and were they recruited from the same population?	Yes	Yes	Yes	Yes	Yes
Were the exposures measured similarly to assign people to both the exposed and unexposed groups?	Yes	Yes	Yes	Yes	Yes
Was the exposure measured in a valid and reliable manner?	Yes	Yes	Yes	Yes	Yes
Were the confounding factors identified?	Yes	Yes	Yes	Yes	Yes
Were strategies to address confounding factors stated?	Yes	Yes	Yes	Yes	Yes
Were the groups/participants free of the outcome at the start of the study (or at the moment of exposure)?	Yes	Yes	Yes	Yes	Yes
Were the outcomes measured in a valid and reliable manner?	Yes	Yes	Yes	UC (graft loss had unclear definition)	Yes
Was the follow-up time reported sufficient to be long enough for outcomes to occur?	Yes	Yes	Yes	Yes	No

Table 2. Continued

JBI Checklist	Dai et al.[16]	Efune et al.[17]	Jin et al.[18]	Villareal et al.[19]	Winters et al.[6]
Was the follow-up complete, and if not, were the reasons for loss to follow-up described and explored?	Yes	Yes	Yes	UC	Yes
Were strategies to address incomplete follow-up utilized?	Yes	Yes	Yes	Yes	NA
Was appropriate statistical analysis employed?	Yes	Yes	Yes	Yes	Yes
Conclusion regarding the study quality	Excellent	Excellent	Excellent	Good	Excellent

NA, not applicable; UC, unclear; JBI, Joanna Briggs Institute.

Discussion

Our systematic review included various outcomes of perioperative fluid management strategies for paediatric LT patients. To the best of our knowledge, we are the first to review these outcomes in the paediatric population.

Haemodynamic instability due to surgical procedures and blood loss necessitates intravascular expansion to ensure optimal tissue perfusion. Dai et al.[16] observed increased mortality rates in children receiving RL compared with those receiving NS. Despite not entirely corresponding to physiological conditions, NS is a commonly used crystalloid; however, it may cause hyperchloremic metabolic acidosis or AKI as a side effect. Because of their more physiological composition, LRs are being increasingly used. However, the liver is the primary lactate metabolizer; hence, impaired function in grafts and reperfusion injury in LT may contribute to further increases in lactate concentrations. This increase was associated with graft failure and death in previous studies and hence may be a potential mechanism of increased mortality in RL-receiving patients. Nevertheless, the choice of crystalloid solution may depend on the indication and morbidities of the patient and hence might affect the population studied.[16,20,21]

Jin et al.[18] reported a lack of a significant difference in the 6-month mortality rate between massive and non-massive transfusion groups. This lack of significance may be because of the various factors that may contribute to the mortality rate in LT recipients, such as the preoperative estimated glomerular filtration rate (eGFR) or the occurrence of perioperative complications, including bacterial infection. Another study by Gordon et al.[22] reported a significant difference in 1-, 5-, and 10-year mortality rates in paediatric patients receiving a high-volume transfusion; however, the definition of MT used differed between the two studies, in that Gordon et al.[22] defined high-volume transfusion as >27.5 mL kg^{-1}. The Gordon et al.[22] study also revealed that even low-volume transfusions are associated with major postoperative complications. Kloesel et al.[23] reported no difference in mortality between the massive and nonmassive bleeding groups receiving LT. Although the definition used was similar to that used by Jin et al.,[18] the follow-up period was only up to 72 h. The varying results of these studies may be due to the various definitions of massive blood loss and transfusion used by the studies and the length of mortality follow-up.

The risk factors for MT that were identified included elevated white blood cell counts, low platelet counts, and the use of cadaveric donors. Children who undergo LT are more likely to be susceptible to bacterial infection because of repeated inflammation of the abdominal cavity and complications of liver failure requiring preoperative invasive procedures. Both of these processes can cause PAs, and their release leads to increased blood loss.[18,24] Previous studies have shown similar results, where a low platelet count is associated with MT because of further impairment of coagulation function, which can cause more bleeding.[25,26] Cadaveric donors were shown in a previous study to be a risk factor for MT because of the severe diseases these patients had. These donors were mostly used when patients underwent emergency operations or did not have a living donor.[27] Ulukaya et al.[28] reported that operative time was an independent risk factor associated with an increased transfusion volume. Kloesel et al.[23] reported that surgeries lasting >600 min were an independent risk factor for massive bleeding events. Both of these studies confirmed the results found in this review. In addition, an elevated preoperative international normalized ratio, decreased hemoglobin level, and decreased platelet count were risk factors for massive bleeding (which may warrant the increased use of specific blood products) and MT.

A positive FB was associated with longer mechanical ventilation in two of the studies reviewed. Patients with a FB are at a risk of increased fluid accumulation, which results in worsening oxygenation. Complications such as pulmonary edema cause impaired gas exchange, requiring oxygenation and prolonged intubation, and increased susceptibility to bacterial infections. The effect size and, however, remains variable between studies. Prolonged mechanical ventilation was associated with increased mortality and morbidity and consumption of 50% of intensive care unit resources.[17,29]

The associations between intraoperative FB and the duration of mechanical ventilation were weak, although another previous study by Carrier et al.[30] reported that restrictive intraoperative fluid management is associated with a shorter duration of mechanical ventilation. The weak correlation observed may be due to the decision to extubate at the discretion of the anaesthesiologist and to the maintenance of open abdomen. The choice of fluid, whether colloid or crystalloid, may also affect the volume of fluid administered because greater volumes of crystalloids than colloids are required to meet targets. Another study by Chang et al.[11] Reported that patients who received > 260 mL kg^{-1} intraoperative fluid had more days of mechanical ventilation than those who received less fluid. Although not a primary concern for reducing the duration of mechanical ventilation, FB is under the control of the anaesthesiologist; hence, the optimization of outcomes through target-controlled FB is important.[17] There is still a need for the best monitoring of fluid responsiveness in children.

The studies we reviewed showed that MT and estimated blood loss, increased total intraoperative blood product administration, and a cumulative FB of >20% within 72 h of the operation lead to a longer LOS. The length of ICU stay was also correlated with the same cumulative FB cut-off and hypotension duration during the operation.[6,17,18] This result also agrees with another study of paediatric LT patients, where patients with high intraoperative fluid volumes (>260 mL kg^{-1}) were found to have longer hospital LOSs and PICU days than those who received less fluid. These patients were also found to have an increased need for RBC transfusion in the postoperative period.[11] Kloesel et al.[23] reported that massive bleeding increases the number of PICU days and that massive bleeding may also correspond to increased blood product administration. Another study also confirmed that FB, in addition to cold ischemia time and the cause of liver disease in LT recipients, affects the length of hospital stay.[31] Furthermore, healthcare is inevitably tied to outcomes relative to cost, where the ultimate goal is to be as efficient as possible.[32] Modifying the LOS and number of PICU days through controlled fluid management may be an impactful factor for efficiency.

Some reported complications included postoperative thrombosis and AKI. Increased intraoperative fluid administration increased the risk of thrombosis in the hepatic artery or portal vein. Vascular thromboses are caused by the hypercoagulable state of transplant recipients. Strategies employed to avoid thrombosis include a positive FB; however, no guidelines are universally adopted for this type of mitigation.[6] Interestingly, Winters et al.[6] reported no association between FB and vascular complications, whereas Efune et al.[17] reported that increased intraoperative fluid levels increase the risk of developing thrombosis. Similarly, conflicting results were found in other studies. Chang et al.[11] also did not find any correlation between intraoperative fluid volume and hepatic artery thrombosis (HAT). Another retrospective study noted that paediatric patients with HAT had greater cumulative fluid levels compared with those without HAT events.[33] Coagulopathy becomes exacerbated in LT patients, especially those with a history of previous operation that consumes coagulation factors; hence, during LT, there may be increased blood loss, which results in increased intraoperative fluid administration.[34] The conflicting results may be due to previous patient conditions that may affect fluid administration.

Although the quantitative evaluation of fluid administration and AKI did not yield any associations, the evaluation of the type of fluid showed that the occurrence of AKI was greater in patients who received LR than in those who received NS. Postoperative AKI was linked to surgical duration and prolonged cold ischemia time in another study. Haemodynamic instability from significant bleeding may decrease the oxygenation of the kidneys, causing injury.[35] The incidence of AKI was not significantly different between patients receiving LR and those receiving NS in this study. This was likely because other factors are related to AKI, such as cold ischemia time, which can be reduced by living donor transplantation and explains the low incidence of AKI in this study. Other factors include pre-transplantation eGFR and patient comorbidities, which may affect AKI occurrence.[16]

Two factors are considered to be associated with graft health: MT and the type of intraoperative fluid. MT was reported to be a risk factor for 30-day graft loss, and graft loss tended to increase within 6 months. In terms of the type of fluid administered, patients receiving LR had a greater incidence of EAD and PNF than those receiving NS.[16] A study using machine learning revealed that elevated sodium levels are a risk factor for graft failure. The hypernatremia observed is hypothesized to reflect the administration of large volumes of pRBCs, fresh frozen plasma (FFP), or albumin and hence can be related to MT during surgery.[36] Nacoti et al.[37] also found that the dosages of perioperative transfusion of packed RBCs and FFP were independently correlated with graft survival. The selection of crystalloid solution may contribute to graft health because lactate is mainly metabolized in the liver. LR infusion is associated with increased lactate levels in paediatric LT recipients. However, graft function is also affected by graft quality, thrombotic events, electrolyte imbalances, cold and warm ischemia time, reperfusion injury, and infections.[16,35]

The studies included in this review had several limitations. First, they were performed on a relatively small sample size, which may have caused the results to be less precise; moreover, they were retrospective cohorts that are prone to selection bias. Second, the studies were conducted in a

specific population within reach of their medical centers and hence may not be generalizable to other institutions. Furthermore, one study had an unclear measurement of outcomes and follow-up and was less reliable than the other four included studies. Consequently, there is a need for future research to validate the results found in these studies and further explore the associations suggested because there is still a sparse evidence in the paediatric literature. Prospective research with larger sample sizes and diverse patient populations is required.

Conclusion

In conclusion, our review highlights the various outcomes of perioperative fluid management strategies in paediatric patients receiving LT in situations where evidence is lacking. Quantitatively and qualitatively, fluid management can impact the mortality rate; the length of mechanical ventilation; the length of hospital and PICU stays; and the incidence of complications such as thrombosis, AKI, and graft dysfunction. These findings underscore the multifaceted impact of perioperative fluid management in this vulnerable patient population, emphasizing the need for better fluid management and evaluation strategies in paediatric LT recipients.

Ethics

Author Contributions: Concept - R.Z., A.A.W.R.; Design - R.Z., A.A.W.R., K.A.F., A.H.M.M.; Data Collection and/or Processing - R.Z., A.A.W.R., K.A.F., A.P., N.B.S.; Analysis and/or/Interpretation - R.Z., A.A.W.R., C.K., R.R., K.A.F., N.B.S.; Literature Review - R.Z., C.K., R.R., K.A.F., A.H.M.M., A.P., N.B.S.; Writing - R.Z., K.A.F., A.H.M.M., N.B.S.

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

Funding: No funding was received for conducting this study.

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DOI: 10.4274/TJAR.2024.241538

Original Article
Obstetric Anaesthesia

Turkish Journal of Anaesthesiology & Reanimation

Turk J Anaesthesiol Reanim 2024;52(3):93-100

Effect of Bilateral Erector Spinae Plane Block on Postoperative Analgesia in Cesarean Section Under Spinal Anaesthesia: A Prospective Randomized Controlled Trial

Bengi Şafak[1], Onat Bermede[1], Süheyla Karadağ Erkoç[1], Volkan Baytaş[1], Bulut Varlı[2], Asuman Uysalel[1]

[1]Ankara University Faculty of Medicine, Department of Anaesthesiology and Intensive Care, Ankara, Turkey
[2]Ankara University Faculty of Medicine, Department of Obstetrics and Gynecology, Ankara, Turkey

Cite this article as: Şafak B, Bermede O, Karadağ Erkoç S, Baytaş V, Varlı B, Uysalel A. Effect of Bilateral Erector Spinae Plane Block on Postoperative Analgesia in Cesarean Section Under Spinal Anaesthesia: A Prospective Randomized Controlled Trial. *Turk J Anaesthesiol Reanim.* 2024;52(3):93-100.

Abstract

Objective: Acute pain after cesarean section (CS) can affect the quality of life of patients. This study aimed to assess the impact of bilateral erector spinae plane block (ESPB) under spinal anaesthesia on postoperative pain, analgesic usage, and patient satisfaction in elective CS.

Methods: A total of 116 ASA II females aged 18-45 years who had elective CS were included in this prospective randomized study. Adjusted for the patient's height and weight, 0.5% bupivacaine and 12.5 µg fentanyl were administered for spinal anaesthesia. In the ESPB group, ultrasonography-guided ESPB with 10 mL 0.5% bupivacaine+10 mL saline was applied bilaterally at the T12 vertebrae level at the end of the surgery. Postoperative analgesia was planned with diclofenac and paracetamol. Patients' satisfaction, analgesic usage, rest, movement, cough, and low back pain were evaluated using a visual analogue scale (VAS) at postoperative hours 2, 4, 6, 12, and 24. The extent of the sensory block level of ESPB was evaluated after the spinal anaesthesia had worn off.

Results: The analysis included 49 patients in the ESPB group and 50 in the control group with comparable demographics. Rest, movement, and cough VAS scores were substantially lower at the 2nd, 4th, 6th, and 12th h in the ESPB group, and satisfaction was better. Total analgesic consumption and the need for rescue analgesics were higher in the control group. VAS scores and ESPB spread levels are negatively correlated.

Conclusion: As a safe component of multimodal analgesia following CS, bilateral ESPB can be effectively performed.

Keywords: Analgesia, cesarean section, nerve block, pain, pain measurement

Main Points

- Cesarean section (CS) is associated with severe postoperative pain.
- It is important to plan a multimodal analgesic treatment for post-CS pain considering both the mother's and the infant's quality of life.
- Erector spinae plane block (ESPB) is an effective component of analgesic treatment for various types of surgical procedures.
- The results of this study revealed that bilateral ESPB in patients delivered by elective CS under spinal anaesthesia can result in decreased visual analogue scale scores, prolonged time until the first analgesic request, decreased usage of rescue analgesics, and increased satisfaction.

Introduction

Cesarean section (CS) is associated with severe postoperative pain.[1] The diversity of acute pain intensity after CS makes pain intensity prediction difficult due to its variability. During the acute period after CS, discomfort might interfere with daily activities such as walking, emotions, sleep, communication, and concentration. Severe acute pain can lead to persistent postpartum pain and depression.[2] Untreated post-CS pain can affect mother-child

Corresponding author: Bengi Şafak, e-mail: bengisafak@hotmail.com

Received: March 04, 2024 Accepted: May 14, 2024

interaction and increase psychosocial and health problems in children.[3] Post-CS pain is a combination of pain from the visceral organs, skin incision, and lower back. The effect of drugs on newborns affects the management of post-CS pain. In multimodal analgesia regimens, the combination of oral analgesic drugs with neuraxial opioids and regional nerve block techniques provides efficient analgesia and improves recovery outcomes.[4]

The erector spinae plane block (ESPB) is a clear example of an interfacial plane block.[5] Since its initial description, it has been used for various clinical conditions.[6] Drug dissemination to the multisegmental epidural and paravertebral spaces, ventral and dorsal rami, sympathetic chain, and intercostal space has been reported.[7] Because it provides effective visceral and somatic analgesia,[8] ESPB could be a beneficial regional block approach for managing post-CS pain. Because of physiological changes during pregnancy, fewer neuraxial anaesthetics are required. A regional nerve block technique and a low-dose neuraxial anaesthetic drug combination can enhance recovery. The effects of ESPB in obstetric anaesthesia have been reported in a limited number of randomized controlled trials.

Patient outcomes following elective CS under spinal anaesthesia were the focus of our investigation; the primary objective was to assess the impact of bilateral ESPB on postoperative pain as measured by the visual analogue scale (VAS). The secondary objectives were to assess the impact of bilateral ESPB on postoperative analgesic medication usage and patient satisfaction.

Methods

This prospective randomized study was conducted between May 2020 and June 2021 in a university hospital with the approval of the Human Research Ethics Committee of Ankara University Faculty of Medicine (date: 13.02.2020, approval no.: İ2-87-20). The study was registered at the Clinical Trials Protocol Registration and Results System (ClinicalTrials.gov ID: NCT05695625) and was conducted following the principles of the Declaration of Helsinki. Enrollment and allocation are shown in the CONSORT flow diagram (Figure 1). The American Society of Anesthesiologists (ASA) health status II female patients aged between 18 and 45 years who delivered by elective CS under spinal anaesthesia were included after waiving written informed consent. Patients under 18 years of age, over 45 years of age, ≥ASA health status III, who refused to participate, with body mass index >35 kg m^{-2}, multiple pregnancy, preeclampsia, any contraindications for regional anaesthesia, known allergy to the study drugs, and a history

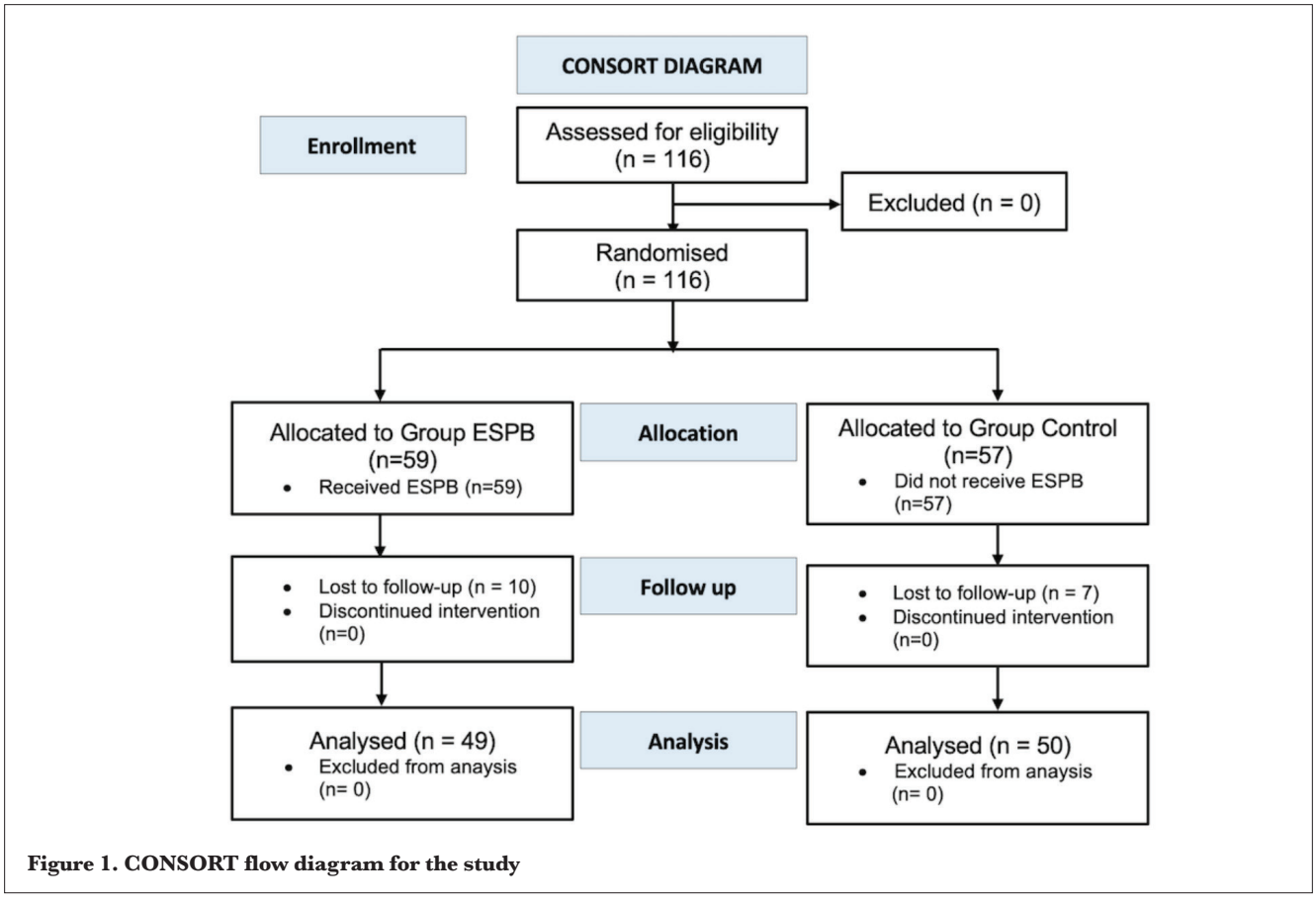

Figure 1. CONSORT flow diagram for the study

of chronic substance or opioid use were excluded. Using the sealed envelope method, patients were randomly assigned to one of two groups: the ESPB group, which received bilateral ESPB at the end of surgery in addition to spinal anaesthesia; or the control group, which received spinal anaesthesia alone.

After standardized monitoring, intravenous (IV) access was achieved, and a balanced electrolyte solution was started. Under standard aseptic precautions, spinal anaesthesia was administered to all patients while they were seated at the lumbar 4-5 interspace. Following the observation of free cerebrospinal fluid flow, spinal anaesthesia was administered with 0.5% bupivacaine, adjusted for the patient's height and weight (Table 1),[9] and 12.5 g (µg) fentanyl. The patient was positioned 15° to the left, and 2 lt/min of oxygen was started via a nasal cannula. The administration time of spinal anaesthesia was recorded as the 0th minute (min). The sensorial block was examined using a pinprick test, and the time required for the block to reach the T4 dermatome level and the Bromage score at that point were recorded. A 20% reduction in systolic blood pressure from baseline was defined as hypotension, and 100 µg of ephedrine was administered. A decrease in the heart rate below 60 beats per minute was defined as bradycardia, and 0.5 mg of atropine was administered.

In the ESPB group, two people assisted the patients into a sitting position at the end of the surgery. The spinous process of the T12 vertebra was confirmed by palpating cranially from the T7 vertebra and caudally from the L5 vertebra. After skin asepsis, a high-frequency linear ultrasonography (USG) probe (Samsung HM70A USG machine and Samsung L5-13IS USG probe, Korea) was placed in the midline. After visualizing the T12 vertebra spinous process, the probe was laterally moved approximately 4 cm to visualize the transverse process. Until the needle tip touched the transverse process, a 20 gauge 10 cm block needle (BRAUN Stimuplex Ultra 360, Germany) proceeded in the plane. The position of the needlepoint was verified by hydrodissection. Twenty milliliters of local anaesthetic solution (10 mL of 0.5% Bupivacaine +10 mL of 0.9% NaCl) was injected between the erector spinae muscle and the transverse process at a standard rate (Figure 2). The block was reproduced with equal volume and content on the opposite side of the back. The same anaesthesiologist performed all the blocks. The control group patients did not receive ESPB.

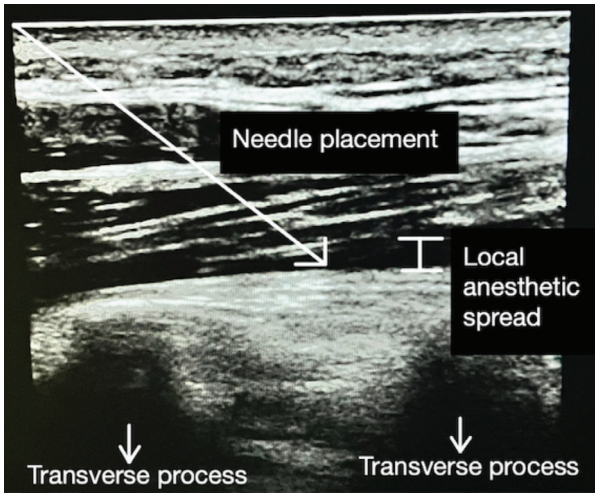

Figure 2. The USG image of the erector spinae plane block

USG, ultrasonography.

Table 1. Amount of Bupivacaine Adjusted for Patient's Height and Weight (mL)[9]

Patient weight (kg)	Patient height (cm)								
	140	145	150	155	160	165	170	175	180
50	1.5	1.7	1.8	1.9					
55	1.5	1.6	1.8	1.9	2.0				
60	1.4	1.6	1.7	1.8	2.0	2.1			
65	1.4	1.5	1.7	1.8	1.9	2.1	2.2		
70	1.3	1.5	1.6	1.8	1.9	2.0	2.2	2.3	
75		1.4	1.6	1.7	1.9	2.0	2.1	2.3	2.4
80		1.4	1.5	1.7	1.8	2.0	2.1	2.2	2.4
85			1.5	1.6	1.8	1.9	2.1	2.2	2.3
90			1.4	1.6	1.7	1.9	2.0	2.2	2.3
95				1.5	1.7	1.8	2.0	2.1	2.3
100				1.5	1.7	1.8	1.9	2.1	2.2
105					1.6	1.7	1.9	2.0	2.2
110						1.7	1.8	2.0	2.2

At the postoperative 2nd, 4th, 6th, 12th, and 24th hours, all patients were visited in their rooms, and their rest, movement, cough, and low back pain VAS scores were evaluated (0: no pain- 10: worst pain). In case patients had a headache, it was planned to be evaluated with a VAS score. For postoperative analgesia, as a rescue analgesic, 75 mg of diclofenac (maximum dose 150 mg day^{-1}) was intramuscularly administered to patients whose VAS score exceeded 4. After 30 min, patients with a VAS score greater than 4 received 1000 mg IV acetaminophen (maximum dose 4 gr day^{-1}). Patients with severe pain were administered IV fentanyl through a patient-controlled analgesia system and were excluded from the study. Using a pinprick test at the midaxillary line and motor skills, the level of ESPB spread was evaluated as dermatomal 4-5 h after spinal anaesthesia had worn off.

The demographics of patients, amount of bupivacaine used for spinal anaesthesia, time of reaching the T4 level of the sensorial block, intraoperative hypotension and bradycardia, ephedrine and atropine requirement, operation time, ESPB application time, first mobilization time, analgesic consumption, first analgesic request time, patient satisfaction (0: very satisfied- 10: not satisfied), postdural puncture headache, breastfeeding, nausea and vomiting, and length of hospital stay were recorded.

Statistical Analysis

The sample size was estimated with 80% power and a significance threshold of 0.05, assuming that a 1-unit change in the VAS value would be considered significant. It was calculated that at least 41 participants would be in each group, for a total of 82, and G*Power 3.1.9.2 was used for the calculation of samples.

The SPSS 11.5 program was used to analyze the data. Qualitative variables were represented by the number of patients stated as a percentage, while quantitative variables were described using the mean ± standard deviation. The presence of a difference was examined using the Mann-Whitney U test in the absence of normal distribution assumptions and the Student's t-test in the presence of a distinction between categories of a qualitative variable and two categories of a quantitative variable. A chi-square test was used to investigate the correlation between the two qualitative variables. In the absence of adherence to the assumptions of normal distribution, the relationship between two quantitative variables was examined using Spearman's correlation. $P < 0.05$ was determined as the statistical significance level.

Table 2. Patients' Demographics and Intraoperative Variables

		Group		
		ESPB (n = 49)	**Control (n = 50)**	**p-value**
Age (year)	Mean ± SD	30.41±5.58	30.82±5.07	0.701[a]
BMI (kg m^{-2})	Mean ± SD	28.96±3.85	30.08±3.24	0.118[a]
Gestational age (week)	Mean ± SD	38.69±1.50	38.72±0.88	0.903[a]
Bupivacaine (mg)	Mean ± SD	9.58±0.76	9.64±0.74	0.699[a]
T4 time (min)	Mean ± SD	6.78±1.76	6.24±2.61	0.094[b]
Bromage score at T4 time				
1	n (%)	0 (0)	1 (2.0)	
2	n (%)	21 (42.9)	25 (50.0)	0.482[c]
3	n (%)	28 (57.1)	24 (48.0)	
Hypotension	n (%)	28 (57.1)	35 (70.0)	0.184[c]
Ephedrine requirement	n (%)	28 (57.1)	35 (70.0)	0.184[c]
Bradycardia	n (%)	6 (12.2)	5 (10.0)	0.722[c]
Atropine requirement	n (%)	6 (12.2)	5 (10.0)	0.722[c]
Surgery time (min.)	Mean ± SD	44.37±13.79	38.24±13.04	0.014[b]
First mobilization time (min.)	Mean ± SD	441.35±83.60	426.68±85.7	0.391[a]
Length of hospital stay (hour)	Mean ± SD	46.16±17.30	51.12±21.86	0.484[b]

[a]Student's t-test, [b]Mann-Whitney U test, [c]Chi-square test.
$p<0.05$ is taken as statistically significant.
SD, standard deviation; BMI, body mass index; ESPB, erector spinae plane block.

Results

One hundred and sixteen patients were included in the study despite the possibility of data loss. Ten patients in the ESPB group and seven in the control group with a lack of postoperative follow-up data were excluded from the statistical analysis. The statistical analysis included 49 patients in the ESPB group and 50 patients in the control group (Figure 1. CONSORT flow diagram). Demographics and intraoperative variables were comparable between the groups (Table 2).

The ESPB group had significantly reduced rest, movement, and cough VAS values in comparison to the control group during the 2nd, 4th, 6th, and 12th h; nevertheless, no significant difference was observed between the groups by the 24th h (Table 3). At all times, satisfaction was significantly better in the ESPB group (Table 3). In the ESPB group, the mean time until the first analgesic request was remarkably longer than that in the control group (5.03±4.99 hours vs. 2.49±1.21 hours, respectively, p<0.001). Total diclofenac consumption and the need for rescue analgesics in the early postoperative period were higher in the control group than in the ESPB group (128.80±56.27 mg vs.178.72±61.67 mg, $P < 0.001$ and 1.61±0.84 vs. 2.22±0.97, respectively, P=0.001). In the ESPB group, the mean number of acetaminophen administrations was 0.71±0.84 and it was 0.98±0.74 in the control group (P=0.047). None of the patients who participated in the study required fentanyl.

There was a weak negative correlation between the 4th and 6th hour VAS value for rest and the range of sensory block level (r=-0.293 and P=0.041, r=-0.298 and P=0.038, respectively). There was a moderately negative correlation between the 6th and 12th hour VAS value for movement and the range of sensory block level (r=-0.404 and P=0.004, r=-0.317 and P=0.027, respectively). There was a moderately negative correlation between the 6th and 12th hour VAS value for cough and the range of sensory block level (r=-0.426 and P=0.002, r=-0.302 and P=0.035, respectively).

The first mobilization time and length of hospital stay were similar between the groups (Table 2). All patients had no difficulty breastfeeding or caring for their infants. Neither nausea or vomiting nor headache was observed in any patient.

Table 3. VAS Scores and Satisfaction Values

Time		Group		
		ESPB (n=49)	Control (n=50)	p-value
2nd hour	VAS rest	0.81±1.39	2.84±2.48	<0.001[a]
	VAS movement	0.84±1.45	3.44±2.70	<0.001[a]
	VAS cough	0.88±1.51	3.64±2.78	<0.001[a]
	Satisfaction	0.88±1.15	2.36±2.15	<0.001[a]
4th hour	VAS rest	2.37±1.48	4.08±2.40	<0.001[a]
	VAS movement	2.45±1.53	5.00±2.31	<0.001[a]
	VAS cough	2.39±1.50	5.02±2.51	<0.001[a]
	Satisfaction	1.00±1.22	2.60±2.31	<0.001[a]
6th hour	VAS rest	2.98±1.53	4.30±2.41	0.002[a]
	VAS movement	3.53±1.68	5.22±2.39	<0.001[a]
	VAS cough	3.53±1.79	5.40±2.48	<0.001[a]
	Satisfaction	1.10±1.50	2.66±2.52	0.001[a]
12th hour	VAS rest	2.71±1.80	3.78±2.49	0.025[a]
	VAS movement	3.12±1.83	4.76±2.57	0.001[a]
	VAS cough	2.98±2.04	4.92±2.73	<0.001[a]
	Satisfaction	1.08±1.72	2.38±2.28	0.001[a]
24th hour	VAS rest	2.04±1.83	1.98±1.83	0.828[a]
	VAS movement	2.49±1.85	2.92±1.68	0.180[a]
	VAS cough	2.31±1.95	3.08±2.06	0.053[a]
	Satisfaction	0.69±1.06	1.54±1.67	0.003[a]

[a]Mann-Whitney U test. Values are presented as mean ± standard deviation.
p<0.05 is taken as statistically significant.
VAS, visual analogue scale; ESPB, erector spinae plane block.

Discussion

This study showed that bilateral ESPB in patients delivered by elective CS under spinal anaesthesia can result in decreased VAS scores, prolonged time until the first analgesic request, decreased usage of rescue analgesics, and increased satisfaction.

Regional anaesthesia is commonly preferred in elective CS because of the adverse effects of systemic drugs on newborns. For postoperative analgesia, the systemic use of opioids should be avoided because they pass into breast milk and may have adverse effects on the newborn.[10] Intrathecal opioids can be added for longer postoperative analgesia; however, they can cause negative effects such as pruritus and respiratory depression.[11] Because of these factors, the combination of regional and spinal anaesthesia has gained popularity. For numerous types of surgical procedures, ESPB has been confirmed to be effective as a part of multimodal analgesia. In a randomized controlled study by Hamed et al.[12] comparing the use of ESPB and intrathecal morphine (ITM) in analgesic treatment after CS, bilateral ESPB was administered at the end of the operation in the ESPB group. During the postoperative period, the ITM group reported higher rest and cough VAS scores.[12] The ESPB group showed significantly reduced rest and cough VAS scores compared with the control group in a randomized study conducted by Dostbil et al.[13] Similarly, in our research, the ESPB group exhibited substantially reduced rest, movement, and cough VAS scores at the 2nd, 4th, 6th, and 12th h. Regarding VAS scores, there was no significant difference between the groups at the 24 h evaluation. This may be because the impact of ESPB reduced after 24 h, and diclofenac and acetaminophen were used instead of opioids as rescue analgesics.

Pain after CS may be caused by the somatic fibers of the incision, uterine incision and contraction, and the peritoneum's interaction with the uterus; therefore, analgesic activity is required to cover the thoracic, lumbar, and sacral nerve roots. ESPB stands out in post-abdominal surgery pain management because the dissemination of local anaesthetic is not limited to the injection level but can expand to the upper and lower vertebral levels. ESPB can extend to the sympathetic chain, dorsal and ventral ramus of the spinal nerves, and epidural and paravertebral areas.[7] Therefore, the somatic and visceral components of abdominal innervation that originate from the lower thoracic levels can be blocked by ESPB.[8,14] Boules et al.[15] and Malawat et al.[16] compared the analgesic effects of transversus abdominis plane block (TAPB) and ESPB following CS, and VAS scores were lower in the ESPB groups. TAPB is effective for treating abdominal wall-related somatic pain with little or no visceral analgesia because of its impact on thoracolumbar nerves.[17] Because of its impact on visceral nerves, ESPB provides more effective analgesia than TAPB.

ESPB spread may not proceed in living organisms, as in cadaveric studies; the amount of drug administered, active muscle tone, and intra-abdominal pressure may impact this spread. According to a study on the spread of local anaesthetics and cutaneous sensation loss following ESPB in volunteers, local anaesthetics consistently spread to the dorsal ramus, paravertebral region, and neural foramina, but epidural space spread was not always observed.[18] The analgesic effects of unilateral ESPB can be bilateral.[19] Due to the pneumoperitoneum and position in laparoscopic procedures, bilateral local anaesthetic spread may occur following unilateral ESPB.[20] Unilateral ESPB applied via a catheter at the lumbar vertebrae level provided bilateral analgesia during labor.[21] In the literature, a single shot bilateral ESPB with 20 mL solution caused sensory block at a mean of 7.36±0.9 dermatome levels, ranging from 6 to 9.[14] ESPB spread is susceptible to variation based on the solution volume and location of administration.[7] Although previous studies have noted an increase in the cephalocaudal spread with higher applied volume,[22] the precise relationship between spread and volume remains obscure. Drug distribution observed because of ESPB is not always correlated with sensorial block.[18] In our study, although the sensory extent of ESPB was recorded after the spinal anaesthesia had worn off, it may not have been correctly measured. It was observed that as the extent of the sensory block level expanded, patients' VAS scores decreased. Considering these findings, it is necessary to conduct prospective research on this topic because additional variables may alter drug distribution. Consequently, the analgesic effectiveness of plane blocks can be revealed with greater clarity.

Our secondary aim was to evaluate the effects of bilateral ESPB on analgesic use and patient satisfaction during the postoperative period. Opioid usage was considerably reduced in the ESPB group compared with the control group in the study by Aygun et al.,[23] evaluating the postoperative analgesic effects of USG-guided ESPB in post-CS patients. Likewise, we observed that the ESPB group consumed fewer analgesics. In a meta-analysis evaluating the effect of USG-guided ESPB following abdominal surgery, ESPB reduced opioid consumption in the first 24 h and prolonged the first analgesic usage time.[24] Hamed et al.[12] found that ESPB provided more long-lasting analgesia than intrathecal morphine. The mean time for the first analgesic usage was 12±2.81 hours in the ESPB group. In our study, the mean time for the first analgesic usage in the ESPB group was 5.03±4.99 hours. This may be the result of using fentanyl as our intrathecal opioid and administering nearly half the amount of bupivacaine used by Hamed et al.[12] Increasing the amount of local anaesthetic used in ESPB may lead to more effective and long-lasting analgesia, but this can cause motor block[25] and other local anaesthetic complications.

Postoperatively, patients with less pain can readily return to their normal activities. This is more crucial for mothers who wish to care for newborns. Our results revealed that patients in the ESPB group were consistently more satisfied. Decreased VAS values exhibited by patients in the ESPB group are a crucial factor in enhancing patient satisfaction. While the ESPB group exhibited lower VAS scores than the TAPB group, Boules et al.[15] found no statistically significant difference in patient satisfaction between the two groups. In a study by Shukla et al.[26] comparing bilateral ESPB and TAPB in patients undergoing hysterectomy, the ESPB group reported higher satisfaction. Patient satisfaction is a complex phenomenon that is affected by many parameters. As mothers' satisfaction increases, their milk production rises, and it becomes better for them to breastfeed and care for their infants.

Because ESPB can be easily performed with USG guidance, it can be a viable alternative when neuraxial anaesthesia cannot be administered, such as in cases of vertebral anomalies or coagulopathy.[27] Patients with a history of nausea and vomiting because of opioids used for postsurgical pain treatment can be candidates for ESPB.[28] A patient who experienced severe post-CS pain after spinal anaesthesia wore off was successfully treated with an ESPB rescue block. The patient's pain score decreased after 20 min, and no additional analgesics were required for approximately 12 h.[29] Adding adjuvant drugs to local anaesthetics can prolong the block duration.

Peripheral nerve block techniques are beneficial in reducing post-CS pain, and these blocks have become an essential component of multimodal analgesia.[30] Neuraxial anaesthesia is frequently preferred for CS. Compared with morphine, intrathecal fentanyl also provides intraoperative analgesia. However, its short duration of action necessitates the administration of additional analgesics during the postoperative period. Regional techniques, combined with acetaminophen and nonsteroidal anti-inflammatory drugs, ensure that the patient may remain IV opioid-free post-CS pain, similar to our study.

Study Limitations

Our research has a few limitations. First, the patients were not blinded. Second, because of the effects of spinal anaesthesia, it is possible that the sensory extent of ESPB was not accurately measured. ESPB can be performed preoperatively, allowing for a more accurate evaluation of sensory extent. We applied ESPB at the end of the surgery because pregnancy makes preoperative application challenging. Therefore, patients could experience the analgesic effects of ESPB for a longer duration when it is performed after surgery. Moreover, the sensory extent was evaluated simultaneously in one plane. The change in extent over time was not evaluated.

Conclusion

Inadequate pain management following CS is detrimental to the mother and the infant's quality of life. In this population, it is essential to minimize IV opioid use and schedule additional analgesic treatment as part of a multimodal analgesic treatment approach. In this regard, USG-guided bilateral ESPB administration with spinal anaesthesia and low-dose local anaesthetics in postoperative pain management is a reliable approach that reduces pain intensity and postoperative analgesic consumption and safely increases patient satisfaction.

Ethics

Ethics Committee Approval: Ethics committee approval was received from the Ankara University Faculty of Medicine, Human Research Ethics Committee (date: 13.02.2020, approval no.: İ2-87-20) before the study execution.

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

Author Contributions: Concept - B.Ş., A.U.; Design - B.Ş., S.K.E., A.U.; Supervision - O.B., A.U.; Materials - B.Ş., S.K.E.; Data Collection and/or Processing - B.Ş., V.B., B.V.; Analysis and/or/Interpretation - B.Ş., V.B., B.V.; Literature Review - B.Ş., O.B., V.B.; Critical Review - O.B., S.K.E., A.U.

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

Funding: No funding was received for conducting this study.

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DOI: 10.4274/TJAR.2024.241609

Original Article
Paediatric Anaesthesia

Turkish Journal of Anaesthesiology & Reanimation

Turk J Anaesthesiol Reanim 2024;52(3):101-106

The Ventilatory Changes of Pediatric Peroral Endoscopic Myotomy Patients

Mete Manici[1], Agah Rauf İşgüzar[2], Umut Deniz Adanur[1], Yavuz Gürkan[1], Muhammed Selman Söğüt[1], Fatih Aslan[3], Çiğdem Arıkan[4]

[1]Koç University Hospital, Clinic of Anaesthesiology and Reanimation, İstanbul, Turkey
[2]University Hospital of Derby and Bourton, Department of Anaesthesiology and Reanimation, Derby, United Kingdom
[3]Koç University Hospital, Clinic of Gasroenterology and Hepatology, İstanbul, Turkey
[4]Koç University Hospital, Clinic of Pediatrics, İstanbul, Turkey

Cite this article as: Manici M, İşgüzar AR, Adanur UD, et al. The Ventilatory Changes of Pediatric Peroral Endoscopic Myotomy Patients.. *Turk J Anaesthesiol Reanim.* 2024;52(3):101-106.

Abstract

Objective: Peroral endoscopic myotomy (POEM) has proven to be a successful treatment method for achalasia in both adult and pediatric patients. Yet, there is a lack of evidence for anaesthetic management of pediatric patients who underwent POEM procedure. In this study, we aim to present perioperative and postoperative management strategies for pediatric patients with achalasia from in anaesthesia aspect.

Methods: Medical records were reviewed for 16 pediatric patients at a single center who underwent POEM procedure for achalasia between 2017 and 2020. Patients' data regarding demographics, preoperative diet, body mass index, perioperative monitoring and vitals, airway management, anaesthesia maintenance, mechanical ventilation settings duration of recovery, length of stay, pain management and adverse events were evaluated.

Results: The study cohort included 7 female and 9 male patients with a mean age of 5.5 years. Anaesthesia maintenance was provided with 0.8-1.2 minimum alveolar concentration sevoflurane in a 40-60% O2-air mixture, Remifentanil infusion and bolus doses of Rocuronium. The median age was 3 years for patients ventilated in pressure controlled ventilation mode and 10 years in volume controlled ventilation mode. Respiration rate and minute ventilation were adjusted to maintain end tidal carbon dioxide (ETCO2) below 45 mmHg. Needle decompression was applied for 14 patients (87.5%) for treatment of capnoperitoneum. The mean procedure duration and recovery room duration were 66 (±22.9) minutes and 62 (±21) minutes, respectively. Postoperative pain management is provided with paracetamol and tramadol in total 8 patients (50%). There was no adverse event during postoperative period and all patients discharged in a mean time of 3 days.

Conclusion: POEM has demonstrated encouraging outcomes in terms of safety and effectiveness in pediatric patients. Due to challenging nature of the pediatric patients, it is important to acknowledge that the procedure requires specialized anaesthesia management. Management of perioperative complications of increased ETCO2 requires understanding the physiologic results of pneumo-mediastinum and pneumo-peritoneum. Beside the known anaesthetic management strategies, a tailored approach should be adopted for each patient. Further investigations should be conducted to develop standardized management.

Keywords: Anaesthesia complications, general anaesthesia, peroral endoscopic myotomy

Main Points

- Peroral endoscopic myotomy in pediatric patients.
- Peak airway pressures.
- Pneumo-mediastinum and pneumo-peritoneum.

Corresponding author: Mete Manici, e-mail: mmanici@kuh.ku.edu.tr

Received: May 03, 2024 Accepted: July 01, 2024

Introduction

Achalasia is a motility disorder of the esophagus, characterized by inadequate relaxation of the lower esophageal sphincter (LES) and loss of peristalsis. It manifests with vomiting, regurgitation, recurrent cough, chest pain and weight loss in children. Untreated achalasia might lead to serious complications like megaesophagus, aspiration pneumonia and esophageal rupture. Treatment options include endoscopic pneumatic balloon dilation, Botulinum toxin injection and Heller myotomy.[1] Treatment of children with achalasia has evolved in recent years with the introduction of peroral endoscopic myotomy (POEM). In 2010 Inoue et al.[2] described POEM as a less invasive procedure to disrupt LES to improve food passage. It is myotomy of the circular esophageal muscle fibers endoscopically during a submucosal tunnel.

Although it is a fairly reliable and effective procedure, anaesthetic management of POEM introduces serious challenges for the anaesthesiologists.[3-5] Carbon dioxide insufflation of esophagus combined with submucosal dissection and myotomy may lead to capnoperitoneum, pneumothorax, pneumomediastinum, subcutaneous emphysema, hypercarbia and increased airway pressure. Impaired esophageal emptying might result in aspiration of esophageal contents. Handling these problems is challenging in young children, especially in infants and requires experience. Current clinical recommendations are based on retrospective case series.[6-9] However, there are no case series involving pediatric patients. Therefore, we conducted this retrospective cohort study to investigate the perioperative complications and anaesthetic management of 16 pediatric patients with achalasia who underwent POEM.

Methods

After approval from Research Ethics Committee of Koç University (approval no.: 2021.433.IRB1.125, date: November 26, 2021), records of patients under 18 years old who underwent POEM procedure were examined. Patient's age, weight, body mass index (BMI) and hospitalization duration were obtained from patient charts. Peroperative monitoring and mechanical ventilation data was extracted from the anaesthesia records. These included heart rate, pulse oximetry, noninvasive blood pressure and end tidal carbon dioxide ($ETCO_2$) measurements recorded at five minutes intervals and ventilation parameters, such as peak airway pressure (Ppeak), ventilation mode and respiration rate. Peak pressure and $ETCO_2$ recorded in three instances as initial (in.), maximum (max.) and before extubation (end.) levels. Since it was a retrospective study, plato pressure, PEEP and compliance could not be accessed. Capnoperitoneum, pneumothorax, subcutaneous emphysema and intraabdominal needle decompression instances and other peroperative complications were also obtained from the anaesthesia recordings.

It is performed endoscopically under general anaesthesia (Figure 1). During the procedure, a mucosal incision is made above LES. A submucosal tunnel is created starting at the incision site and ending below the gastroesophageal junction (Figure 2). Through the tunnel, myotomy of the circular esophageal muscle fibers are performed with an electrosurgical knife (Figure 3). Throughout the procedure, CO_2 is insufflated through the endoscope.

Preparation for POEM

Gastroscopy was performed in all the patients prior to POEM to exclude esophageal candidiasis and ulceration due to stasis related esophagitis. In subjects with esophageal candidiasis, oral antifungals were given for 2 weeks prior to the procedure.

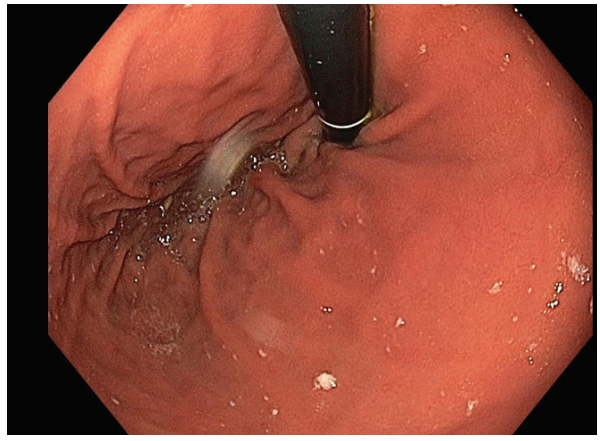

Figure 1. Endoscope, during the procedure

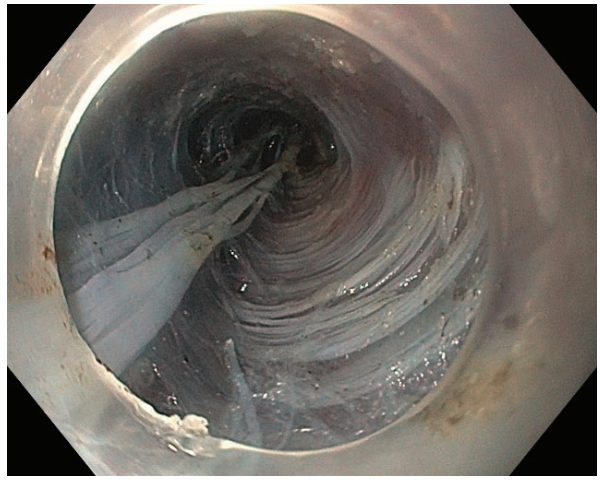

Figure 2. Submucosal tunnel, circular and longitudinal esophageal muscle fibers before myotomy

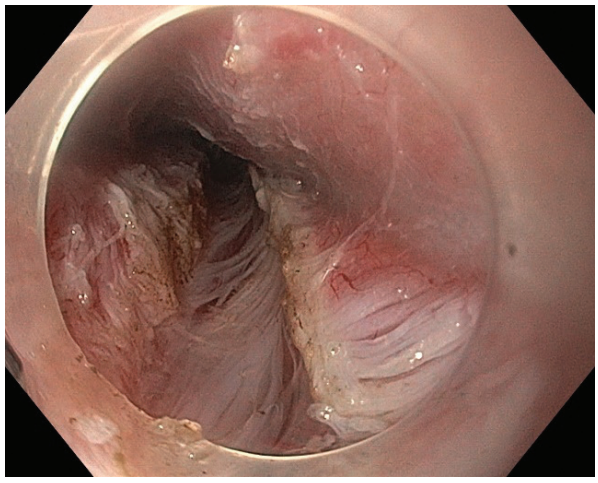

Figure 3. Longitudinal fibers and selective circular myotomy

According to instutional policy four days before the operation, patients were given a liquid diet with no particulates for 3 days. Twenty-four hours before the operation the diet was changed to a clear liquid diet and 6 hours before the operation all oral intake was stopped. No preprocedural esophagoscopy to empty the esophagus was performed.

Proton pump inhibitor therapy (pantoprazole; 0.5 mg kg^{-1} IV, twice daily) and prophylactic intravenous antibiotics (ampicillin/sulbactam or ciprofloxacin for those with penicillin allergy) were initiated before the procedure and continued throughout the hospital stay.

Anaesthesia Induction and Maintenance

Patients were monitored with ECG, pulse oximetry, noninvasive blood pressure measurement initially and additionally with an $ETCO_2$ monitor after intubation. Patients were positioned supine with the upper abdomen, thorax and neck exposed to facilitate observation of abdominal distension and subcutaneous emphysema.

Anaesthesia was initiated by rapid sequence induction (RSI) with propofol (2-3 mg kg^{-1}), fentanyl (0.5-1 µg kg^{-1}) and rocuronium (1 mg kg^{-1}). Cricoid pressure was applied after the loss of consciousness until the cuff of the endotracheal tube was inflated. During the induction of anaesthesia, no regurgitation or aspiration was observed in any of the patients.

Anaesthesia maintenance was provided with 0.8-1.2 minimum alveolar concentration sevoflurane in a 40-60% O2-air mixture. Remifentanil infusion and bolus doses of rocuronium (0.1-0.2 mg kg^{-1}) were administered throughout the procedure. Patients were ventilated in volume controlled ventilation mode (VCV) or pressure controlled ventilation mode (PCV) mode, depending on the attending anaesthesiologist's preference. In PCV mode, inspirium pressures were adjusted when necessary to maintain adequate tidal volume. Respiration rate and minute ventilation were adjusted to maintain $ETCO_2$ below 45 mmHg. There have been no hemodynamic changes requiring inotropic medication during either induction or maintenance

Drugs and doses used for preoperative sedation, induction and maintenance of anaesthesia, perioperative analgesia and others were obtained. Narcotic analgesic doses were converted to morphine equivalents.

While POEM is generally considered safe and effective, there are certain patient groups for whom POEM might not be suitable in an endoscopy unit and who may require operating room conditions. Patients with complex anatomy or who have undergone prior surgeries in the upper gastrointestinal tract may have adhesions or altered anatomy that makes it difficult to perform POEM safely in an endoscopy unit. In such cases, the procedure may be better suited for an operating room where there is more space and equipment available. Patients with significant comorbidities such as severe cardiopulmonary disease or bleeding disorders may benefit from the controlled environment of an operating room where additional medical support and resources are readily available.

If a patient requires concurrent procedures along with POEM, such as laparoscopic fundoplication for reflux disease or a gastric procedure, performing these in an operating room may be more practical and efficient. Patients with high-risk features such as large esophageal diverticula or severe esophageal strictures may require additional interventions or monitoring that are more easily managed in an operating room environment.

Ultimately, the decision regarding the appropriate setting for performing POEM depends on various factors including patient-specific characteristics, procedural complexity, and available resources and expertise. The treating physician, in consultation with the patient and other healthcare providers, will determine the most suitable setting for performing POEM on a case-by-case basis.

Management of Procedural Complications

Upper abdominal distension, elevated $ETCO_2$ and Ppeak were initially managed by decompressing the stomach by suctioning with the endoscope. When this failed to lower the $ETCO_2$ and/or Ppeak, and when significant upper abdominal distension was observed, needle decompression of the intraabdominal cavity was performed by the gastroenterologist. The median Ppeak value and peak airway pressure were recorded.

After the myotomy, paracetamol 10 mg kg^{-1} IV and narcotic analgesics were administered for analgesia. The mean

narcotic analgesic dose converted to Morphine equivalent was 0.05 mg kg^{-1}. Paracetamol 10 mg kg^{-1} four times each day was administered until the discharge from the hospital.

Results

From June 2017 to September 2020, 16 patients under the age 18 underwent POEM procedure in our hospital. Median age was 5.5 with a range of 1-16 years (18-199 months) and 46% of the patients were males. Median BMI was 15.3 (12.5-27.1) kg m^{-2} 6 patients (40%) were ventilated in volume control mode and 10 (60%) in pressure control mode. Anaesthesiologists preferred PCV mode in younger patients. The median age was 3 (1-6) years for patients ventilated in PCV mode and 10 (3-16) years in VCV mode.

The median Ppeak value after the induction (inPpeak) was 24.5 cmH_2O with a range of 15-34 cmH_2O (Table 1). During the procedure Ppeak pressure of 11 patients were found higher than the Pin (69%).

$ETCO_2$ increased in all cases. In 10 cases (62%) it was above 45 mmHg. The median increase was 7.5 mmHg with a range of 1-23 mmHg, which is difference between max and min $ETCO_2$. The median of max $ETCO_2$ was 45.5 (33-60) mmHg and the median of $\Delta ETCO_2$ was 7.5 (1-23) mmHg. Table 2 shows the summary of $ETCO_2$ levels among ventilation modes.

Capnoperitoneum was observed in all 16 patients as upper abdominal distention that persisted after suctioning of the stomach. Fourteen patients required needle decompression of the intraabdominal cavity due to a persistent increase of Ppeak or $ETCO_2$ or observation of significant upper abdominal distension. Among these 14 needle decompressions, 9 of them were performed due to an increase of $ETCO_2$, 1 due to the increase of Ppeak, 1 due to increases of both $ETCO_2$ and Ppeak and 3 due to significant upper abdominal distension. Out of 10 patients who had elevated $ETCO_2$ before the needle decompression, 6 had $ETCO_2$ levels between 45 and 50 mmHg, 4 above 50 mmHg. $ETCO_2$ decreased after the decompression in all of the cases with $ETCO_2$ >50 mmHg, whereas in 3 (50%) cases with $ETCO_2$ between 45 and 50 mmHg.

The only patient who required needle decompression solely for high Ppeak was decompressed when Ppeak was 35 cmH_2O and remained at the same level after decompression. No complications related to needle decompression such as bleeding, bowel injury or peritonitis were observed in any of the patients.

Overall, 10 (71%) out of 14 decompressions were effective in improving the parameter that led to the need for decompression. Median ages of the patients with successful decompressions were lower than the ones with unsuccessful decompressions [49 (16-148) vs 182 (94-200) months respectively].

All patients had subcutaneous emphysema of the neck and upper thorax during the procedure. The diagnosis was performed by detection of crepitus and swelling of the neck and chest wall. No patient had emphysema below the chest or above the neck. In all cases emphysema was self-limiting and no complications such as dyspnea or hypoxemia were observed after extubation.

One patient has been inadvertently extubated during the procedure while removing the endoscope. The procedure was stopped and the patient was intubated again without any complications.

The mean procedure duration was 66.9 (22.9) minutes. The mean duration of anaesthesia from induction to extubation was 97.5 (31) minutes. All patients were extubated in the endoscopy unit without any emergence complications.

Table 1. Perioperative Airway Pressures During POEM Procedures

Mode	inP_{peak}	$maxP_{peak}$	ΔP_{peak}
PCV	22.5 (15-28)	27 (18-40)	4.5 (2-12)
VCV	25.5 (17-34)	26 (17-35)	0.5 (0-3)

inP_{peak}, peak airway pressure after induction of anaesthesia; $maxP_{peak}$, maximum peak airway pressure during the procedure; ΔP_{peak}, $maxP_{peak}$ - inP_{peak}; all units are in cmH_2O, data represented as median (range).
POEM, peroral endoscopic myotomy; PCV, pressure controlled ventilation mode; VCV, volume controlled ventilation mode.

Table 2. Perioperative $ETCO_2$ Levels and Ventilation Modes

Mode	$inETCO_2$	$maxETCO_2$	$\Delta ETCO_2$
PCV	38.5 (35-50)	47.5 (40-60)	9 (1-22)
VCV	33 (31-45)	45.5 (33-55)	7 (1-23)

$inETCO_2$, $ETCO_2$ after induction of anaesthesia; $maxETCO_2$, maximum $ETCO_2$ during the procedure; $\Delta ETCO_2$, $maxETCO_2$ - $inETCO_2$, all units are in mmHg, data represented as median (range).
$ETCO_2$, end tidal carbon dioxide; PCV, pressure controlled ventilation mode; VCV, volume controlled ventilation mode.

Discussion

In our case series, regardless of ventilation strategies, $ETCO_2$ values increased during the procedure, due to mediastinal and peritoneal absorption, increasing the minute ventilation does not lower the $ETCO_2$, if abdominal distension is observed, needle decompression of the intraabdominal cavity can be performed. The threshold of $ETCO_2$ value was determined by the attending anaesthesiologist's discretion. When $ETCO_2$ >50 mmHg, 100% of needle decompressions lowered the $ETCO_2$ whereas when $ETCO_2$ was between 45 and 50 mmHg this

ratio was 50%. Although this suggests that the threshold should be closer to 50 mmHg, further research is needed to determine the appropriate $ETCO_2$ threshold in pediatric patients. However, complications like bleeding, bowel perforation and peritonitis should be taken into account. While there is no consensus on $ETCO_2$ threshold for needle decompression in the literature, $ETCO_2$ > 50 mmHg was proposed as a threshold in two studies on adults.[10,11] If the problem is not resolved with needle decompression, the procedure is stopped and the $ETCO_2$ level is expected to return to normal.

The first concern in the anaesthetic management of patients undergoing POEM procedures is the risk of aspiration during the induction of anaesthesia. Some authors suggest preprocedural esophagoscopy to remove esophageal content.[3,7,8] while others argue that this intervention itself carries its own risk of aspiration.[6,9] Esophagoscopic cleaning is especially important in patients with megaesophagus which is seen up to 10% of patients with disease duration longer than 10 years.[12-15] Since disease duration in pediatric patients is lower than in adults, megaesophagus is less likely to develop in children. Furthermore, preprocedural esophagoscopy is performed in awake or lightly sedated patients to minimize the risk of aspiration. This limits its use in pediatric patients.

As expected, none of the patients in this case series had megaesophagus and no preprocedural esophagoscopy was performed. RSI with cricoid pressure was used in all cases without any regurgitation or aspiration. However, in cases with megaesophagus, preprocedural esophagoscopy might be safer than RSI with cricoid pressure.

Pediatric patients may have smaller anatomy, which can make the procedure technically challenging and the esophageal wall in pediatric patients may be thinner and more delicate, increasing the risk of inadvertent perforation during the procedure. Pediatric patients may require specialized anaesthesia management due to their age and size, which adds complexity to the procedure. Children may have difficulty communicating symptoms postoperatively, making it challenging to assess their recovery and manage any complications.

Performing a POEM procedure on a pediatric patient in an endoscopy unit requires careful consideration of several factors, including anaesthesia. POEM procedures are typically performed under general anaesthesia to ensure the patient is unconscious and unable to feel pain during the procedure. It's essential to have an anaesthesiologist experienced in pediatric anaesthesia present during the procedure. Pediatric patients have unique physiological and pharmacological considerations that require specialized expertise. Pediatric patients may require specialized airway management techniques, such as the use of smaller endotracheal tubes or supraglottic devices, to maintain a clear airway and adequate ventilation during anaesthesia. Continuous monitoring of vital signs, including heart rate, blood pressure, oxygen saturation, and end-tidal carbon dioxide, is essential throughout the procedure to ensure the patient's safety. Adequate intravenous access should be established before the procedure to administer medications and fluids as needed during anaesthesia. A thorough preoperative evaluation of the patient's medical history, physical examination, and laboratory tests should be conducted to assess the patient's overall health and identify any potential risk factors. A tailored anaesthesia plan should be developed based on the patient's age, weight, medical history, and the specific requirements of the POEM procedure. Adequate post-anaesthesia care should be provided to ensure the patient safely recovers from anaesthesia and any potential side effects or complications are promptly addressed. The endoscopy unit should be equipped with pediatric-sized equipment and supplies, including endoscopes, monitors, and anaesthesia delivery devices, to accommodate the needs of pediatric patients. Collaboration between gastroenterologists, anaesthesiologists, nurses, and other healthcare professionals is essential to ensure the safe and successful performance of POEM procedures in pediatric patients.

In total, there were 14 needle decompressions performed which correspond to 87.5% of the patients in this case series. In the previous 3 studies comprising a total of 739 adult patients, needle decompressions were performed in 126 (17.1%) of patients.[13] Higher incidence in our study might be due to a lower threshold of $ETCO_2$ used in 6 of the cases. However, the remaining indications for decompression ($ETCO_2$ > 50 mmHg, Ppeak ≥ 35 cmH_2O and significant upper abdominal distension) still amounts to 8 (50%) of the cases. This difference between adults and children is most likely due to the thinner muscle barrier in the esophageal wall leading to easier diffusion and escape of CO_2 to the mediastinum and intraabdominal cavity.

In all previous studies on anaesthesia of POEM, inferences were made on the $ETCO_2$ monitoring and complications in adult patients. In this study, better information was gained about $ETCO_2$ monitoring and complications in pediatric cases.

Conclusion

During the POEM procedure, end-tidal CO_2 rises in all cases and needle decompression of abdominal cavity might be required. $ETCO_2$ and Ppeak thresholds for needle decompressions need to be determined in further studies.

Ethics

Ethics Committee Approval: This study approved by Research Ethics Committee of Koç University (approval no.: 2021.433.IRB1.125, date: November 26, 2021).

Informed Consent: Retrospective study.

Author Contributions: Surgical and Medical Practices - M.M., A.R.İ., U.D.A., Y.G., M.S.S., F.A., Ç.A.; Concept - M.M., A.R.İ., Y.G., M.S.S.; Design - M.M., A.R.İ., Y.G., M.S.S.; Data Collection and/or Processing - U.D.A.; Analysis and/or/Interpretation - U.D.A.; Literature Search - M.M., U.D.A., F.A., Ç.A.; Writing - M.M., A.R.İ., U.D.A., Y.G., M.S.S.

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

Funding: No funding was received for conducting this study.

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DOI: 10.4274/TJAR.2024.241426

Original Article
Perioperative Care

Turkish Journal of Anaesthesiology & Reanimation

Turk J Anaesthesiol Reanim 2024;52(3):107-112

How to Prevent Ventilator-Induced Lung Injury in Intraoperative Mechanical Ventilation? A Randomized Prospective Study

Mesut Türk[1], Furkan Tontu[2], Sinan Aşar[3], Nalan Saygı Emir[3], Gülsüm Oya Hergünsel[3]

[1]Ağrı Training and Research Hospital, Clinic of Anaesthesiology and Reanimation, Ağrı, Turkey
[2]University of Health Sciences Turkey, Başakşehir Çam and Sakura City Hospital, Clinic of Anaesthesiology and Reanimation, İstanbul, Turkey
[3]University of Health Sciences Turkey, Bakırköy Dr. Sadi Konuk Training and Research Hospital, Clinic of Anaesthesiology and Reanimation, İstanbul, Turkey

Cite this article as: Türk M, Tontu F, Aşar S, Saygı Emir N, Hergünsel GO. How to Prevent Ventilator-Induced Lung Injury in Intraoperative Mechanical Ventilation? A Randomized Prospective Study. *Turk J Anaesthesiol Reanim.* 2024;52(3):107-112.

Abstract

Objective: Intraoperative mechanical ventilation practices can lead to ventilator-induced lung injury (VILI) and postoperative pulmonary complications in healthy lungs. Mechanical power (MP) has been developed as a new concept in reducing the risk of postoperative pulmonary complications as it considers all respiratory mechanics that cause VILI. The most commonly used intraoperative modes are volume control ventilation (VCV) and pressure control ventilation (PCV). In this study, VCV and PCV modes were compared in terms of respiratory mechanics in patients operated in the supine and prone positions.

Methods: The patients were divided into 4 groups (80 patients), volume control supine and prone, pressure control supine and prone with 20 patients each. MP, respiratory rate, positive end-expiratory pressure, tidal volume, peak pressure, plato pressure, driving pressure, inspiratory time, height, age, gender, body mass index, and predictive body weight data of the patients included in the groups have been obtained from "electronic data pool" with Structured Query Language queries.

Results: The supine and prone MP values of the VCV group were statistically significantly lower than the PCV group (*P* values were 0.010 and 0.001, respectively).

Conclusion: Supine and prone MP values of the VCV group were calculated significantly lower than the PCV group. Intraoperative PCV may be considered disadvantageous regarding the risk of VILI in the supine and prone positions.

Keywords: Lung injury, mechanical power, mechanical ventilator, perioperative care, prone position, supine position

Main Points

- Intraoperative mechanical ventilation can cause ventilator-induced lung injury (VILI).
- Increased mechanical power may be associated with postoperative pulmonary complications.
- Volume control mode may have some advantages over pressure control mode in reducing intraoperative VILI.

Introduction

Although mechanical ventilation is a life-saving intervention, it can lead to ventilator-induced lung injury (VILI). VILI is the damage caused by positive pressure ventilation that starts with the use of mechanical ventilators.[1] Many factors cause VILI such as tidal volume, driving pressure, flow, respiratory rate, and positive end-expiratory pressure (PEEP). Mechanical power (MP), which collects these different variables in a single parameter, offers

Corresponding author: Furkan Tontu, e-mail: furkantontu@gmail.com

Received: January 31, 2024 Accepted: July 01, 2024

us new possibilities in predicting VILI at the bedside.[2-6] The MP is above a certain threshold causes damage ranging from pulmonary parenchymal rupture to severe inflammation and edema.[5,7] Also, higher MP values are associated with higher mortality.[8] The protective ventilation strategy in intensive care units is also applied in operating rooms (ORs) to minimize the risk of postoperative pulmonary complications due to VILI.[9] While the volume control mode was at the forefront of the old anaesthesia devices used in the OR, today there are anaesthesia devices with many modes and features, as in intensive care units. This confuses the use of mechanical ventilators in the perioperative period. Although the respiratory parameters (tidal volume, drive pressure and respiratory rate) that contribute to the calculation of MP are similar, lower power values are calculated in volume control ventilation (VCV) mode compared to pressure control ventilation (PCV) in acute respiratory distress syndrome (ARDS) patients.[10] However, in a study comparing the MP values of ventilation modes (VCV and PCV) in patients undergoing laparoscopic surgery, lower MP values were observed in the PCV mode.[11] The hypothesis of our study posits that lower MP values will be observed in the VCV mode in both prone and supine positions for patients with healthy lungs undergoing elective surgery. The primary outcome variable of this study is the MP values of PCV and VCV modes in both prone and supine positions.

Methods

Study Design and Population

This prospective randomized controlled observational clinical study was approved by the University of Health Sciences Turkey, Bakırköy Dr. Sadi Konuk Training and Research Hospital, Clinical Research Ethics Committee (approval no.: 2019-15-04, date: 05.08.2019). The study has been registered on ClinicalTrials.gov (decision number: NCT05814081).

Cervical hernia, lumbar hernia, and lumbar stabilization cases who were operated in the neurosurgery OR of the anaesthesia and reanimation clinic were examined.

The patients (n=80) were divided into four groups;

PCV Group

Subgroup A: PCV Supine Group (20 patients).

Subgroup B: PCV Prone Group (20 patients).

VCV Group

Subgroup A: VCV Supine Group (20 patients).

Subgroup B: VCV Prone Group (20 patients).

All patients were seen one day before the operation, their anamnesis was taken, physical examinations were made, and vital signs and laboratory measurements were evaluated. Informed consent was obtained from all patients before the operation.

Electrocardiogram, non-invasive blood pressure measurement, and SpO_2 monitoring were provided to the patients who were taken to the OR. Vascular access was established with a 20 G intravenous cannula. An infusion of 4-5 mL kg^{-1} h^{-1} balanced fluid (isolyte, ringer lactate) was started. Balanced anaesthesia was applied to all patients. Ventilation of all patients was adjusted to be 45% O_2/air, flow 3 Lt/min, respiratory rate 12 breaths/min, PEEP: 5 cmH_2O, tidal volume 6-8 mL kg^{-1} according to predicted body weight (PBW), inspiration/expiration time ratio 1:2 and SpO_2: 92-96% was targeted. Ventilation was provided in PCV mode with a tidal volume of 6-8 mL kg^{-1} per kilogram of PBW while maintaining constant driving pressure values with the VCV group. All patients were ventilated with the Maquet Flow-i (Sweden) anaesthesia device. Patient data were recorded on the anaesthesia device ventilator at a sweep speed of 20 mm s. At the end of the operation, when spontaneous breathing started, 0.01 mg kg^{-1} atropine and 0.03 mg kg^{-1} neostigmine were administered. The patients were extubated when spontaneous respiration was sufficient. Patients taken to the postoperative recovery room were observed here, and patients with a Modified Aldrete Score above 9 were sent to the service. Other drugs administered during the operation and intraoperative complications were recorded. All respiratory parameters and other vital signs of the patients were recorded electronically at 1-minute intervals with the ImdSoft/Metavision (Canada) software system, which is used as clinical decision support software in our OR.

Respiratory system power values in VCV were calculated with the practical power formula of Gattinoni et al.,[6] which was predefined in the software [$(MP_{vcv(simp.)} = 0.098 \times \Delta V \times RR \times (Ppeak - ½ \times \Delta Pinsp)$]. For PCV, power was calculated with the pressure control practical power equation developed by Becher et al.[12] [$(MP_{pcv(simp.)} = 0.098 \times RR \times \Delta V \times (\Delta Pinsp + PEEP)$].

In VCV, Pplato is calculated automatically by the ventilator with an inspiratory pause. Since such an adjustment cannot be made in PCV due to the variable gas flow, Pplato pressure cannot be obtained without hold maneuvers. However, in the pressure control mode, the Ppeak pressure is considered equal to Pplato, since the driver pressure is fixed in advance.

In PCV, if there is no chronic obstructive pulmonary disease (COPD) and bronchoalveolar fistula and PEEP

is zero EEP, the peak inspiratory pressure (Ppeak) and the alveolar pressure (Pplato) were considered equal because the airway pressure (ΔPinsp) at the end of inspiration was fixed beforehand (Pplato = Ppeak).[13,14]

Pplato = Ppeak = ΔPinsp. In the presence of PEEP, the airway pressure (Ppeak = Pplato) will be ΔPinsp + PEEP at the end of inspiration. DeltaP = ΔPinsp = Pplato-PEEP = Ppeak-PEEP. Cdyn = ΔV/(Ppeak-PEEP) and Cstatic = ΔV/(Ppalto-PEEP), Cstatic = Cdyn = Compliance.

Inclusion Criteria

• American Society of Anesthesiologists I-III risk group patients.

• Patients between the ages of 18-70.

• At least 2 hours of mechanical ventilation time.

Exclusion Criteria

• Patients with COPD or asthma bronchial.

• Patients with a functional capacity of less than 7 Measurement of Exercise Tolerance before Surgery.

• Pregnant and lactating female patients.

• Patients who have had thoracic surgery before.

• Patients with body mass index (BMI) above 35.

• Patients who had hemodynamic instability or desaturation (SpO_2<92%) during the operation.

• Patients with hemorrhage.

Obtaining Patient Data

The respiratory parameters (respiratory rate, PEEP, TVe, Ppeak, Pplato, driving pressure, Tinsp, etc.) of the patients included in the study were taken from the Maquet Flow-i (Sweden) anaesthesia machine and recorded in the "ImdSoft-Metavision/QlinICU Clinical Decision Support Software" (Canada) data pool. Patients' demographic information (height, age, gender, BMI, pedicure body weight) and minute mechanical ventilator data were obtained from the data pool using Structured Query Language queries. Statistical analyses were made after taking the mean values of every parameter in excel.

Statistical Analysis

The homogeneity of the data was evaluated with the Shapiro-Wilk test. Student's t-test and Mann-Whitney U test were used for pairwise comparison of data. The chi-square test was used in the comparison of qualitative data. The Kruskal-Wallis test was used for multiple group comparisons. Mean ± standard deviation (SD) values are based on statistical representation. Values with $P < 0.05$ were considered statistically significant. Statistical analyses were made with the GraphPad Prism V5.01 (San Diego, California, USA) program.

120-minute measurements were made for each patient. A total of 2,400 minutes of measurements were made for 20 patients in each group. Data were saved in ImdSoftMetavision/QlinICU Clinical Decision Support Software. Statistical analyses were performed based on patient averages. In the preliminary statistical analyses performed with 10 patients, the mean MP difference between the VCV group and the PCV group patients was calculated as 2 J/minute and the standard deviation as 2.5 J/minute. The number of patients required to be included in each group was calculated as 20 for the power of the study to be over 80% with alfa 0.5 error and 95% confidence interval (G*power version 3).

Results

In this study, there was no significant difference between the groups' demographic data, [including BMI, operation duration, length of stay in hospital, perioperative fluid admission, and Assess Respiratory Risk in Surgical Patients in Catalonia (ARISCAT) score]. The mean ± SD and *P* values of the groups are shown in Table 1.

A statistically significant difference was observed between the mean values of the supine MPrs, Ppeak, and TVe of the VCV and PCV groups. The *P* values were calculated as 0.010, 0.024, and 0.001, respectively. No statistically significant difference was observed between the mean values of Pplato, Cstatic, Cdyn, and Tinsp.

A statistically significant difference was observed between the mean values of prone MPrs and TVe of the VCV and PCV groups. *P* values were calculated as 0.001 and 0.011, respectively. No statistically significant difference was observed between the mean values of Cstatic, Tinsp, Pplato, Cdyn, and Ppeak.

The supine and prone mean ± SD and *P* values of the above-mentioned respiratory parameters of the VCV and PCV groups are shown in Table 2.

No statistically significant difference was observed between the mean values of MPrs, Ppeak, Pplato, Cstatic, TVe, Cdyn, and Tinsp of the VCV supine and prone groups. This is accurate for the PCV supine and prone groups.

The supine and prone mean ± SD and *P* values of the above-mentioned respiratory parameters of the VCV and PCV groups are shown in Table 3.

Table 1. Demographic Data of Patients

	VCV Prone (n=20) (Mean ± SD)	VCV Supine (n=20) (Mean ± SD)	PCV Prone (n=20) (Mean ± SD)	PCV Supine (n=20) (Mean ± SD)	*P* value
Gender, female (%)	13 (65)	13 (65)	11 (55)	7 (35)	0.1
Weight (kg)	75.5±9.6	71.3±10.9	75.4±10.6	74.7±10.2	0.9
Height (cm)	168±9	168±11	171±9	171±10	0.6
PBW (cm)	64.6±10.9	60.8±10.9	64.2±11.2	66.2±115	0.4
BMI (kg/m^2)	26.5±4.2	25.2±2.3	25.7±.3.6	25.3±2.9	0.07
Operation time (hours)	2.6±0.9	2.9±1.0	3.1±1.7	2.5±0.9	0.4
Length of stay in hospital (days)	3.1±1.2	3.3±1.4	3.2±1.2	3.4±1.6	0.8
Peroperative given fluid (mL)	1640±636	1755±705	1810±1190	1510±786	0.6
ARISCAT score	20±5	22±6	23±8	21±8	0.6

The chi-square test was used to determine the high-risk group category and gender percentage and significance level shown in the table between the groups, and the Kruskal-Wallis test was used for the analysis of other parameters.

ARISCAT, Assess Respiratory Risk in Surgical Patients in Catalonia; BMI, body mass index; PBW, predictive body weight; PCV, pressure control ventilation; VCV, volume control ventilation.

Table 2. Respiratory Parameters

VCV vs. PCV	VCV supine vs. PCV supine (Mean ± SD)	*P* value	VCV prone vs. PCV prone (Mean ± SD)	*P* value
MPrs, J min	7.4±2.0 vs. 9.7±2.7	**0.010**	7.9±2.0 vs. 10.9±3.0	**0.001**
Pplato, cmH_2O	15.1±2.5 vs. 16.0±3.3	0.78	17.4±4.5 vs. 17.4±3.2	0.9
Ppeak, cmH_2O	18.1±3.8 vs. 16.0±3.3	**0.024**	20.1±4.8 vs. 17.4±3.2	0.6
TVe, mL	479±37 vs. 423±58	**0.001**	478±20 vs. 428±59	**0.011**
Cdyn, mL cmH_2O	40.5±12 vs. 43.5±11	0.3	34.8±9.5 vs. 37.1±8.2	0.3
Cstatic, mL cmH_2O	45.7±25.3 vs. 43.5±11	0.3	44.0±15.5 vs. 42.5±10	0.4
Tinsp, second	4.3±0.7 vs. 4.4±0.8	0.4	4.4±0.8 vs. 4.3±1.1	0.2

Statistical analysis of the respiratory parameters of the supine and prone positions of the VCV and PCV groups were performed with the Mann-Whitney U test.

Cstatic, static compliance; Cdyn, dynamic compliance; MPrs, respiratory system mechanical power; PCV, pressure control ventilation; PEEP, positive end-expiratory pressure; Ppeak, peak inspiratory pressure; Pplato, plateau pressure; Tinsp, inspiratory time; TVe, expiratory tidal volume; VCV, volume control ventilation.

Table 3. Respiratory Parameters

Supine vs. prone	VCV supine vs VCV prone	*P* value	PCV supine vs PCV prone	*P* value
MPrs, J min	7.4±2.0 vs. 7.9±2.0	0.5	9.7±2.7 vs. 10.9±3.0	0.1
Pplato, cmH_2O	15.1±2.5 vs. 7.4±4.5	0.07	16.0±3.3 vs. 17.4±3.2	0.61
Ppeak, cmH_2O	18.1±3.8 vs. 20.1±4.8	0.2	16.0±3.3 vs. 17.4±3.2	0.61
TVe, mL	479±37 vs. 478±20	0.8	423±58 vs. 428±59	0.7
Cdyn, mL cmH_2O	40.5±12 vs. 34.8±9.5	0.1	43.5±11 vs. 37.1±8.2	0.06
Cstatic, mL cmH_2O	45.7±25.3 vs. 44.0±15.5	0.07	43.5±11 vs. 42.5±10	0.8
Tinsp, second	4.1±0.4 vs. 4.1±0.4	0.9	4.4±0.8 vs. 4.3±1.1	0.8

Statistical analysis of the supine and prone positions' parameters of the VCV group and the supine and prone positions' parameters of the PCV group were performed with the Mann-Whitney U test.

Cstatic, static compliance; Cdyn, dynamic compliance; MPrs, respiratory system mechanical power; PCV, pressure control ventilation; Ppeak, peak inspiratory pressure; Pplato, plateau pressure; TVe, expiratory tidal volume; VCV, volume control ventilation.

Discussion

In the old anaesthesia devices used in the OR, the VCV mode was at the forefront. Today, there are anaesthesia devices with many modes and features, as in the intensive care units (ICUs). This confuses the use of mechanical ventilators. VCV, PCV, and many different modes are used in ICU. The primary outcome of the study is to calculate and compare the MP values of the PCV and VCV groups in both supine and prone positions.

In this study, the expiratory tidal volume TVe and Ppeak values of the PCV group in the supine position were found to be lower than the values of the VCV group. There was no difference between the Pplato, PEEP, DP values. Although TVe and Ppeak was low in PCV, the MP was calculated higher. The P-V loop where the power is calculated in both ventilation modes is different. The volume control P-V loop is triangular, while the pressure control P-V loop is square. This difference is due to the high inspiratory resistance created by the variable gas flow in the PCV.[15] Again, due to this variable gas flow in PCV, inspiratory resistance values cannot be measured. Therefore, the inspiratory resistances of the two ventilation modes could not be objectively compared. However, the gas flow pattern (decelerating flow) in PCV and the high power calculations measured despite similar respiratory parameters compared to VCV, place PCV at a distinct disadvantage.[16] In addition, in the PCV, rapid transmission of per cycle energy to the lungs in early inspiration may increase the damage.[17] However, the most accurate formula for calculating power in pressure control mode is still controversial. The simplified MPpcv formula used in this study calculates high MP values according to the geometric method.[17] The margin of error in MP calculated by the $MP_{pcv(simp.)}$ formula and the relationship between the decelerating gas flow pattern in PCV and MP need to be clarified. For this reason, the statement that the PCV mode is disadvantageous compared to the VCV mode may have been premature.

In VCV, a higher Ppeak is needed to maintain the same tidal volume set in the supine position, and also in the prone position. This is the reason for the difference in Ppeak values between the two ventilation modes in the prone position. It is also known that in the prone position, since the thoracic wall motion is limited, thoracic compliance decreases and Ppeak values increase.[18,19]

There was no difference in respiratory mechanics values (including MP) between the supine and prone positions in both VCV and PCV modes. In a paper presented at the American Thoracic Society conference in 2018, MP was found to decrease in ARDS patients after a prone position of at least 8 hours.[20] This condition, which is due to alveolar recruitment, is not seen in this patient group with normal lungs in the OR.

There was no difference in the postoperative pulmonary complication score (ARISCAT score) of the VCV and PCV modes in the supine and prone positions. In all groups, the MP values were calculated far below 17 J, which was determined as the threshold MP value for the risk of VILI for patients with healthy lung.[8]

Therefore, the risk of postoperative pulmonary complications is not predicted with the applied MP values.

MP as defined here relates to the inspiratory phase. All the energy accumulated in end-inspiration must be dissipated to the lung tissue and atmosphere when exhalation is complete. It is not clear whether controlling the potentially important expiratory flow will help reduce VILI. However, it is estimated to have a damaging effect in the early expiratory phase.[7] This energy in the early expiratory phase cannot currently be calculated in any ventilator mode.

There was no significant difference between the BMI values of the patient groups.

Study Limitations

Since VCV and PCV modes are frequently compared with arterial blood gases in the literature, blood gas measurements were not evaluated.

Conclusion

It is challenging to ascertain the superiority of one mechanical ventilation mode over another.However, MP values are lower in VCV compared to PCV in both prone and supine positions. In addition, all respiratory mechanics in VCV mode can be obtained easily without the need for hold maneuvers (Pplato, Cstatic, etc.), and learning VCV is simpler.

Ethics

Ethics Committee Approval: This prospective randomized controlled observational clinical study was approved by the University of Health Sciences Turkey, Bakırköy Dr. Sadi Konuk Training and Research Hospital, Clinical Research Ethics Committee (approval no.: 2019-15-04, date: 05.08.2019).

Informed Consent: Informed consent was obtained from all patients before the operation.

Author Contributions: Surgical and Medical Practices - M.T., N.S.E., S.A.; Concept - M.T., F.T., S.A., G.O.H.; Design - M.T., F.T., S.A., G.O.H.; Data Collection and/or Processing - M.T., N.S.E., S.A.; Analysis and/or/ Interpretation - F.T., S.A.; Literature Search - F.T., S.A.; Writing - F.T., S.A., G.O.H.

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

Funding: No funding was received for conducting this study.

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DOI: 10.4274/TJAR.2024.241622

Original Article

Cardiovascular and Thoracic Anaesthesia

Turkish Journal of Anaesthesiology & Reanimation

Turk J Anaesthesiol Reanim 2024;52(3):113-121

Comparison of Propofol and Sevoflurane Anaesthesia in Terms of Postoperative Nausea-Vomiting Complication in Cardiac Surgery Patients Undergoing Enhanced Recovery After Surgery Protocol: A Prospective Randomized Study

Aslıhan Aykut[1], Nevriye Salman[1], Zeliha Aslı Demir[1], Ayşegül Özgök[1], Serdar Günaydın[2]

[1]University of Health Sciences Turkey, Ankara Bilkent City Hospital, Clinic of Anaesthesiology and Reanimation, Ankara, Turkey

[2]University of Health Sciences Turkey, Ankara Bilkent City Hospital, Clinic of Cardiovascular Surgery, Ankara, Turkey

Cite this article as: Aykut A, Salman N, Demir ZA, Özgök A, Günaydın S. Comparison of Propofol and Sevoflurane Anaesthesia in Terms of Postoperative Nausea-Vomiting Complication in Cardiac Surgery Patients Undergoing Enhanced Recovery After Surgery Protocol: A Prospective Randomized Study. *Turk J Anaesthesiol Reanim.* 2024;52(3):113-121.

Abstract

Objective: Postoperative nausea (PN) and vomiting (PONV) in cardiac surgery increases adrenergic stimulation, limits mobilization and oral intake, and can be distressing for patients. The primary aim of our study was to investigate the effect of sevoflurane and propofol anaesthesia on the incidence of PONV in cardiac surgery patients undergoing Enhanced Recovery After Surgery (ERAS) protocol.

Methods: Following ethics committee approval, 62 patients undergoing elective coronary artery bypass surgery with ERAS protocol were included in this prospective randomized study. After standard induction of anaesthesia, Group S received 1.5-2% sevoflurane and Group P received 50-100 μg kg^{-1} min^{-1} propofol infusion as maintenance anaesthetic agent with a bispectral index of 40-50. The incidence of PN and PONV between 0-6 hours (early) and 6-24 hours (late) after extubation was compared as the primary outcome. The incidence of delirium was analyzed as a secondary outcome for similar periods.

Results: In the propofol group, 3 patients were excluded due to postoperative tamponade revision and prolonged mechanical ventilation. PN in the early post-extubation period (29% vs. 7.1%, P=0.031) was significantly higher in Group S. The incidence of delirium was similar between the groups in both periods.

Conclusion: Propofol may reduce the incidence of PN in the first 6 hours after extubation compared with sevoflurane. We believe that this period will be beneficial for gastrointestinal tolerance as it is the period when oral intake is initiated in patients. In conclusion, propofol maintenance in cardiac surgery patients may facilitate patient rehabilitation as part of the ERAS protocol.

Keywords: Cardiac surgery, ERAS, postoperative nausea-vomiting, propofol, sevoflurane

Main Points

- The Enhanced Recovery After Surgery (ERAS) protocol is a set of evidence-based practices that accelerate the healing process of patients. One of these is the initiation of oral intake and transition to physiological nutrition as soon as possible. One of the obstacles to this is postoperative nausea and vomiting (PONV).
- Propofol-based anaesthesia maintenance may be preferred in patients at risk of PONV undergoing cardiac surgery. When PONV decrease, patient rehabilitation becomes easier and this may contribute as a gain within the scope of the ERAS protocol.

Corresponding author: Aslıhan Aykut, e-mail: asli_dncr@hotmail.com

Received: May 14, 2024 Accepted: July 05, 2024

Introduction

Postoperative nausea (PN) and vomiting (PONV) is frequently encountered following general anaesthesia, causing discomfort and complaints in patients.[1] Sometimes PONV can lead to significant postoperative complications such as aspiration pneumonia, increased intracranial pressure.[1,2] It is known that the frequency of PONV is around 80% in high-risk populations and 30% in the general population. Increased medical costs, prolonged hospital stays, and hospital readmissions are common in cases of PONV.[1] Several risk factors have been associated with PONV, including female gender, non-smoking status, previous history of PONV, motion sickness, young age, certain types of surgery, prolonged anaesthesia, use of nitrous oxide, postoperative opioids and volatile anaesthetics.[2,3]

Enhanced Recovery After Surgery (ERAS) is an initiative that aims to develop multimodal, interdisciplinary care to support the perioperative recovery of patients undergoing surgery.[4] This strategy focuses on reducing complications and allowing patients to return to normal activities sooner. ERAS protocols place great emphasis on PONV, which affects 20% to 67% of patients in cardiac surgery, increases adrenergic stimulation, limits mobilization and oral intake, and can be distressing for patients.[5] Within the scope of the ERAS protocol in cardiac surgery, methods such as routine antiemetic treatment, short fasting periods and early nutrition are applied to prevent and/or treat the development of PONV.[6,7]

Another important part of the ERAS protocol is early routine delirium screening in the postoperative period.[6] Studies in non-cardiac surgeries have found very different results on the effects of inhalation and propofol anaesthesia maintenance on the incidence of postoperative delirium.[8,9] The pathogenesis of delirium in cardiac surgery is more complicated with the addition of many factors such as cardiopulmonary bypass (CPB), hypothermia-rewarming, preoperative anxiety, prolonged mechanical ventilation, comorbidities. Optimizing these factors with the Enhanced Recovery After Cardiac Surgery (ERACS) program can exclude confounding factors in the relationship between anaesthesia maintenance and delirium.

To our knowledge, the relationship between PONV and maintenance of anaesthesia in patients undergoing ERAS protocol in cardiac surgery has not been investigated before. It is known that propofol has a direct antiemetic effect, but on the contrary, the risk of nausea and vomiting increases with inhalation anaesthesia.[10] The hypothesis of our study is that the residual effects of anaesthetic agents are evident in the first 24 hours postoperatively, and therefore, anaesthesia with propofol causes less PONV compared to sevoflurane.

The primary aim of our study is to compare the effects of propofol and sevoflurane anaesthesia on PONV complications in patients undergoing coronary surgery who underwent ERAS protocol. In addition, the secondary aim is to determine the relationship between these two different anaesthesia maintenance and postoperative delirium.

Methods

This prospective randomized study was conducted according to Consolidated Standards of Reporting Trials guidelines[11] and approved by the University of Health Sciences Tutkey, Ankara Bilkent City Hospital No. 1 Clinical Research Ethics Committee (approval no.: E1-23-3601, date: 07.06.2023). Study included 62 adult male patients with American Society of Anesthesiologists (ASA) physical status II or III, scheduled for elective on-pump coronary artery bypass grafting (CABG) with median sternotomy under the ERAS program (Figure 1). Emergency surgery, redo or off-pump surgery, intolerance to one of the study drugs, female gender, ejection fraction <%40, obese patients (body mass index >30 kg m^{-2}), history of motion sickness, history of antiemetic use including steroids in the last two weeks, gastro-esophageal reflux disease, neurological disease (e.g., Parkinson's, mental retardation), psychiatric disease (e.g., major depressive disorder, schizophrenia,), failed fascial plan block before induction and lack of informed consent were determined as exclusion criteria. Patients were evaluated at the anaesthesia visit the night before surgery and written informed consent was obtained. In the preoperative period, all patients received peroral pregabalin 150 mg (12 hours before) and intravenous cefazolin sodium 1000 mg (30 minute before) according to the ERAS protocol. Twenty-four hours before surgery, the patients were visited by a physiotherapist and respiratory exercises were implemented. Patients were fasted for 6 hours for solid foods and 2 hours for clear liquids. Also were given 400 mL 12.5% maltodextrin 2 hours before surgery. Maltodextrin solution was also given to diabetic patients, but a different insulin protocol was applied to them with the recommendation of endocrine clinicians.

Before anaesthesia induction, bilateral erector spinae plane (ESP) block (ESP, 40 mL 0.25% bupivacaine, 20 mL) was applied to the patients in the prone position under ultrasound guidance (PHILIPS Affiniti 50 color Doppler ultrasound device, Philips L12-5 50 mm linear array transducer). Local anaesthetic was applied to the lateral T5-6 spinous processes with a single shot method without inserting a catheter, a total of 40 mL on both sides. Afterwards, patients were turned to supine position and pulse oximetry, five-channel electrocardiography, invasive arterial blood pressure and bispectral index monitoring (BIS™, Covidien, MN, USA) were performed. Sensory blockade of ESP block was controlled; failed block was not observed in any patient. Anaesthesia induction was performed with intravenous propofol (2-2.5 mg kg^{-1}), fentanyl (1 µg kg^{-1}), rocuronium (0.8 mg kg^{-1}) and lidocaine (1 mg kg^{-1}).

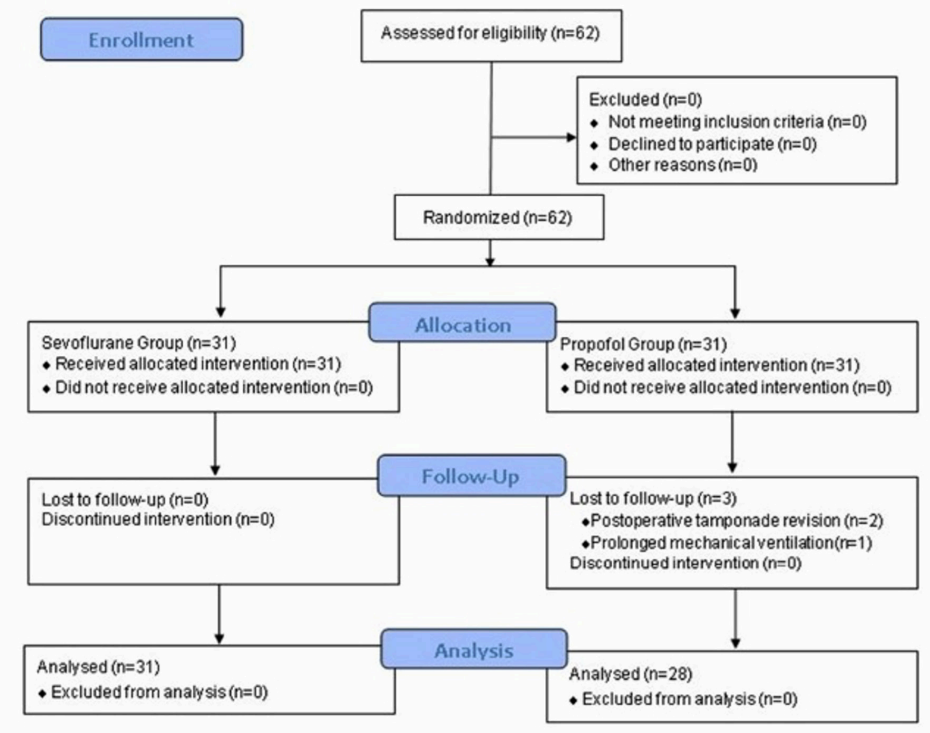

Figure 1. Flow diagram

After endotracheal intubation, ventilation was adjusted to end tidal carbon dioxide 35-40 mmHg and an internal jugular venous catheter was inserted under ultrasound guidance. For the selection of the agent to be used for maintenance of anaesthesia, the patients were divided into groups using a computer-generated random number sequence. Anaesthesia was maintained by titrating 1.5-2% sevoflurane in Group S and 50-100 μg kg^{-1} min^{-1} propofol infusion in Group P to achieve a bispectral index between 40-50. Sevoflurane was continued to be administered during the CPB period by means of a vaporizer integrated into the heart-lung machine. Both groups received a remifentanil infusion of 0.05-to-0.25 μg kg^{-1} min^{-1} throughout the operation, the dose was increased during CPB, rocuronium added when necessary.[12]

After sufficient activated clotting time (>480 s), aortic and venous cannulations were performed and CPB was started with retrograde autologous priming. CPB was performed at moderate hypothermia (28-31 °C). The target pump flow rate was 2-2.5 L min m^{-2}. During the operation, erythrocyte suspension was administered if the hemoglobin concentration was below 7.5 g dL^{-1} and insulin infusion was administered if glucose was above 200 mg dL^{-1}. Lidocaine 1 mg kg^{-1} and magnesium 1500 mg were administered during aortic clamp removal, and heparin was reversed with protamine in a 1:1 ratio at the end of CPB. Paracetamol (1 g), fentanyl 1 μg kg^{-1} and ondansetron 4 mg were given to both groups of patients during sternal closure. Patients were sedated with dexmedetomidine (0.2-0.7 μg kg^{-1} h^{-1}) until extubation in the intensive care unit (ICU). Postoperative analgesia was maintained with intravenous paracetamol (1 g) every 8 hours in both groups. In cases where postoperative analgesia was not sufficient (visual analogue scale >4), tramadol (0.5-1 mg kg^{-1}) was given as a rescue analgesic in both groups.

The primary and secondary outcomes of the study were evaluated in the first 0 to 6 hours (early) after extubation, when the residual effects of anaesthetics are intense, and in the 6 to 24 hours (late) periods, when they are less intense. The surgical team assessing postoperative complications was blinded to the method of intraoperative anaesthesia. Nausea or retching alone was defined as PN. Nausea accompanied by vomiting was defined as PONV. In case of PONV, ondansetron 4 mg (at least 6 hours after the previous dose) was given as a rescue antiemetic. The incidence of PN and PONV was determined by the number of patients who experienced nausea and/or vomiting during the 24-hour. Within the scope of ERAS, oral intake began as soon as the swallowing reflex was restored (often immediately after extubation). Patients were evaluated with the Nursing Delirium Screening Scale (Nu-DESC) in the early and late periods, and patients with a Nu-DESC score ≥2 were also considered delirium.[13] Extubation, ICU and hospitalization times were also recorded.

The minimum required sample size with 95% power at a significance level of 5% was obtained with 28 patients in each group, with reference to a study reporting a PN rate of 13.3% in patients receiving propofol, compared with 53.3% for sevoflurane.[14] Considering the possibility of exclusion, 31 patients per group were included in the study. Since anaesthetics and PONV in ERACS patients is a subject that has not been investigated before, existing studies were used as reference despite limitations. Therefore, we believe that the incidence values of this study will be a reliable reference for subsequent studies.

Statistical Analysis

The IBM SPSS.26.0 software was used for all dates analyzed. Descriptive statistics were presented as absolute numbers (n) and percentages (%) for categorical variables, the median-interquartile range (25^{th}-75^{th} percentiles) for non-normally distributed data, and the mean ± standard deviation for normally distributed data. Categorical variables were compared using χ^2 or Fisher's exact test. Continuous variables between two groups were compared using Mann-Whitney U or independent samples t-test, based on a Kolmogorov-Smirnov test for normality. For the overall incident rate, a Fisher's exact test was used to estimate the relative risk and 95% confidence interval (CI) of incidence. For all analyses, $P < 0.05$ was considered statistically significant.

Results

From May 2023 to June 2023, a total of 62 adult patients who underwent elective CABG with CPB under the ERAS protocol in our cardiac center were included the study, statistical analysis was completed with 59 patients. In the propofol group, 2 patients were excluded from the study due to surgical bleeding requiring surgery in the postoperative period and 1 patient due to the need for mechanical ventilation for more than 12 hours. There was no significant difference between the two groups in terms of demographic data, ASA physical status, comorbidities and preoperative laboratory data (Table 1).

The total intraoperative remifentanil requirement was significantly lower in the sevoflurane group (*P*=0.001). The duration of cross clamp, CPB and operation, total intravenous fluid volume and urine output, blood and blood product transfusion, inotropic and vasopressor medication requirements were similar between the groups (Table 2). There was no difference in terms of extubation time (*P*=0.931), ICU (*P*=0.987), and hospital (*P*=0.973) length of stay (Figure 2). There was no 30-day mortality in the study patients.

Within the first six hours after extubation, PN occurred in 18.6% and PONV in 10.1% of all patients. In the same time interval, the incidence of nausea was significantly lower in the propofol group compared to sevoflurane group (7.1% and 29%, respectively, *P*=0.031). The relative risk and 95% CI for propofol anaesthesia was found as 0.24 (0.05-1.04) for PN (*P*=0.031). In the 6-24 h late period, the incidence of PN was similar between the groups and never encountered vomited (Table 3). As secondary outcome in our study, there was no difference between the groups in terms of delirium scores assessed by Nu-DESC in the early and late periods.

Table 1. Demographic Data, Comorbidities and Preoperative Laboratory Data

	Group P (n = 28)	Group S (n = 31)	*P* value*
Age (years), Mean ± SD	60.50±5.7	61.64±9.3	0.571
BMI (kg m^{2-1}), Mean ± SD	29.14±3.5	28.47±4.5	0.533
ASA physical status (II/III), n (%)	8/20 (28.6/71.4)	12/19 (38.7/61.3)	0.411
Smoker, n (%)	16 (57.1)	11 (35.5)	0.095
Diabetes mellitus, n (%)	12 (42.9)	15 (48.4)	0.670
Hypertension, n (%)	20 (71.4)	20 (64.5)	0.570
COPD, n (%)	4 (14.3)	2 (6.5)	0.320
LVEF (%), Mean ± SD	53.50±8.7	52.93±7.4	0.792
Preoperative laboratory data			
Hemoglobin (gr dL^{-1}), Mean ± SD	13.85±1.8	13.46±2.1	0.447
White blood cell (10^3 uL), Mean ± SD	8.01±2.5	8.88±2.5	0.197
Platelet, (10^3 uL), Mean ± SD	254.00±94.0	248.77±56.5	0.800
HbA1c, (%), Mean ± SD	7.30±2.1	7.18±1.8	0.820
Creatinine, (mg dL^{-1}), Mean ± SD	0.94±0.2	0.99±0.2	0.368

*The independent samples t-test was used for continuous variables; the χ^2 was performed for categorical variables.

ASA, American Society of Anesthesiologists; BMI, body mass index; COPD, chronic pulmonary disease; LVEF, left ventricular ejection fraction; SD, standard deviation.

Table 2. Intraoperative Data			
	Group P (n = 28)	**Group S (n = 31)**	***P* value***
Remifentanil (mg), Mean ± SD	4.12±1.7	2.84±1.0	0.001
Propofol (mg), Mean ± SD	1128.57±363.9	-	-
Sevoflurane (mL), Mean ± SD	-	57.96±31.87	-
CC time (min), Mean ± SD	79.46±27.4	68.16±19.5	0.072
CPB time (min), Mean ± SD	118.07±34.8	104.09±22.4	0.070
Operation time (min), Mean ± SD	322.85±71.6	306.93±60.8	0.360
Crystalloid (mL), Median (IQR)	1625.00 (1500.0-1900.0)	1700.00 (1300.0-2000.0)	0.537
Urine output (mL), Median (IQR)	850.00 (600.0-1200.0)	800.00 (600.0-1100.0)	0.964
Red blood cell transfusion, n (%)			0.799
None	20 (71.4)	23 (76.7)	
1 Unit	2 (7.1)	3 (10.0)	
2 Units	2 (7.1)	2 (6.7)	
3 Units	4 (14.3)	2 (6.7)	
Fresh frozen plasma use, n (%)			0.135
None	26 (92.9)	28 (93.3)	
1 Unit	0 (0.0)	2 (6.7)	
3 Units	2 (7.1)	0 (0.0)	
Platelet concentrates, 1 unit, n (%)	2 (7.1)	0 (0.0)	0.136
Dopamine, n (%)	8 (28.6)	10 (32.3)	0.759
Dobutamine, n (%)	2 (7.1)	3 (9.7)	0.727
Norepinephrine, n (%)	6 (21.4)	6 (19.4)	0.843

*The independent samples t-test and Mann-Whitney U test were used for continuous variables; the χ^2 was performed for categorical variables.
CC, cross clamp; CPB, cardiopulmonary bypass.

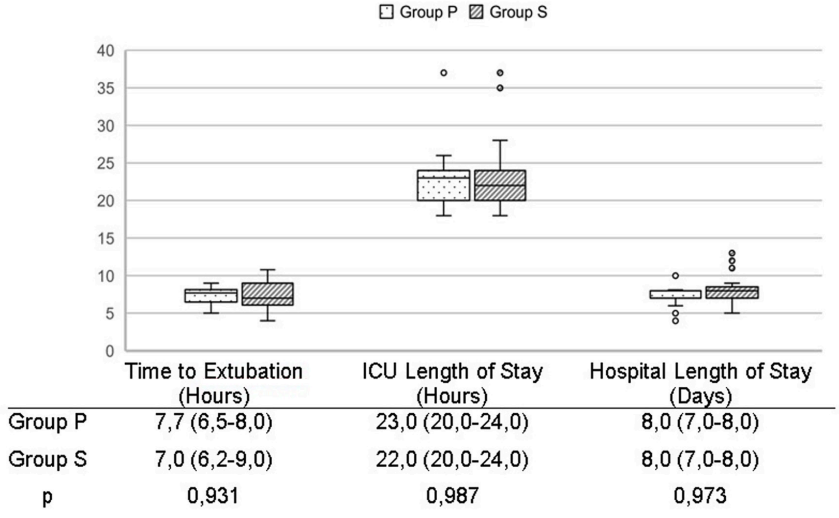

Figure 2. Extubation time, length of ICU and hospital stay of the groups. The Mann-Whitney U test was used for continuous variables (median, IQR); box plot represent data as median values (bold horizontal line) and interquartile range (box)

ICU, intensive care unit; IQR, interquartile range

Table 3. Postoperative Outcomes				
	Group P (n=28)	**Group S (n=31)**	**Relative risk* (95% CI)**	***P* value****
Post-extubation 0-6. hours				
Pain VAS >4, n (%)	10 (35.7)	12 (38.7)	0.94 (0.57-1.54)	0.513
Delirium (Nu-DESC ≥2), n (%)	0 (0)	2 (6.5)	-	0.272
Incidence of nausea, n (%)	2 (7.1)	9 (29.0)	0.24 (0.05-1.04)	**0.031**
Incidence of PONV, n (%)	2 (7.1)	4 (12.9)	0.55 (0.11-2.79)	0.386
Post-extubation 6-24. hours				
Pain VAS >4, n (%)	4 (14.3)	8 (25.8)	0.55 (0.18-1.64)	0.272
Delirium (Nu-DESC ≥2), n (%)	2 (7.1)	3 (9.7)	0.73 (0.13-4.10)	0.549
Incidence of nausea, n (%)	2 (7.1)	6 (19.4)	0.36 (0.08-1.68)	0.162
Incidence of PONV, n (%)	0 (0.0)	0 (0.0)	-	-
Patients requiring rescue analgesics in the first 24 hours, n (%)	10 (35.7)	15 (48.4)	(0.74-2.35)	0.325

*Relative risk in the incidence of PONV for propofol versus sevoflurane.
**χ^2 test or Fisher's exact test.
PONV, postoperative nausea and vomiting; Nu-DESC, nursing delirium screening scale; VAS, visual analogue scale; CI, confidence interval.

Discussion

In this study, lesser nausea was observed in the first 6 h after extubation with the use of propofol in anaesthesia maintenance in patients undergoing CABG with the ERAS protocol, no difference was found in terms of PONV. In the late period (6-24 h), it was not found difference between the groups in parameters PN and PONV. Besides, with regard to delirium, no difference was found between the groups in the early and late periods.

Anaesthesia maintenance in cardiac surgery has been the subject of numerous studies. Organs protection seems to be the most important factor in the choice of anaesthetic management. Volatile anaesthetics protect the myocardium from ischemic damage by decreasing myocardial oxygen demand and increasing oxygen supply through moderate vasodilation.[15] The assumption of improvement in mortality and morbidity due to myocardial protection through preconditioning causes volatile agents to be preferred in cardiac surgery.[16] Similarly, preclinical studies have shown that propofol attenuates myocardial ischemia-reperfusion injury (IRI) by inhibition of the Wnt/β-catenin signaling pathway and blocking autophagy.[17,18] However, myocardial ischemia is inevitable when aortic cross-clamping is performed in on-pump cardiac surgery and its severity depends more on the severity of the underlying disease, duration of cross-clamping and myocardial protection with cardioplegia.[19] Clinical studies have shown that the use of volatile anaesthetics in cardiac surgery has no superiority over propofol in myocardial infarction, hospital readmission, short-term or one-year mortality.[20,21] Ştefan et al.[20] suggest that IRI and mortality in cardiac surgery are too complex to be reduced solely to the choice of anaesthesia regimen. It is more valuable to reveal the relationship between minor outcomes such as nausea and vomiting and maintenance of anaesthesia, rather than discovering highly dependent outcomes such as mortality.

PN is described by patients as the most distressing complication of anaesthesia.[22] The occurrence of PONV is thought to be a multifactorial complication involving operative, anaesthetic, and patient-specific risk factors.[23] In this study, in order to examine the isolated effect of anaesthesia management on PN and PONV, it was adjusted the study group from CABG surgery male patients who underwent ERAS protocol which minimized other risk factors. In scope of this protocol, ESP block and opioid-reducing analgesia method such as paracetamol were applied in all patients. In addition, in the preoperative period, patients were given carbohydrates two hours before surgery to eliminate the effect of catabolism and empty stomach that would cause nausea and vomiting. Routine antiemetics were administered while closing the sternum at the end of the operation. In the light of these nausea and vomiting preventive measures applied to both groups, nausea was seen more frequently in the early period in patients who were maintained with sevoflurane (7.1% vs. 29%).

In a systematic review and meta-analysis, the incidence of PONV following outpatient surgery was found lower in patients receiving propofol than in patients receiving volatils.[24] In a study in which patients at high risk for postoperative PONV were included, the 72-hour cumulative PONV was found 46% in total intravenous anaesthesia group with propofol, 60% in volatile group (isoflurane + nitrous oxide), and the highest PONV was observed in the post-anaesthesia care unit period.[25] Undoubtedly, the

incidence of PONV was found high in that study due to reasons such as the inclusion of high-risk patients, the use of nitrous oxide, and the three-day cumulative incidence. The low incidence of PONV in our study is related to the application of the ERAS protocol, the inclusion of only male patients, the fact that patients were intubated in the first 6 hours when postoperative PONV was highest, and the use of opioid-sparing multimodal analgesia. A Randomized controlled study examining risk factors for PONV, effects of volatile anaesthetics was found to be dose-dependent and also several times riskier than all other PONV risk factors (including lack of routine antiemetic use) in the early postoperative period.[26] In line with this in our study, the incidence of nausea was found higher in the sevoflurane group in the first 6 hours. This may be explained by the pharmacokinetic profile of propofol, where therapeutic anti-emetic plasma levels are unlikely to persist in the late period after anaesthesia administration because of its short half-life.[24] However, although the low incidence of PONV associated with propofol has been attributed to the antiemetic property of propofol, no relationship has been found between PONV and the degree of exposure to propofol, but in contrast, volatile anaesthetics have a pro-emetic effect in proportion to the degree of exposure.[26] Therefore, the question arises whether the difference between sevoflurane and propofol anaesthesia is due to the antiemetic properties of propofol or the emetogenic properties of volatile anaesthetics? In any case, it may be more logical to avoid inhalation anaesthesia instead of adding an antiemetic to prevent PN in high-risk patients.

In cardiac surgery, preoperative oral nutrition support with carbohydrate-based beverages as well as early postoperative feeding is associated with shorter hospitalization and ICU length of stay.[27] Delayed initiation of nutritional support in surgical intensive care patients leads to delayed restoration of gastrointestinal activity and energy deficits.[28] Therefore, early postoperative enteral nutrition is an essential component of the ERAS protocol and, it is recommended to start early oral nutrition after the return of the swallowing reflex is confirmed.[29,30] Decreasing effect of propofol anaesthesia on the incidence of early PN may facilitate patients to start oral nutrition in this period. This may lead to earlier recovery and shorter ICU stay.

As part of the ERAS program, routine postoperative delirium screening is recommended to diagnosed and early treatment.[6] Delirium after cardiac surgery is associated with decreased in-hospital and long-term survival, increased hospital readmission, and poor cognitive and functional recovery.[31] Determining the risk factors of delirium is also important to identify preventable causes. According to various preclinical and animal studies, it has been reported that inhalation anaesthetics cause neurodegeneration, whereas propofol causes less cognitive impairment with a strong anti-inflammatory effect.[32-35] However, in numerous clinical studies postoperative delirium after cardiac surgery has not been found different between patients receiving sevoflurane and propofol anaesthesia.[36-38] Risk factors for delirium after cardiac surgery include advanced age, dementia, prolonged CPB duration, high perioperative transfusion requirement, low preoperative albumin level, high postoperative C-reactive protein concentration and longer ICU stay.[39,40] In our study, there were no confounding factors such as advanced age, emergency surgery and low preoperative albumin and, similar to the literature, postoperative delirium did not differ in patients receiving propofol versus sevoflurane. It was also considered that interventions such as pregabalin administration, multimodal analgesia and early extubation within the scope of the ERAS protocol also can contribute to the low incidence of delirium.

Study Limitations

Since this study was conducted using data from a single center, its generalizability is limited. In our study, PONV was evaluated quantitatively and not graded (present/absent). Although Nu-DESC is assessed by well-trained ICU nurses, the hypoactive form of delirium may have been overlooked because the fully hypoactive form of delirium is generally more difficult to detect than the hyperactive form. Additionally, the study referred for sample analysis included patients with a higher risk of PONV (our patient group was at lower risk). Therefore, studies planned with a larger number of patient groups are needed.

Conclusion

In conclusion, it is expected that small gains in cardiac ERAS applications will accumulate and turn into large gains, therefore, reducing PONV, which is a significant discomfort, by choosing a patient-specific anaesthetic is a valuable result. Propofol-based anaesthesia maintenance may be preferred in patients at risk for PONV who will undergo cardiac surgery. When PONV decreases, patient rehabilitation becomes easier and this may contribute as a gain within the scope of the ERAS protocol.

Ethics

Ethics Committee Approval: This study was approved by the University of Health Sciences Turkey, Ankara Bilkent City Hospital No. 1 Clinical Research Ethics Committee (approval no.: E1-23-3601, date: 07.06.2023).

Informed Consent: Patients were evaluated at the anaesthesia visit the night before surgery and written informed consent was obtained**.**

Author Contributions: Surgical and Medical Practices - A.A., N.S., A.Ö.; Concept - N.S., Z.A.D.; Design - Z.A.D., A.Ö., S.G.; Data Collection and/or Processing - A.A., N.S.; Analysis and/or/Interpretation - A.A., S.G.; Literature Search - Z.A.D., S.G.; Writing - A.A., Z.A.D.

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

Funding: No funding was received for conducting this study.

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DOI: 10.4274/TJAR.2024.241651

Case Report
Turk J Anaesthesiol Reanim

Turkish Journal of Anaesthesiology & Reanimation

Turk J Anaesthesiol Reanim 2024;52(3):122-124

Alternative Hybrid Technique of Intubation Using C-MAC and Yankauer Suction Catheter: Case of A Floppy Supraglottic Mass

Renjith Viswanath[1], Sryma PB[2], Krishnendu S[1]

[1]PSG Institute of Medical Sciences & Research, Department of Anaesthesiology, Tamil Nadu, India
[2]PSG Institute of Medical Sciences & Research, Department of Pulmonary, Critical Care and Sleep Medicine, Tamil Nadu, India

Cite this article as: Viswanath R, PB S, S K. Alternative Hybrid Technique of Intubation Using C-MAC and Yankauer Suction Catheter: Case of A Floppy Supraglottic Mass. *Turk J Anaesthesiol Reanim.* 2024;52(3):122-124.

Abstract

Supraglottic masses can be an anaesthesiologist's nightmare due to the difficult airway scenario and bleeding risk during airway manipulation. Awake fibreoptic intubation is the primary method to secure the airway in such cases. However, most practising anaesthesiologists are not experts at handling the fibreoptic scope, especially in cases with a floppy supraglottic mass where it becomes difficult to displace the mask with the thin flexible bronchoscope. A hybrid technique of intubation in supraglottic masses using Bonfils rigid scope and C-MAC is often described but frequently not available. Here we describe a case of an elderly patient in their 80s presenting with a floppy supraglottic mass where an awake fibreoptic bronchoscope failed to secure the airway. Without access to a rigid Bonfils scope, we intuitively used a C-MAC to visualize the larynx and a yankauer suction catheter to displace the mass and perform a bougie-guided endotracheal intubation.

Keywords: Airway management, bougie, difficult airway, difficult intubation, endotracheal intubation

Main Points

- Supraglottic masses are challenging and need individualized management for safely securing the airway.
- Awake fibreoptic intubation, though gold standard in a difficult airway may not be successful in supraglottic masses due to risks of bleeding and shearing of mass into the airway.
- Appropriate safety measures should be in place while dealing with intubation of supraglottic masses.

Introduction

Awake fibreoptic intubation is the gold standard for securing the airway in difficult airway cases. Supraglottic masses can be extremely challenging to intubate with a flexible bronchoscope using awake intubation. Herein we describe a case with a floppy supraglottic mass that was handled with an alternative dual endoscopy technique using a yankauer suction catheter.

Case Report

A patient in their 80s, a smoker, presented with hoarseness of voice and episodic noisy breathing for 2 months. There was no history of cough, dyspnea or hemoptysis. There was no neck swelling. Airway examination revealed Mallampati class III, normal mouth opening and neck movements. Awake nasoendoscopy showed a floppy

Corresponding author: Renjith Viswanath, e-mail: renjithv2007@gmail.com

Received: June 29, 2024 Accepted: July 05, 2024

supraglottic mass which completely covered the glottic opening with each expiration and showed a small opening during inspiration (Figure 1). There was no vocal cord palsy. Biopsy was planned under general anaesthesia with consent for emergency tracheostomy.

The patient received 1 g paracetamol intravenous, 50 µg dexmedetomidine over 30 minutes, glycopyrrolate 0.2 mg injection and nebulization with 5 mL of 4% lignocaine hydrochloride topical solution via a nebulizer and face mask over 15 minutes, starting 30 minutes before intubation. The oropharynx was topically anaesthetized with four puffs of 10% lignocaine. The ENT surgeon marked the tracheostomy site and was on standby in case of any need for a surgical airway. The patient was started on oxygen at 4LPM using nasal prongs which was continued till intubation. Awake fibreoptic intubation with a 4 mm bronchoscope showed the mass completely obstructing the glottis with expiration, part of the left vocal cord was visible with inspiration.

Displacing the mass with the flexible bronchoscope was attempted but the floppy mass kept falling into the glottis. A modified hybrid technique was tried. Propofol target controlled infusion was started and fentanyl 50 µg bolus was given. Under C-MAC vision, a Yankauer suction catheter was used to gently displace the mass to the right side, pediatric gum elastic bougie was introduced through the yankauer catheter and directed into the glottis by Seldinger technique. The setup of the Yankauer suction catheter with bougie inside is depicted in Figure 1. Yankauer catheter was removed over the bougie and reintroduced to keep the mass displaced to the right side, held in place by the assistant operator while being guided by the C-MAC view. A flexometallic tube of size 6 mm was railroaded over the bougie. Surgery proceeded with resection of the mass.

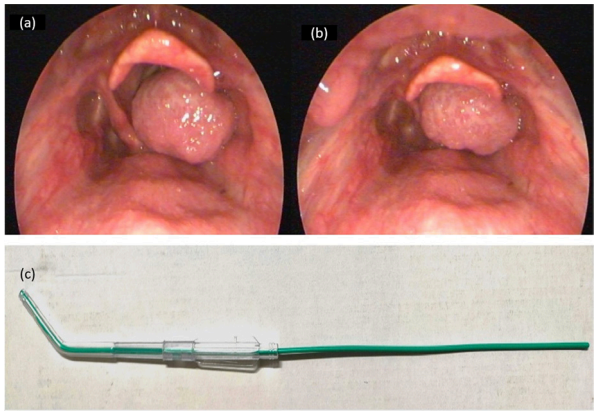

Figure 1. Nasoendoscopy view in inspiration showing small anterior glottic opening (a), view in expiration with mass blocking the entire glottis (b), Yankauer suction catheter with pediatric gum elastic bougie inside. The suction tip was used to displace the mass and direct the bougie into the trachea (c)

The patient was extubated on the table. Histopathology of resected specimen showed moderately differentiated squamous cell carcinoma.

Discussion

This case represents a challenging scenario where the intuitive use of the Yankauer suction catheter avoided a tracheostomy by facilitating intubation. Several safety measures were in place during the procedure. These included avoiding multiple flexible bronchoscopy attempts to reduce the chances of bleeding, carefully displacing the mass laterally before passage of the endotracheal tube to avoid shearing the mass into the airway to avoid a catastrophic complete airway obstruction, choosing a smaller size endotracheal tube and keeping the patient ready for tracheostomy before attempting to secure the airway. The use of neuromuscular blockers was avoided due to fear of mass falling into the glottis causing complete airway obstruction and inability to ventilate.

Manipulating the flexible bronchoscope is challenging in such cases. Navigating the thin flexible bronchoscope through vocal cords with a floppy supraglottic mass may need multiple attempts due to the inability to displace the mass effectively with the thin scope. This can lead to risks of bleeding, and losing the airway. Even if navigating the scope into the glottis is successful, railroading the endotracheal tube over the scope could potentially cause shearing of the mass into the airway and bleeding. The benefit of using a C-MAC in this scenario ensures complete visualization of the mass along with the tip of the endotracheal tube during intubation which is impossible while intubating with a flexible bronchoscope.

Hybrid technique refers to using two devices usually a rigid or flexible endoscope and a video-laryngoscopy (VLS).[1] Video-assisted fibreoptic intubation (VAFI) using VLS and fibreoptic bronchoscope as well as the use of VLS and rigid endoscopes like Bonfils are the usual hybrid techniques of intubation. Hybrid techniques combine the best aspects of airway management. The VLS displaces upper airway structures making endoscope insertion easier. Endoscopes act as steerable stylet in cases with an inadequate glottic view with VLS or when intubation becomes difficult with hyper-angulated blades of VLS. The availability of two different optics helps in cases with bleeding or mucus where both views become complementary in assisting intubation. VAFI has several advantages over VLS demonstrating better glottic view and intubation success rates in cases with difficult airway,[2] however was not useful in our case due to the floppy nature of the mass. Bonfils is a rigid fibreoptic intubating endoscope with a 40-degree curved tip, which acts like a rigid optical stylet over which endotracheal tube is loaded. It is useful in such scenarios by simultaneously

providing vision and the ability to displace supraglottic mass. Being a rigid scope, it can easily navigate soft tissues, lift airway structures and can be used as a method of awake intubation.[3] Because of the limited availability of this scope, cost and the steep learning curve involved in the use of Bonfils scope,[4] innovative solutions used in this case with necessary precautions in place can help in avoiding a surgical airway. The yankauer suction catheter mimics the Bonfils by being a rigid angulated structure through which a pediatric bougie was inserted. In our case, since the glottic view with VLS was adequate, this technique worked as a good substitute enabling smooth intubation.

Conclusion

Though a universal algorithm for the management of difficult airway exists,[5] at times, such an individualized approach helps to ensure optimal outcomes rather than using conventional methods. Hybrid techniques of intubation have advantages in difficult airway scenarios like supraglottic masses where awake fibre optic intubation fails.

Ethics

Informed Consent: Biopsy was planned under general anaesthesia with consent for emergency tracheostomy.

Author Contributions: Surgical and Medical Practices - Concept - Design - Data Collection and/or Processing - Analysis and/or/ Interpretation - Literature Search - Writing - All authors contributed equally to this work.

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

Funding: No funding was received for conducting this study.

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