Journal of The Cardiovascular Thoracic Anaesthesia and Intensive Care Society

GKDA Derg 2025;31(1):32-37
Doi: 10.14744/GKDAD.2025.53486

RESEARCH ARTICLE

Bedside Ductal Clipping in the Neonatal Intensive Care Unit: A Single-centre Experience

Pınar Özdemir Yaşar,[1] Şafak Alpat,[2] Timuçin Sabuncu,[2] Hasan Tolga Çelik,[3] Başak Akça,[1] Mustafa Yılmaz[2]

[1]Department of Anesthesiology and Reanimation, Hacettepe University Faculty of Medicine, Ankara, Türkiye
[2]Division of Pediatric Cardiac Surgery, Department of Cardiovascular Surgery, Hacettepe University Faculty of Medicine, Ankara, Türkiye
[3]Division of Neonatology, Department of Pediatrics, Hacettepe University Faculty of Medicine, Ankara, Türkiye

ABSTRACT

Objectives: Patent ductus arteriosus is a common problem in preterm neonates and may lead to pulmonary hypertension, heart failure, and neurodevelopmental disorders in the long term if not treated in time. Bedside PDA clipping in the neonatal intensive care unit is crucial for achieving satisfactory outcomes. However, the ideal anesthetic management to ensure optimal results remains debatable. Herein, we report our unit's anesthetic management and surgical outcomes.

Methods: Between January 2023 and September 2024, 10 neonates underwent bedside ductal clipping at our unit. Relevant information, including preoperative, operative, and early postoperative data, was retrospectively collected.

Results: A total of 10 patients, with a median age of 33.5 days (27–55.5 days) and a median weight of 1297.5 g (1088.75–2350 g), were included in the study. The median total surgical time, from skin incision to closure, was 41.5 minutes (30.5–49 minutes). All patients were monitored with NIRS in addition to standard monitoring. There was no operative mortality, and postoperative recovery was uneventful. One patient died during hospitalization due to sepsis. The remaining patients stayed a median of 35 days (15–36.75 days) after PDA clipping before discharge.

Conclusion: We concluded that close monitoring of vital parameters, including near-infrared spectroscopy, is of utmost importance for the early detection of intraoperative complications. Thus, we achieved satisfactory early outcomes. However, the long-term neurodevelopmental consequences must be monitored.

Keywords: Bedside, clipping, near-infrared spectroscopy, patent ductus arteriosus

Please cite this article as: "Özdemir Yaşar P, Alpat Ş, Sabuncu T, Çelik HT, Akça B, Yılmaz M. Bedside Ductal Clipping in the Neonatal Intensive Care Unit: A Single-centre Experience. GKDA Derg 2025;31(1):32-37".

Introduction

Patent ductus arteriosus (PDA) is a common problem in very low birth weight (VLBW) preterm neonates and may lead to pulmonary hypertension, heart failure, and neurodevelopmental disorders in the long term if not treated in time.[1,2] Perioperative ductal clipping in preterm neonates requires special attention in anesthesia. With the introduction of relatively high-dose fentanyl in 1981, a marked improvement was achieved, and more stable hemodynamic parameters were obtained throughout the procedure.[3,4] Providing adequate analgesia during PDA clipping improves postoperative recovery by suppressing undesired metabolic and hormonal responses and contributes to a better outcome by reducing complications.

Ongoing real-time assessment of organ perfusion adequacy is critically important in bedside procedures. The existing clinical accessibility of various non-invasive near-infrared spectroscopy (NIRS)-based cerebral oximetry devices signifies a potentially significant advancement in the identification of cerebral ischaemia. Moreover, the use of cerebral oximetry sensors in several tissue beds, including splanchnic, renal, and spinal cord regions, also provides

Address for correspondence: Pınar Özdemir Yaşar, MD. Hacettepe Üniversitesi Tıp Fakültesi, Anesteziyoloji ve Reanimasyon Anabilim Dalı, Ankara, Türkiye

Phone: +90 533 684 23 12 **E-mail:** pozdemiryasar@gmail.com

Submitted: December 17, 2024 **Revised:** February 02, 2025 **Accepted:** February 04, 2025 **Available Online:** March 17, 2025

The Cardiovascular Thoracic Anaesthesia and Intensive Care - Available online at www.gkdaybd.org

insights into organ perfusion adequacy. In addition, its use is especially important in preterm neonates, as hypocapnia may lead to neurologic complications, resulting in decreased cerebral blood flow and cerebral ischemia.[5,6]

A further enhancement was achieved through the widespread adoption of bedside PDA clipping protocols.[2,6,7] Although there is still no clear preference for an operating room or the NICU, bedside clipping offers a suitable environment to ensure patient stability. Fluid and temperature monitoring can be performed more closely in the NICU. Moreover, the bedside approach obviates the need for patient transport, which may cause additional problems.

Herein, we retrospectively evaluated neonates who underwent bedside PDA clipping surgery at our unit and presented our data with a specific focus on perioperative anesthesia management.

Methods

Study Design

Between January 2023 and September 2024, 10 neonates underwent a bedside PDA clipping procedure at our unit. Informed consent was obtained from the participants after providing them with the necessary information. Hacettepe University Health Sciences Research Ethics Committee approved the study (Approval number: 2024/20-72, approval date: 27.11.2024). The study adhered to the ethical principles outlined in the Declaration of Helsinki. A comprehensive examination of patient records was conducted.

Preoperative demographics included age and weight at the time of operation, sex, additional cardiac anomalies, preoperative oxygen saturation level, non-cardiac anomalies, and syndromes. Operational data included surgery time, anesthesia parameters, and IV fluid management. The postoperative parameters that were examined included postoperative oxygen saturation level and early postoperative complications. Early mortality was defined as the occurrence of death within 30 days after surgery or at any point during the initial hospital stay. Follow-up was conducted and completed for all patients.

Anaesthetic Management

It is of utmost importance to keep in mind that the success of bedside PDA clipping hinges on effective communication and coordination between the "parent" neonatology team and the "visiting" anesthetic team. Patients' temperatures were strictly maintained at normothermia with the use of servo-controlled radiant warmers. At least two peripheral intravenous (IV) accesses were established in individuals when no central lines were in place. IV maintenance fluid and/or parenteral nutrition (PN) was administered throughout the surgery.

Continuous heart rate (HR), pulse oximetry (SpO_2), end-tidal carbon dioxide ($EtCO_2$), NIRS, and noninvasive blood pressure (BP) measurements every 3 minutes were monitored. An arterial line was not required. All patients were intubated and ventilated preoperatively (Fig. 1). Balanced anesthetic management was utilized for inducing anesthesia, employing a mixture of ketamine (1 mcg/kg), midazolam (1 mg/kg), fentanyl (2 mcg/kg), and rocuronium (1 mg/kg). We intentionally favored the use of potent opioids like fentanyl to maintain hemodynamic stability.

Peak inspiratory pressure was set to achieve tidal volumes of 5 ml/kg, ventilatory rates were set to target an $EtCO_2$ of 40–45 mmHg, and fractional inspired oxygen concentration (FiO_2) was adjusted to achieve an SpO_2 of 94%–95%. Careful observation was maintained to prevent the dislodgment of the endotracheal tube and the displacement of lines during positioning.

With the patient positioned in the right lateral decubitus, intraoperative hemodynamic instability was managed with manual hyperventilation and communication with the surgeon to intermittently release retraction, as lung retraction may not be tolerated, thereby leading to hypercarbia and/or a hypoxic crisis. Occasionally, inotropic support was required. Prior to closure, the lungs were inflated either manually or by inspiratory hold on the ventilator before rib approximation. The baby was then placed back in the supine position.[2,6–9]

Surgical Technique

PDA clipping was routine and standard in all cases. The patient was positioned in the right lateral decubitus (Fig. 2). After performing the left mini-posterolateral thoracotomy incision, the pleura was incised, and the lung was retracted anteriorly and inferiorly. The descending aorta, left subclavian artery, aortic arch, and PDA were mobilized. The recurrent laryngeal and phrenic nerves were isolated.

Test occlusion of the PDA was performed in all cases. After confirming the PDA, a medium-sized surgical clip was implanted across its entire length, avoiding esophageal and aortic injury. Diastolic augmentation and loss of thrill on the aorta were confirmed in all cases. Hemostasis was achieved, and either a 6- or 8-Fr chest tube was inserted. The thoracotomy and incision were closed in the usual fashion. Immediate and 12-hour postoperative transthoracic echocardiograms were performed to ensure PDA closure.[6,10]

Immediate Postoperative Care

A fentanyl (1 mcg/kg/h) infusion was chosen for postoperative analgesia. The inotropic requirements were

Figure 1. Intubated and ventilated patient in the NICU bed.
NICU: Neonatal Intensive Care Unit.

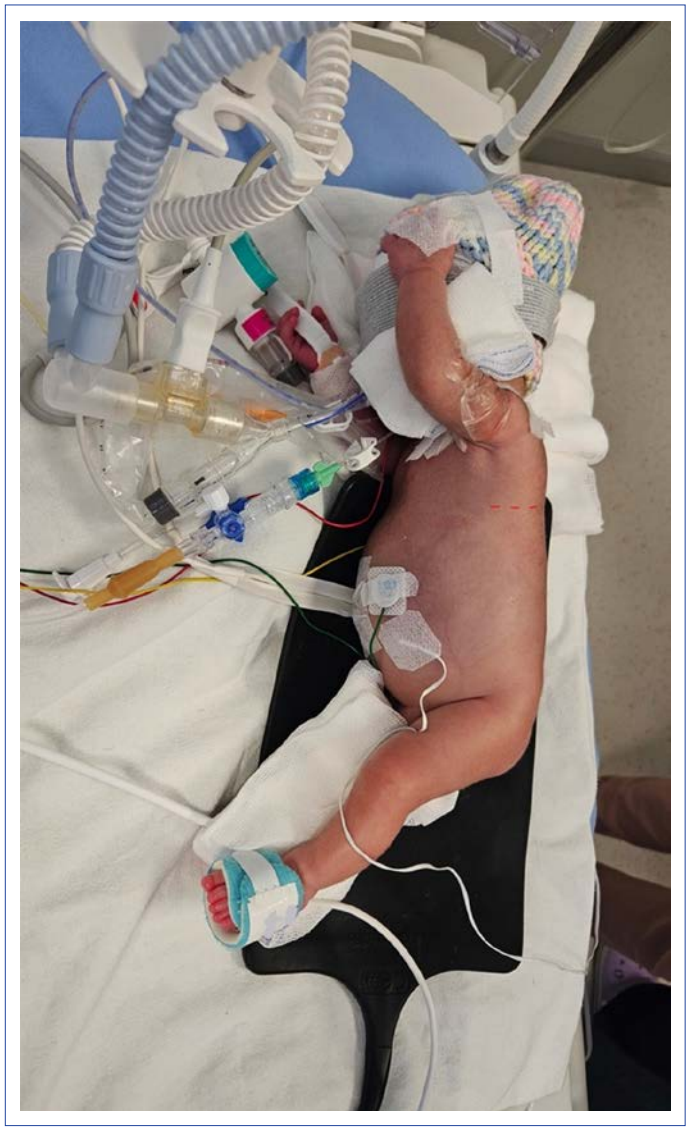

Figure 2. Patient positioned in right lateral decubitus and surgical incision shown in red line.

determined by neonatologists and cardiologists based on clinical and echocardiographic evaluations. A chest X-ray was performed to check endotracheal tube position, lung expansion, pneumothorax, hemothorax, and chest tube position. It is essential that the neonatology team receives a thorough handover, particularly regarding fluid balance and alterations in intraoperative ventilation parameters.

Statistical Analysis

Statistical analysis was performed using Jamovi Version 2.3.18.0 (Jamovi Projects). Descriptive data for continuous variables are presented as medians and interquartile ranges. Categorical variables are presented as relative frequencies.

Results

Ten preterm neonates underwent bedside PDA clipping. The median gestational age was 26 weeks (24–28 weeks), and the median birth weight was 1261 g (630–1725 g). Six were male (60%), and four were female (40%). Two patients (20%) had Down syndrome, one (10%) had combined immunodeficiency syndrome, two (20%) had necrotizing enterocolitis, one (10%) had intraventricular hemorrhage, one (10%) had late neonatal sepsis, one (10%) had severe thrombocytopenia, and one (10%) had bronchopulmonary dysplasia.

All patients had a large and hemodynamically significant PDA and had received NSAID therapy prior to surgical closure. Seven patients (70%) had three cycles, and two patients (20%) had two cycles of NSAID treatment. One patient had a contraindication for NSAID use due to severe thrombocytopenia. Pharmacologic interventions to close the PDA were unsuccessful, leading to a decision for surgical closure. At the time of PDA clipping, the median age and weight were 33.5 days (27–55.5 days) and 1297.5 g (1088.75–2350 g), respectively. All patients were intubated and ventilated (PC mode) preoperatively. The median preoperative oxygen saturation was 92% (91–93.75%).

Table 1. Demographics and clinical characteristics of patients

Variable	Value	
	n	%
Median gestation age, weeks	26 (24–28)	
Median gestation weight, grams	1261 (630–1725)	
Male sex (%)	6	60
Non-cardiac disorders/syndromes		
Down syndrome	2	20
Combined immunodeficiency syndrome	1	10
Necrotizing enterecolitis	2	20
Intraventricular hemorrhage	1	10
Culture positive sepsis	1	10
Severe thrombocytopenia	1	10
Bronchopulmonnary dysplasia	1	10
NSAID treatment duration		
Two cycles	2	20
Three cycles	7	70
Contraindicated	1	10
Median preoperative SaO_2 (%)	92 (91–93.75)	
Median age at operation, days	33.5 (27–55.5)	
Median weight at operation, grams	1297.5 (1088.75–2350)	
Intraop manual-hyperventilation	8	80
Blood product requirement	4	40
Surgical time (minute)	41.5 (30.5–49)	
Median postoperative SaO_2 (%)	94 (92.25–94.75)	
Postoperative NICU stay (days)	35 (15–36.75)	

n: Number; NSAID: Non-steroidal anti-inflammatory drug; SaO_2: Systemic arterial oxygen saturation; NICU: Neonatal intensive care unit.

Intraoperatively, no hemodynamic instability was encountered. All intraoperative monitoring parameters remained stable, with NIRS change percentages within a median of 5% (5–8%). No patient had intraoperative NIRS values that decreased by more than 10% from their baseline. Manual hyperventilation was required in eight (80%) patients when the left lung was retracted. The airway pressures in these patients returned to their preoperative levels immediately after the chest retractor was removed and the lungs were expanded at the end of surgery. Only four patients (40%) required blood products during surgery. Two patients received erythrocyte suspension, with a median transfusion amount per patient of 3.5 mL/kg (1.2–4.5 mL/kg). Another two patients required platelet transfusions. The total surgical time, from skin incision to closure, was 41.5 minutes (30.5–49 minutes). The median postoperative oxygen saturation was 94% (92.25–94.75%).

There were no operative mortalities; however, one patient died during his in-hospital stay due to gram-negative sepsis on postoperative day 32. There were no intraoperative anesthetic or surgical complications. None developed chylothorax or hemothorax, and all chest tubes were removed within a median postoperative time of 20 hours (15.25–24 hours). No residual or recurrent pneumothorax was identified after chest tube removal.

Seven (70%) patients required the initiation of postoperative inotrope/vasodilator therapy within six hours of clipping. None of the patients experienced hypothermia. After the procedure, no patient required the administration of blood products intraoperatively or within six hours. We did not encounter pulmonary complications, hypotension, or hemorrhage within the first 24 hours postoperatively. None of the patients required reoperation. Control echocardiographic examinations revealed a closed PDA in all cases. The median stay in the NICU after PDA clipping was 35 days (15–36.75 days). All relevant data are summarized in Table 1.

Discussion

PDA closure is a critical treatment, particularly for preterm neonates, as persistent ductal patency may result in decreased systemic blood flow and increased pulmonary blood flow. This can contribute to severe complications such as pulmonary hypertension, heart failure, and neurodevelopmental disorders in the long term.[1,2]

However, the anesthetic management of PDA clipping in the NICU should not only address the challenges associated with performing a surgical intervention outside the operating room but also the issues inherent to sick preterm infants, who pose a significant risk for anesthesia. It is crucial to maintain ventilation at an optimal level and ensure hemodynamic stability during surgery in the NICU.[6,8,11]

Anesthesiologists must be aware that intravascular depletion due to preoperative restrictive fluid management and/or diuretics results in poor tolerance to anesthetics. Consequently, despite the appearance of edema, IV fluid replacement may be necessary.[2,6,7] Currently, there is no consensus regarding the optimal anesthetic regimen for bedside surgical ductus clipping of preterm infants. Alternatives are already limited in the NICU due to the unavailability of inhalational agents. As our research has underscored, the use of potent opioids such as fentanyl during the intraoperative period enables the maintenance of stable hemodynamic parameters during anesthesia in the NICU.[3,4,6]

It has been reported in the literature that fentanyl use reduces hemodynamic alterations in preterm neonates and enhances stability during surgery. Furthermore, fentanyl can alleviate the physiological stress and hormonal response to surgery and may also reduce protein lysis. This effect of fentanyl is essential in preventing perioperative complications, including hypercapnia and hypoxia.[3,4] Although there are reports of chest wall rigidity and laryngospasm with fentanyl in preterm infants, we did not encounter these complications in our cohort. We strongly believe that achieving an ideal balance in opioid dosing is a nuanced discipline, as low doses are believed to offer inadequate analgesia while being safer, whereas high doses mitigate the stress response but may induce hypotension.

Another advantage of bedside PDA clipping is the use of a standard neonatal ventilator, as most anesthetic machines cannot safely deliver low tidal volumes compared to a standard neonatal ventilator. Moreover, transport-related ventilation complications, such as endotracheal tube dislodgement and ventilator discrepancies, are mitigated.[2,6,7]

Despite these advantages, these patients frequently experience respiratory deterioration due to the right lateral decubitus position and lung retraction, an intraoperative complication unique to PDA clipping surgery.[12] The ventilation-perfusion mismatch in a decubitus position impairs the respiratory mechanics of already congested neonatal lungs, potentially resulting in intermittent desaturation and bradycardia, which may be exacerbated by lung retraction during dissection. If not recognized promptly, this may lead to hemodynamic instability. Thus, it is imperative to meticulously monitor ventilation parameters and oxygenation.

We strongly believe that a critical aspect of this procedure is the monitoring of cerebral oxygenation using techniques such as NIRS, along with other basic hemodynamic parameters. The use of NIRS can enable the early detection of hypoxia, which may be caused by factors such as manipulation of the left lung or obstruction of the right lung, particularly during PDA clipping, facilitating the implementation of preventive interventions.[5,6] We also observed this prevalent problem in our cohort and, as suggested in the literature, performed manual hyperventilation when required.[8] Upon closure of the incision, we were able to ventilate patients within their baseline ventilator parameters.

It is also imperative to consider the potential for cerebral ischemia and hypocapnia in these patients during the intraoperative period. It has been emphasized that hyperventilation and hypocapnia, which may develop particularly during manual hyperventilation, can result in unacceptable neurological outcomes by reducing cerebral blood flow.[5,13] The patients in our study exhibited minimal hemodynamic instability and cerebral oxygenation alterations due to hypocapnia, as evidenced by the slight fluctuations in NIRS values compared to baseline. Similarly, the literature recommends the use of NIRS as a critical tool for preventing neurological damage caused by hypocapnia and for preserving cerebral oxygenation.[5,6]

In our cohort, no adverse events occurred during the initial postoperative period, including hypothermia, pulmonary complications, or hemorrhage. Preterm neonates are at a high risk of postoperative hypothermia, which has been reported to have a substantial impact on postoperative mortality and morbidity.[2,6,7] Their diminished homeothermic response renders them vulnerable to hypothermia-induced acidosis and bradycardic arrest. Conversely, hyperthermia can be equally catastrophic, leading to tachycardia and seizures. The literature emphasizes the importance of rigorously regulating and maintaining thermoregulation in preterm neonates.[6,7,14] Bedside PDA clipping plays a crucial role in preserving normothermia, as it eliminates the need for neonatal transport. Our study demonstrated that, with the use of servo-controlled radiant warmers in the NICU, all patients remained normothermic throughout the procedure. Consequently, no postoperative complications were encountered, and recovery was uneventful.

The risk of intraoperative and/or postoperative hemorrhage is a significant concern in preterm neonates, as their coagulation system is underdeveloped. In our study, four patients required blood transfusions during surgery—two received erythrocyte transfusions, while the other two required platelet transfusions. These transfusions were administered to maintain hemodynamic stability rather than

to manage active hemorrhage. The literature suggests that intraoperative transfusions effectively compensate for volume loss and reduce the incidence of postoperative complications.[2,6,8] Blood transfusions are frequently necessary in preterm neonates with low birth weight, as they serve as a preventive measure against postoperative instability.

There is a common misconception that performing surgical procedures outside the operating room poses a significant risk for surgical infections. However, no reports substantiate this claim. Previous studies have shown that no local or systemic infections occurred within 72 hours post-procedure, indicating that the NICU provides a safe environment for surgical interventions.[14] Consistent with these findings, our study did not record any instances of new systemic sepsis or surgical site infection.

Conclusion

In conclusion, our findings demonstrate that a rigorous multidisciplinary strategy, incorporating expertise from neonatology, anesthesiology, and cardiac surgery teams, ensures the safety of bedside PDA clipping. Potential complications are significantly minimized through meticulous intraoperative anesthetic management and vigilant postoperative thermal and hemodynamic monitoring, as evidenced in our study. Although the use of NIRS during the intraoperative and postoperative periods contributed to the preservation of cerebral oxygenation, which is a promising indicator of long-term neurodevelopmental outcomes, close follow-up of these patients remains essential.

Disclosures

Ethics Committee Approval: The study was approved by The Hacettepe University Health Sciences Research Ethics Committee (no: 2024/20-72, date: 27/11/2024).

Authorship Contributions: Concept – P.Ö.Y., Ş.A., B.A.; Design – P.Ö.Y., Ş.A.; Supervision – H.T.Ç., B.A., M.Y.; Fundings – H.T.Ç., B.A., M.Y.; Materials – P.Ö.Y., Ş.A., T.S., H.T.Ç.; Data collection &/or processing – P.Ö.Y., Ş.A.; Analysis and/or interpretation – P.Ö.Y., Ş.A.; Literature search – P.Ö.Y., Ş.A.; Writing – P.Ö.Y., Ş.A.; Critical review – T.S., H.T.Ç., B.A., M.Y.

Informed Consent: Informed consent was obtained after the participants were given the necessary information.

Conflict of Interest: All authors declared no conflict of interest.

Use of AI for Writing Assistance: No AI technologies utilized.

Financial Disclosure: The authors declared that this study has received no financial support.
Peer-review: Externally peer-reviewed.

References

1. Hamrick SEG, Sallmon H, Rose AT, Porras D, Shelton EL, Reese J, et al. Patent ductus arteriosus of the preterm infant. Pediatrics 2020;146:e20201209.
2. Gould DS, Montenegro LM, Gaynor JW, Lacy SP, Ittenbach R, Stephens P, et al. A comparison of on-site and off-site patent ductus arteriosus ligation in premature infants. Pediatrics 2003;112:1298–301.
3. Shew SB, Keshen TH, Glass NL, Jahoor F, Jaksic T. Ligation of a patent ductus arteriosus under fentanyl anesthesia improves protein metabolism in premature neonates. J Pediatr Surg 2000;35:1277–81.
4. Anand KJ, Sippell WG, Aynsley-Green A. Randomised trial of fentanyl anaesthesia in preterm babies undergoing surgery: Effects on the stress response. Lancet 1987;1:243–8.
5. Prescott, S. Near infrared spectroscopy and patent ductus arteriosus in the preterm neonate: A systematic review. J Neonatal Nurs 2017;23:9–27.
6. Joshi RK, Aggarwal N, Agarwal M, Joshi R. Anesthesia protocols for "bedside" preterm patent ductus arteriosus ligation: A single-institutional experience. Ann Pediatr Cardiol 2021;14:343–9.
7. Lee LK, Woodfin MY, Vadi MG, Grogan TR, Ross PJ, Applegate RL 2nd, et al. A comparison of postoperative outcomes with PDA ligation in the OR versus the NICU: A retrospective cohort study on the risks of transport. BMC Anesthesiol 2018;18:199.
8. Kritzmire SM, Boyer TJ, Singh P. Anesthesia for patients with patent ductus arteriosus. StatPearls; 2022.
9. Cao H, Qiu J, Hu Y, Huang W, Liu X, Jin H. Anesthesia management experience for pediatric day-case PDA ligation under thoracoscopy assisted by a robot: A retrospective study. J Cardiothorac Surg 2023;18:360.
10. Vida VL, Lago P, Salvatori S, Boccuzzo G, Padalino MA, Milanesi O, et al. Is there an optimal timing for surgical ligation of patent ductus arteriosus in preterm infants? Ann Thorac Surg 2009;87:1509–16.
11. Wolf AR. Ductal ligation in the very low-birth weight infant: Simple anesthesia or extreme art? Paediatr Anaesth 2012;22:558–63.
12. Wheeler CR, Vogel ER, Cusano MA, Friedman KG, Callahan R, Porras D, et al. Definitive closure of the patent ductus arteriosus in preterm infants and subsequent short-term respiratory outcomes. Respir Care 2022;67:594–606.
13. Vanderhaegen J, De Smet D, Meyns B, Van De Velde M, Van Huffel S, Naulaers G. Surgical closure of the patent ductus arteriosus and its effect on the cerebral tissue oxygenation. Acta Paediatr 2008;97:1640–4.
14. Gavilanes AW, Heineman E, Herpers MJ, Blanco CE. Use of neonatal intensive care unit as a safe place for neonatal surgery. Arch Dis Child Fetal Neonatal Ed 1997;76:F51–3.