Comparative Study of PDA Ligation in the OR versus in the NICU: A 10-Year Retrospective Cohort Study

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ABSTRACT

Objective: This study aimed to compare the outcomes of PDA (patent ductus arteriosus) ligation performed in NICU (neonatal intensive care unit) versus OR (operating room) and identify relevant influencing factors.

Materials and Methods: In this retrospective review, spanning a decade (2012-2021) of NICU patients at Siriraj Hospital who underwent PDA ligation, patients were categorized into two groups: OR and NICU. Baseline clinical characteristics, operative details, and postoperative results (including hospital mortality, cause of death, and complications) were collected and analyzed.

Results: A total of 118 patients were included, with 52 patients in the OR group and 66 patients in the NICU group. There were no statistically significant differences in postoperative outcomes between the two groups. The hospital mortality rates were 1.9% (1/52) and 10.6% (7/66), respectively (p = 0.08). Post hoc multivariable binary logistic regression analysis further confirmed that the location of PDA ligation was not associated with hospital mortality. However, higher oxygen requirements and lower postmenstrual age (PMA) were found to be independently associated with hospital mortality (OR 1.10, p =0.02 and OR 0.82, p<0.01 respectively). Hypothermia, defined as a body temperature less than 36C, was more prevalent in the OR group (30.8% vs 16.7%, p=0.07). Other postoperative complications were not statistically different between the two groups. Lastly, no case of surgical site infection was observed in the NICU group.

Conclusion: PDA ligation can be safely and effectively performed in the NICU with comparable hospital mortality, potentially offering better temperature control, and without an increased risk of complications, including surgical site infection.

Keywords: Patent ductus arteriosus; Patent ductus arteriosus ligation; NICU surgery; Bedside surgery (Siriraj Med J 2024; 76: 31-39)

INTRODUCTION

Patent ductus arteriosus (PDA) is the most common congenital cardiac defect in newborns, particularly among premature infants.[1] Hemodynamically significant PDA can lead to impaired cardiac and respiratory function, resulting in increased morbidity and mortality.[2] When medication trials fail or are contraindicated, PDA ligation is the standard of care.

Traditionally, PDA ligation has been exclusively performed in the operating room (OR), which involves transporting newborns across buildings and subjecting them to less monitored and controlled conditions. Transporting these sick newborns to the operating theater can result in various negative consequences, such as inadequate monitoring, hemodynamic instability, temperature instability, respiratory compromise, and dislodgment

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of intravenous access sites. To minimize transportation-related risks, PDA ligation can be performed bedside in neonatal intensive care units (NICUs).[3]

However, PDA ligation in NICU also carries risks, such as limited availability of equipment, poor surgical lighting, less sterile surgical fields, and lack of cardiopulmonary bypass standby. A study by Mallick et al.[4] has demonstrated the safety and feasibility of performing several procedures in NICU, including PDA ligation. Several studies have also reported outcomes of bedside PDA ligation in NICUs, with hospital mortality rates ranging from 4.20% to 19.20%.[5-8]

To the best of our knowledge, only one study directly compares PDA ligation performed in the OR to the same procedure performed in the NICU. The retrospective cohort study (n = 189) was conducted in 2018 by Lisa K. Lee et al.[9] from the University of California, Los Angeles, reported outcomes and compared PDA ligation in the NICU with ligation in the OR. After adjusting for baseline patient characteristics using mixed effect models and propensity score matching, hospital mortality rates were 14.3% and 5.1%, respectively, which were not significant. Hemodynamic instability upon arrival to the NICU was statistically more prevalent in the OR group. Other outcomes, including perioperative hypothermia, loss of vascular access, sepsis arising after PDA ligation, change in saturation, days requiring ventilator support, and length of stay after PDA ligation, were not statistically significant.

At our center, PDA ligation has been performed in the OR for over sixty years (since 1956), but bedside PDA ligation in the NICU was only initiated within the last decade. This study aims to evaluate hospital mortality and other outcomes of PDA ligation in our NICU patient cohort performed both in the NICU and in the OR over a ten-year period (2012-2021), compare outcomes of both groups, and identify factors that may be associated with differences in the outcomes.

MATERIALS AND METHODS

A retrospective chart review of all NICU patients who had undergone PDA ligation in a ten-year period (2012-2021) at Siriraj Hospital was performed. Approval from the Institutional review board (IRB) was obtained. Patients were initially identified through hospital summary records and subsequently cross-referenced with operating room records. The exclusion criteria included patients who underwent concomitant procedures in addition to PDA ligation, patients not originally from the NICU and patients with incomplete medical records. Data was obtained from a variety of sources, including operative notes, anesthetic records, progress notes, nursing flow sheets, and discharge summary notes.

Patients were categorized into two groups, the OR group and the NICU group, based on the location where PDA ligation was performed. The choice of the location was a collaborative judgment of neonatologists, anesthesiologists and attending cardiothoracic surgeons. In the OR group, newborns were transferred from the NICU to the operating room. During the transfer, all newborns were enclosed in neonatal transport 'Isolette TI500' (Dräger, Lübeck, Germany) units and were manually ventilated using a bag-valve mask.

In the NICU group, newborns underwent the surgery in a radiant warmer, Babyleo TN500 model (Drägerwerk AG & Co. Lübeck, Germany). Surgical instruments were obtained from the OR, and the surgeon used a wearable headlight to enhance visualization.

In both groups, PDA ligation was performed by the same team, consisting of a cardiothoracic surgeon, a cardiothoracic anesthesiologist and scrub nurses. Patients were positioned in the right lateral decubitus position and a posterolateral approach was employed in all cases.

Baseline clinical characteristic data included the following parameters: gestational age (GA), postmenstrual age (PMA), postnatal age, birthweight, weight at the time of procedure, PDA size, concomitant cardiac lesions, preoperative comorbidities, ventilator support parameters (types and settings), inotropic support and details of medication administered for PDA closure trials (drug, number of courses given).

Operative details encompassed incision type and surgical technique, anesthetic approach (intravenous and/or inhalation), intraoperative findings (PDA size and other findings), blood loss, and immediate complications.

Postoperative outcomes included hospital mortality, causes of death, length of stay in the NICU, length of hospital stay and postoperative complications (surgical site infection, cultured-confirmed postoperative sepsis, bleeding, pneumothorax, chylothorax, recurrent laryngeal nerve injury, phrenic nerve injury), body temperature, hypothermia (defined as body temperature below 36C Celsius), and changes in oxygen saturation and hemodynamic instability.

Oxygen saturation changes and hemodynamic instability definition were defined as follows:

For oxygen saturation changes, measurements were measured at two distinct time points:

1) Saturation changes after arrival at the OR: between the last recorded SpO2 at the ward and upon arrival at the OR (for NICU group; last NICU record and first anesthetic record)

2) Saturation changes after returning to the NICU:

between the last recorded SpO2 in the OR and upon arrival to the NICU (for NICU group: first NICU record after surgery and last anesthetic record).

Hemodynamic instability, defined as a change in mean arterial pressure (MAP) greater than 20%, was measured at three different time points:

1) Between the last recorded MAP at the ward and upon arrival at the OR (for NICU group: last NICU record and first anesthetic record).

2) Between the last recorded MAP at the ward and the lowest intraoperative MAP

3) Between the last recorded MAP in the OR and upon arrival to the NICU (for NICU group, first NICU record after surgery and last anesthetic record).

Statistical analyses were conducted using SPSS Statistics version 26 (IBM, Armonk, NY). Descriptive statistics were employed to characterize patient baseline clinical variables and outcomes. To compare variables, Chi-square tests or Fisher's exact test were used for categorical variables, while Student's t-test or Wilcoxon-Mann-Whitney Test were used for continuous variables. Univariable analyses were performed through binary logistic regression, followed by subsequent multivariable binary logistic regression analyses to assess factors associated with primary outcome.

RESULTS

Out of the 130 patients initially identified, 12 were excluded due to concomitant procedures or for not being part of the NICU cohort (Fig 1). The remaining 118 patients, including 66 in the NICU group and 52 in the OR group, were analyzed.

Baseline characteristics (Table 1): There were no significant differences in gender between the two groups ($p = 0.56$). Half of all patients (53%) were classified as extremely low birth weight (ELBW) infants, with very low birth weight (VLBW) infants making up the second-highest proportion (31%). The NICU group exhibitied significantly lower birth weights than the OR group (972 gm versus 1261 gm, $p < 0.01$), significantly lower mean body weights at the time of surgery (1193 gm versus 1442 gm, $p < 0.01$), and also significantly lower gestational age compared to the OR group (27.8 weeks versus 29.2 weeks, $p = 0.02$). Postnatal age, measured as the number of days since birth at the time of surgery, did not significantly differ between the two groups, with the NICU and OR groups having mean ages of 23.9 and 24.6 days respectively ($p = 0.52$).

Regarding concomitant cardiac lesions, there was no significant difference in the percentage of newborns with PFO/ASD (Patent foramen ovale/Atrial septal defect) and VSD (Ventricular septal defect) ($p = 0.37$ and 0.85, respectively). Hypertrophic cardiomyopathy, cardiac rhabdomyoma, and common atrium were also rarely identified in this study.

Both groups exhibited a median of approximately 5 preoperative comorbidities, without significant differences observed between them ($p = 0.51$). Although there were tendencies for a higher prevalence of certain comorbidities (such as Transient tachypnea of the newborn (TTN), Pulmonary hemorrhage, Acute kidney injury (AKI), Sepsis, and Persistent pulmonary hypertension of the newborn (PPHN)) in the NICU group, only the incidence of intraventricular hemorrhage (IVH) showed a statistically significant difference, being notably higher in the NICU group (53.0% vs 19.2%, $p < 0.01$).

Nearly all patients (98.3%) received invasive respiratory support (Conventional ventilator or High frequency oscillatory ventilation - HFOV). The NICU group had a significantly higher percentage of patients

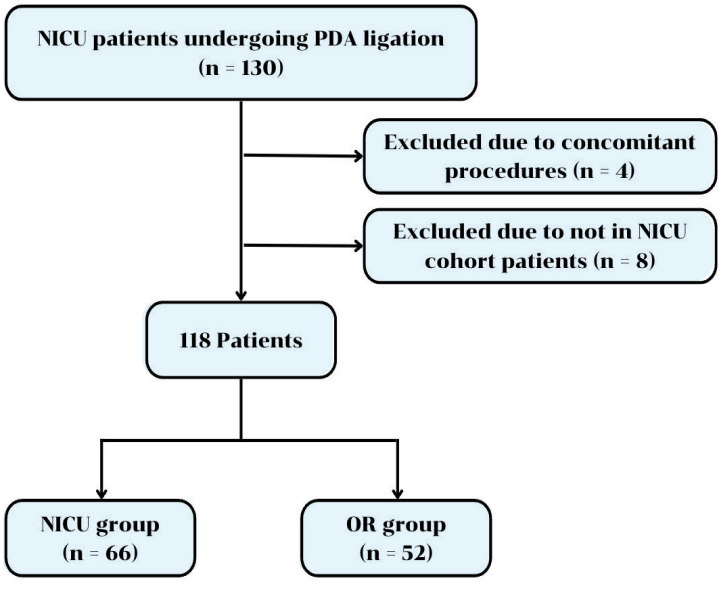

Fig 1. Flow diagram of the patient selection process.

TABLE 1. Baseline characteristics.

	NICU (n = 66)	OR (n = 52)	p value
Sex (Male, n (%))	24 (46.2%)	34 (51.5%)	0.56
Birthweight (grams, median (Q1, Q3))	850 (660, 1070)	1050 (875, 1415)	<0.01
NBW (n (%))	1 (1.5%)	2 (3.8%)	0.09
LBW (<2,500 gm) (n (%))	6 (9.1%)	9 (17.3%)	
VLBW (<1,500 gm) (n (%))	17 (25.8%)	20 (38.5%)	
ELBW (<1,000 gm) (n (%))	42 (63.6%)	21 (40.4%)	
Weight at time of procedure (grams, median (Q1, Q3))	1110 (800, 1302)	1295 (1043, 1683)	<0.01
GA (weeks, median (Q1, Q3))	27.1 (26.1, 28.7)	28.0 (26.6, 31.6)	0.02
PMA at time of procedure (weeks, median (Q1, Q3))	30.7 (28.7, 32.1)	32.7 (30.7, 35.0)	<0.01
Postnatal age (days, median (Q1, Q3))	21.0 (16.0, 31.0)	24.0 (16.0, 32.0)	0.52
Other congenital cardiac lesions			
PFO/ASD (n (%))	30 (45.5%)	28 (53.8%)	0.37
VSD (n (%))	3 (4.5%)	2 (3.8%)	0.85
Other lesions			
Hypertrophic cardiomyopathy	0	1	
Cardiac rhabdomyoma	0	1	
Common atrium	1	0	
Number of comorbidities**			
Number of comorbidities	5 (IQR 4 - 6)	5 (IQR 4 - 6)	0.51
IVH (n (%))	35 (53%)	10 (19.2%)	<0.01
ROP (n (%))	3 (4.5%)	2 (3.8%)	0.85
RDS (n (%))	50 (75.8%)	41 (78.8%)	0.69
TTN (n (%))	10 (15.2%)	4 (7.7%)	0.21
BPD (n (%))	4 (6.1%)	9 (17.3%)	0.05
AOP (n (%))	13 (19.7%)	17 (32.7%)	0.16
Pulmonary hemorrhage (n (%))	18 (27.3%)	10 (19.2%)	0.31
AKI (n (%))	18 (27.3%)	7 (13.5%)	0.07
Hyperbilirubinemia (n (%))	61 (92.4%)	48 (92.3%)	0.98
NEC (n (%))	12 (18.2%)	13 (25%)	0.37
Anemia (n (%))	44 (66.7%)	34 (65.4%)	0.88
Sepsis (n (%))	49 (74.2%)	34 (65.4%)	0.30
Pneumonia (n (%))	14 (21.2%)	18 (34.6%)	0.104
PPHN (n (%))	3 (4.5%)	1 (1.9%)	0.44
Ventilation requirement			
HFNC (n (%))	1 (1.5%)	1 (1.9%)	<0.01
Conventional (n (%))	38 (57.6%)	50 (96.2%)	
HFOV (n (%))	27 (40.9%)	1 (1.9%)	

TABLE 1. Baseline characteristics. (Continue)

	NICU (n = 66)	OR (n = 52)	p value
HFNC			
FiO2 (%)	- 0.21	- 0.25	N/A
Flow (LPM)	- 5	- 4	
Conventional			
FiO2 (%)	- 0.31	- 0.29	0.47
PIP (cmH2O)	- 16.2	- 13.7	0.04
PEEP(cmH2O)	- 5.3	- 4.7	0.01
HFOV			
FiO2 (%)	- 0.33	- 0.5	N/A
MAP (cmH2O)	- 14.1	- 12.0	
Inotropic requirement (n (%))	42 (63.6%)	28 (53.8%)	0.28
Dopamine (n (%))	4 (6.1%)	1 (1.9%)	0.38
(5/118) (mcg/kg/min)	Mean dose 11.8	Mean dose 12.0	N/A
Dobutamine (n (%))	40 (60.6%)	27 (51.9%)	0.35
(67/118) (mcg/kg/min)	Mean dose 8.6	Mean dose 9.2	0.41
Milrinone (n (%))	3 (4.5%)	1 (1.9%)	0.63
(4/118) (mcg/kg/min)	Mean dose 0.2	Mean dose 0.3	N/A
Norepinephrine (n (%))	1 (1.5%)	0 (0%)	1.000
(1/118) (mcg/kg/min)	Mean dose 0.4	Mean dose N/A	0.38
Modified inotropic score* (median, (Q1, Q3))**	6 (0, 10)	6 (IQR 0, 10)	0.65
Medical closure trials	34 (51.5%)	20 (38.5%)	0.16
NSAIDs	22 (33.3%)	20 (38.5%)	0.56
Indomethacin	11 (16.7%)	17 (32.7%)	<0.01
Ibuprofen	12 (18.2%)	12 (18.2%)	0.12
Paracetamol	19 (28.8%)	0	<0.01
Number of courses (median, (Q1, Q3))	1 (0, 2)	0 (0, 1)	0.03
0	32 (48.5%)	32 (61.5%)	-
1	16 (24.2%)	16 (30.8%)	-
2	16 (24.2%)	2 (3.8%)	p < 0.05
3	2 (3.0%)	2 (3.8%)	-
PDA size (mm, mean, (SD))	3.3 (1.3)	3.8 (1.0)	0.01
Anesthetic technique			
Total IV (n, (%))	66 (100%)	8 (15.4%)	
IV with Inhalation (n, (%))	0	43 (82.7%)	

*American College of Cardiology Task Force 1 of the 32nd Bethesda Conference (http://www.pted.org/?id=overview1)
**Comorbidities: RDS/CLD/Pneumonia, IVH, NEC, AKI, ROP, Anemia, Hyperbilirubinemia, etc
***VIS (Vasoactive-Inotropic score)

requiring HFOV ventilatory support compared to the OR group (40.9% vs 1.9%, p < 0.01). There were no significant differences in FiO2 between patients receiving conventional ventilation in the NICU and OR groups (0.31 vs 0.29, p=0.35). However, the NICU group had significantly higher PIP (16.2 vs 13.7, p=0.04) and PEEP (5.3 vs 4.7, p=0.01) compared to the OR group.

Inotropic support was required in 59.3% of all patients (63.6% vs 53.8% in NICU and OR group respectively, p = 0.28), and dobutamine was the dominant inotrope used (56.8%). The median of modified inotropic scores did not differ between the two groups (6 vs 6 for the NICU and OR group, respectively, p = 0.65).

In this study, medical closure attempts of PDA were made in 45.8% of all patients. There was a trend towards more patients in the NICU group receiving medical closure trials (51.5% vs 38.5%), but this difference was not statistically significant (p = 0.16). The most frequently used drugs for medical closure were NSAIDs (Nonsteroidal anti-inflammatory drugs - Indomethacin, Ibuprofen), which were administered to 35.6% of all patients. Paracetamol was found to be exclusively used in the NICU group, with 19 patients (28.8%) receiving this medication.

In the NICU group, all patients received total intravenous anesthesia, while in the OR group, 82.7% of patients received a combination of inhalation and intravenous anesthesia, and the remaining 15.4% received total intravenous anesthesia.

Postoperative outcomes (Table 2&3)

The study revealed that hospital mortality rates in the NICU group were higher than those in the OR group (10.6% vs. 1.9%). However, this difference was not statistically significant (p = 0.08). Of the eight hospital mortalities, none were PDA-related. The predominant cause was respiratory-related issues, accounting for five deaths: three due to ARDS and two to BPD. Additionally, there were two fatalities from septicemia and one from PPHN.

After conducting both univariable and multivariable binary logistic regression analyses, the location of PDA ligation-whether in the NICU or OR-was not found to be associated with hospital mortality. Nevertheless, lower PMA and higher FiO2 emerged as independent predictors of hospital mortality (OR 0.82, p < 0.01 and OR = 1.10, p = 0.02, respectively). Other factors were not found to be associated with mortality.

Postoperative complications, including infection, sepsis, bleeding, pneumothorax, chylothorax, nerve injury, and rib fractures, were not statistically different between the two groups. There were no cases with surgical site infection in the NICU group.

However, postoperative temperature was significantly lower in the OR group (36.2 C vs 36.5 C, p = 0.04), and hypothermia was more prevalent in the OR group, although it did not reach statistical significance (30.8% vs 16.7% for OR group and NICU group, respectively, p = 0.07).

Following arrival in the OR, the change in oxygen saturation was +1% in the NICU group and +3% in the OR group (p = 0.01). Upon return to the NICU, the change in oxygen saturation was 0% for the NICU group and -2% for the OR group (p < 0.01). Hemodynamic instability at OR arrival, during the operation, and when returning to the NICU was more pronounced in the OR group, with incidences of 23.5%, 32.7%, and 35.3%, respectively, compared to 18.8%, 24.2%, and 28.1% in the NICU group. However, these differences did not reach statistical significance, with p-values of 0.53, 0.33, and 0.41, respectively.

The study also found that hospital and NICU length of stays were longer in the NICU group (138.3 vs 99.8 days, p<0.01 and 92.6 vs 59.1 days, p<0.01, respectively).

DISCUSSION

Consistent with other studies[9-13], the patients in the NICU group were more premature and had lower weight, which may suggest a preference for bedside surgery for smaller patients due to perceived risks associated with

TABLE 2. Independent predictors of hospital mortality.

Factors	Unadjusted OR	p-value	Adjusted OR	p-value
PMA	0.96 (0.74-1.23)	0.74	0.82 (0.74-0.91)	<0.01
FiO2	1.11 (1.05-1.18)	0.001	1.10 (1.02-1.19)	0.02

(Adjusted for PMA, Weight at time of surgery, Location of PDA ligation, Number of comorbidities, FiO2, PIP, HFOV, PDA size)

TABLE 3. Postoperative data.

	NICU (n=66)	OR (n=52)	p value
Hospital mortality (n (%))	7 (10.6%)	1 (1.9%)	0.08
Cause of death			
PDA-related (n (%))	0 (0.0%)	0 (0.0%)	
ARDS (n (%))	2 (3.0%)	1 (1.9%)	
BPD (n (%))	2 (3.0%)	0 (0.0%)	
Septicemia (n (%))	2 (3.0%)	0 (0.0%)	
PPHN (n (%))	1 (1.5%)	0 (0.0%)	
Complications			
Surgical site infection (n (%))	0	2 (3.8%)	0.19
CS-confirmed sepsis (n (%))	9 (13.6%)	6 (11.5%)	0.73
Bleeding (n (%))	0	0	
Pneumothorax (n (%))	2 (3.0%)	1 (1.9%)	1.00
Chylothorax (n (%))	2 (3.0%)	2 (3.8%)	1.00
Recurrent laryngeal nerve injury (n (%))	1 (1.5%)	3 (5.8%)	0.32
Phrenic nerve injury (n (%))	1 (1.5%)	1 (1.9%)	1.00
Rib fracture (n (%))	1 (1.5%)	2 (3.8%)	0.58
Body temp (C, median (Q1, Q3))	36.5 (36.0, 37.0)	36.2 (35.8, 36.6)	0.04
Hypothermia (<36C, n (%))	11 (16.7%)	16 (30.8%)	0.07
Saturation change after arrival at OR (% (Q1, Q3))	1 % (-1, 3)	3 % (0, 5)	0.01
Saturation change after return to NICU (% (Q1, Q3))	0 % (-2, 2)	-2 % (-5, 0) %	<0.01
Hemodynamic instability after arrival (n (%))	12 (18.8%)	12 (23.5%)	0.53
Hemodynamic instability intraoperative (n (%))	16 (24.2%)	17 (32.7%)	0.33
Hemodynamic instability after return (n (%))	18 (28.1%)	18 (35.3%)	0.41
Length of stay in NICU (days (Q1, Q3))	78 (49, 105)	51 (39, 78)	<0.01
Length of NICU stay after the procedure (days, (Q1, Q3))	57 (28.5, 81)	30 (12, 52)	<0.01
Total hospital stay (days, (Q1, Q3))	125 (92, 179)	91 (70, 119)	<0.01

transporting them to the operating room. Also, IVH was more prevalent in the NICU group, possibly due to the group having more premature gestational ages.

Additionally, nearly half of the NICU group required HFOV or a higher setting of conventional ventilator. This reflects that those patients were younger and more severely ill, which is also consistent with findings from other studies.[9,10,13] Other preoperative comorbidities and inotropic support between the two groups were not significantly different.

The predominant use of paracetamol in the NICU group may be due to the high prevalence of contraindications for NSAIDs, such as intraventricular hemorrhage (IVH), which was significantly more common in the NICU group. In addition, there was an increase in paracetamol usage in later years of this study. This trend is supported by recent evidence from El-Meshed et al, which demonstrated that paracetamol is as effective as NSAIDs but with fewer side effects.

The mortality rates observed in this study (10.6% vs 1.9%, NICU and OR group, p=0.08) were comparable to those reported in contemporary studies (14.3% vs 5.1% by Lisa K. Lee).[9] These findings suggest that the location of surgery does not affect hospital mortality. Additionally, respiratory-related causes were the most common reported mortalities (5 deaths), with two deaths

attributed to septicemia, which occurred exclusively in the NICU group. The absence of surgical site infections in the NICU group suggests that septicemia cases were caused by sources other than surgical site infections.

Table 4 presents hospital mortality rates stratified by year and location of operation (OR or NICU). In recent years, PDA ligation has been conducted more frequently in the NICU than in the OR. However, the low rate of hospital mortality limits the potential for further meaningful analysis.

TABLE 4. . PDA ligation location trends in recent years.

		Hospital mortality			
Year		No	Yes	Total (n, (%))	p value
2011	NICU (n, (%))	0 (0%)	0 (0%)	0 (0%)	NA
	OR (n, (%))	2 (100%)	0 (0%)	2 (100%)	
	Total (n, (%))	2 (100%)	0 (0%)	2 (100%)	
2012	NICU (n, (%))	0 (0%)	0 (0%)	0 (0%)	NA
	OR (n, (%))	8 (88.89%)	1 (1.11%)	9 (100%)	
	Total (n, (%))	8 (88.89%)	1 (1.11%)	9 (100%)	
2013	NICU (n, (%))	0 (0%)	0 (0%)	0 (0%)	NA
	OR (n, (%))	4 (100%)	0 (0%)	4 (100%)	
	Total (n, (%))	4 (100%)	0 (0%)	4 (100%)	
2014	NICU (n, (%))	2 (50%)	2 (50%)	4 (26.67%)	0.01
	OR (n, (%))	11 (100%)	0 (0%)	11 (73.33%)	
	Total (n, (%))	13 (86.67%)	2 (13.33%)	15 (100%)	
2015	NICU (n, (%))	1 (100%)	0 (0%)	1 (6.67%)	NA
	OR (n, (%))	14 (100%)	0 (0%)	14 (93.33 %)	
	Total (n, (%))	15 (100%)	0 (0%)	15 (100%)	
2016	NICU (n, (%))	5 (83.33%)	1 (16.67%)	6 (60%)	0.39
	OR (n, (%))	4 (100%)	0 (0%)	4 (40%)	
	Total (n, (%))	9 (90%)	1 (10%)	10 (100%)	
2017	NICU (n, (%))	12 (85.71%)	2 (14.29%)	14 (82.35%)	0.49
	OR (n, (%))	3 (100%)	0 (0%)	3 (17.65%)	
	Total (n, (%))	15 (88.24%)	2 (11.76%)	17 (100%)	
2018	NICU (n, (%))	6 (100%)	0 (0%)	6 (66.67%)	NA
	OR (n, (%))	3 (100%)	0 (0%)	3 (33.33%)	
	Total (n, (%))	9 (100%)	0 (0%)	9 (100%)	
2019	NICU (n, (%))	12 (100%)	0 (0%)	12 (100%)	NA
	OR (n, (%))	0 (0%)	0 (0%)	0 (0%)	
	Total (n, (%))	12 (100%)	0 (0%)	12 (100%)	
2020	NICU (n, (%))	12 (92.31%)	1 (7.69%)	13 (86.67%)	0.69
	OR (n, (%))	2 (100%)	0 (0%)	2 (13.33%)	
	Total (n, (%))	14 (93.33%)	1 (6.67%)	15 (100%)	
2021	NICU (n, (%))	9 (90%)	1 (10%)	10 (100%)	NA
	OR (n, (%))	0 (0%)	0 (0%)	0 (0%)	
	Total (n, (%))	9 (90%)	1 (10%)	10 (100%)	
Total	NICU (n, (%))	59 (89.39%)	7 (10.61%)	66 (55.93%)	0.06
	OR (n, (%))	51 (98.08%)	1 (1.92%)	52 (44.07%)	
	Total (n, (%))	110 (93.22%)	8 (6.78%)	118 (100%)	

The incidence of surgical site infections was comparable between the two groups, with no statistically significant difference observed (0% vs 3.8%, p=0.19). This finding, along with similar findings from other studies, including those by Gavilanes et al. in 1997 and Lisa K. Lee in 2018, reaffirmed that the location of the operation, whether in the OR or NICU, does not appear to increase the risk of surgical site infections.[9,14]

The OR group had a lower postoperative body temperature, possibly due to factors like transportation and temperature control during the operation. The OR group also had a higher incidence of hypothermia, defined as a body temperature under 36C, but the difference (16.7% vs 30.8%) did not reach statistical significance (p=0.07). This suggests that PDA ligation in the NICU might offer better temperature control, though the difference in hypothermia rates was not statistically significant.

This study identified statistically significant differences in oxygen saturation at various time points; however, the differences observed were clinically insignificant (-2% to 3%). These findings are consistent with previous research.[9] Additionally, while there was a trend towards a higher incidence of hemodynamic instability in the OR group, the difference was not statistically significant. This contrasts with a study by Lisa K. Lee, which reported a significantly higher incidence of hemodynamic instability in the OR group upon returning to the NICU, suggesting a need for further research to specifically address hemodynamic instability during transportation of newborns to the operating room.

Limitations: Firstly, this study was retrospective and relies on existing medical records, which may have been incomplete or of varying quality. Additionally, the decision to perform PDA ligation in the NICU or OR was not randomized, introducing selection bias. Furthermore, the incidence of mortality was relatively low, making it difficult to conduct further analysis on factors that may affect the outcome.

CONCLUSION

PDA ligation can be safely and effectively performed in the NICU with comparable hospital mortality, potentially providing better temperature control, and without an increased risk of complications, including surgical site infection.

REFERENCES

1. Mitchell SC, Korones SB, Berendes HW. Congenital heart disease in 56,109 births: incidence and natural history. Circulation. 1971;43:323-32.
2. Noori S, McCoy M, Friedlich P, Bright B, Gottipati V, Seri I, et al. Failure of ductus arteriosus closure is associated with increased mortality in preterm infants. Pediatrics. 2009; 123: e138-44.
3. Oxnard SC, McGough C, Jung AL, Ruttenberg HD. Ligation of the patent ductus arteriosus in the newborn intensive care unit. Ann Thorac Surg. 1977;23(6):564-7.
4. Mohammad Saquib Mallick, Abdul Monem Jado, Abdul Rahman Al-Bassam. Surgical procedures performed in the neonatal intensive care unit on critically ill neonates: feasibility and safety. Ann Saudi Med. 2008;28(2):105-8.
5. Lee GY, Sohn YB, Kim MJ, Jeon GW, Shim JW, Chang YS, et al. Outcome following surgical closure of patent ductus arteriosus in very low birth weight infants in neonatal intensive care unit. Yonsei Med J. 2008;49(2):265-71.
6. Ko YC, Chang CI, Chiu IS, Chen YS, Huang SC, Hsieh WS. Surgical ligation of patent ductus arteriosus in very-low-birth-weight premature infants in the neonatal intensive care unit. J Formos Med Assoc. 2009;108(1):69-71.
7. Avsar MK, Demir T, Celiksular C, Zeybek C. Bedside PDA ligation in premature infants less than 28 weeks and 1000 grams. J Cardiothorac Surg. 2016;11(1):146.
8. Turkcan BS, Atalay A, Bozkaya D, Kulahcioglu E, Tasoglu I. Bedside Patent Ductus Arteriosus Ligation in Premature Infants. J Coll Physicians Surg Pak. 2022;32(2):208-12.
9. 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(1): 199.
10. 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.
11. Coster DD, Gorton ME, Grooters RK, Thieman KC, Schneider RF, Soltanzadeh H. Surgical closure of the patent ductus arteriosus in the neonatal intensive care unit. Ann Thorac Surg. 1989;48:386-9.
12. Tsang FHF, Cheng LC, Yung TC, Chau AKT, Chiu CSW. Ligation of patent ductus arteriosus for premature infants in intensive care unit. HK J Paediatr. (new series) 2005;10:282-5.
13. Finer NN, Woo BC, Hayashi A, Hayes B. Neonatal surgery: intensive care unit versus operating room. J Pediatr Surg 1993; 28:645-9.
14. Gavilanes AWD, Heineman E, Herpers MJHM, Blanco CE. Use of neonatal intensive care unit as a safe place for neonatal surgery. Arch Dis Child Fetal Neonatal Ed. 1997;76(1):F51–3.