Efficacy of paravertebral block in "Fast-tracking" pediatric cardiac surgery - Experiences from a tertiary care center

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ABSTRACT

Introduction: Fast tracking plays a crucial role in reducing perioperative morbidity and financial burden by facilitating early extubation and discharge from hospital. Paravertebral block (PVB) is becoming more popular in paediatric surgeries as an alternative to epidural and caudal analgesia. There is scarcity of data regarding the efficacy and safety of PVB in paediatric cardiac surgery.

Methods: We performed a review of records of paediatric cardiac patients who underwent cardiac surgery under general anaesthesia with single shot PVB and compared the analgesia and postoperative outcomes with matched historical controls who underwent cardiac surgery with same anaesthesia protocol without PVB.

Results: The data from 200 children were analysed. 100 children who received paravertebral block were compared with a matched historical controls. The median time to extubation was shorter in the PVB group (0 hr, IQR 0-3 hrs) compared to the control group (16 hrs, IQR 4-20 hrs) (*P* value 0.017*). Intraoperative and postoperative fentanyl requirement was much lower in the PVB group (3.49 (0.91)) compared to the control group (9.86 (1.37)) *P* value <0.01*. Time to first rescue dose of analgesic was longer (7 hrs vs 5 hrs, *P* 0.01*), while time to extubation and duration of ICU stay were significantly less in PVB group . Mean postoperative pain scores were significantly lower in the PVB group at the time of ICU admission (0.85 vs 3.12, *P* 0.001*) till 4 hours (2.11 vs 3.32, *P* 0.001*).

Conclusion: PVB provides an effective and safe anaesthetic approach which can form an important component of "fast-track" care in paediatric cardiac surgery.

Keywords: Bupivacaine, fast-tracking, paravertebral block, pediatric cardiac surgery

INTRODUCTION

"Fast-tracking" plays a crucial role in reducing perioperative morbidity and financial burden by facilitating early extubation and discharge from the hospital. Pain after cardiac surgery can be excruciating hence adequate postoperative analgesia plays a key role in fast-tracking, post cardiac surgery.

Paravertebral block (PVB) is becoming more popular in pediatric surgeries, as an alternative to epidural and caudal analgesia. It is considered superior in controlling the pain than the parenteral opioids, nonsteroidal anti-inflammatory drugs (NSAIDs) and equally at par with epidural analgesia in thoracotomy procedures.[1] It can be safely practiced in cardiac surgeries with heparin use, as there is no risk of neuraxial hematoma as with epidural.[2]

There is a scarcity of data regarding the efficacy and safety of PVB in pediatric cardiac surgery. The fast-track approach has been applied to low-risk noncomplex congenital cardiac defects undergoing cardiac surgery. We describe our experience in the management of a cohort of pediatric cardiac patients who received a single shot bilateral/unilateral PVB as part of our standard anesthesia protocol for fast-tracking.

MATERIALS AND METHODS

After obtaining approval from the institutional review board (IRB), we performed a retrospective review of records of pediatric cardiac patients (age less than 8 years) who underwent cardiac surgery under general anesthesia (GA) with bilateral/unilateral single shot PVB. To assess the efficacy and safety of PVB administration, we compared the analgesic and postoperative outcomes of this cohort with matched historical controls who underwent cardiac surgery with same anesthesia protocol without PVB. The entire cohort included children with noncomplex congenital cardiac defects with RACHS scores 1 to 3. Stratified random sampling was done to ensure equal assignment of the two groups.

All patients had received standard anesthesia care. In addition, children fasted for 6 h for solids, 4 h for breast milk, and 2 h for clear fluids. All children were premedicated with syrup trichlorphos 75 mg/kg. Inhalational induction was done using sevoflurane in oxygen for all children. After establishing intravenous access, fentanyl 2 mcg/kg and rocuronium 0.1 mg/kg were used to facilitate intubation. Additional fentanyl was given as per hemodynamic response to a maximum of 15 mcg/kg. Internal jugular central line and femoral arterial line were inserted after intubation. The maintenance of anesthesia was achieved with 0.7 to 1 MAC sevoflurane. Patients in the PVB group received bilateral single-shot paravertebral block with 0.5 ml/kg of 0.25% bupivacaine at T4 level for sternotomies and unilateral paravertebral block with 0.75 ml/kg of 0.25% bupivacaine at T6 level for thoracotomies.

Paravertebral block technique
We used an ultrasound system (GE Venue 40) in anesthesia mode, with a high-frequency linear probe (L 12i), with a 35 mm footprint for children more than 3 kg and a 25 mm hockey stick probe for children less than 3 kg. "In-plane approach" was used for the right-sided block and "out -of-plane approach" for the left-sided block. The patient was positioned in the left lateral position and T3 vertebral level (spine of scapula) and T7 vertebral level (angle of scapula) were identified [Figure 1]. The spine
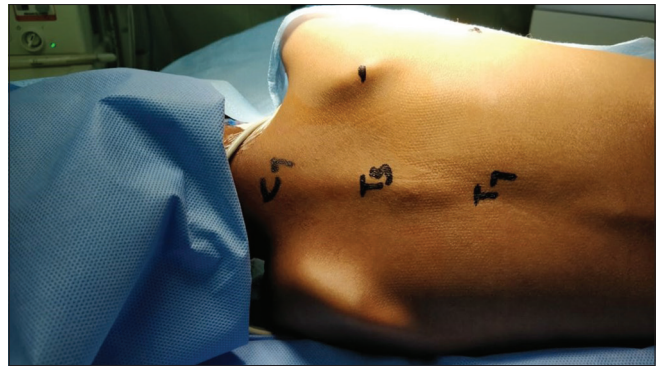

Figure 1: Patient in the left lateral position with the anatomical landmarks marked

of T4 vertebra was confirmed by counting down from the T3 vertebra under aseptic precautions and marked. The ultrasound probe was draped in a sterile sheath and landmarks were identified. The probe was placed in transverse orientation at T4 level [Figure 2a]. Depth was adjusted according to the age of the patient (mostly 2–4 cm). The probe was moved laterally to identify T4 transverse process. Colour doppler was used to identify any vascular structures in the path. The needle entry point was 0.5 cm lateral to the probe [Figure 2b]. Needles (pajunksonoplex) 5 or 10 cm were used for <5 kg and >5 kg, respectively. The needle was advanced to pierce the costotransverse ligament and a give way was appreciated to enter the paravertebral space. [Figure 3a] Further, the drug was deposited after negative aspiration. The desired spread was indicated by the parietal pleura getting pushed anteriorly [Figure 3b].

For the "out-of-plane" technique [Figure 2c], the probe was placed transversely on the T4 spine and moved laterally to identify the triangular space. The needle entry point was approximately the same distance from the probe as the distance from skin to the costotransverse ligament. The probe was tilted towards the needle and the needle was advanced till the tip was visualized on the screen as a dot. The probe was then tilted away and the needle was advanced again till the tip was visualized as a dot. With this process of tilting and needle advancement, the needle tip entering the paravertebral space was confirmed by loss of resistance and the anterior pushing of pleura by the test saline. Once placement of needle into the paravertebral space was confirmed, the drug was injected into space.

Cardiopulmonary bypass (CPB) techniques were standardized and all children underwent surgery on CPB and underwent modified ultrafiltration after separation from CPB.

Postoperative care and assessment
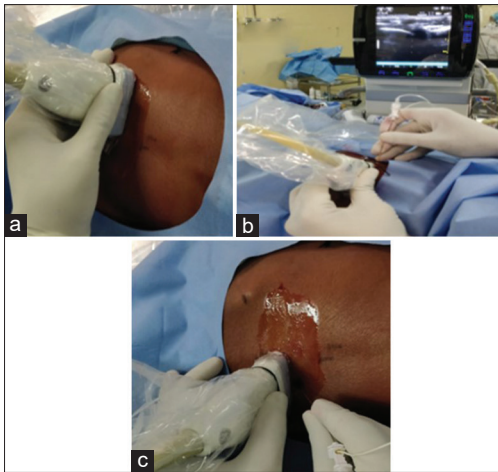All patients received intravenous paracetamol 15 mg/kg after weaning from CPB at six-hourly intervals. The bedside

Figure 2: (a) Probe placement for in-plane technique on the right side. (b) Needle entry for in-plane technique (c) Probe placement and needle entry for out-of-plane technique on the left side

nurse documented the pain scores on a "two-hourly" basis using appropriate pain scores (objective pain scale for children between 0–3 years and FLACC score above 4 years, all pain scales ranging from 0–10). Pain scores were maintained less than 4 and rescue analgesics (fentanyl boluses) were administered as per the discretion of the cardiac intensivist. The practice of "documenting appropriate pain scores" and "deciding need for rescue analgesics under supervision of the cardiac intensivist" has been routinely practiced in all postoperative patients admitted to the cardiothoracic ICU of our institution as per standard of care. A "two-hourly" pain score was recorded until the patient was discharged to the step-down ICU.

Outcome measures
Demographic data, diagnosis, type of operation, duration of surgery, cardiopulmonary bypass time, and aortic cross-clamp time were obtained from the inpatient records. Outcome measures assessed included a total intraoperative and postoperative opioid requirement (for initial 12 h postsurgery), time to extubation, the timing of the first rescue analgesia, number of rescue analgesics, and postoperative pain scores (for the initial 24 h postsurgery). Other data collected also included hemodynamic changes including intraoperative hypotension defined as fall in MAP more than 20% below baseline and bradycardia defined as <80 bpm (<1 year),<70 bpm (1–3 yrs), <65 (3–6 yrs,), and <60 (6–12 yrs), postoperative vomiting, PVB related complications (hematoma, abscess), total duration of ICU stay, need for reintubation with reason, postoperative complications, and mortality.

Statistics
Statistical analysis were done using SPSS version 16. Continuous variables were presented as mean, median, and
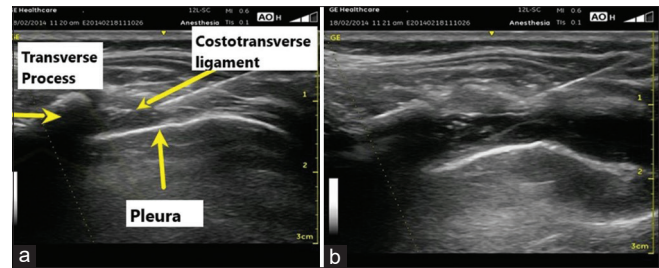

Figure 3: (a) USG-guided visualization of needle entry (b) Deposition of drug in the paravertebral space

standard deviation. Further, *t*-test and Chi-square tests were done for statistical comparisons for parametric variables. Mann Whitney U test was done for nonparametric variables. *P*- value of less than 0.05 was considered statistically significant.

RESULTS

Demographic data
The data from 200 children were analyzed. Around 100 children who received paravertebral block were compared with matched historical controls. The main indications of surgery included atrial septal defect, ventricular septal defect, tetralogy of fallot, patent ductus arteriosus, coarctation of the aorta, and miscellaneous group (including shunts, aortopulmonary window, an anomalous left coronary artery from pulmonary artery - ALCAPA). The baseline demographic details and perioperative variables were comparable between the two groups. However, we had more patients with pulmonary artery hypertension in the paravertebral group and the difference was statistically significant. The data has been depicted in Table 1.

Time to extubation, analgesic requirements, and pain scores
The median time to extubation was shorter in the PVB group (0 h, IQR 0–3 h) compared to the control group (16 h, IQR 4–20 h) (*P*-value 0.017*) [Table 2]. The majority of the children in the PVB group were extubated within the first hour compared to the control group where extubation was done between 4–20 h. This difference was statistically significant. Few children (20) in the paravertebral group were extubated after 6 h. This subset mainly comprised of children who were operated in the latter half of the day. These children were ventilated overnight and extubated the next morning as per unit policy.

Intraoperative and postoperative fentanyl requirement was much lower in the PVB group. Time to first rescue dose of analgesia was longer, while time to extubation and duration of ICU stay were significantly less in PVB group [Table 2]. Mean

postoperative pain scores were significantly lower in the PVB group at the time of ICU admission (0.85 vs 3.12, *P* 0.001) till 4 h (2.11 vs 3.32, *P* 0.001) [Figure 4]. The interpretation of pain scores beyond 4 h was difficult considering the use of rescue analgesics whenever pain scores exceeded 3.

No children in the PVB group needed reintubation for extubation failure. Moreover, five children in the control group needed reintubation for lung collapse while two children required bronchoscopy for suspected mucous plugs resulting in collapse. Morbidity associated with splinting of chest due to pain was significantly less in the PVB group.

Adverse events

PVB did not result in hemodynamic instability in any of the patients. The incidence of postoperative vomiting was lower in the PVB group (11.7 vs 31.7%) which was significant. Three children in the PVB group (2 re-exploration, 1 sepsis) and four children in the control group (2 re-exploration, 1 sepsis, 1 pneumothorax) required reintubation. There was no mortality in the entire cohort. Injection site complications including hematoma were not noted in any of the subjects.

DISCUSSION

Fast-track care and postoperative analgesia

"Fast-track" care plays an important role in improved outcomes after pediatric cardiac surgery. Benefits of the same

include reduced nosocomial infections, lesser unplanned extubations, increased patient, and parent satisfaction with a reduced financial burden.[3-5] Postoperative pain is thought to be the single most important factor leading to ineffective ventilation and impaired secretion clearance after thoracotomy. Severe or inadequately treated acute pain after thoracotomy also predicts conversion to chronic post-thoracotomy pain. An adverse stress response with higher cortisol levels may also affect wound healing, platelet adhesion, and natural killer cell activity. The surgical stress response can be suppressed by the proper selection of regional anesthesia.

Role of paravertebral block

Several studies have demonstrated the opioid-sparing effect and better analgesic profile of neuraxial anesthesia following cardiac surgery. The various techniques used are intrathecal morphine, thoracic epidural block, or caudal epidural anesthesia.[6,7] There is a theoretical risk of hematoma in the spinal cord with these techniques. However, cardiac surgery is done after systemic anticoagulation.
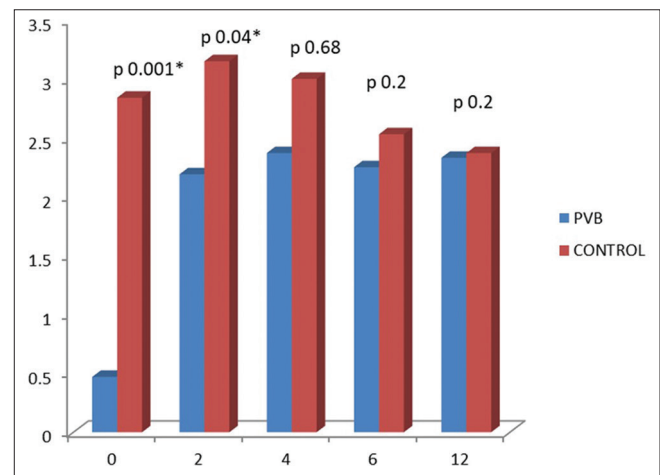
Figure 4: Bar chart showing the comparison of mean pain scores (0–10) between the two groups at the time of admission to ICU (0) h, 2 h, 4 h, 6 h, and 12 h. Pain score have been depicted in y-axis and time period in x-axis

Table 1: Comparison of baseline demographic data, perioperative details, and type of surgery between the two groups (Data are represented as mean [standard deviation] and number (%))

Parameter	PVB group (100)	Control group (100)	P
Age (years)	6.14 (5.05)	5.32 (4.51)	0.21
Sex (males/females)	66/34	69/31	0.25
Body weight (kg)	16.64 (10.69)	15.41 (10.35)	0.39
CPB duration (min)	60.20 (29.21)	64.14 (29.31)	0.34
Aortic clamp time (min)	34.9 (21.63)	36.73 (18.83)	0.41
Duration of surgery (h)	3.32 (0.74)	2.98 (0.61)	0.08
RACHS score 1	32	28	0.6
RACHS score 2	56	57	
RACHS score 3	12	15	
Pulmonary hypertension	33	16	<0.001*

Table 2: Comparison of analgesic requirements, extubation times, and postoperative intensive care unit stay between the two groups

Parameter	PVB group	Control group	P
Intraoperative Fentanyl (mcg/kg)	3.49 (0.91)	9.86 (1.37)	<0.01*
Postoperative Fentanyl (mcg/kg) within 12 h	17.93 (7.15)	39.36 (16.17)	<0.01*
Time to Extubation (median) (IQR)	0 h (0-3)	16 h (4-20)	0.01*
<1 h	65	2	<0.001*
1 to 4 h	15	24	
4-6 h	0	18	
>6 h	20	55	
	65	2	
Timing of first rescue analgesic postop (h)	7 (2.4)	5.05 (1.32)	0.01*
Duration of ICU stay (days)	1.61 (1.07)	3.07 (3.92)	<0.001*

Data in table are represented as mean [standard deviation] and number (%)

The paravertebral space is a triangular space that is bordered by the transverse process and superior costotransverse ligament posteriorly, the parietal pleura anteriorly, and the lateral edge of the vertebral body and intervertebral discs medially. The spaces communicate, allowing the local anesthetic to spread cranially and caudally (limited by the psoas muscle at L1) to cover multiple dermatomes and produce a multilevel block, even from a single injection.[8]

The paravertebral block is performed outside the central nervous system, outside the closed spinal space. The procedure is done under ultrasound guidance which makes it a very safe technique. Previous studies done in post-thoracotomy pain had reported good outcomes with PVB compared to thoracic epidural anesthesia.[9,10] Davies *et al.*[11] also reported reduction in postsurgical pulmonary complications by nearly 64% in PVB group compared to epidural anesthesia which is similar to our study. Kotze *et al.* in a systematic review and meta-regression analysis had reported the effectiveness of different techniques for PVB for post-thoracotomy analgesia.[12] They reported that higher doses of bupivacaine had better pain relief and earlier recovery of pulmonary functions. The addition of fentanyl, clonidine, or patient-controlled analgesia with morphine did not provide improved analgesia. Adverse events reported with epidural anesthesia include higher failure rates, hematoma, and abscess formation. A recent meta-analysis by Scarfe *et al.* reported significantly lower incidence of emesis, hypotension, and urinary retention compared to epidural analgesia.[13] Tahara *et al.* had reported the safety of continuous PVB in a case series of patients who underwent minimally invasive cardiac surgery.[14]

Relevance of PVB in pediatric cardiac surgery

Children differ from adults as they are often unable to express their pain and discomfort. This applies especially to neonates and smaller children. Pediatric cardiac surgery done on cardiopulmonary bypass machine mounts a huge amount of stress response as pain pathways are stimulated which results in immune system response, inflammatory response, hormonal, and metabolic changes. One way to abolish this response is to use intravenous fentanyl. The various doses of fentanyl required to provide analgesia, hemodynamic stability, and suppression of stress response are 1–5 mcg/kg, 5–10 mcg/kg, and 25–50 mcg/kg, respectively.[15-17] Pediatric opioid infusions are associated with a higher risk of adverse events such as emesis (interferes with enteral nutrition), itching, and respiratory depression. Regional techniques such as epidural block can be potentially technically difficult due to narrow epidural space especially in the setting of anticoagulant use. Garg *et al.* have shown the

efficacy of caudal bupivacaine plus dexmedetomidine for fast-tracking pediatric cardiac surgical patients.[18] However, the recommended time between the caudal puncture and heparinization is 1 h which is often difficult to maintain. PVB provides an attractive option for providing adequate analgesia as there is only a negligible risk of closed space hematoma using an ultrasound-guided technique. However, there is scarce evidence regarding the efficacy of PVB in the pediatric age group especially with respect to pediatric cardiac surgery. Karmakar *et al.* had reported the use of continuous paravertebral infusion of bupivacaine for post-thoracotomy analgesia in young infants.[19] El-Morsy *et al.* had compared the outcomes of PVB with epidural block in 60 children undergoing cardiac surgery. The main indications for surgery in this study included PDA ligation and coarctation of aorta. The study reported comparable pain scores and hormonal responses. However, high failure rate and adverse events were noted in the epidural blockade group.

El Bendary[20] and El Baser, in their study, concluded that a single bilateral bupivacaine injection by ultrasound-guided paravertebral block reduced postoperative opioid requirement and facilitated early extubation. Although the study profile of the children was similar to our study, their sample size was much smaller.

To our knowledge, this is the largest series reporting the utility of PVB in pediatric cardiac surgery. The study included a large cohort of children with noncomplex congenital cardiac defects. The salient observations from the study include reduced intraoperative and postoperative opioid use, earlier time to extubation with the majority of them having a "very early extubation/on table extubation" (<1 h), longer time to first rescue analgesia, and better early postoperative pain scores. No adverse events or "block failure" was noted. The reduced use of intravenous opioids accounts for the earlier extubation and lesser incidence of emesis. Based on these observations, PVB has become an integral part of the "fast-tracking" process for pediatric cardiac surgery in our institution.

One of the limitations of the study was the retrospective nature of the study. PVB had become an established standard of care in our institution by 2015. Hence, a randomized control trial could not be justified. Although we did not get information on patient and parent satisfaction, we believe parental satisfaction would have been high seeing their children awake and being comfortable. The use of more validated pain scores such as the COMFORT scale could have provided better evidence regarding the efficacy of analgesia. Our unit protocol of not extubating patients

after 6 pm resulted in delayed extubations in certain cases. We have not studied the stress response suppression by paravertebral block in terms of serum cortisol rise.

CONCLUSIONS

PVB provides an effective and safe anesthetic approach which can form an important component of "fast-track" care in pediatric cardiac surgery. Prospective studies to assess the role of continuous PVB and addition of dexmedetomidine to local anesthetic may provide high-quality evidence in the field of pediatric fast-tracking.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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