Original Article

A randomised controlled comparison of serratus anterior plane, pectoral nerves and intercostal nerve block for post-thoracotomy analgesia in adult cardiac surgery

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ABSTRACT

Background and Aims: Enhanced recovery after cardiac surgery is centred around multimodal analgesia which is becoming increasingly feasible with the advent of safer regional analgesic techniques such as fascial plane blocks. We designed this prospective, single-blind, randomised controlled study to compare the efficacy of serratus anterior plane block (SAPB), pectoral nerves (Pecs) II block, and intercostal nerve block (ICNB) for post-thoracotomy analgesia in cardiac surgery. **Methods:** 100 adults posted for cardiac surgery through a thoracotomy were randomly allocated to one of the three groups: SAPB, Pecs II or, ICNB wherein the patients received 2.5 mg/kg of 0.5% ropivacaine for ultrasound-guided block after completion of surgery. Postoperatively, intravenous (IV) paracetamol was used for multimodal and fentanyl was employed as rescue analgesia. Visual analogue scale (VAS) was evaluated at 2, 4, 6, 8, 10 and 12 hours post-extubation. **Results:** The early mean VAS scores at 2, 4 and 6 hours were comparable in the 3 groups. The late mean VAS (8, 10 and 12 hours) was significantly lower in the SAPB and Pecs II group compared with that of the ICNB group (*P* value <0.05). The cumulative rescue fentanyl dose was significantly higher in ICNB group compared to SAPB and Pecs II group (*P* value <0.001). The SAPB group had the highest time to 1st rescue analgesic requirement in contrast to the other groups. **Conclusion:** SAPB and Pecs II blocks are simple single-shot effective alternatives to ICNB with a prolonged analgesic duration following thoracotomy and can potentially enhance pain-free recovery after cardiac surgery.

Key words: Adult cardiac surgery, intercostal nerve block, pectoral nerve block, postoperative pain, serratus anterior plane block, thoracotomy

INTRODUCTION

A conventional cardiac surgical setting presents peculiar impediments to an unabated incorporation of regional analgesic modalities considering the technical difficulties, risks associated with haemodynamic perturbations and epidural haematoma against the background of the requirement of systemic heparinisation.[1,2] Nevertheless, an augmented embracement of the modern safer regional analgesic techniques increasingly motivates the cardiac anaesthesiologists to formulate effective regional-centric multimodal analgesic schemes, particularly pertinent to the present era of opioid sparing.[1-4]

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Despite the advent of minimally invasive cardiac surgery (contemplating alternative surgical approach such as an anterolateral thoracotomy compared to the traditional midline sternotomy), postoperative pain, respiratory compromise and consequential pulmonary morbidity present significant management concerns.[5] In addition, a conglomeration of factors ranging from surgical incision, chest wall retraction and muscle layer splitting to postoperative insertion of the chest drain collectively contribute to the nociceptive-pathway stimulation culminating as post-thoracotomy pain (PTP). PTP adversely affects the depth of breathing and the ability to cough leading to hypoxemia, atelectasis and other post-operative respiratory impediments to an early recovery.[5,6]

The aforementioned elucidation of the importance of ensuring effective post-thoracotomy analgesia in conjunction with an early recovery continues to evoke interest in the regional analgesic approach to PTP management. While the intercostal nerve block (ICNB)[7] has been extensively studied and employed for post-thoracotomy analgesia, the literature on improved analgesia with fascial plane blocks such as serratus anterior plane block (SAPB) and pectoral nerves (Pecs II) block is promising.[8,9] Nevertheless, the dearth of comparative evaluation of the existing and upcoming regional analgesic modalities, particularly in the setting of thoracotomy for adult cardiac surgery prompted this index study staging a randomised controlled comparison of post-thoracotomy analgesic efficacy of SAPB, Pecs II and ICNB.

METHODS

This prospective, single-blind, randomised comparative trial was conducted at a tertiary care cardiothoracic center and was duly approved by the institutional ethical committee (IECPG-284/7.09.2017, RT-37/28.09.2017) and registered at ctri.nic.in (CTRI/2018/01/011610). The study complied with the CONSORT 2010 randomised controlled trial (RCT) statement guidelines [Figure 1].

The index study included 100 American Society of Anesthesiologists (ASA) physical status II-III participants in 15–40 years age group scheduled for an elective cardiac surgery through a thoracotomy incision in the time period from February 2018 to September 2019. The patients were excluded if they were unable to perform the visual analogue scale (VAS), or had previous thoracic surgeries. An emergency

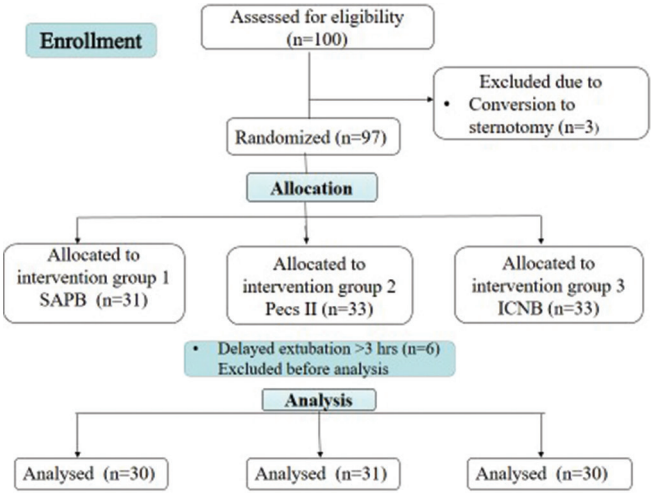

Figure 1: CONSORT flow diagram

surgical setting, known ropivacaine allergy; infection at the injection site; or derangement in the coagulation parameters (platelet count $<100\times10^3/\mu L$, prothrombin and activated partial thromboplastin time >1.5 times of the normal, or an international normalised ratio >1.5) constituted additional study exclusions.

A written informed consent was obtained from all the study participants. The preoperative cardiac medications were continued and premedication was administered in the form of (0.l mg/kg morphine and 0.5 mg/kg promethazine) intramuscularly. After wheeling into the operating room, standard ASA monitoring was initiated including: 5-lead electrocardiogram, non-invasive blood pressure and pulse oximetry following which a peripheral intravenous (IV) and an arterial line were secured. General anaesthesia was induced and maintained alongside capnography and bispectral index monitoring as per standard institutional protocol. The hemodynamic parameters were maintained within 20% of the baseline. A posterolateral incision in the 4^{th} or 5^{th} intercostal space was performed. In the patients requiring extracorporeal support for assisting a surgical correction, cardiopulmonary bypass (CPB) was instituted under adequate heparinisation. Following the successful CPB weaning, the anticoagulant effect of heparin was adequately reversed with injection protamine in order to achieve baseline activated clotting time.

After completion of surgery, one of the 3 regional nerve blocks (SAPB, Pecs II, or ICNB) was performed under ultrasound-guidance wherein the group allocation was assisted by a computer-generated random number

table and concealed with the help of coded, opaque and sealed envelopes. The blocks were performed under aseptic precautions using a Philips – L 12–3 linear array transducer (Philips Inc, USA) in a sterile cover with jelly and a 21-gauge 100 mm Stimuplex A sterile block needle (B. Braun, Melsungen, Germany).

SAPB was performed in a lateral decubitus position with the ultrasound probe oriented in a sagittal plane over the mid-clavicular thoracic region. The fifth rib and the overlying muscles such as latissimus dorsi, teres major and serratus anterior were identified in the mid-axillary line. The needle was introduced into the plane deep to the serratus anterior muscle and 2.5 mg/kg of 0.5% ropivacaine was injected in this plane under ultrasound-guidance [Figure 2a].

Pecs II block was performed in a supine position with the ultrasound probe oriented inferolaterally in the mid-clavicular region. The pectoralis major and minor muscles were outlined [Figure 2b]. The needle was introduced at the level corresponding to the 4th rib, heading, from medial to lateral direction toward the anterior axillary line. Thereby the needle was advanced until the rib and then it was withdrawn so as to position the tip in the plane between serratus anterior and pectoralis minor muscle. A total of 1.25 mg/kg of 0.5% ropivacaine (half the total dose) was injected after confirming a negative aspiration. Following the initial drug injection, the needle was meticulously withdrawn so that the tip lay between the two pectoral muscles, and 1.25 mg/kg of 0.5% ropivacaine (rest of the dose) was injected after careful aspiration [Figure 2c].

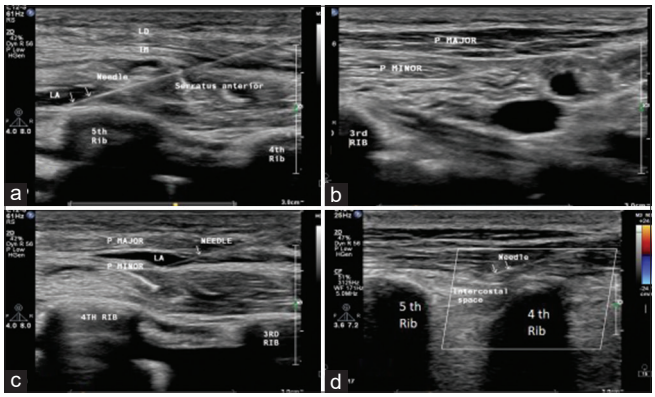

Figure 2: Depiction of the SAPB sonoanatomy with the needle directed (at the level of the fifth rib) toward the optimal plane for local anaesthetic deposition below the serratus anterior muscle (a); Ultra-sonographic image outlining the Pectoralis major and minor muscles (b); Pecs II block with the needle drug injection hydro-dissecting the plane between the pectoral muscles (c); Sonoanatomy of the intercostal musculature and adjacent ribs for administering ICNB (d). LA: Local anaesthetic; LD: Latissimus dorsi; TM: Teres Major; P Major: Pectoralis major; P Minor: Pectoralis minor

ICNB was performed in a lateral decubitus position with the ultrasound probe oriented longitudinally and the cranial aspect (of the probe) slightly laterally rotated at the posterior angulation of the concerned rib. The three layers of intercostal muscle (innermost, internal and external) were outlined in the space between the adjacent ribs. Subsequently, the needle was introduced and advanced carefully into the innermost intercostal muscle layer, and 0.5% ropivacaine was administered (after negative aspiration for air or blood) in divided doses at the incisional level and two spaces below and above the incision. The total drug administered amounted to 2.5 mg/kg, in congruence with other two study groups [Figure 2d].

Following the administration of the block, the patients were shifted to the intensive care unit (ICU). The study participants were extubated on meeting the following criteria (conscious, haemodynamic stability, peak inspiratory pressure <20 cmH_2O, no residual neuromuscular blockade and satisfactory arterial blood gas analysis). The patients requiring postoperative ventilation for more than three hours were excluded from the analysis. VAS score was assessed at 2, 4, 6, 8, 10 and 12 h post-extubation. The mean computed scores were classified as early (2, 4 and 6 h) and late (8, 10 and 12 h) VAS. All the patients received IV paracetamol, 15 mg/kg, 8 hourly. Rescue analgesia was provided in the form 0.5–1 μg/kg IV fentanyl so as to maintain the post-extubation VAS score ≤4 premised on the assessment of the observer anaesthesiologist who was blinded to the group allocation. The intraoperative and 12-h postoperative fentanyl consumption was recorded. The time to first rescue analgesic requirement was estimated as the duration elapsed following the block administration. Participants were discharged from the ICU once the haemodynamic parameters were stable (on minimal inotropic/vasopressor support), satisfactory respiratory status (extubated with acceptable arterial blood gases and airway patency), oxygen requirement no more than an FiO_2 of 60%, neurologic stability and no other significant post-operative complications such as vomiting which could preclude oral acceptance.

A sample size of 90 adults was estimated based on the finding of a pilot study evaluating the mean post-extubation VAS amongst the SAPB, Pecs II and ICNB groups (2.9 ± 0.47, 3.22 ± 0.51 and 3.75 ± 0.56,

respectively) to ensure 90% power at $\alpha = 0.05$. Hence, 100 adults were included considering the possibility of dropouts.

The statistical analysis was performed using The Stata software, Version 14 (StataCorp LP, College Station, TX). The continuous data was expressed as mean and standard deviation, whereas the qualitative data were expressed as frequencies and percentages. The association between qualitative variables was examined using the Chi-square test/Fisher's exact test. One-way analysis of variance followed by Bonferroni correction was performed for comparison among the groups. A *P* value <0.05 was considered to be statistically significant.

RESULTS

A total of 100 patients undergoing cardiac surgery through a thoracotomy incision were initially recruited. After exclusion of 9 patients (3 patients excluded due to intraoperative conversion to sternotomy prior to randomisation and 6 patients excluded after randomisation due to prolonged intubation >3 h postoperatively) the data of 91 participants (30 in SAPB group, 31 in Pecs II group and 30 in ICNB group) was analysed [Figure 1]. The demographic profile, baseline characteristics and the extubation time were comparable in the three groups [Table 1].

The trend of the post-extubation mean VAS scores is depicted in Figure 3, wherein the early VAS scores (2, 4, 6 h, post-extubation) were comparable in the SAPB, Pecs II and ICNB group. However, the late VAS scores (8, 10 and 12 h, post-extubation) were significantly lower in the SAPB group in contrast to the ICNB group (*P* value <0.001). The Pecs II group also demonstrated significantly lower VAS score as compared to the ICNB group at 10 hours ($P < 0.001$) and 8, 12 h post extubation ($P < 0.05$). With regards to the comparison within the fascial plane blocks, there was no significant difference between the SAPB and Pecs II groups except the mean post-extubation VAS score at 12 h which was significantly lower in SAPB (3.23 ± 0.50) compared to the Pecs II group (3.71 ± 0.69) (*P* value <0.05) [Table 2].

The cumulative postoperative rescue fentanyl consumption was greatest in the ICNB group (0.67 ± 0.16 μg/Kg) and was considerably higher than the SAPB (0.21 ± 0.04 μg/Kg) and Pecs II groups (0.23 ± 0.06 μg/Kg) (*P* value <0.001). The mean time to rescue analgesic requirement was highest in the SAPB group (11.7 ± 0.29 h) signifying a prolonged analgesic duration in contrast to other blocks (Pecs II: 11.44 ± 0.34 h; ICNB: 10.92 ± 0.61 h). The length of stay in the ICU was significantly lower in the fascial plane groups (SAPB, Pecs II) as opposed to the ICNB group [Table 3].

No noteworthy complication related to the block performance, such as an intravascular injection, haematoma formation or neural injury was observed in any of the study participants. Other postoperative adverse effects: nausea, vomiting, bradycardia, hypotension, pruritus and respiratory depression, were comparable among the three groups.

DISCUSSION

The study demonstrates a satisfactory efficacy of the fascial plane blocks and ICNB in the early PTP

Table 1: Demographic profile and peri-operative characteristics of the study participants

Variable	Group SAPB (*n*=30) (Mean±SD)	Group Pecs II (*n*=31) (Mean±SD)	Group ICNB (*n*=30) (Mean±SD)	*P*
Age (Years)	24.86±5.50	25.29±5.80	24.77±4.98	0.923
Gender (Male/Female)	17/13	15/16	16/14	0.836
Duration of Surgery (Min)	208.42±33.93	203.14±25.36	206.07±29.34	0.80
Surgical Procedures				
ASD Closure	19	20	18	0.949
MVR	7	8	9	
PDA Ligation	3	3	2	
Coarctation repair	1	0	1	
Surgery requiring CPB	26	28	27	
CPB duration (min)	105.11±18.22	102.85±17.95	102.29±17.10	0.830
Aortic cross clamp time (min)	52.07±7.91	51.5±8.62	53.03±8.35	0.787
Total intraoperative fentanyl administered (μg/kg)	5.20±1.11	5.26±0.93	5.30±1.15	0.942
Time to extubation (hours)	1.93±0.22	1.96±0.16	2.01±0.20	0.377

ASD: Atrial septal defect; MVR: Mitral valve replacement; PDA: Patent ductus arteriosus; CPB: Cardiopulmonary bypass. SD: Standard deviation. *P*<0.05 is considered as a statistically significant difference

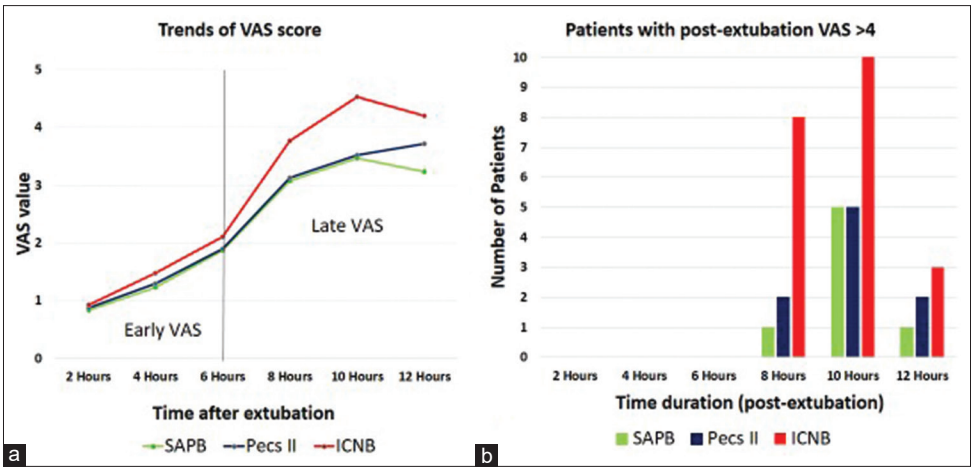

Figure 3: VAS trends upto 12 h post-extubation (a); Number of patients demonstrating a VAS >4 in the three groups at different time points (b)

Table 2: Mean VAS in the three groups throughout the first 12 h post extubation

Time after extubation	Group SAPB Mean±SD	Group Pecs II Mean±SD	Group ICNB Mean±SD	*P* for Overall Group Effect	*P* for pairwise comparison		
					SAPB vs. Pecs II	SAPB vs. ICNB	Pecs II vs. ICNB
2 h	0.83±0.37	0.87±0.34	0.93±0.36	0.559	1.000	0.862	1.000
4 h	1.23±0.50	1.29±0.53	1.47±0.63	0.243	1.000	0.323	0.657
6 h	1.87±0.43	1.90±0.39	2.1±0.66	0.167	1.000	0.239	0.406
8 h	3.07±0.52	3.13±0.56	3.76±0.85	<0.001	1.000	<0.001	0.001
10 h	3.47±0.82	3.52±0.77	4.53±0.82	<0.001	1.000	<0.001	<0.001
12 h	3.23±0.50	3.71±0.69	4.2±0.61	<0.001	0.009	<0.001	0.007

SD: Standard deviation. *P*<0.05 is considered as a statistically significant difference

Table 3: Comparison of the secondary outcomes among the three Groups

Variable	Group SAPB (Mean±SD)	Group Pecs II (Mean±SD)	Group ICNB (Mean±SD)	*P* for overall Group Effect	*P* for pairwise comparison		
					SAPB vs. Pecs II	SAPB vs. ICNB	Pecs II vs. ICNB
Post-operative Fentanyl dose (μg/kg)	0.21±0.04	0.23±0.06	0.67±0.16	<0.001	0.997	<0.001	<0.001
Mean time to rescue analgesic requirement (h)	11.7±0.29	11.44±0.34	10.92±0.61	0.0035	1.000	0.005	0.087
Length of stay in intensive care unit (h)	11.33±1.26	11.29±1.57	13.75±1.61	<0.001	1.000	<0.001	<0.001

SD: Standard deviation. *P*<0.05 is considered as a statistically significant difference

management (within 6 h of extubation) while a superior efficacy of the fascial plane blocks in the late postoperative period (6–12 h following extubation) is outlined by the significantly lower mean VAS scores in the fascial plane block groups compared to the ICNB group [Table 2].

The liaison between minimising invasion in cardiac surgery (such as thoracotomy approach) and an effective PTP can prove instrumental to attain fast-tracking in cardiac surgery.[1,2] While the PTP management can be particularly challenging owing to the richly innervated thorax (necessitating the administration of systemic opioids and other non-opioid analgesics precluding an early recovery), safe and effective regional thoracic analgesic techniques can potentially provide a viable solution.[5]

In this context, ultrasound-guided fascial plane blocks are receiving increased attention closely backed up by a refined comprehension of the sonoanatomy of these blocks.[10] Originally described in the setting of breast surgery by Blanco *et al*.,[11,12] the initial literature accumulating on the role of these innovative blocks in post-thoracotomy analgesia is encouraging.[8] However, the majority of the available research focuses on SAPB in thoracotomy with only scarce literature pertaining to the application of Pecs II in thoracotomy.[8] A three-armed RCT by Saad and colleagues evaluated the efficacy of pre-incisional SAPB, thoracic paravertebral block (TPVB) in comparison to systemic analgesic approach following thoracotomy in 90 patients.[13] They revealed lower VAS scores in the SAPB and TPVB groups compared to systemic analgesia up to 9 postoperative hours. However, the pain scores beyond 12 h were lower for the TPVB group in contrast to

the SAPB group although the haemodynamics were better maintained in the patients receiving SAPB.[13] There are a few case series depicting reduced pain following thoracic trauma with the contemplation of Pecs II block.[14,15] Kumar *et al*. delineated the analgesic and opioid-sparing benefits of Pecs II block in their case series of 10 patients undergoing video-assisted thoracoscopic surgery.[16]

The demonstration of a superior analgesic profile of SAPB and Pecs II compared to ICNB in this index study [Figure 3] is the extension of our previous experience with the pre-incisional administration of blocks in a RCT in paediatric thoracotomies for congenital cardiac surgery.[5] However, we performed a post-operative block in the present study given the highly variable surgical duration in adult cardiac surgery (incorporating relatively smaller procedures like patent ductus arteriosus ligation to more time consuming valve replacement surgeries). Similar finding elucidating the superiority of postoperative SAPB over ICNB has also been discovered in a retrospective cohort study involving 42 post-thoracotomy patients by Öksüz et al.[17] Moreover, the duration of analgesic cover provided by SAPB in the present study (11.7 ± 0.29 h) is in congruence with the previous literature.[18]

To the best of our knowledge, this was the first trial comparing SAPB, Pecs II and ICNB for acute post-operative PTP management in adult cardiac surgical subset. The prolonged analgesic duration of SAPB and Pecs II blocks explain the much lower, almost one-third post-operative rescue fentanyl requirement in the former groups compared to the ICNB group [Table 3].[19,20] This can be attributed to the elevated systemic absorption and rapid clearance of the drug from the highly vascular intercostal bed[21,22] whereas the deposition of the local anaesthetic (LA) drug in a myofascial plane of interest is expected to more selectively block the higher-order ramifications of the branches of the intercostal nerves.[8,23-25] In addition, other analgesics such as non-steroidal anti-inflammatory drugs were avoided in all the study participants, particularly given a cardiac surgical setting where the former can potentially predispose to postoperative bleeding and/or acute-kidney injury.[2] Moreover, ropivacaine constitutes a safer LA option in cardiac patients considering a lower cardiotoxicity potential.[26]

There were a few limitations in our study. First, inclusion of a control group could have substantiated the methodological credibility of the RCT furthermore. Second, the lack of assessment of VAS beyond 12 h post extubation limits the conclusiveness of interesting study observations such as lower VAS in the SAPB compared to the Pecs II group at the 12th h after extubation. Third, patient controlled rescue analgesia could have been incorporated. Lastly, the addition of other adjuvants and/or continuous catheters constituted additional feasible options to prolong postoperative analgesia.

CONCLUSION

The study concludes that the fascial plane blocks like SAPB and Pecs II block are simple, single-shot and effective alternatives to ICNB with a longer postoperative analgesic duration, thereby representing a promising inclusion to the regional analgesic repertoire for PTP management in cardiac surgical arena. The increasing recognition and incorporation of such novel analgesic modalities as the major component of multimodal analgesic scheme can potentially minimise the opioid requirement and augment an enhanced postoperative recovery after cardiac surgery.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient (s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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