Original Article

Analgesic efficacy and spread of local anesthetic in ultrasound-guided paravertebral, pectoralis II, and serratus anterior plane block for breast surgeries: A randomized controlled trial

ABSTRACT

Background: Thoracic paravertebral block (TPVB) has become the gold standard to provide postoperative analgesia in breast surgery. Recently, ultrasound-guided (USG) pectoralis (PECS) block and serratus anterior plane (SAP) block have been described as an alternative to TPVB. The objectives were to compare TPVB, PECS, and SAP block in terms of analgesic efficacy and the spread of local anesthetic by ultrasound imaging, correlating it with the sensory blockade.

Materials and Methods: Prospective randomized interventional study conducted in 45 ASA grades I–II patients scheduled for the elective breast surgery. Patients were randomly allocated into three groups, i.e., Gr.1 (USG –TPVB) (ropivacaine 0.375% 20 ml), Gr.2 (USG-PECS II) block (ropivacaine 0.375% 30 ml), and Gr.3 (USG-SAP) (ropivacaine 0.375% 30 ml). Spread of the local anesthetics was seen with ultrasound imaging. Onset of sensory blockade, postoperative fentanyl consumption, and pain scores was measured.

Results: TPVB and SAP group had comparatively higher spread and sensory block compared to PECS group. Postoperative fentanyl requirement (mean ± SD) was 428.33 ± 243.1 μg, 644.67 ± 260.15 μg, and 415 ± 182.44 μg in the TPVB group, PECS II group, and SAP group, respectively. SAP group had significantly lesser requirement than PECS II group ($P = 0.028$) but similar requirement as in TPVB group ($P = 1.0$). Pain scores were not significantly different among the group in the postoperative period.

Conclusion: TPVB and SAP group result in a greater spread of the drug and provide equivalent analgesia and are superior to the PECS II block in providing analgesia for breast surgeries. SAP block is easier to perform than TPVB with lesser chances of complications and results in faster onset.

Key words: Breast surgery; nerve block; PECS block; regional anesthesia; serratus plane block; thoracic paravertebral block

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Introduction

Breast surgeries can result in significant postoperative pain and may lead to chronic pain in more than 50% of the cases.[1] Breast cancer surgery may result in complications and nerve damage leading to postmastectomy pain, including phantom breast pain, intercostobranchial neuralgia, or neuropathic pain.[2]

Regional anesthesia techniques in breast surgery result in fewer incidences of chronic pain,[3-5] decreased morbidity, lesser duration of hospital stay, and decreased requirements of opioids.

Among the various regional techniques, thoracic paravertebral block (TPVB) has become the gold standard for patients undergoing breast surgeries providing good postoperative pain control[6]. However, it carries the risk of complications, such as pneumothorax, inadvertent vascular injection, epidural or intrathecal spread, and total spinal anesthesia.[7]

Recently ultrasound-guided (USG), less invasive thoracic wall interfascial plane blocks have been described as an alternative to paravertebral block. Pectoralis (PECS 1) block is one such block, which targets the medial and lateral pectoral nerves and is useful for breast expanding/prosthesis surgeries.[8] A modification of this, known as the PECS II block, includes the PECS 1 block and targets the T2-T6 intercostal nerves with long thoracic nerve providing analgesia,[9,10] for more extensive surgeries of breast like tumor resection/mastectomies with axillary node clearance. It is a two-step procedure involving deposition of local anesthetic i) between two pectoral muscles and ii) between serratus anterior and pectoralis minor muscle.[11]

Another recently described interfascial block is the serratus anterior plane (SAP) block, which blocks the intercostal nerves with levels varying from T2 to T9. This includes deposition of local anesthetic between serratus anterior and intercostals muscles.[12] Another technique involves deposition between serratus anterior and lattismus dorsi. It has been used to provide analgesia in VATS[13] and rib fractures[14] as well.

Unlike TPVB, these interfascial plane blocks do not cause sympathetic blockade and have fewer side effects as they are superficial blocks. There is no single study comparing these two new blocks with paravertebral block.

We hypothesized that serratus plane block will provide better analgesia and sensory block than the paravertebral block and PECS II block for breast surgeries with lesser side effects.

The primary objective of the study was to compare the postoperative 24-h fentanyl consumption in each of the three blocks. Secondary objectives were to compare spread of local anesthetic, sensory blockade produced, onset of the sensory blockade, intraoperative opioids requirement, pain scores for 24 h postoperative period, time to first postoperative analgesia requirement and incidence of postoperative nausea and vomiting (PONV).

Materials and Methods

This prospective, randomized interventional nonblinded study was approved by institutional review board and ethics committee. Trial was registered in Clinical Registry Trial of India (CTRI no. CTRI/2016/06/007047). ASA grades I and II female patients aged 18–65 years undergoing elective unilateral mastectomies with or without axillary dissection were included. Using a computer-generated random number table, all the patients were randomly allocated into three groups.

- Group 1 (TPVB): USG single injection TPVB
- Group 2 (PECS): USG modified PECS (PECS II) block
- Group 3 (SAP): USG SAP block.

Patients with infection at the site of proposed block, chest wall deformity, coagulopathy, or receiving any anticoagulants, body mass index ≥ 35 kg/m^2, mental retardation were excluded from the study. Allocation concealment was done by sequentially numbered, opaque, sealed envelopes.

All the selected patients underwent a routine preanesthetic check-up. They were explained about the study and interventions they were going to receive. The use of visual analog scale score (VAS 0-10) was explained to all patients with 0 corresponding to no pain and 10 being the worst imaginable pain. An informed written consent was obtained from all patients.

After random allocation to receive any one of the blocks, patients were taken to anesthesia room. Intravenous (I.V.) line was secured and routine monitors were attached. Patients were given premedication with 1–1.5 mg midazolam and oxygen supplementation by facemask. A 18G Tuohy needle was used for conduct of paravertebral block. A 22G blunt tip, echogenic needle was used for conduct of PECS II and SAP block. A linear high frequency (6-13 MHz) ultrasound (US) probe (Sono Site M-Turbo™, Sono Site Inc., Bothell, WA, USA) was used for guidance of the blocks. The drug solution injected in each block was 0.375% ropivacaine.

After conduct of the block, spread of local anesthetic was seen with help of US and area of the sensory blockade was

marked. Loss of cold sensation was evaluated by spirit swab and loss of pain sensation by pin prick. The onset to block was noted for both sensations by evaluating after every 1 min of the block.

After the block, the patient was given GA with fentanyl 2 mcg/kg + propofol in titrated doses + atracurium 0.5 mg/kg followed by proseal laryngeal mask (LMA) insertion. Patient was maintained on isoflurane + oxygen/air mixture and intermittent positive pressure ventilation. Fentanyl boluses of 25 μg were given if blood pressure or heart rate exceeds 20% of baseline. Any complication or event was managed as per standard treatment. Total intraoperative fentanyl consumption was recorded. Dexamethasone 0.2 mg/kg at start of surgery was given. Paracetamol 1 gm i.v. and ondansetron 0.1 mg/kg mg 30 min before end of surgery were given. Residual neuromuscular blockade was reversed with neostigmine (50 μg/kg) and glycopyrrolate (10 μg/kg) IV. LMA was removed after patient demonstrated good respiratory effort and airway reflexes. All patients were transferred to the postanesthetic care unit (PACU) for further monitoring, observation, pain assessment, and rescue analgesia.

In PACU, pain assessment was done with VAS scoring system measured at both during rest and ipsilateral abduction of arm. Rescue analgesia with fentanyl 50 μg was given if VAS ≥3. Patient controlled analgesia (PCA) pump was attached and programmed to deliver bolus of 25 mcg of fentanyl per press with a lockout interval of 10 min. A maximum of 125 μg of fentanyl could be delivered in 1 h. Time to first analgesic requirement was noted when patient first complained of pain indicated by VAS score ≥3 at rest or demanded a bolus from PCA pump. Total fentanyl consumption in 24 h was measured. Pain scores (VAS 1-10) were measured at rest and ipsilateral abduction of arm at 1, 2, 3, 6, 12, and 24-hour postoperative. PONV was treated by 4 mg ondansetron and number of episodes were recorded. Patient was kept in PACU for 24 h postoperative period and then shifted to ward if her condition was stable.

Block techniques

Paravertebral block

Patient was placed in a sitting kyphotic position. The spinous process of T4 vertebrae was identified and a point 2.5 cm lateral on the side of surgery was marked and US probe was placed at the marked point. The transverse processes and ribs were visualized as hyperechoic structures and the transducer was moved slightly caudal into the intercostal space between adjacent ribs to identify the thoracic paravertebral space. The block needle was inserted below the probe in an in-plane approach under US guidance to reach the paravertebral space under vision. A total of 20 mlof drug solution was given [Figure 1].

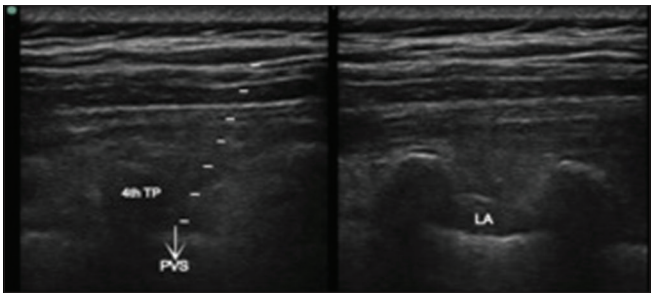

Figure 1: Paravertebral block with needle (horizontal bars) in paravertebral space (left) and spread of local anesthetic (right). [PVS-paravertebral space, LA – local anesthetic]

Pectoralis II block

Patient was placed in supine position with abduction of arm. A US probe was first placed in the infraclavicular area at lateral one-third of the clavicle and moved laterally to locate the axillary artery and vein directly above 1st rib where pectoralis major and pectoralis minor muscles were identified. The pectoral branch of thoracoacromial artery was identified as a pulsatile structure or on color Doppler at the level of 2nd rib. The needle was inserted in-plane with US probe from supero-medial to infero-lateral direction between pectoralis muscles and 10 ml of drug solution was injected. Then, probe was moved toward axilla until serratus anterior muscle was identified above 2nd, 3rd and 4th ribs, lateral border of pectoralis minor and Gerdy's ligament. The needle was reinserted into the fascial plane between pectoralis minor muscle and serratus anterior muscle. A total of 20 ml of drug was given after negative aspiration. Total volume of drug solution was 30 ml [Figure 2].

Serratus anterior plane block

Patients were positioned in supine with abduction of arm. A US probe was placed in midaxillary line in medial to lateral direction at 3rd intercostal space. US scanning was performed and structures from superficial to deep were identified as the subcutaneous tissue, SAM, the intercostal muscles (external, internal and intimate) the ribs, pleura, and lung. In an in-plane approach, and in caudal to cranial direction, block needle was inserted until the tip was placed between serratus anterior muscle and external intercostal muscle. A total of 30 ml of drug solution was injected after negative aspiration [Figure 3].

Statistical analysis

Because no study was available for comparison of the three blocks, considering the mean (SD) opioid consumption in the paravertebral group is 42.6 (11) mg[28]. We anticipated 30% decrease in opioid consumption in other two groups. In this study, with power of 80% and α of 5%, 15 patients were included in each group.

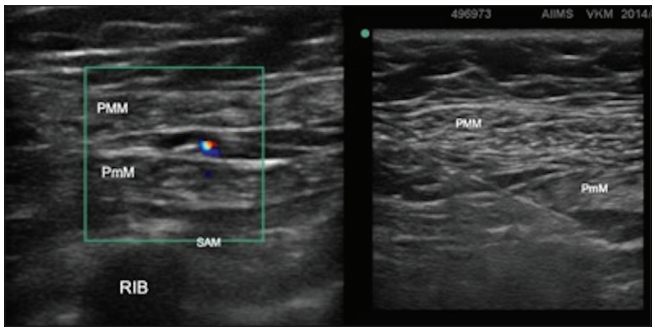

Figure 2: Sonoanatomy of PECS block with color Doppler showing pectoral branch of thoracoacromial artery (left) and PECS II block (right) [PMM - pectoralis major muscle, PmM - pectoralis minor muscle, SAM - serratus anterior muscle]

Shapiro–Wilk test was used to look for normality of data. For parametric data, analysis of variance was performed followed by bonferroni correction for intergroup analysis. For nonparametric data, Kruskal–Wallis test was performed followed by Dunn's intergroup analysis. Categorical data were analyzed by Fischer's exact test. $P < 0.05$ was considered statistically significant The data were analyzed using STATA 12.0 statistical software.

Results

A total of 52 patients were recruited from July 2015 to December 2016. Participant flow diagram is shown in Figure 4. And 15 patients in each group were analyzed. The demographic parameters of the patients and procedural data are presented in Table 1.

Primary objective

Post-operative fentanyl requirement (mean ± SD) in TPVB group was 428.33 ± 243.1 μg [95% CI 308.33–548.33], PECS group was 644.67 ± 260.15 μg [95% CI 514.67–774.67], and SAP group was 415 ± 182.44 μg [95% CI 323–507] ($P = 0.015$). Intergroup analysis is shown in Table 2.

Secondary objectives

The level of spread (mean ± SD) in TPVB group was 5.1 ± 0.43 [95% CI 4.88–5.32], PECS group was 3.37 ± 0.48 [95% CI 3.13–3.61] and SAP group was 4.1 ± 0.74 [95% CI 3.73 to 4.47] ($P = 0.00001$). Level of spread was significantly more in TPVB group compared to PECS group ($P = 0.00001$) and SAP group ($P = 0.0001$).

The drug spread at each thoracic level is show in Figure 5. At T6 level, none of the patients in PECS group and only six patients in SAP group had drug spread, whereas all the patients in TPVB group had drug spread. Thus there was significant difference amongst the three groups at T6 level ($P = 0.0001$). Only three patients in TPVB group had spread of drug at T7 level. None of the patients in the other two groups had drug spread at this level which was significant ($P = 0.023$).

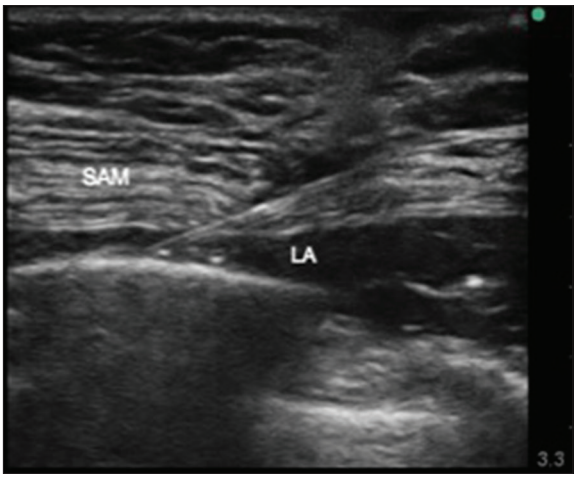

Figure 3: Serratus plane block with spread of local anesthetic between muscle and rib. (SAM – serratus anterior muscle, LA – local anesthetic)

Sensory level of spread is shown in Figure 6. Two patients in PECS group did not develop sensory blockade at any level. At T2 level, 13 patients in SAP group developed sensory block which was significantly greater than other two groups ($P = 0.026$). At T4, only six patients in PECS group developed sensory block at this level which was significantly less than other two groups ($P = 0.027$). At T6, 13 patients in TPVB group and 7 patients in SAP group had sensory blockade, whereas no patient in PECS group had sensory block ($P = 0.0001$).

Other secondary outcomes are presented in Table 3. Time to put the block was significantly less in group SAP compared to TPVB group ($P = 0.0001$) and PECS group ($P = 0.007$). There was no difference in intraoperative fentanyl requirement between TPVB group and PECS group. However, SAP group had significantly lesser requirement than PECS group ($P = 0.045$) but similar requirement compared to TPVB group ($P = 0.93$). Time to onset of block to cold and pain sensation was significantly longer in TPVB group compared to PECS and SAP group. Pain scores were not significantly different among the group in the postoperative 24 h period. Only three patients gave a response at immediate postoperative and therefore VAS scores were not assessed at this point of time. At 6 h, VAS scores were reaching significant difference among PECS and SAP block. No complication like inadverdent vascular puncture, pneumothorax, hypotension was seen in any group.

Discussion

In this study, TPVB and SAP block provide comparable analgesia in respect to intraoperative and postoperative

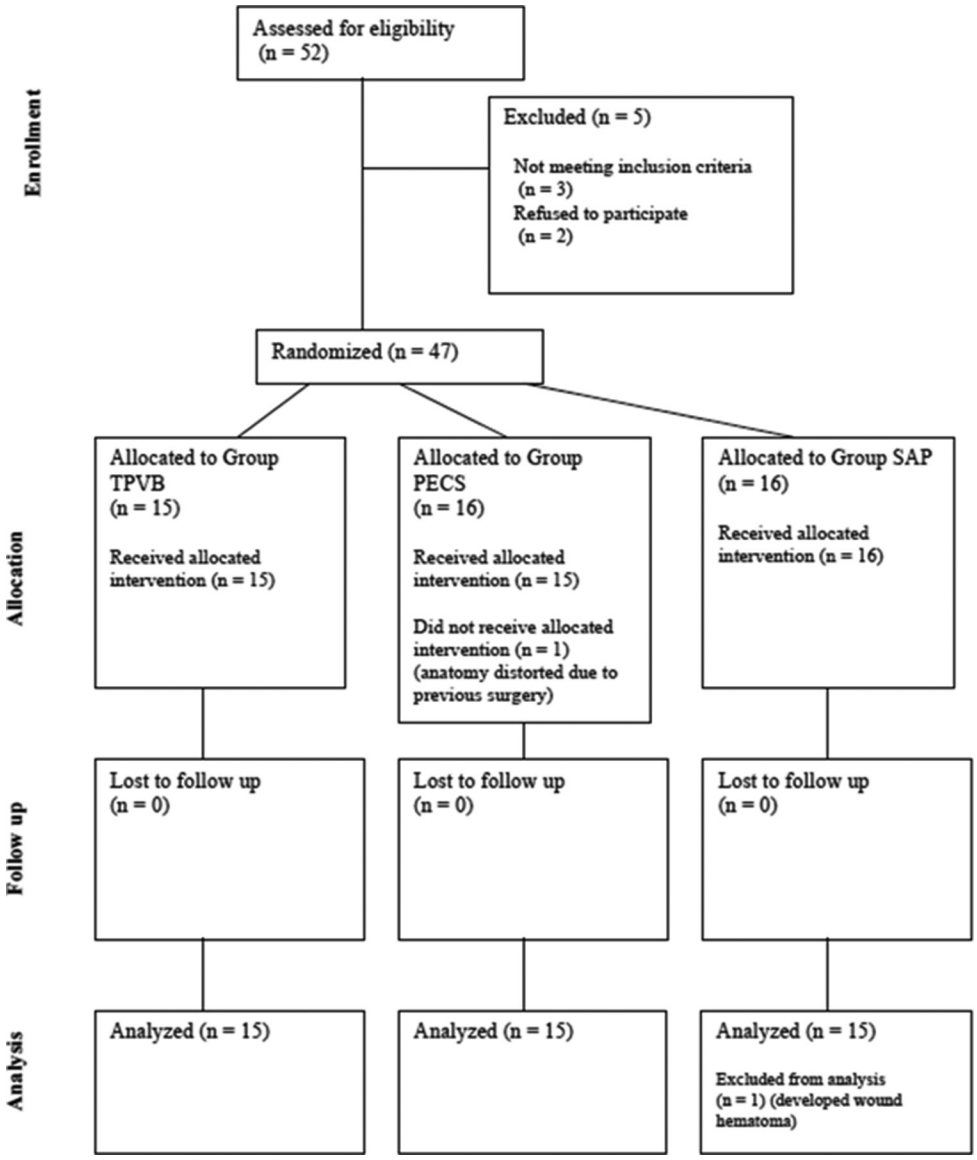

Figure 4: Consort diagram showing participant flow

Table 1: Demographic and procedural data

Variable	Group TPVB (*n*=15)	Group PECS (*n*=15)	Group SAP (*n*=15)	*P*
Age (years) mean±SD	44.47±11.62	45.47±8.98	60.87±11.9	0.84
Weight (kg) mean±SD	58.87±11.46	58.2±10.69	± 11.9	0.80
Height (cm) mean±SD	154.27±4.15	154.67±5.59	155±5.19	0.93
Body mass Index (kg/m^2) mean±SD	24.66±4.36	24.19±3.49	25.13±3.71	0.80
ASA (I/II) *n* (%)	12 (80)/3 (20)	12 (80)/3 (20)	11 (73.33)/4 (26.67)	1.0
Surgical duration (min) mean±SD	123.33±31.43	109±27.14	100.67±28.53	0.11

n=Number of patients, SD=Standard deviation

fentanyl requirement. On the contrary, PECS block had higher perioperative fentanyl requirement. Spread of drug was maximum in TPVB group with consistent spread seen from T2-T6 (up to T7). In SAP block, consistent spread was seen from T2-T5 (upto T6), whereas least spread of the injectate was seen in PECS II block. Maximum sensory blockade was seen in TPVB and SAP group. Both blocks had consistent sensory blockade from T2 to T6. Least sensory blockade was seen in PECS II block from T2 to T4.

In previous studies, PECS block was found superior to TPVB in terms of opioid (morphine) requirement which is contradictory to our results, where similar volume of drugs have been used.[15,16] However pectoral serratus interfascial

Table 2: Intergroup analysis for postoperative fentanyl requirement

	Group TPVB vs PECS			Group TPVB vs SAP			Group SAP vs PECS		
	MD	95% CI	*P*	MD	95% CI	*P*	MD	95% CI	*P*
Portoperative fentanyl requirement	216.33	6-426.66	0.042	13.33	-197 - +223.66	1.0	229.67	19.34-440	0.028

MD – Mean difference

Table 3: Secondary outcomes

Variables	Group TBVB	Group PECS	Group SAP	*P*
Time to put the block (min) mean±SD	15.1±5.18	13.63±3.8	8.53±3.82	0.0004
Time to onset of block (min) mean±SD	14.2±2.67	6±2.96	6.9±4.39	0.00001
Intraoperative fentanyl requirement (mg) median	25	50	25	0.07
Time to first analgesic requirement (min) Median	55	35	45	0.66
PONV, *n* (%)	1 (6.67%)	2 (13.33%)	2 (13.33%)	0.8

n=Number of patients, SD=Standard deviation

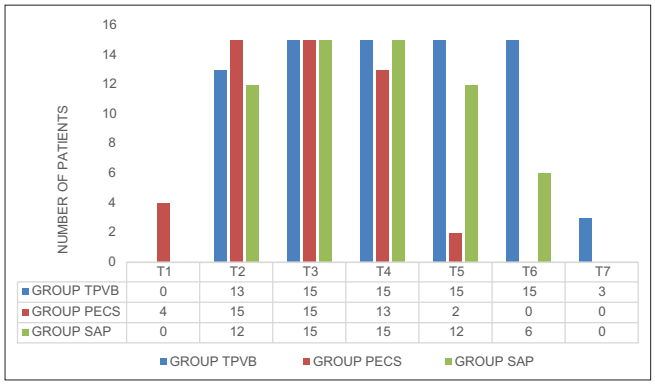

Figure 5: Spread of drug at each dermatomal level

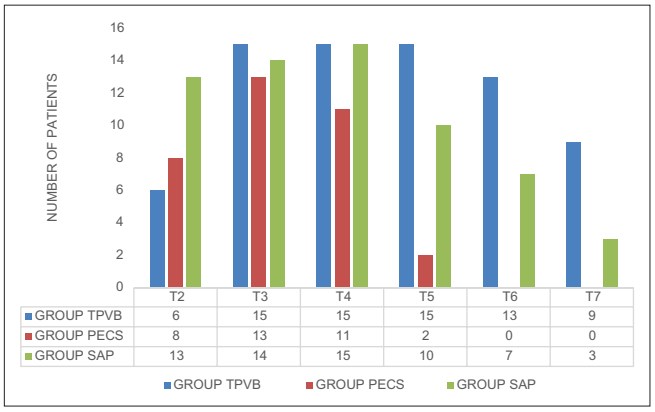

Figure 6: Sensory block at each dermtomal level

block with 30 ml of drug was found inferior to TPVB in another clinical trial.[17] In our study, SAP block had similar analgesic efficacy as compared to TPVB. In a randomized study TPVB was superior to SAP block; however, they only used 20 ml of drug in SAP.[18] Patients in the SAP block required less fentanyl and was found superior to PECS block. This observation is in accordance with our hypothesis that SAP block would provide better analgesia than PECS block.

Vertical spread of drug and area of blockade was highest in TPVB. Similar result was found in another study[19] where mean somatic block distribution of five dermatomes and sympathetic block of eight dermatomes was observed after injecting 15 ml of drug. In another study, the mean dermatomal level spread was 4.5[20] and 4.6[21] in patients receiving paravertebral block with 20 ml and 15 ml of drug, respectively. It has been suggested that single-site injection of 15–20 ml or 0.3 ml/kg of 0.375–0.5% bupivacaine, produces anesthesia over four to five thoracic dermatomes[22] and therefore we chose 20 ml of drug in TPVB. The level of spread and sensory block in PECS group was significantly less compared to both group TPVB and group SAP. Spread to T5 was inconsistent with only 1 patient out of 15 (6.67%) reaching this level. In a study, where PECS block was originally described, the drug spread reached posteriorly into axilla and caudally up to T8. This produced consistent anesthesia of the dermatomes from T2 to T4 with variable spread to T6.[11] In another study comparing PECS II and paravertebral block for radical mastectomies in 40 patients,[16] 85% reached sensory block level at T2 in PECS block which is higher than our study. However, they reported that only 20% patients in TPVB group developed sensory block at T2, whereas we observed 40% patients developing T2 blockade. Caudal spread of drug in PECS block in our study was limited by Gerdy's ligament to T4 with limited spread to T5. This accounted for inferior analgesic efficacy of PECS block. The mean level of spread of drug in SAP block was 4.1 levels with consistent blockade from T2 to T5. This correlates with cadaveric studies, where SAP block was performed with 20 ml of contrast, which resulted in spread from T2 to T6[23] and from T2 to subcostal margin.[24] In another study, SAP block was given with 0.4 ml/kg of drug which lead to sensory blockade from T2 to T7.[25] Another study showed sensory loss in five to six dermatomes when SAPB was given with 30 ml of drug at 4th-5th rib.[26] The spread and sensory block in our study was

similar to TPVB, hence, the similar opioid requirement and analgesic efficacy. This was reflected in a study where quality of postoperative recovery was compared between TPVB and SAP block in breast surgeries. Both the blocks showed comparable results.[27] Though PECS II and SAPB, both block intercostal nerves, serratus plane block was more consistent in blocking T2-T6 intercostal nerves than PECS II, resulting in a superior analgesic efficacy. In our study, assessment of spread in all the blocks was done by US. On the contrary, X-ray imaging or magnetic resonance imaging (MRI) was done to assess the spread in previous studies.

Time to onset of block was significantly higher in TPVB as larger diameter spinal nerves need to be blocked. In peripheral fascial plane blocks like PECS and SAP block, smaller diameter nerve fibers are blocked which require less time for the local anesthetic to penetrate the nerve. Time to first analgesic requirement was comparable in all the three groups. This can be attributed to the fact that none of the blocks provided consistent complete sensory block for breast surgeries. In both PECS II block and SAP block, only the lateral cutaneous branches of intercostal nerves are blocked, whereas the anterior cutaneous branches are spared resulting in absence of sensory blockade over the ipsilateral anterior parasternal area of thorax. This was noted on sensory mapping in our study and leads to pain response when the surgical incision was extended to area innervated by anterior cutaneous nerves. For complete blockade of the anterior and lateral hemithorax, both the cutaneous branches need to be blocked separately for effective analgesia.[25] Also, in TPVB, consistent sensory blockade from T2 to T6 was not observed in every patient. These blocks are not surgical blocks but are useful for providing analgesia and reducing requirement of opioid. A background analgesia is required in postoperative period, but it was not provided in the study so as to accurately assess the analgesic efficacy of the blocks.

A point of debate that needs further evaluation is that, whether in SAP block, drug needs to be injected below or above the muscle. The lateral branch of intercostal nerve pierces the serratus anterior muscle before branching out on the surface of muscle. Depositing the drug below the muscle would block the main perforating lateral cutaneous intercostal nerve. As the space is less distensible, it can result in wider drug spread with respiratory movements aiding in dispersion. Depositing the drug above the muscle would too block the nerve and its branches, but can block the long thoracic nerve and can cause temporary paralysis of serratus anterior muscle.[28] In a study, longer duration of paresthesia (752 vs. 386 min) and higher drug spread was seen when drug was given superficial to muscle compared to deep to muscle in SAP block.[12]

The VAS scores in our study showed no difference among the three groups. The VAS scores were higher in PECS group at rest but they were not statistically significant. This can be explained by the fact that VAS was measured at specific time points during postoperative period. If a patient demands a fentanyl bolus before the specified time point for measuring VAS, then the VAS would come less at the measured time point leading to similar scores. Time to put the block was significantly higher in TPVB group and PECS group as compared to SAP group. As PECS II is a two-site injection block, it requires more time to perform. TPVB, on the contrary requires more expertise to visualize the space and the needling is more difficult than SAP block due to narrow space between the transverse process. Such a problem did not arise in SAP block as needle visualization was much easier and pleural puncture was prevented by going over the rib. The SAP block was technically much easier than TPVB, although this was not objectively measured and is just an observation in our study. Further studies are required to objectively assess the learning curves of these blocks. No complications were seen in any of the blocks in our studies. Incidence of PONV was comparable among the groups.

TPVB, though is an efficacious block for breast surgeries causes more patient discomfort because of the uncomfortable position and use of larger caliber Tuohy needle which causes pain during insertion. On the contrary, SAP block can be easily given after giving general anesthesia, requires less expertise and no serious complications have been noted. It provides comparable analgesia to TPVB and therefore could be a better alternative in breast surgeries. In our study, PECS II and SAP block were given before induction of general anesthesia so as to assess the sensory block. More studies are required to compare TPVB and SAP block involving a larger sample size.

Limitations

- Sample size was less to find out smaller differences (<30%) between the blocks and was calculated on a single-tailed hypothesis that PECS block would provide better analgesia than TPVB
- Spread of drug was visualized using US which is not very sensitive. Spread should have been visualized with the help of computed tomography scan or MRI. However, due to logistic issues, we used US which could have underestimated our results
- The volume of drug to be given in each block was prefixed. The drug volume should have been given either

according to weight or height. These two factors might affect the spread of the drug

- Sensory block was not assessed on the posterior hemithorax. This does not have an implication in breast surgeries, but could be useful in other surgeries and lattismus dorsi flap surgeries where incision goes beyond posterior axillary line.

Conclusion

TPVB and SAP group provide equivalent analgesia in patients undergoing mastectomies. PECS II block is inferior to TPVB and SAP block in providing analgesia for breast surgeries. Single-shot TPVB and SAP block also result in greater spread of the drug along with sensory block compared to PECS II block. SAP block is easier to perform than TPVB with lesser chances of complications and results in faster onset. Thus, we recommend SAP block for patients undergoing mastectomies for effective analgesia.

Clinical Trial Registration (India). CTRI no. CTRI/2016/06/007047

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Conflicts of interest

There are no conflicts of interest.

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