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Ultrasound Guided Serratus Anterior Plane Block Versus Thoracic Epidural Analgesia for Thoracotomy Pain

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ABSTRACT

1. **Objective**: Thoracotomy is one of the most painful surgical procedures. The aim of this study is to assess efficacy and safety of ultrasound-guided serratus anterior plane block (SAPB) compared to thoracic epidural analgesia (TEA) for controlling acute thoracotomy pain.

2. **Design**: A prospective randomized observer blinded controlled study.

3. **Setting**: Study was carried out as a single institution study, in the National Cancer Institute, Cairo University, Egypt.

4. **Participants**: All participants were cancer patients scheduled for a thoracotomy.

5. **Interventions**: This study was carried out in the period from February 2015 to December 2015. Forty patients scheduled for thoracotomy under general anesthesia were randomly allocated into one of two groups 20 patients each. Group (SAPB); SAPB was performed before extubation with injection of 30 ml of 0.25% levobupivacaine followed by 5 ml/hr of 0.125% levobupivacaine and Group (TEA); thoracic epidural catheters were inserted preoperatively to be activated before extubation using the same dose regimen. Heart rate, mean arterial pressure and VAS pain score were recorded for 24 hours. Rescue analgesia as morphine IV in a dose of 0.1 ml/kg was administered if the VAS score was > 3.

6. **Measurements and Main Results**: In comparison to preoperative values group (SAPB), MAP didn’t change significantly (p = 0.181), while it decreased significantly (p = 0.006) in TEA group. VAS scores as well as the total dose of morphine consumed were comparable in the two groups in TEA groups.
7. **Conclusions**: Serratus anterior plane block appears to be a safe and effective alternative for postoperative analgesia after thoracotomy.

**KEY WORDS**

thoracotomy; acute pain; thoracic epidural analgesia; serratus anterior plane; postoperative pain
INTRODUCTION

Thoracotomy is widely recognized to cause severe excruciating acute pain. Acute pain increases postoperative morbidity and prolongs hospital stay. If not treated adequately, chronic post-thoracotomy pain may develop, preventing patients to regain their regular activities for prolonged periods. Retraction, resection, or fracture of ribs as well as dislocation of costovertebral joints, injury of intercostal nerves, and further irritation of the pleura by chest tubes are all causes of thoracotomy pain. Many analgesic modalities have been suggested for thoracotomy pain including thoracic epidural analgesia (TEA), paravertebral blocks, intercostal nerve blocks, inter-pleural blocks as well as systemic and intrathecal analgesics. While TEA has been believed to be most effective method and is considered the gold standard for acute post-thoracotomy pain, it is not always ideal and other regional methods of analgesia have been always thought for. TEA has been found to be more effective than intercostal, interpleural, and I.V. opioid analgesia in clinical studies.

A recent ultrasound guided regional anesthetic block, the serratus anterior plane block (SAPB), targeting the plane above or below the serratus anterior muscle in the mid axillary line had been described. It was believed to provide analgesia to a hemithorax by blocking the lateral branches of the intercostal nerves. The block is expected to avoid autonomic blockade associated with TEA as well as the risk of serious complications involving the pleura and central neuraxial structures. Moreover, the sono-anatomy of SAPB is easy to identify, and the relatively shallow needle angle allows for easy block administration.

The aim of this study was to assess the safety and efficacy of SAPB compared to TEA for relieving acute thoracotomy pain. Our primary end point was mean arterial blood pressure (MAP) after administration of SAPB and TEA in patients with thoracotomies. Secondary end
points were pain scores, morphine consumption, and incidence of postoperative nausea and vomiting in the first 24 hours after surgery.

PATIENTS AND METHODS

This randomized, comparative, observer blinded study was carried out at National Cancer Institute, Cairo in the period from February 2015 to December 2015 after approval of the institutional ethical committee. Informed written consent had been signed by every patient prior enrollment in the study. Forty patients scheduled for thoracic surgeries (metastatectomy, lobectomy, pneumonectomy or pleuro-pneumonectomy) completed the study. Enrolled patients were 20 to 60 years old with ASA physical status of class II and III. Patients on current chronic analgesic therapy, having history of opioid dependence, unable to communicate with the investigators and receiving anticoagulation or suffering from any bleeding disorder, were excluded. Patients who had sever intra or postoperative bleeding or who required postoperative mechanical ventilation were excluded from the study.

Routine preoperative assessment was done to all patients. The study protocol was explained to the patients and their consents were taken. All patients were made familiar with the use of the visual analog scale (VAS) in the preoperative visit. Where 0 score as no pain and 10 as the worst imaginable pain. Consenting patients were assigned randomly (1:1) to receive postoperative analgesia for the first 24 h via serratus anterior plane (SAP) or thoracic epidural (TE) catheters. Group SAPB received general anesthesia and before extubation, an ultrasound guided SAPB was performed with insertion of a catheter. Group TEA had a thoracic epidural catheter fixed before surgery while the patients still awake to avoid neural injury. In both groups a loading dose of the local anesthetic (LA) solution was injected at the end of surgical procedure, just before extubation.
General anesthesia was conducted for all patients using the same protocol. Induction of anesthesia was by propofol 2–3 mg/kg, fentanyl 200 μg IV, and rocuronium 0.5–0.8 mg/kg to facilitate endotracheal intubation. Anesthesia was maintained with isoflurane (1-2%) in 50% air in oxygen mixture, rocuronium 0.15 mg/kg when 2 responses to train-of-four stimulation (TOF) are present, and titration of fentanyl to maintain blood pressures and heart rates within 20% the baseline values. All patients were intubated and mechanically ventilated using volume-controlled positive-pressure ventilation with tidal volume of 6-8 mL/kg and I/E ratio 1:2 to maintain end tidal carbon dioxide tension around 35 mmHg. All patients were monitored with 5 leads electrocardiogram (ECG), non-invasive blood pressure monitoring (NIBP), pulse oximetry and end-tidal CO2, TOF monitoring. All thoracotomies were standard posterolateral incision. At the end of surgical procedure, patients were extubated and transferred to surgical ICU.

**The ultrasound guided Serratus Anterior Plane block (SAPB):**

Under sterile conditions, and while the patients were still on the lateral position with the diseased side up, a linear ultrasound transducer (10-12 MHz) was placed in a sagittal plane over the mid-clavicular region of the thoracic cage. Then counting down ribs till the fifth rib was identified in the mid-axillary line (Figure 1). The following muscles were identified overlying the fifth rib: the latissimus dorsi (superficial and posterior), teres major (superior) and serratus muscles (deep and inferior). The needle (22-G, 50-mm Touhy needle) was introduced in-plane with respect to the ultrasound probe targeting the plane superficial to the serratus anterior muscle (figure 2). Under continuous ultrasound guidance, 30 ml of 0.25% levobupivacaine was injected then a catheter was threaded. A continuous infusion of 5 ml/hr of 0.125% levobupivacaine was then started through the catheter.
Thoracic epidural:

In the preoperative holding area just before surgery a thoracic epidural catheters were inserted. Using the loss of resistance to air technique an epidural catheter was inserted 3-4 cm into the T6/T7 space. A test dose of 3 ml of 1.5% preservative free lidocaine with 1:200,000 epinephrine was administered in the catheter or directly in the needle to exclude intravascular and/or intrathecal catheter insertion. At the end of surgery, a loading dose of 15 ml of 0.25% levobupivacaine, was gradually administered into the TE catheter under continuous monitoring of blood pressure and heart rate during injection. Then 5 ml/hr. of 0.125% levobupivacaine infusion was started.

Postoperative heart rate and MAP were recorded at 0, 15 min, 30 min, 1 hr. and then every 2 hours for 24 hours. Hypotension (systolic blood pressure ≤ 80 mmHg) was treated by IV ephedrine 5-25 mg and reduction LA infusion rate. Postoperative VAS pain scores; while patients were breathing quietly, were recorded as soon as the patient is alert enough to report pain, then every two hours for 24 hours. All patients received regular Paracetamol 1 gm/8 hours (Injectemol, Pharco B International, Phama-Tech). Rescue analgesia was provided as morphine IV (0.1 mg/kg) then titration of 1mg/15min as required to keep the VAS scores less than 3. The total 24 hrs morphine consumption was recorded for every patient.

Postoperative nausea and vomiting (PONV) scores was documented together with frequency of rescue antiemetic use if any in the first 24 hours. Nausea and/or vomiting were treated by IV injection of 10 mg metoclopramide.

The sample size was estimated statistically to detect a difference in MAP of 5.2 mmHg after one hour of the block with a pooled standard deviation of 4.6 between the two groups with an alpha error of 0.05 and power of 90%. A minimum of 20 patients per group was needed.
Statistical analysis was done using IBM® SPSS® Statistics version 22 (IBM® Corp., Armonk, NY, USA). Numerical data were expressed as mean and standard deviation or median and range as appropriate. Qualitative data were expressed as frequency and percentage. Chi-square test (Fisher’s exact test) was used to examine the relation between qualitative variables. For quantitative data, comparison between two groups was done using independent sample t-test or Mann-Whitney test. Two-way ANOVA revealed interaction between groups and measures, thus each group was tested separately for repeated measures. Comparison of repeated measures was done using ANOVA for repeated measures of Friedman test followed by the suitable post-hoc test. All tests were two-tailed. A p-value < 0.05 was considered significant.

RESULTS

Forty-six patients were randomly assigned into the study. Sex patients were not studied in the final analysis and forty patients completed the study (Figure 3). Both groups in this study were comparable as regard age, sex, BMI, ASA physical class and duration of surgery (table 1). The baseline heart rates and MAPs were comparable in the two groups (p = 0.079). MAP was significantly lower in group TEA than group SAPB during the whole study period (p < 0.001). In SAPB group, MAP did not show statistically significant changes along the postoperative 24 hours when compare with the baseline values (p = 0.181). On the other hand, MAP decreased significantly compared to baseline values in group TEA starting one hour after surgery (p = 0.006) (Figure 4). Heart rate did not show significant changes over time in the group SAPB (p=0.113) or group TEA (0.093). There was no significant difference between the two groups in the heart rate throughout the 24 hours (Figure 5).

VAS pain scores (Figure 6) were comparable in the two groups except in 14, 16 and 22 hrs,
time points, where pain scores were higher in group SAPB (Table 2). Rescue analgesia was required by 4 patients (20%) of group SAPB compared to 3 patients (15%) of group TEA (p = 0.478). The total 24 hrs’ morphine consumption by group SAPB was 10.3±3 mg/24h. While it was 9.6±4.3 mg/24 for group TEA (p =0.171). Arterial oxygen saturation showed trivial non-significant changes in the two groups (Figure 6). The recorded adverse events observed were one case of nausea in group SAPB and none in group TEA. Five cases of hypotension in group TEA was treated with ephedrine while no hypotension incidents were reported in group SAPB (p = 0.020). Apart from that, the study observation period was uneventful.

DISCUSSION

In this study, we found that, the recently described SAPB, while maintaining a stable blood pressure, it provided good analgesia comparable to that provided by TEA for acute post thoracotomy pain. Hypotension was more remarkable in those who had epidurals than those with SAP catheters. Morphine rescue analgesia as well as VAS pain scores during normal tidal breathing were similar in both study groups. Nausea and vomiting scores as well as oxygen saturations were comparable in all patients during the study period. As far as our knowledge this was the first trial of SAPB in acute thoracotomy pain compared with thoracic epidurals. This novel technique is an interfacial plane block that may be considered the TAP (Transversus Abdominis Plane Block) of the chest wall. LA solution is injected either into the facial plane superficial or deep to the serratus anterior muscle. The lateral cutaneous branches of the intercostal nerves are blocked as they pass through, before dividing into anterior and posterior branches to supply sensation to most of the chest wall. The first description of SAPB demonstrated its effectiveness to block the lateral branches of inter-costal nerves T2-T9 in healthy volunteers. It produced a prolonged block
(750-840 min) with a dose of levobupivacaine of 0.4 ml/kg 0.125%. Blanco et al. proposed a reliable and wide spread block while the LA solution is injected into a plane with relatively low vascularity and consequently less absorption and decreased local anesthetic toxicity\textsuperscript{16}. SAPB is believed to be easy to perform, with a high success rate and minimal incidence of complications, when performed with anesthesiologist skilled in ultrasound blocks. The block might miss the posterior primary rami (posteriorly), the anterior cutaneous branches of the intercostal nerve (close to the sternum) and the supraclavicular nerves (immediately below the clavicle). Also autonomic block that accompanies paravertebral and epidural blocks is not present in SAPB\textsuperscript{20}. That is why it was associated with hemodynamic stability as we demonstrated in the current study.

Theoretically SAPB misses the Posterior cutaneous branches but this did not appear to affect the clinical efficacy of the block in our study. One explanation to that findings may be retrograde spread of the local anesthetic solution like in TAP block. In posterior TAP block it was found that there was retrograde spread of the injectate to reach around the quadratus lumborum and the paravertebral space\textsuperscript{21}. Recently, Mayes and colleague studied the anatomical spread of the injectate in the SAP in a cadaver study. They specifically studied the situation when the injection is below the muscle. They come with a conclusion that the block is not equivalent to thoracic paravertebral block\textsuperscript{22}. There is no similar study evaluating the distribution of the LA solution in the plane above the muscle. In the original Blanco et al. study, they compared the two modalities of the SAPB in volunteers. The MRI demonstrated that when the injectate was above the muscle, the spread of contrast dye was evidently wider than when it was below the muscle\textsuperscript{16}. Moreover, they suggested even greater extension of the injected solution, as the clinical effects were more than expected from the MRI images due to similar intensity of fat and gadolinium. That might explain the success of
the SAPB in our current trial in providing comparable analgesia as epidurals. More studies are yet needed to examine the extent of local anesthetic spread in the SAPB. Only few small studies have been published using SAPB for providing analgesia in thoracotomy, rib fracture, thoracoscopy, and shoulder surgery as well as breast surgery. A case study demonstrated a patient who had an esophagectomy through an anterolateral thoracotomy incision, and had severe pain during weaning from mechanical ventilation. The preoperatively placed epidural catheter was blocked as IV opioids were used for analgesia instead due to hypotension. SAPB was performed as a rescue analgesia, and provided excellent analgesia that facilitated weaning from mechanical ventilation and facilitated an uneventful recovery\textsuperscript{23}. In another case study SABP was performed for a morbidly obese man with 4-rib fractures irresponsive to analgesic drugs. SABP provided good analgesia within 15 minutes after injection of 0.125% bupivacaine that was followed by continuous LA infusion\textsuperscript{24}. Bilateral SAPBs have been triad in thoracoscopic sympathectomy in two patients with encouraging results. Researchers have chosen SAPB in such surgery as it represents a peripheral block of the thoracic wall and might provide analgesia of good quality with fewer complications\textsuperscript{25}. The block was also successfully performed in three cases of shoulder arthroplasty. In spite of that interscalene catheter placement for postoperative analgesia, occasionally, patients experience transient pain related to insufficient blockade of thoracic innervation. Such pain has been better tolerated in the three patients in whom SAPB was performed\textsuperscript{26}. Serratus-intercostal plane block (SIPB) described by Fajardo et al. is a block equivalent to SAPB; below the muscle approach. It was shown to be effective in providing postoperative analgesia in a prospective study involving 30 patients undergoing breast and axilla surgery\textsuperscript{27}. A more recent study confirmed the postoperative analgesic effectiveness and safety of SIPB
in a group of patients with breast cancer undergoing partial mastectomy under general anesthesia\textsuperscript{28}. One more case study SAPB provided good analgesia in a morbidly obese patient after breast surgery\textsuperscript{29}. Also combination of ultrasound-guided Pecs-I block and serratus anterior plane block was triad in two cases of mastectomy with breast reconstruction and was found safe and effective to provide excellent intra- and postoperative analgesia\textsuperscript{30}.

SAPB is currently the subject of a number of future clinical trials in thoracic surgery not published yet. Those trials include evaluating ultrasound-guided SAPB analgesic efficacy in thoracoscopic surgery, video-assisted thoracoscopic surgery, and last study comparing thoracic epidural anesthesia, SAPB and local anesthetic infiltration at the site of performing the thoracoscopy. It’s expected that the results of these studies and more will boost our understanding of the block and it might gain popularity like TAP block.

In conclusion, SAPB appears to be a good alternative to thoracic epidural blockade for achieving paresthesia of a hemithorax. As it maintained hemodynamic stability as compared to TEA, SAPB provided low pain scores and less total morphine consumption in the early postoperative period after thoracotomy, without noteworthy complications.
REFERENCES


Figure Legends list

**Figure 1**: Patient position during the block.\(^{18}\)

Patients are in lateral position with the upper arm over their head. The anesthesiologist is behind the patient, with the ultrasound screen in front.

**Figure 2**: Diagram demonstrating the optimal plane for local anesthetic deposition above serratus anterior muscle, (right). Ultrasound image of serratus anterior plane block with needle in place (left).

**Figure 3**: CONSORT Diagram.

**Figure 4**: Changes of mean arterial pressure (MAP) over time. Values are mean ±SD.

**Figure 5**: Changes of heart rates during the observation period. Values are mean ±SD.

**Figure 6**: VAS scores at rest over time for patients receiving Serratus Anterior Plane Block (SAB) or Thoracic Epidural Analgesia (Epi).

The middle black solid line represents the median VAS score, the upper and lower margins of the box represent the IQR (25th-75th) of data, and whiskers are minimum and maximum.

**Figure 7**: Changes of arterial oxygen saturation throughout the first 24 postoperative hours in the two studied groups (mean±SD)
Table 1: Demographic and clinical characteristics of the two studied groups

<table>
<thead>
<tr>
<th></th>
<th>SAPB Group n=20</th>
<th>TEA Group n=20</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>34.9±10.1</td>
<td>35.4±8.3</td>
<td>0.852</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>10/10</td>
<td>11/9</td>
<td>0.752</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>24.7±1.6</td>
<td>25.1±1.8</td>
<td>0.524</td>
</tr>
<tr>
<td>ASA (II/III)</td>
<td>10/10</td>
<td>12/8</td>
<td>0.525</td>
</tr>
<tr>
<td>Duration of surgery (min.)</td>
<td>145.2±8.0</td>
<td>149.3±6.3</td>
<td>0.088</td>
</tr>
</tbody>
</table>

Data are presented as mean ±SD or ratio

P value < 0.05 is considered significant difference.
Table 2: The VAS score values in the two studied groups throughout the first 24 postoperative hours

<table>
<thead>
<tr>
<th>Time</th>
<th>SAPB Group n=20</th>
<th>TEA Group n=20</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>2 (1-6)</td>
<td>2 (1-4)</td>
<td>0.314</td>
</tr>
<tr>
<td>2 h</td>
<td>2 (1-6)</td>
<td>2 (1-3)</td>
<td>0.277</td>
</tr>
<tr>
<td>4 h</td>
<td>2 (1-3)</td>
<td>2 (1-4)</td>
<td>0.383</td>
</tr>
<tr>
<td>6 h</td>
<td>2 (1-6)</td>
<td>2 (1-3)</td>
<td>0.414</td>
</tr>
<tr>
<td>8 h</td>
<td>2 (1-3)</td>
<td>2 (1-3)</td>
<td>0.201</td>
</tr>
<tr>
<td>10 h</td>
<td>2 (1-2)</td>
<td>2 (1-4)</td>
<td>0.289</td>
</tr>
<tr>
<td>12 h</td>
<td>2 (1-2)</td>
<td>2 (1-3)</td>
<td>0.947</td>
</tr>
<tr>
<td>14 h</td>
<td>2 (2-2)</td>
<td>2 (1-2)</td>
<td>*0.011</td>
</tr>
<tr>
<td>16 h</td>
<td>4 (3-4)</td>
<td>1 (1-2)</td>
<td>*0.001</td>
</tr>
<tr>
<td>18 h</td>
<td>2 (2-2)</td>
<td>2 (1-5)</td>
<td>0.792</td>
</tr>
<tr>
<td>20 h</td>
<td>2 (1-2)</td>
<td>2 (1-2)</td>
<td>0.247</td>
</tr>
<tr>
<td>22 h</td>
<td>4 (3-4)</td>
<td>2 (1-2)</td>
<td>*0.001</td>
</tr>
<tr>
<td>24 h</td>
<td>1 (1-2)</td>
<td>2 (1-2)</td>
<td>0.351</td>
</tr>
</tbody>
</table>

Data presented as median (inter-quartile range)

*P value < 0.05 is considered statistically significant difference.
**Enrollment**

- Assessed for eligibility (n=65)
  - Excluded (n=19)
    - Not meeting inclusion criteria (n=6)
    - Declined to participate (n=13)

**Randomized (n=46)**

**Allocation**

- Allocated to intervention (SAPB)
  - Received allocated intervention (n=21)
  - Did not receive allocated intervention (n=2) (severe intraoperative bleeding)
- Allocated to intervention (TEA)
  - Received allocated intervention (n=22)
  - Did not receive allocated intervention (refused the procedure at time of intervention) (n=1)

**Follow-Up**

- Lost to follow-up (died) (n=1)
- Discontinued intervention (severe post-operative bleeding) (n=1)

**Analysis**

- Analysed (n=20)
  - Excluded from analysis (needed mechanical ventilation) (n=1)
MAP (mmHg)

- Group SABP
- Group TEA

Heart Rate (bpm)

- Group SABP
- Group TEA