Original Article

The efficacy of ultrasound-guided upper thoracic erector spinae plane block for postoperative analgesia in proximal shoulder surgery and its effect on phrenic nerve function: A prospective exploratory study

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Abstract

Background and Aims: The upper thoracic (T2) erector spinae plane block (UT-ESPB) has been proposed as an alternative to interscalene brachial plexus block for postoperative analgesia in shoulder surgery. The current study was conducted to evaluate the same.

Material and Methods: Patients scheduled for shoulder surgery under general anesthesia (GA) received ultrasound-guided UT-ESPB. The outcomes measured were diaphragmatic movements, block characteristics, and quality of recovery at 24 h.

Results: A total of 43 patients were recruited. The incidence of phrenic nerve palsy was 0%. The sensory level achieved by the maximum number of patients at the end of 30 min was C7-T5 level, and none had a motor block. Forty-two percent of patients did not require rescue analgesia till 24 h postoperative. In the rest of the patients, the mean (SD) duration of analgesia was 724.2 ± 486.80 min, and the mean postoperative requirement of fentanyl was 98.80 ± 47.02 μg. The median pain score (NRS) during rest and movement is 2 to 3 and 3 to 4, respectively. The median quality of recovery score at the end of 24 h after the block was 14 (15–14).

Conclusion: The upper thoracic ESPB resulted in a sensory loss from C7-T5 dermatomes without any weakness of the diaphragm and upper limb. However, the block was moderately effective in terms of the total duration of analgesia, postoperative pain scores, analgesic requirement, and quality of recovery in patients undergoing proximal shoulder surgeries under GA. Further studies are required to establish its role due to its poor correlation with sensory spread.

Keywords: Brachial plexus block, erector spinae plane block, phrenic nerve, postoperative pain, shoulder arthroplasty, thoracic vertebrae

Introduction

Shoulder surgery is one of the most painful surgeries,[1,2] the Interscalene Brachial Plexus Block (ISPB) is considered the gold standard for providing postoperative analgesia for shoulder surgery.[2,3] However, its use is limited by complications like ipsilateral phrenic nerve block and hemidiaphragmatic paralysis (HDP), which has 43%–100% incidence.[4,5] Diaphragmatic paralysis is due to the proximity of the phrenic nerve to the brachial plexus and the spillage of the local anesthetic to it

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Access this article online

Quick Response Code:

Website: https://journals.lww.com/joacp

DOI: 10.4103/joacp.joacp_434_22

How to cite this article: Kumar D, Talawar P, Dhar M, Azam Q, Tripathy DK, Singla D, *et al*. The efficacy of ultrasound-guided upper thoracic erector spinae plane block for postoperative analgesia in proximal shoulder surgery and its effect on phrenic nerve function: A prospective exploratory study. J Anaesthesiol Clin Pharmacol 2024;40:312-7.

Submitted: 15-Dec-2022 **Revised:** 25-Jan-2023
Accepted: 30-Jan-2023 **Published:** 08-Apr-2024

due to the volume of the drug used. Phrenic nerve palsy is of concern in patients with preexisting pulmonary compromise. Strategies to avoid phrenic nerve palsy have been explored, such as limiting the volume of the local anesthetic,[6-8] targeting only the superior trunk of the brachial plexus,[9] and using a supraclavicular approach[10-13] to the brachial plexus but with limited success.

The erector spinae plane block (ESPB) (cervical/thoracic) involves the deposition of local anesthetic in a plane between the transverse process of vertebrae and erector spinae muscle. The drug then tracks to the nerve roots to cause an analgesic effect. Forero *et al*.[14] described ESPB for thoracic neuropathic pain in two patients. It was found to be useful in treating chronic shoulder pain[15] and acute postsurgical pain and the block was motor-sparing[16] without causing phrenic nerve palsy/HDP.[14,17]

We hypothesize that an upper thoracic (T2) ESPB is a better alternative for an interscalene brachial plexus block for providing acute postoperative pain relief in patients without causing phrenic nerve palsy/HDP. The present study was planned to evaluate the block characteristics of upper thoracic (T2) ESPB in patients undergoing shoulder surgery under GA.

Material and Methods

A prospective exploratory study was conducted in tertiary care hospital in India over 11 months, from November 2021 to September 2022. The protocol of this study was approved by the Institutional Ethics Committee (AIIMS/IEC/21/116 dated 12th March 2021) and was registered in Clinical Trial Registry, India (CTRI/2021/11/037793 dated 3rd November 2021). We have followed the STROBE guidelines (STrengthening the Reporting of OBservational studies in Epidemiology) for our study.

Patients were screened in preanesthetic clinic (PAC) using the following inclusion criteria: age >18 years, both sexes, undergoing open shoulder surgery/arthroscopic procedure, belonging to American Society of Anaesthesiology (ASA) physical status I-III. Exclusion criteria for the study were patient refusal, any contraindications for the block (local site infection, open wound at the site of block, and coagulopathy), severe systemic disease, and allergic to local anesthesia drugs. Written informed consent was taken before involving the eligible patients and patients were allowed to withdraw from the study at any point of time. The basic demographic data, including age, sex, weight, comorbidities, diagnosis, procedure planned, and ASA physical status, were noted. At this time, consenting patients were explained about upper thoracic ESPB, the numerical rating scale score (NRS), and about use of patient-controlled analgesia (PCA) pump. The standard institutional protocol was followed regarding preoperative premedication. Patients were kept at nil per oral for 8 h for solid and 2 h for clear fluids.

On the day of surgery, the patients were shifted to the operation theatre (OT), and routine monitoring, consisting of heart rate (HR), oxygen saturation (SpO_2), and noninvasive blood pressure (NIBP), was started. An intravenous (IV) access was established, and a balanced salt solution (Ringer lactate) was started according to the Holliday Segar formula. The procedure was done under complete aseptic precautions. Patients were then positioned for the block in a sitting position. The patients were draped from the nape of the neck to the inferior border of the scapula. The linear ultrasound probe was placed longitudinally 2–3 cm lateral to the T2 spinous process in the sagittal plane. The T2 spinous process was identified by counting down anatomically from the vertebra prominence (C7), and the T2 transverse process was visualized via real-time ultrasound guidance. The erector spinae muscle was visualized above the T2 transverse process and a 22 G needle were inserted in a caudal to cranial direction using the in-plane technique. One to two milliliters (mL) of normal saline were injected into the interfacial area between the erector spinae muscle and the transverse process for the localisation of the plane. After hydro dissection, 0.4 mL/kg of 0.25% bupivacaine + 4 mg of dexamethasone was injected, and the linear spread of the solution was visualized in the interfacial plane.

After the procedure, the diaphragmatic movements were assessed at 15 min, 30 min after the block, and 1 h after the surgery and compared with preblock diaphragmatic movements to identify hemidiaphragmatic palsy. A 2–5 MHz curvilinear US transducer, placed longitudinally with the pointer pointing upward in M-mode, was employed in all subjects. Patients were scanned along the anterior axillary line. HDP was defined as the absence of diaphragmatic motion during normal respiration coupled with absent or (paradoxical) cranial diaphragmatic movement when the patient forcefully sniffs. The sensory level was assessed by the perception of cold, using spirit swab along the cervical and thoracic dermatomes, and motor power was assessed by using the Modified Bromage scale for the upper limb at 15 min and 30 min after the block.

After the block assessment, patients were made supine and received general anesthesia with 2 μg/kg fentanyl, 1.5 to 2.5 mg/kg of propofol, and 0.1 mg/kg of vecuronium intravenously (iv) as induction agents, following which the airway was secured with the appropriate size-cuffed endotracheal tube or supraglottic airway device. Sevoflurane in a mixture of oxygen and nitrous oxide in a ratio of 50:50 was used to maintain general anesthesia, along with boluses of vecuronium for muscle relaxation.

Any increase in HR or SBP >20% from the baseline was considered a response to pain, and patients were given rescue analgesia at 0.5 μg/kg of fentanyl iv. Half an hour before the end of the surgery, all patients received antiemetic prophylaxis with 4 mg of ondansetron iv. After the surgery, once the patient had adequate spontaneous respiratory efforts, the neuromuscular blockade was reversed, and patients were extubated and shifted to the postanesthesia care unit (PACU).

All patients were monitored in PACU followed by ward. Inj. paracetamol (PCM) 1 g iv was given every 6 h. As assessed by numerical rating scale (NRS), pain scores were noted at the end of the surgery, at 6 h, 12 h, 18 h, and 24 h after surgery. Patients received intravenous patient-controlled analgesia (IV-PCA) through an electronic pump with fentanyl bolus of 25 μg, lockout interval of 15 min, and a maximum 4-h dose limit of 400 μg. The duration of analgesia was defined as the onset of the block to the request for first rescue analgesia (time of first press on PCA pump). The total fentanyl requirement was noted at the end of 24 h by counting the number of bolus doses delivered displayed on the PCA pump. Ondansetron, 4 mg iv, was administered if any patient complained of nausea and vomiting. Any other complications like pneumothorax, neurovascular injury, and local anesthesia systemic toxicity (LAST) were also noted.

The study's primary outcome was to evaluate the effect of upper thoracic ESPB on the incidence of phrenic nerve palsy, as confirmed by hemidiaphragm paralysis by ultrasound examination. The secondary outcomes measured were the block onset times, i.e. sensory loss by cold cotton swab and motor blockade by using the Modified Bromage scale of the upper limb at the end of 30 min, pain scores by NRS at the end of the surgery, at 6 h, at 12 h, at 18 h, at 24 h after surgery, total rescue analgesia requirement in the first 24 h after surgery, quality of recovery score at 24 h.

Sample size estimation

Based on previous years' data, we estimated that there would be 40–45 cases of shoulder surgery in the entire study period. Assuming a 50% incidence of phrenic nerve palsy with upper thoracic erector spinae block, with absolute precision of 5% and 95% confidence level, the sample size will be calculated as 37 patients (n = 37). However, we included as many patients as we could to improve accuracy.

Statistical analysis

The study data was compiled in Microsoft Excel (2020) and analyzed using Statistical Package for Social Sciences software (SPSS Version 23.0, IBM Inc.). The data were presented as mean ± standard deviation and median (interquartile range) for continuous data and frequencies and percentages for categorical data. Graphical representation of data was done as appropriate using bar charts and line diagrams. The normal distribution of the data was checked using the Shapiro–Wilk test.

Results

We screened 46 patients scheduled for proximal shoulder surgery, meeting the inclusion criteria for our study. Three patients were excluded due to negative consent, and a total of 43 patients were included in the study [Figure 1]. The demographic parameters (age, sex, weight, comorbidities, diagnosis, surgical procedure done, duration of anesthesia, and duration of analgesia) of the patients are shown in Table 1.

The sensory level achieved at the end of 30 min of the block was mostly between C7-T5 dermatome levels. None of the patients had any upper limb motor weakness, and the diaphragmatic movements were normal in all subjects [Table 2]. The patients were assessed for pain in the postoperative period using NRS Scale at rest and movement [Table 3]. The duration of analgesia (patients who received rescue analgesia) and postoperative fentanyl rescue dose at 24 h and quality of recovery are presented in Table 4. We did not observe any procedure-related or block effect-related complications.

Discussion

The primary objective of this study was to evaluate the phrenic nerve function following single-shot upper thoracic (T2) ESPB

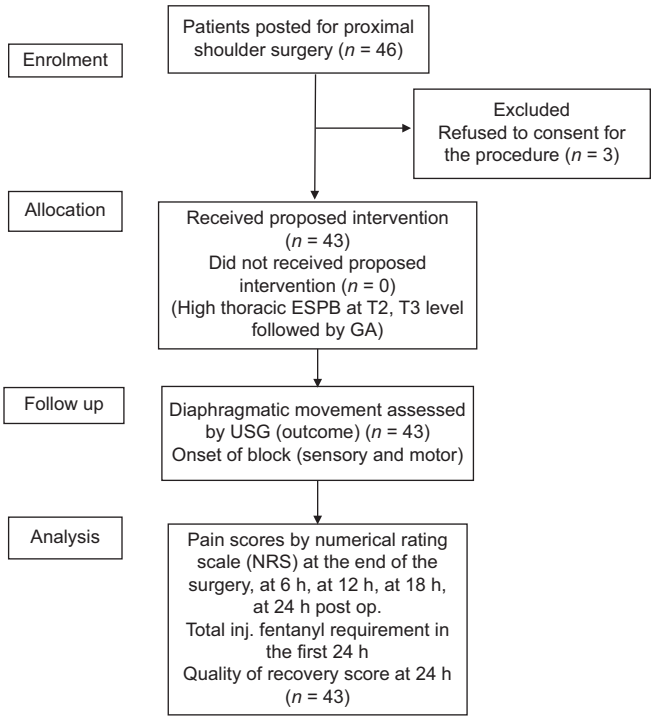

Figure 1: Methodology flow chart

Table 1: Demographic variables, types of surgery, and duration of anesthesia and surgery

Basic Details	Mean±SD || Frequency (%)
Age (years)	35.95±14.78
18–30 Years	21 (48.8%)
31–40 Years	6 (14.0%)
41–50 Years	8 (18.6%)
51–60 Years	3 (7.0%)
61–70 Years	5 (11.6%)
Gender	
Male	29 (67.4%)
Female	14 (32.6%)
Weight	59.74±8.99
41–50 kg	7 (16.20%)
51–60 kg	13 (30.23%)
61–70 kg	18 (41.86%)
71–80 kg	5 (11.63%)
ASA physical status	
I	31 (72.1%)
II	10 (23.3%)
III	2 (4.7%)
Comorbidities	
None	33 (76.7%)
HTN	6 (14.0%)
DM	4 (9.3%)
Diagnosis	
Dislocation around shoulder joint	34 (79.1%)
Ligament tear	7 (16.3%)
Fracture around shoulder joint	2 (4.7%)
Surgical procedures	
Arthroscopic	41 (95.3%)
Open	2 (4.7%)
Duration of anesthesia (minutes)	1044.88±602.49
Duration of surgery (minutes)	155.23±44.83

**DM, diabetes mellitus, HTN, hypertension; ASA, American Society of Anaesthesiology*

Table 2: Block characteristics

Block characteristics	Frequency	Percentage
Sensory loss at the end of 30 min		
Cranial Spread		
C6	1	2.3%
C7	21	48.8%
C8	10	23.3%
T1	2	4.2%
T2	9	20.9%
Caudal spread		
T2	10	23.3%
T3	1	2.3%
T4	14	32.6%
T5	15	34.9%
T6	2	4.7%
T7	1	2.3%
Motor function	43	100.0%
Diaphragmatic movement		
Preoperative	WNL	100%
15 min	WNL	100%
30 min	WNL	100%
Postoperative	WNL	100%

**WNL, within normal range*

by observing diaphragmatic movements on ultrasonography in patients undergoing shoulder surgery. The incidence of phrenic nerve palsy was 0% in this series, maybe there was no spread of local anesthetics to cervical nerve roots forming the phrenic nerve (C3,C4,C5).

The sensory spread produced by the single-shot upper thoracic ESPB administered at T2 level using 0.4 mL/kg volume of 0.25% bupivacaine +4 mg dexamethasone was inadequate to cover all the dermatomes of the brachial plexus itself hence no cervical plexus coverage was assumed. The C6 level was the highest sensory level reached in only one (2.3%) patient, whereas in most patients, it could reach C7-C8 levels only. Eighteen out of 43 (41.86%) patients did not require a single rescue analgesic requirement through a PCA pump in the first 24 h, whereas 25 out of 43 (58.14%) patients required rescue fentanyl with a mean dose of 98.80 ± 47.02 μg. On analysis, it was observed that patients who did not require any rescue analgesia achieved sensory loss up to C7 level in 44% of patients while only 28% of the patients achieved C7 in those who required rescue analgesia. For the patients who required rescue analgesia, their analgesia request time from the time of block placement was 724 ± 486.80 min.

The innervation of the shoulder joint is complex, and the cutaneous supply is provided by C5-C6 nerve roots (axillary, supra-scapular nerves) and C3-C4 (supraclavicular nerves). Bones and capsules get the innervations from C5-C7 (supra-scapular, lateral pectoral, axillary, musculocutaneous, and long thoracic nerves). The C5-C7 roots supply the majority of joint structures.[18] The regional anesthesia technique chosen should be able to cover the majority of the nerves that are responsible for the pain during shoulder procedures.

The mechanism of action of ESPB is still not clear, the nil requirement of rescue analgesia in patients who achieved even C7 level shows inconsistent apparent cutaneous sensory loss and clinically successful outcomes. Various probable mechanisms have been postulated by Chin and El-Boghdadly[19] comprising of differential block of C-fibers, systemic absorption of local anesthetic drug.

The upper thoracic ESPB is known to produce variable results when it was administered at T2-T3 level, in terms of postoperative pain scores,[17,20-25] analgesia provided[25,26] and the sensory spread,[22,25,27,28] motor weakness in the upper limb.[16,17,28] Up to 37% of publications of ESP blocks reported on sensory or motor blockade show inconsistent blockade and poor correlation between clinical effects and the spread of local anesthetics.[25,29] The variability might be due to the systemic absorption of local anesthetics, inconsistent patient reporting,[25] and an inherent property of fascial plane blocks.[25,29]

Table 3: Postoperative pain score at rest and movement (NRS)

NRS	Median (IQR) of NRS at rest	Median (IQR) of NRS at movement
0th h	2.00 (1.50–3.00)	3.00 (3.00–4.00)
1st h	3.00 (2.00–3.00)	3.00 (3.00–4.00)
6th h	3.00 (2.00–4.00)	4.00 (3.00–4.00)
12th h	3.00 (2.00–4.00)	3.00 (2.50–5.00)
18th h	3.00 (2.00–4.00)	3.00 (2.00–4.00)
24th h	3.00 (2.00–4.00)	3.00 (2.00–4.50)

**IQR, interquartile range, NRS, numerical rating scale*

Table 4: Intraoperative and postoperative fentanyl requirement (μg), duration of analgesia, quality of recovery score (*n*=43)

Characteristics	Mean±SD or Median (IQR)
Intraoperative fentanyl requirement (including induction dose) (μg)	128.37±29.68
Intraoperative rescue analgesia (fentanyl) (μg)	15±26.2
Fentanyl dose (μg) (postoperative)	98.80±47.02
Duration of analgesia (minutes)	724.2±486.80
Quality of recovery score	14 (14–15)

Phrenic nerve palsy was not reported in any of the literature on the thoracic ESPB, though the possibility of phrenic nerve palsy cannot be ruled out as the muscle plane is continuous with the cervical area. A cadaver study by Elsharkawy *et al.*[30] demonstrated that the phrenic nerve was deeply stained in 1/10 injection and faintly stained in 2/10 injections when lower cervical ESPB was given at C6 on one side and C7 level on another side in five cadavers (10 blocks) with 20 mL of dye. Clinical case reports of lower cervical ESPB confirm the same.[23,29]

The variability of the block characteristics of thoracic or lower cervical ESPB, reported in the literature, might be due to various factors that influence the spread of local anesthesia. These include the size of the needle used,[17] whether a single shot[20] or an intermittent bolus[16,23] or continuous injection,[27] the level of injection (upper thoracic[20] or cervical[27]), type, concentration[22] and volume[20] of the local anesthetic used. Therefore, future studies, taking care of all the variables, could define the role of upper thoracic ESPB in upper limb procedures.

Our study had some limitations, such as being single center, single shot, without comparator group, with no radiological confirmation of dye spread, used only qualitative method to detect diaphragmatic movements. We have performed ESPB at the T2 level. Our results would have been different if we have done at the cervical level, so further studies are warranted, comparing thoracic ESPB and cervical ESPB to validate our findings. Our study consisted of 43 participants, which was an exploratory study, and the sample size was based on the feasibility of surgeries during the study period. So, more studies with larger sample sizes could lead to further validation of erector spinae plane block for proximal shoulder surgeries.

Conclusion

Ultrasound-guided upper thoracic erector spinae plane block administered at the T2 level produced sensory loss from C7-T5 dermatomes without any upper limb motor blockade and phrenic nerve palsy. However, the block was moderately effective in terms of the postoperative pain scores, total duration of analgesia, postoperative analgesia requirement, quality of recovery, and safety profile in the patient cohort of the current study.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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