Original Article

The subcostal nerve as the target for nerve stimulator guided transverse abdominis plane blocks – A feasibility study

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ABSTRACT

Background and Aims: Transverse Abdominis Plane (TAP) block was originally described as a landmark-based technique. Peripheral nerve stimulator (PNS) guided blocks are still widely performed, where ultrasound is unavailable. **Methods:** Cadaveric dissections were performed which showed the subcostal nerve following a predictable course at the lateral abdominal wall in the TAP. The subcostal nerve was identified by ultrasound in three volunteers. Stimulation of the subcostal nerve was performed using PNS and landmarks as guidance in and 20 patients. Twitches of the anterior abdominal wall muscles were elicited, and needle position and drug dispersion were confirmed using ultrasound. **Results:** Out of 32 attempts made, the drug dispersion was appropriate in 24, not appropriate on four insertions and twitches were not elicited in 4 attempts. **Conclusion:** Nerve stimulator can be used as a guidance for TAP blocks where the availability of ultrasound is limited.

Key words: Nerve stimulator, transverse abdominis plane block, ultrasound

INTRODUCTION

Transverse Abdominis Plane block is a widely-used technique to provide analgesia for various abdominal surgeries. Ultrasound guidance has thus become the gold standard to achieve an effective block.

TAP block was initially described as a landmark based technique in the lumbar Petit triangle.[1] The initial studies used Computed tomography and Magnetic Resonance Imaging (MRI) to demonstrate the spread of drug in the transverse plane.[2] Controversy regarding whether single or double pop technique being the ideal technique remains.[3,4] Inaccurate injection into the muscles itself may also provide analgesia,[5] but intramuscular injection of large quantities of local anaesthetic may cause post-operative muscle weakness, as local anaesthetics are myotoxic.[6] Complications like peritoneal perforation are effectively diminished by using ultrasound guidance. When ultrasound is not available, nerve stimulator guided techniques are the next best option for nerve localisation which in turn is more effective than landmark-based techniques. Nerve stimulator guided ilioinguinal and iliohypogastric nerve blocks have been described.[7]

The intercostal nerve of T12 (subcostal nerve), the largest of the intercostal nerves travels below the 12th rib, passes behind the kidney, gives off the lateral cutaneous nerve, proceeds obliquely and innervates the transverse abdominis and pierces its aponeurosis at the lateral border of the quadratus lumborum to enter the TAP space. The subcostal nerve provides motor supply to the rectus abdominis, intercostal muscles and anterior abdominal wall muscles. The nerve communicates with the iliohypogastric nerve

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and gives a motor branch to pyramidalis.[8] We aimed to stimulate the nerve using landmark guidance. Once located, depositing sufficient volume of local anaesthetic produces, in effect, a TAP block.

METHODS

Cadaveric dissections were performed in two specimens and the subcostal nerve was traced as it penetrated the transverse abdominis to enter the TAP [Figures 1 and 2]. Upon separating the internal oblique and transverse abdominis planes, the nerve was located approximately midway between the iliac crest and the subcostal margins [Figures 3 and 4]. The subcostal nerve consistently gave a communicating branch to the iliohypogastric nerve (L1) which ran below and much closer to the iliac crest.

Targeting this nerve would provide a simple way to locate the TAP plane. We aimed to achieve a TAP block by stimulating the subcostal nerve, relying upon its predictable course in the lateral abdominal wall. When stimulated, contractions of the transversalis and rectus muscle can be elicited. Direct stimulation of the muscles can be ruled out by using a low intensity current (≤0.5 mA).

After obtaining Institutional Ethics Committee's (IEC) approval, the volunteers and patients were explained about the procedure, and then informed consent was obtained. On ultrasound examination done in three volunteers, we could identify an oval hypoechoic structure in the midaxillary line between the subcostal margin and iliac crest, which when traced posteriorly and superiorly, disappeared at the lateral border of the quadratus lumborum just beneath the 12th rib [Figure 5]. The structure when stimulated using a current strength of 0.4 mA produced contraction of the abdominal wall muscles (videos 1-3 in Online Supplementary material) and was possibly the subcostal nerve which is the largest of the intercostal nerves.

We recruited twenty consecutive patients undergoing elective lower abdominal surgical procedures under spinal anaesthesia. The sample size was chosen in accordance to a general rule by Browne that it takes a minimum of 30 patients to estimate a parameter,[9] and TAP can be performed bilaterally. The only exclusion

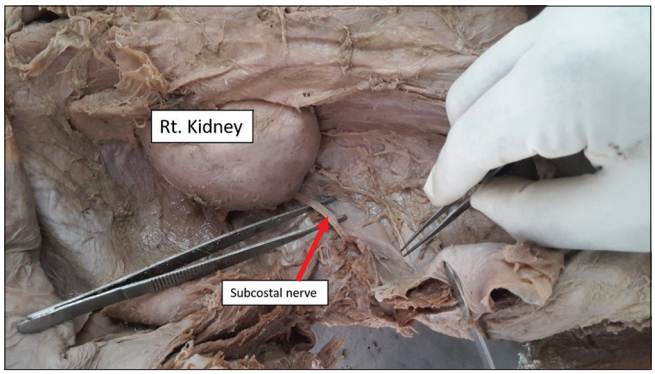

Figure 1: Dissection of the anterior abdominal wall to trace the subcostal nerve. The nerve emerges behind the lower pole of the kidney and enters the abdominal wall at the lateral margin of quadratus lumborum

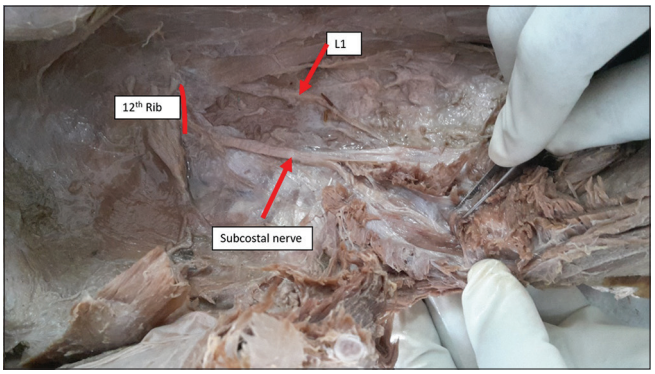

Figure 2: The nerve leaving the 12th rib and sending a communicating branch to L1 nerve

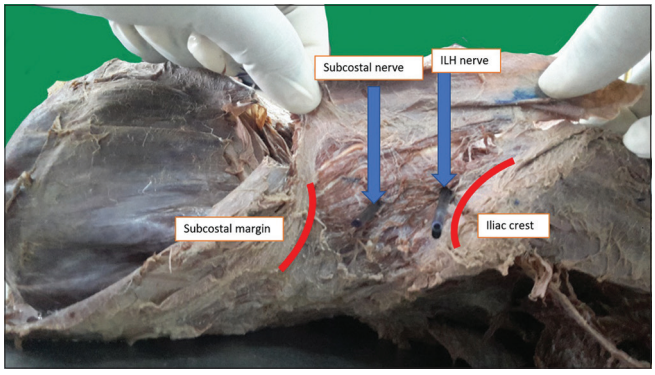

Figure 3: Lateral view of the costo-crestal area with markers introduced perpendicular to the course of the subcostal nerve and Iliohypogastric nerve

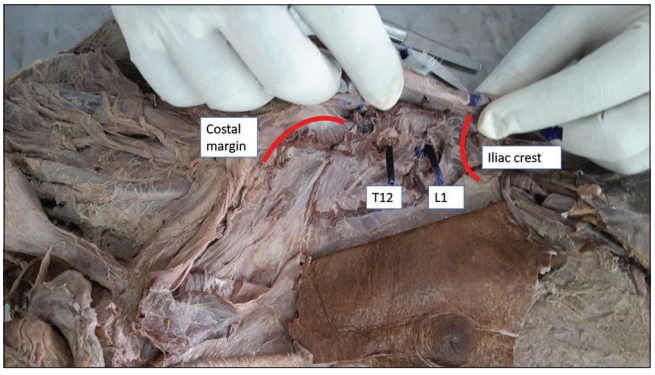

Figure 4: The markers in figure 3 as seen from inside the abdominal cavity marking the position of the subcostal nerve and Iliohypogastric nerve

criterion was the incision extending in to the lateral abdominal wall. After completion of the surgery, a scout scan using a linear high frequency probe (Sonosite M Turbo™) was done at the midpoint between the costal margin and the iliac crest in the mid-axillary line and depth of the transverse abdominis plane measured. The scout scan was performed to prevent too deep a needle penetration and visceral injury during subsequent blind punctures. No attempts were made to locate the subcostal nerve by ultrasound at this point. A second anaesthesiologist blinded to the measured depth of the TA plane attempted to locate twitches of the anterior abdominal wall with a graduated nerve stimulation needle (Stimuplex™, Braun and Inmed, Vadodara) at the same point. The direction of the needle was perpendicular and initial current was 1 mA. When the twitches were obtained, the current intensity was brought down to 0.4 mA, to rule out direct muscle stimulation. Fine needle adjustments were made to obtain the twitches. The position of the needle was verified by ultrasound by placing the linear probe on the anterior abdominal wall, visualising the needle in long axis. Injection of local anaesthetic was done under ultrasound guidance to confirm spread of the injectate in the proper plane. Appropriate needle manipulations were made to achieve drug deposition at the target site.

If the depth of the needle exceeded the previously measured depth and no twitches were elicited, the operator was asked to stop and redirect the needle slightly cephalad or caudad by approximately up to 15 degrees. This was done to prevent too deep a needle placement into the peritoneal cavity. On redirection, the allowed depth was increased by another 0.5 cm to accommodate the extra depth the needle has to traverse while inserted at an angle, considering the initial perpendicular trajectory as the first (adjacent) side, oblique trajectory as the hypotenuse and the TA plane as the third (opposite) side of a right angled triangle, with the angle between the adjacent and hypotenuse being 15 degrees. Also, if the operator was able to appreciate two 'pops' as the needle traversed the fascial planes, the procedure was halted. If twitches were not obtained, the stimulation was stopped and further procedure was performed under ultrasound guidance. The number of successful blocks (twitches obtained *and* needle at TA plane) was noted. The position of the needle tip was observed whether at the proper plane or below/above it.

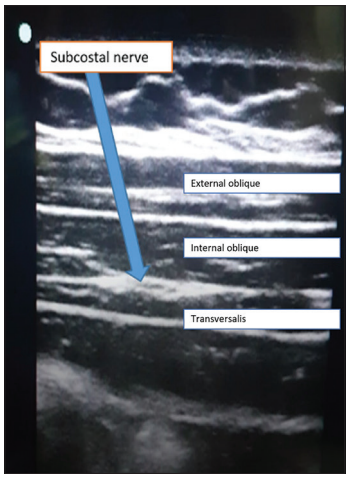

Figure 5: US image of anterior abdominal wall at the midpoint of iliac crest and subcostal margin along the midaxillary line demonstrating an oval hypoechoic structure in between the internal oblique and transverse abdominis. The structure when stimulated, produced twitches of the anterior abdominal wall, probably the subcostal nerve

RESULTS

Twenty patients were recruited for the study. Twelve patients received bilateral block (2 vesicolithotomies, 4 caesarean sections, 4 abdominal hysterectomies and 2 tubectomies) and eight patients received unilateral block (6 Hernioplasties, 2 open appendicectomies)—a total of 32 attempts. The mean depth of the transversalis plane was 2.8 ± 0.9 cm from the skin at the puncture site as measured by the initial scout scans Out of 32 attempts, twitches were located at the first pass in 28 attempts [Figure 6]. Among them, three punctures needed cephalad/caudad adjustments to elicit twitches. In most patients, an appreciable loss of resistance was felt while entering the plane. Among the four attempts where twitches were not elicited, in three punctures, subsequent ultrasound examinations showed the nerve posterior to the puncture site. In one, the nerve was not appreciable in the plane.

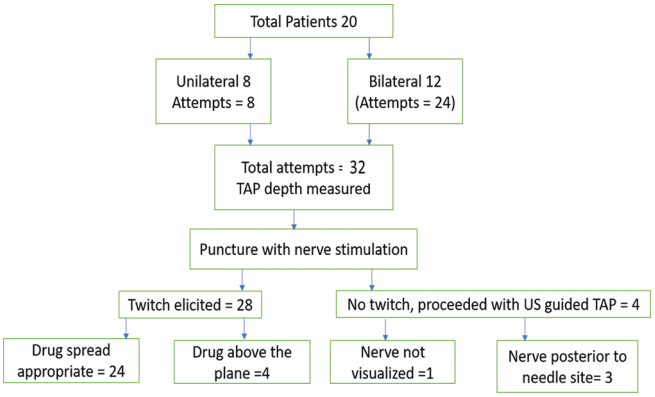

Figure 6: Procedure outcomes

Among the attempts where the twitch was elicited (with or without cephalocaudal adjustments) in all but four, the injectate spread in the appropriate plane. In those four attempts, the initial drug spread was superficial to the plane, the needle tip was adjusted under ultrasound guidance to permit drug spread in the appropriate plane. So, the stimulator positive but ultrasound negative injections were 4 out of 28 – around 14% false positive. In all these attempts, the drug was spreading just above the transverse abdominis plane and when the needle was advanced by few millimeters, the drug spread was appropriate, usually accompanied by a distinctive 'pop'. So the four observed outcomes were – (a) twitches obtained, US showed needle and drug spread in proper site (n = 24), (b) twitches obtained, US showed needle superficial to the TA plane (n = 4), (c) twitches not obtained, nerve visible in ultrasound (n = 3) and (d) twitches not obtained, nerve not visible (n = 1). The overall success rate was 75% (24 out of 32). In none of the patients, the needle passed beyond the plane without eliciting twitch, as the operator was alerted when the depth exceeded the previously measured value by the scout scan.

DISCUSSION

The subcostal nerve—the largest of the intercostal nerves—follows a predictable path in the transverse abdominis plane, which was evident from the cadaveric dissections. The findings corroborate similar dissections of the 10th and 11th intercostal and subcostal nerves performed by Van der Graff *et al*.[10] In a recent study by Alonso *et al*., the subcostal nerve was described as larger, covering a wider area with more branches (8 on average as opposed to 4 of the L1) and travels 5 cm below the 12th rib in its initial course.[11] Beneath the rib, the nerve either travels anterior or inferior to the lumbocostal ligament[12] or even pierces it.[13] The nerve was also identifiable by ultrasound. Based on the cadaveric study by Tran *et al*.[14] that analysed the spread of injectate, TAP blocks administered cephalad to the iliac crest reliably covered the T10 to L1 nerves. As the subcostal nerve provides motor innervation to the rectus, pyramidalis and transversalis, widespread twitches can be expected when stimulated. A current of 0.4 mA intensity would not result in widespread visible twitches due to direct muscle stimulation. This fact is depicted in the video in the online Supplementary material, where a current of 0.4 mA is shown stimulating the subcostal nerve and eliciting widespread twitches of the anterior abdominal wall. Ultrasound still is a costly investment in many places. Adding to these are the legal hurdles in acquiring the machine in India. Peripheral nerve stimulation was the widely used method to identify nerves and plexuses before the era of ultrasound. With the advent of ultrasound, landmark and nerve stimulation based regional blocks are becoming a fast dying art. For compartment blocks like TAP block, the role of nerve stimulation is limited. The nerves are difficult to locate and it is a known fact that twitches may not be elicited even when the needle is close to or even inside the nerve.[15] However, it might be possible to utilise the subcostal or iliohypogastric nerves to locate the transverse abdominis plane to achieve an effective block as these nerves are larger. So far, no studies have attempted to locate these nerves as a means of identifying the transversalis plane. The duration of post-operative analgesia was not measured in the study as all patients effectively received a proper TAP block under ultrasound guidance. Landmark-based TAP block using the double pop technique has the potential for too deep a needle placement and peritoneal entry. This is possible with PNS guided technique also, as in some cases the needle did not elicit twitches. In our study the depth of the TA plane was measured beforehand by ultrasound hence there were no instances of peritoneal perforation. If the block is performed only by PNS guidance, the probability of intra-peritoneal needle placement may be higher, on par with the original landmark based technique which might be around 2%.[5] The overall false positive rate was 14% (4/28)—if the drug had been deposited without ultrasound confirmation, it would have resulted in a failed block. The failure rate is similar to or better than that of other PNS guided blocks.[16,17] However, being a feasibility study, it may not be adequately powered to determine success and failure rates. Also, anatomically inaccurate blocks need not necessarily imply complete block failure,[5] as local anaesthetics diffuse through fascial planes and can result in partial blocks.

The small sample size may not depict the actual success and failure rates. Also if the scout scan - the 'safety net' is not available, risk of deeper needle placement and visceral injury exists. The site of initial needle placement takes into account the most common location of the nerve, observed in few volunteers and 2 cadaveric specimens (4 sides). Anatomical variation might be more common resulting in failed stimulations. The subsequent needle redirection

angles of up to 15 degrees was followed to allow for the nerve's deviation of approximately 1-2 cm cephalad or caudad from the expected location and is imprecise, as with all landmark based PNS guided techniques.

CONCLUSION

In conclusion, we report a method for locating the transversus abdominis plane utilising the predictable course of the subcostal nerve using a nerve stimulator. Further studies comparing the analgesic efficacy of the PNS guided approach and ultrasound guided technique is warranted.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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