Transversus Abdominis Plane Block: A Cadaveric and Radiological Evaluation

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Background and Objectives: The abdominal wall is a significant source of pain after abdominal surgery. Anterior abdominal wall analgesia may assist in improving postoperative analgesia. We have recently described a novel approach to block the abdominal wall neural afferents via the bilateral lumbar triangles of Petit, which we have termed a transversus abdominis plane block. The clinical efficacy of the transversus abdominis plane block has recently been demonstrated in a randomized controlled clinical trial of adults undergoing abdominal surgery.

Methods: After institutional review board approval, anatomic studies were conducted to determine the deposition and spread of methylene blue injected into the transversus abdominis plane via the triangles of Petit. Computerized tomographic and magnetic resonance imaging studies were then conducted in volunteers to ascertain the deposition and time course of spread of solution within the transversus abdominis fascial plane in vivo.

Results: Cadaveric studies demonstrated that the injection of methylene blue via the triangle of Petit using the "double pop" technique results in reliable deposition into the transversus abdominis plane. In volunteers, the injection of local anesthetic and contrast produced a reliable sensory block, and demonstrated deposition throughout the transversus abdominis plane. The sensory block produced by lidocaine 0.5% extended from T7 to L1, and receded over 4 to 6 hours, and this finding was supported by magnetic resonance imaging studies that showed a gradual reduction in contrast in the transversus abdominis plane over time.

Conclusions: These findings define the anatomic characteristics of the transversus abdominis plane block, and underline the clinical potential of this novel block. *Reg Anesth Pain Med 2007;32:399-404.*

Key Words: Anatomy, Triangle of Petit anatomy, Transversus abdominis plane analgesia, Postoperative regional analgesia, Neural plexus blockade.

Patients undergoing abdominal surgery suffer substantial postoperative discomfort and pain arising from the abdominal wall incision.[1] The potential for inadequately treated postoperative pain to result in significant sequelae such as reduced organ function, prolonged hospital stay, and poor surgical outcome in certain circumstances, is increasingly clear.[2-4] While a lower thoracic or lumbar epidural technique may constitute the gold standard for postoperative analgesia, it is not always possible to provide neuraxial analgesia, due to logistic issues and/or the presence of medical contraindications.[5,6] A promising alternative approach to the provision of postoperative analgesia after abdominal incision is to block the entire sensory nerve supply to the anterior abdominal wall.[7,8]

The lateral abdominal wall consists of 3 muscle layers, the external oblique, the internal oblique,

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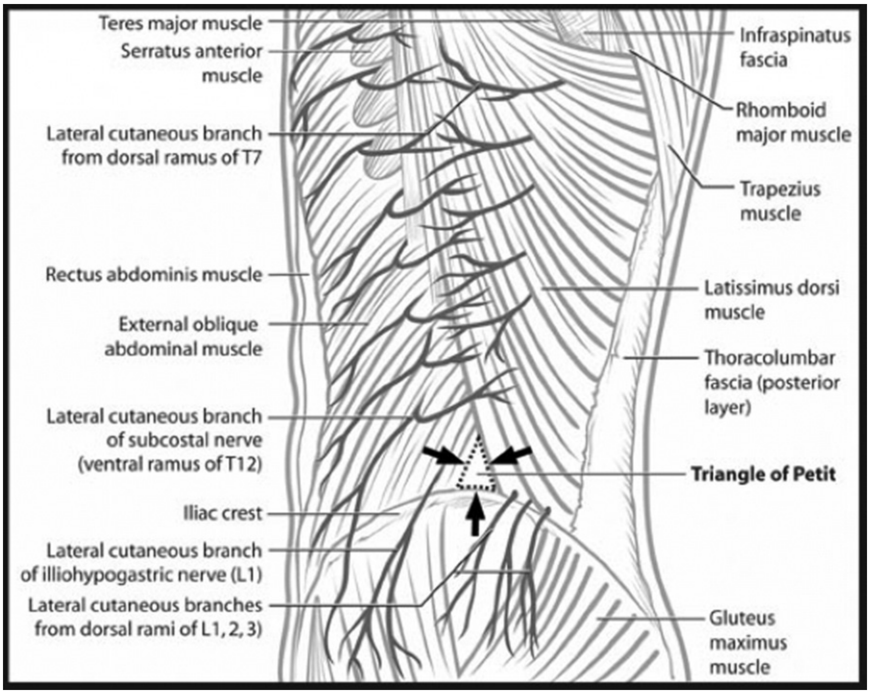

Fig 1. Line drawing of the anatomy of the abdominal wall, including the lumbar triangle of Petit (arrows). As can be seen from the diagram, the triangle is bounded posteriorly by the latissimus dorsi muscle, anteriorly by the external oblique with the iliac crest forming the base of the triangle.

and the transversus abdominis, and their associated fascial sheaths. The central abdominal wall also includes the rectus abdominis muscles and its associated fascial sheath. The sensory supply of the skin, muscles, and parietal peritoneum of the anterior abdominal wall is derived from the anterior rami of the lower 6 thoracic nerves and the first lumbar nerve. These nerves course through the lateral abdominal wall within a fascial plane between the internal oblique and transversus abdominis muscles, termed the transversus abdominis fascial plane.[9]

We have recently described a novel approach to block the abdominal wall neural afferents via the bilateral lumbar triangles of Petit, which we have termed a transversus abdominis plane (TAP) block.[10,11] By introducing local anaesthetic agents into this space via the triangle of Petit it is possible to block the sensory nerves of the anterior abdominal wall before they pierce the musculature to innervate the abdomen. We have demonstrated the clinical efficacy of the TAP block in a case series,[11] and more recently in a randomized controlled clinical trial of adults undergoing abdominal surgery.[10] However, the detailed anatomic characteristics of the TAP block have not been characterized to date.

Our objectives in these studies were to characterize the anatomy of the triangle of Petit, and determine the extent, and time course, of spread of agents introduced via the triangle of Petit, in order to determine the analgesic potential of the TAP block.

Methods

Institutional Approval

Institutional review board approval was obtained to conduct the computerized tomographic (CT) and magnetic resonance imaging (MRI) studies in human volunteers. These studies were performed in order to ascertain deposition and spread of solution within the transversus abdominis fascial plane using the TAP block technique.

Surface Anatomy and Block Technique

The triangle of Petit is bounded posteriorly by the latissimus dorsi muscle, anteriorly by the external oblique with the iliac crest forming the inferior border of the triangle, and is a fixed and easily palpable landmark (Fig 1).[12] The floor of the triangle is formed by the external oblique fascia. The block is performed with the subject in the supine position, and the iliac crest palpated from anterior to posterior until the latissimus dorsi muscle can be appreciated. The triangle of Petit is then located just anterior to the latissimus dorsi muscle (Fig 2A). Using a blunt regional anesthesia needle (Plexufix®, B. Braun, Melsungen, Germany), the skin is pierced just cephalad to the iliac crest over the triangle of Petit (Fig 2B). The needle is advanced perpendicular to the skin, in a coronal plane. Initial resistance indicates arrival of the needle tip at the external oblique fascia. Advancement of the needle results in a "pop"

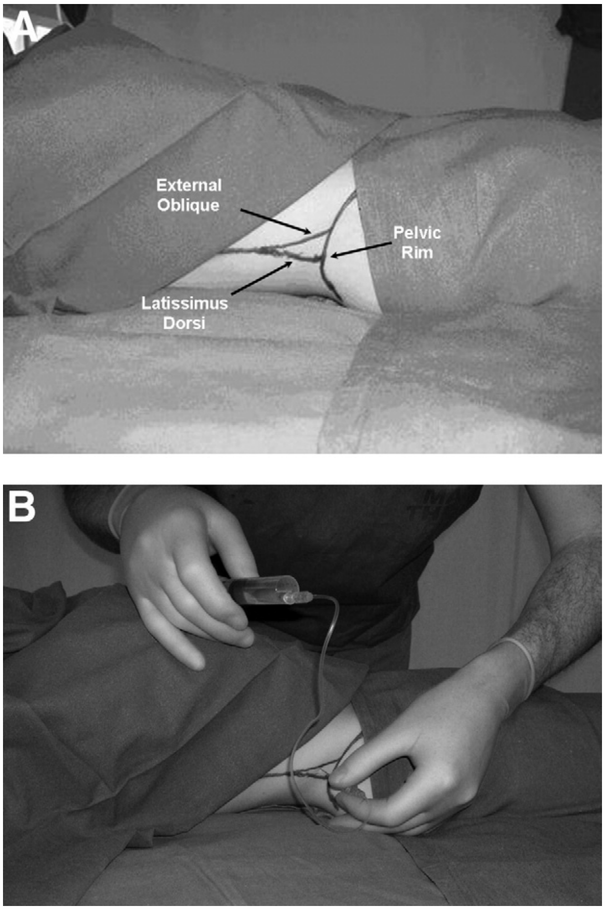

Fig 2. (A) Surface anatomy of the Lumbar triangle of Petit. This triangle is bounded posteriorly by the latissimus dorsi muscle, anteriorly by the external oblique with the iliac crest forming the base of the triangle. (B) Injection of local anaesthetic through the needle inserted into the transversus abdominis neurofascial plane via the lumbar triangle of Petit.

sensation as the needle penetrates the external oblique fascial layer, and enters the plane between the external and internal oblique muscles. Further advancement results in a second "pop" being appreciated. This second "pop" indicates penetration of the internal oblique fascial layer and entry into the transversus abdominis fascial plane (Fig 2B). After aspiration to exclude vascular puncture, 20 mL of solution is then injected. For surgical procedures involving a midline abdominal incision, the TAP block is then performed on the opposite side using an identical technique.

Study 1: Validation of Transversus Abdominis Plane Block Technique in a Cadaveric Model

The aim of this study was to validate the block technique as described above, by demonstrating that the technique results in the deposition of injectate within the TAP. The TAP block was performed on 3 fresh, unfixed cadaveric specimens. Twenty mL of methylene blue dye was injected using a Plexufix 24-gauge needle (B. Braun, Melsungen, Germany) and the loss of resistance technique. The cadavers were then fixed by the perfusion of embalming fluid (4 parts methylated spirit, 3 parts glycerine, 1 part formaldehyde, 1 part phenol) via the femoral artery. Up to 20 L was infused depending on body size. Dissection of the cadaveric specimens was carried out at a later date after fixation.

Study 2: Validation of the Transversus Abdominis Plane Block Technique in Human Volunteers Using Computerized Tomography

The primary aim of this study was to confirm that the block technique facilitates deposition of injectate within the TAP, in the in vivo setting. The secondary aim was to demonstrate that the block produced a sensory blockade of the anterior abdominal wall. Following written informed consent, 3 healthy male volunteers were recruited to this study. Intravenous access was established, and routine monitoring (electrocardiogram, non-invasive blood pressure, oxygen saturation) was used. The TAP block was performed bilaterally. Twenty mL of a mixture of the radiopaque dye iopamidol (Niopam 200, Merck Pharmaceuticals, Middlesex, UK) and lidocaine to a final concentration of 0.5% was injected via the bilateral triangles of Petit. CT imaging was performed 20 minutes following TAP blockade. The extent of sensory blockade to fine touch and sharp touch was then determined using cotton wool and pin prick, respectively.

Study 3: Determination of Injectate Spread and Time Course of Transversus Abdominis Plane Block Using Magnetic Resonance Imaging

The aim of this study was to determine the time course and extent of spread of solution within the TAP. After written informed consent, 3 healthy male volunteers were recruited to this study. Intravenous access was established, and routine monitoring (electrocardiogram, NIBP, oxygen saturation) was used. The TAP block was performed bilaterally. Twenty mL of solution, which consisted of gadopentetate dimeglumine (Magnevist, Bayer Healthcare Pharmaceuticals, Inc., Leverkusen, Germany) and 0.1% levobupivacaine, was injected via the bilateral triangles of Petit. The volunteers were imaged using T1-weighted axial and coronal MRI (Siemens Symphony 1.5 Tesla, Siemens AG, Erlangen, Germany) at 1, 2, and 4 hours postperformance of the block to determine the spread of

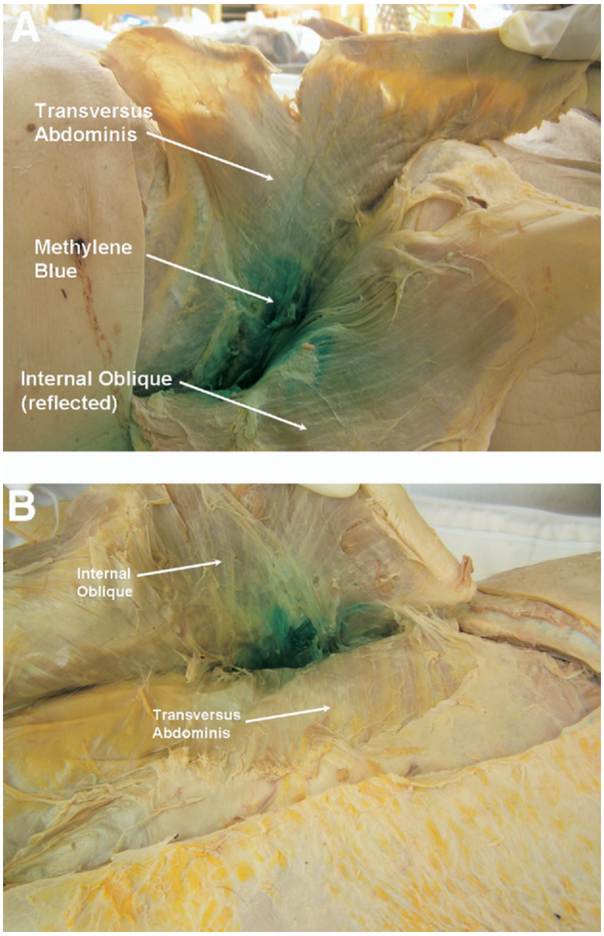

Fig 3. (A) Anatomic dissection of the abdominal wall, including the lumbar triangle of Petit following injection of methylene blue. As can be seen, the dye has penetrated into the transversus abdominis plane between the internal oblique and transversus abdominis muscles. (B) Anatomic dissection of the abdominal wall, with the external oblique and internal oblique muscles dissected and reflected back from the abdominal midline. Again, the dye has penetrated into the transversus abdominis plane between the internal oblique and transversus abdominis muscles.

solution within the TAP. The extent of sensory blockade to fine touch and sharp touch was then determined using cotton wool and pinprick respectively, at each time point.

Results

Study 1: Validation of Transversus Abdominis Plane Block Technique in a Cadaveric Model

After fixation of the 3 cadavers, as described above, anatomic dissection revealed dense deposition of dye in the TAP from the iliac crest to the costal margin in all 3 cadavers (Fig 3). The study confirms that reliable injectate deposition within the transversus abdominis plane is achieved using the TAP technique.

Study 2: Human Volunteer Computerized Tomographic Studies

Twenty minutes after performance of the TAP block, CT imaging clearly identified the presence of dye in both the transversus abdominis plane and in the more superficial plane between the external oblique and internal oblique muscles, termed the oblique plane (Fig 4). The more superficial oblique plane appears to have been infiltrated by both backflow along connective tissue channels perforating from the TAP to the superficial plane, thought to contain superficial nerve branches, as well as backflow along the needle path at the time of injection. Examination of the volunteers for signs of sensory blockade revealed a sensory deficit on the anterior abdominal wall from T7 to L1 in each of the volunteers. One of the volunteers reported altered sensation as high as the T4 dermatome. There were no adverse incidents and the volunteers' recovery was uneventful.

This study demonstrates the ability to deposit injectate within the TAP in volunteers in vivo using the TAP technique. The deposition of injectate

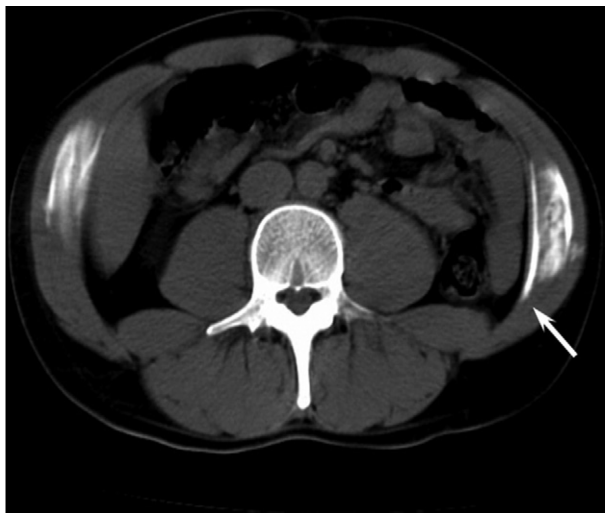

Fig 4. Computed tomographic image of the abdominal wall in a volunteer, 20 minutes after the injection of iopamidol contrast. An arrow on the right demonstrates contrast enhancement (high signal) between the internal oblique and transversus abdominis muscles. The contrast is less discrete on the left, as some contrast had penetrated through to the more superficial plane between the external oblique and internal oblique muscles, which appears to have been infiltrated by both backflow along connective tissue channels perforating from the transversus abdominis plane to the superficial plane and backflow along the needle path at the time of injection.

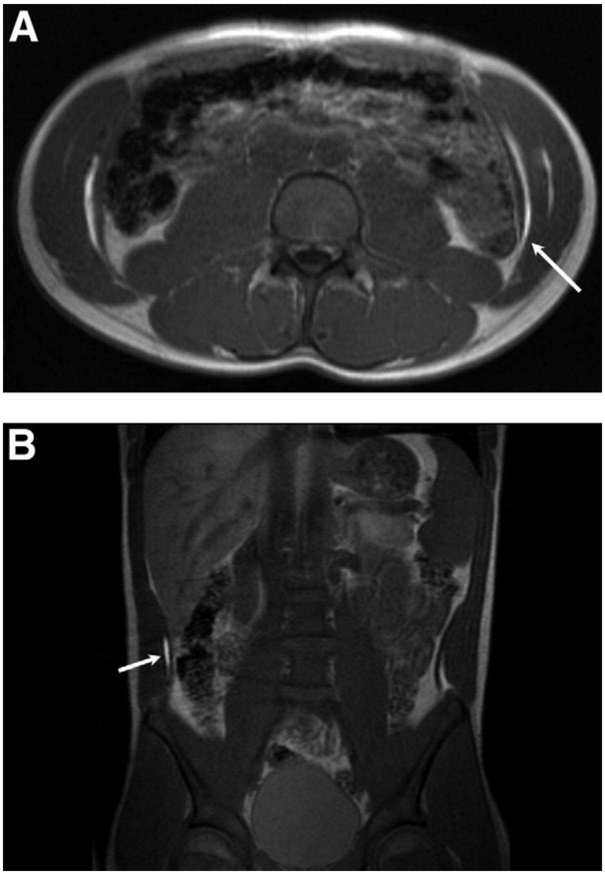

Fig 5. (A) Magnetic resonance T1-weighted axial section through abdomen on a volunteer, 240 minutes after injection of gadolinium. An arrow on the right points to gadolinium enhancement (high signal) between the internal oblique and transversus abdominis muscles. The enhancement has reduced in volume and intensity compared with that seen at 60 and 120 minutes post injection. (B) Magnetic resonance T1-weighted sagittal section through abdomen on a volunteer, 240 minutes after the injection of contrast. The arrow points to gadolinium enhancement (high signal) between the internal oblique and transversus abdominis muscles.

within the TAP produced a demonstrable sensory blockade of the abdominal wall.

Study 3: Human Volunteer Magnetic Resonance Imaging Studies

T1-weighted axial and coronal images clearly showed the presence of injectate in the TAP in each of the volunteers (Fig 5). The injectate was noted to spread within the TAP from the superior margin of the iliac crest to the level of the costal margin, and as far posteriorly as the quadratus lumborum muscles in all subjects. The gadolinium dye was clearly evident within the plane at 1, 2, and 4 hours, with a reduction in signal intensity at 4 hours (Fig 5).

Again, the volunteers were examined for signs of sensory blockade to fine touch using cotton wool and sharp touch using pinprick. A sensory deficit was found on the anterior abdominal wall, which was maximal (i.e., extended from the T7 to L1 dermatomes) at 90 minutes, had started to recede at 4 hours, with complete regression of the block evident at 24 hours.

Discussion

This series of cadaveric and radiological studies shows that the TAP provides a potential space into which local anesthetic can be deposited to achieve sensory blockade of the lateral and anterior abdominal wall. We have shown that it is possible to reproducibly deposit injectate within the TAP, both in vivo and ex vivo, using the "two pop" loss of resistance technique that we have described. The clinical utility of the block is underlined by the fact that deposition of local anaesthetic agent within this plane produces a reproducible sensory block over the anterior abdominal wall from T7 to L1. Finally, these studies demonstrate that the triangle of Petit offers an easily identifiable, fixed, and palpable access point to the TAP.

We have gained significant clinical experience with this technique over the past few years.[10,11] The TAP block produces effective and prolonged postoperative analgesia in patients undergoing major abdominal surgery via a midline incision. When compared with patient-controlled analgesia morphine alone, the addition of the TAP block significantly improved pain scores and reduced opiate consumption in patients after major abdominal surgery in a recent randomized controlled clinical trial.[10] The TAP block has proven easy to perform and appears to carry little risk of major complications.

There are important limitations to this study. First the sample size in each of the studies was small with only 3 subjects studied. We deemed it unnecessary to subject a larger number of subjects to invasive investigation as we obtained sufficient information to achieve our initial goals with small numbers. Second, at present, neither the duration of the sensory block achieved nor the pharmacokinetic profile of local anaesthetic agents within the TAP is known. These parameters are the subject of further investigation by our group. Third, the use of direct visualization of the TAP and needle position with 2-dimensional ultrasound may prove to improve success rates, quality of blockade, and safety of the TAP block. The application of ultrasound will also be subject to ongoing evaluation by the group. Finally, notwithstanding the findings of a recent randomized controlled trial demonstrating its successful use in patients undergoing abdominal surgery, the relative lack of clinical data regarding the efficacy of the TAP block must be acknowledged. Further clinical studies are necessary in order to fully characterize the clinical utility of this novel block.

In conclusion, these studies represent the first detailed characterization of the anatomic characteristics of the TAP block, confirm that the performance of the block as described results in the deposition of solution into the TAP, and provides important information supporting the validity of the block technique.

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