The Analgesic Efficacy of Transversus Abdominis Plane Block After Abdominal Surgery: A Prospective Randomized Controlled Trial

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BACKGROUND: The transversus abdominis plane (TAP) block is a novel approach for blocking the abdominal wall neural afferents via the bilateral lumbar triangles of Petit. We evaluated its analgesic efficacy in patients during the first 24 postoperative hours after abdominal surgery, in a randomized, controlled, double-blind clinical trial.

METHODS: Thirty-two adults undergoing large bowel resection via a midline abdominal incision were randomized to receive standard care, including patient-controlled morphine analgesia and regular nonsteroidal antiinflammatory drugs and acetaminophen ($n = 16$), or to undergo TAP block ($n = 16$) in addition to standard care ($n = 16$). After induction of anesthesia, 20 mL of 0.375% levobupivacaine was deposited into the transversus abdominis neuro-fascial plane via the bilateral lumbar triangles of Petit. Each patient was assessed by a blinded investigator in the postanesthesia care unit and at 2, 4, 6, and 24 h postoperatively.

RESULTS: The TAP block reduced visual analog scale pain scores (TAP versus control, mean ± SD) on emergence (1 ± 1.4 vs 6.6 ± 2.8, $P < 0.05$), and at all postoperative time points, including at 24 h (1.7 ± 1.7 vs 3.1 ± 1.5, $P < 0.05$). Morphine requirements in the first 24 postoperative hours were also reduced (21.9 ± 8.9 mg vs 80.4 ± 19.2 mg, $P < 0.05$). There were no complications attributable to the TAP block. All TAP patients reported high levels of satisfaction with their postoperative analgesic regimen.

CONCLUSIONS: The TAP block provided highly effective postoperative analgesia in the first 24 postoperative hours after major abdominal surgery.

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A substantial component of the pain experienced by patients after abdominal surgery is derived from the abdominal wall incision (1). The abdominal wall consists of three muscle layers, the external oblique, the internal oblique, and the transversus abdominis, and their associated fascial sheaths. The central abdominal wall also includes the rectus abdominis muscles and its associated fascial sheath. This muscular wall is innervated by nerve afferents that course through the transversus abdominis neuro-fascial plane (2).

A promising approach to the provision of postoperative analgesia after abdominal incision is to block the sensory nerve supply to the anterior abdominal wall (3,4). However, the clinical utility of current approaches to the blockade of these nerve afferents, such as abdominal field blocks, is limited, and the degree of block achieved can be unpredictable. A major reason for the relative lack of efficacy of these blocks is the lack of clearly defined anatomic landmarks, leading to uncertainty regarding the exact needle positioning, and the lack of a clear indication that the local anesthetic is being deposited in the correct anatomical plane.

We have sought an alternative, reliable approach to the blockade of the neural afferents to the anterior abdominal wall. These neural afferents course through the neurofascial plane between the internal oblique and the transversus abdominis muscles (2). On the basis of anatomic studies, our group identified the lumbar triangle of Petit as a potential access point to this neurofascial plane (Fig. 1). This triangle is bounded posteriorly by the latissimus dorsi muscle and anteriorly by the external oblique, with the iliac crest forming the base of the triangle, and is a fixed and easily palpable landmark (5) (Fig. 1). By introducing local anesthetics into the transversus abdominis

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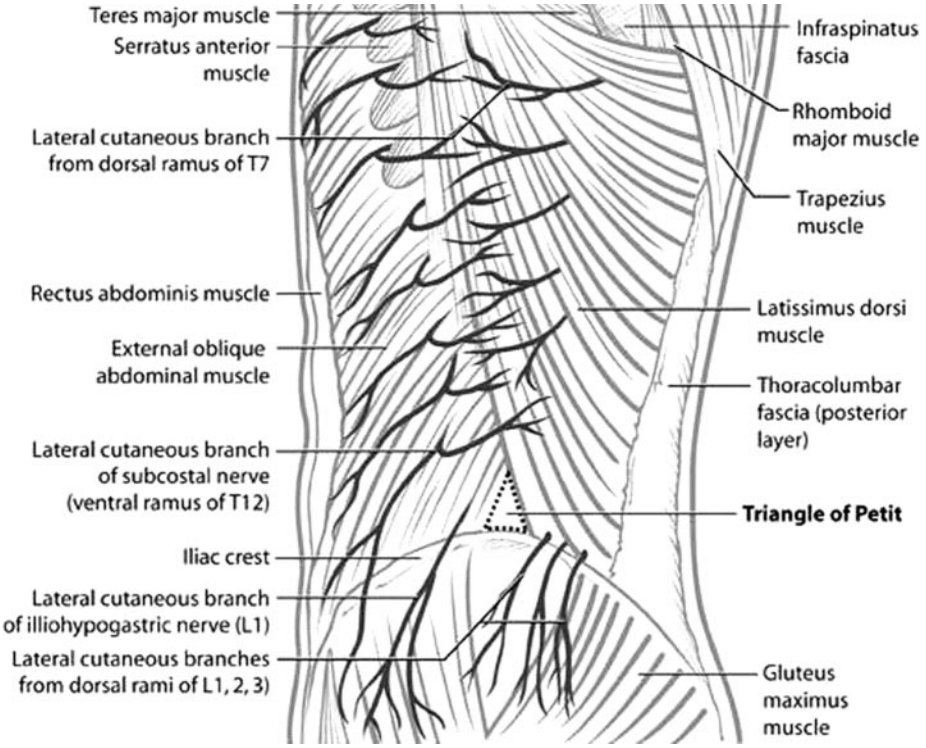

Figure 1. Line drawing of the anatomy of the abdominal wall, including the lumbar triangle of Petit (TOP). The triangle is bounded posteriorly by the latissimus dorsi muscle, anteriorly by the external oblique, with the iliac crest forming the base of the triangle.

plane 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 call this novel block the "transversus abdominis plane" (TAP) block.

Preliminary cadaveric studies, followed by volunteer studies, have demonstrated the potential for the TAP block to produce a dermatomal sensory block of the lower six thoracic and upper lumbar abdominal afferents (6). In addition, we have demonstrated the analgesic potential of the TAP block in a series of patients undergoing radical prostatectomy (7). In this study, we evaluated the analgesic efficacy of TAP blockade for the first 24 postoperative hours, in patients undergoing large bowel resection via a midline abdominal wall incision.

METHODS

After obtaining approval by the Hospital Ethics Committee, and written informed patient consent, we studied 32 ASA physical status I–III patients scheduled for large bowel resection via a midline abdominal incision, in a prospective, randomized, double-blind, controlled clinical trial. Patients were excluded if there was a history of relevant drug allergy, or if they were receiving medical therapies considered to result in tolerance to opiates. After study entry, patients were also excluded if the surgery did not proceed to bowel resection.

Patients were randomized, by sealed envelopes, to undergo TAP block ($n = 16$) or to receive standard care ($n = 16$). The patients, their anesthesiologists, and the staff providing postoperative care were blinded to group assignment. All patients received a standardized general anesthetic. Standard monitoring, including electrocardiogram, arterial blood pressure, arterial oxygen saturation, and end-tidal carbon dioxide monitoring were used throughout, and patients were placed in the supine position. Anesthesia was induced with IV fentanyl (1–1.5 μg/kg to a maximum of 100 μg) and propofol (2–3 mg/kg). All patients also received morphine 0.15 mg/kg, rectal diclofenac 1 mg/kg to a maximum of 100 mg and rectal acetaminophen 1 g immediately before surgical incision. Prophylactic antiemetics were not administered.

All patients randomized to undergo TAP block had the block performed after induction of anesthesia, by one of two investigators (JMcD, BO'D). The iliac crest was palpated from anterior to posterior until the latissimus dorsi muscle could be felt (Fig. 2A). The triangle of Petit was then located just anterior to the latissimus dorsi muscle. Using a blunt regional anesthesia needle (22G, Plexufix®, B. Braun, Melsungen AG, Germany), the skin was pierced just cephalad to the iliac crest over the triangle of Petit (Fig. 2B). The needle was then advanced at right angles to the skin, in a coronal plane, until resistance was encountered. This resistance indicated that the needle tip was at the external oblique muscle. Gentle advancement of the needle resulted in a "pop" sensation as the needle entered the plane between the external and internal oblique fascial layers. Further gentle advancement of the needle resulted in a second pop, which indicated entry into the transversus abdominis fascial plane. After careful aspiration to exclude vascular puncture, 20 mL of 0.375% levobupivacaine solution (to a maximum dose of 1

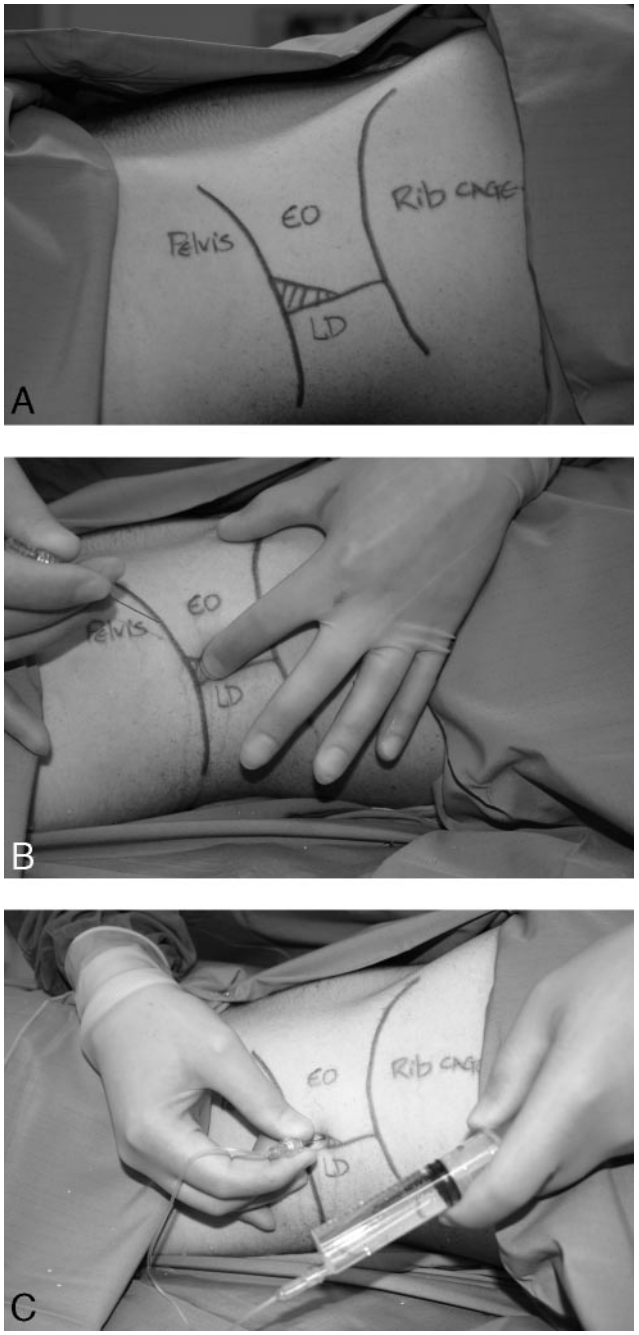

Figure 2. Panel A: Surface anatomy of the TOP. Panel B: Site of needle insertion into of the TOP. Panel C: Injection of local anesthetic through the needle inserted into the transverses abdominis neurofascial plane via the TOP. TOP = lumbar triangle of Petit; LD = latissimus dorsi muscle; EO = external oblique muscle.

mg/kg each side) was then injected through the needle (Fig. 2C). The TAP block was then performed on the opposite side, using an identical technique.

After completion of the surgical procedure, and emergence from anesthesia, patients were transferred to the postanesthesia care unit (PACU). A standard postoperative analgesic regimen, consisting of oral acetaminophen 1 g every 6 h and rectal diclofenac 100 mg every 18 h, combined with patient-controlled morphine analgesia (bolus 1 mg, 6-min lockout, maximum dose 40 mg every 4 h), was used in both groups. The presence and severity of pain, nausea, and sedation were assessed systematically by an investigator blinded to group allocation. These assessments were performed in the PACU and at 2, 4, 6, and 24 h postoperatively. All patients were asked to give scores for their pain at rest and on movement, and for the degree of nausea at each time point. Pain severity was measured using both a visual analog scale (0 = no pain, 10 = worst imaginable) and a categorical pain scoring system (none = 0; mild = 1; moderate = 2; severe = 3). Nausea was measured using a categorical scoring system (none = 0; mild = 1; moderate = 2; severe = 3). Sedation scores were assigned by the blinded assessor, using a sedation scale (awake and alert = 0; quietly awake = 1; asleep but easily roused = 2; deep sleep = 3). Rescue antiemetics were offered to any patient who complained of nausea or vomiting.

We estimated our sample size on the basis of the 24-h morphine requirement of patients undergoing large bowel surgery. For the purposes of sample size calculation, we considered that a clinically important reduction in 24-h morphine consumption would be a 25% absolute reduction. This was a conservative assumption based on our pilot data. On the basis of initial pilot studies, we projected a 24-h morphine requirement of 60 mg, with a standard deviation of ±10 mg, in the control group. We calculated that 14 patients per group would be required for an experimental design incorporating two equal sized groups, using an $\alpha = 0.05$ and $\beta = 0.2$. To minimize any effect of data loss, we elected to recruit 16 patients per group into the study.

Statistical analyses were performed using a standard statistical program (SPSS, Sigma Stat©, Version 2.0 Jandel Scientific, Chicago, IL). Demographic data were analyzed using Student's *t*-test or Fisher's exact test as appropriate. Repeated measurements (pain scores, nausea scores) were analyzed by repeated measures ANOVA or ANOVA on ranks, with further paired comparisons at each time interval performed using the *t*-test or Mann–Whitney *U*-test as appropriate. Categorical data were analyzed using χ^2 analysis or Fisher's exact test where applicable. Normally distributed data are presented as means ± SE of the mean (SEM), non-normally distributed data are presented as medians ± quartiles (interquartile range), and categorical data are presented as raw data and as frequencies. The α level for all analyses was set as $P < 0.05$.

RESULTS

Thirty-four patients were entered into the study. Two patients were excluded after enrollment due to the deferral of their surgical procedures. Of the remaining patients, 16 were randomized to undergo TAP blockade, and 16 were randomized to standard therapy.

All patients underwent abdominal surgical procedures requiring a midline abdominal incision (Table 1). Both groups were comparable in age, gender, and

Table 1. Baseline Patient Characteristics

	Control ($n = 16$)	TAP block ($n = 16$)
Age (yr)	54.6 ± 4.2	58.9 ± 4.0
Sex ratio (M:F)	8:8	7:9
Weight (kg)	67.4 ± 3.5	64.7 ± 2.3
Height (m)	1.63 ± 0.04	1.66 ± 0.04
Duration of surgery (min)	163.6 ± 8.5	170.4 ± 17.8
Intraoperative morphine (mg/kg)	0.15 ± 0.0	0.15 ± 0.0
Surgical procedure		
Large bowel resection	14	10
Small bowel resection	1	2
Other procedure	1	4

Categorical variables as presented as number and proportion, and continuous variables are presented as mean ± SEM.

TAP = tranversus abdominis plane block.

There were no significant differences between groups.

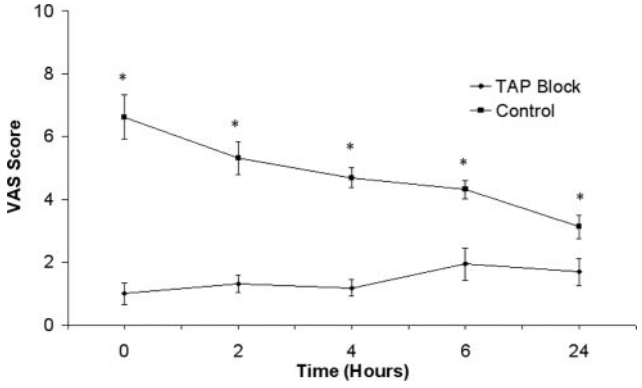

Figure 3. Mean postoperative verbal analog scale (VAS) pain scores at rest in each group over the first 24 postoperative hours. *Indicates significantly ($P < 0.05$, *t*-test after ANOVA) higher VAS score when compared with the transversus abdominis plane (TAP) block group.

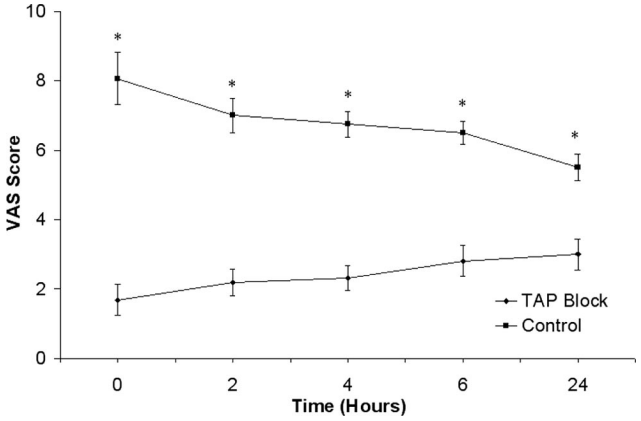

Figure 4. Mean postoperative verbal analog scale (VAS) pain scores on movement in each group over the first 24 postoperative hours. *Indicates significantly ($P < 0.05$, *t*-test after ANOVA) higher VAS score when compared with the transversus abdominis plane (TAP) block group.

Table 2. Postoperative Pain Scores and Analgesic Requirement

	Control ($n = 16$)	TAP block ($n = 16$)
Time to first request for morphine (min)	24.1 ± 6.9	157.2 ± 27.9‡
Mean 24 h morphine requirement (mg)	80.44 ± 4.8	21.94 ± 2.2†
Categorical pain severity		
PACU	2.5 (2, 3)	0 (0, 1)‡
2 Hours	2 (2, 2)	0 (0, 1)‡
4 h	2 (1.5, 2)	0 (0, 1)‡
6 h	2 (1, 2)	1 (0, 1)‡
24 h	1 (1, 2)	1 (0, 1)

Ordinal data are presented as medians and interquartile ranges (given in parentheses), and continuous variables are presented as mean ± SEM.

TAP = transverses abdominis plane; PACU = postoperative anesthesia care unit.

† $P \leq 0.01$; and ‡ $P \leq 0.001$ when controlled with control.

operative procedures performed (Table 1). In all patients randomized to receive TAP block, the triangle of Petit was located easily on palpation, the transversus abdominis neuro-fascial plane was localized after one to two attempts, and the block performed without complication.

Patients undergoing TAP block had a longer time to first request for morphine, and reduced overall morphine requirements (Table 2). TAP block reduced cumulative postoperative morphine consumption (control versus TAP) at 4 h (29.2 ± 2.5 mg vs 5.8 ± 1.3 mg), 6 h (40.4 ± 3.1 mg vs 7.8 ± 1.6 mg) and at 24 h (Table 2). Postoperative pain scores were reduced at all time points assessed after TAP block, both at rest (Fig. 3) and on movement (Fig. 4). Categorical pain scores were also reduced in patients who received the TAP block, in the PACU and at 2, 4, and 6 h postoperatively (Table 2).

In patients who received the TAP block, postoperative sedation scores were reduced at 4 and 6 h postoperatively, but not at the other time points assessed (Table 3). The incidence of postoperative nausea and vomiting (PONV) was substantially reduced in patients in the TAP block group (Table 3). However, the decrease in PONV scores in the TAP block group was modest (Table 3).

DISCUSSION

The benefits of adequate postoperative analgesia are clear, and include a reduction in the postoperative stress response (8), reduction in postoperative morbidity (9), and in certain types of surgery, improved surgical outcome (10). Effective pain control also facilitates rehabilitation and accelerates recovery from surgery (9,11). Other benefits of effective regional analgesic techniques include reduced pain intensity, decrease incidence of side effects from analgesics, and improved patient comfort (11).

Direct blockade of the neural afferent supply of the abdominal wall, such as abdominal field blocks, ilioinguinal, and hypogastric nerve blocks, have long been recognized as capable of providing significant postoperative analgesia in patients undergoing abdominal surgical procedures such as cesarean delivery (3) and inguinal herniorrhaphy (4). However, the lack of clearly defined anatomic landmarks has meant that

Table 3. Postoperative Sedation and Nausea Scores

Group	Control ($n = 16$)	TAP block ($n = 16$)
Sedation scores		
PACU	1 (1, 1.5)	1 (1, 1.5)
2 h	1 (1, 1.5)	0.5 (0, 1)
4 h	1 (1, 2)	0 (0, 0.5)†
6 h	1 (1, 1.5)	0 (0, 0)†
24 h	0 (0, 0)	0 (0, 0)
Incidence of PONV (%)	31	69*
Nausea scores		
PACU	0 (0, 1)	0 (0, 0.5)
2 h	1 (0, 1)	0 (0, 0)*
4 h	0 (0, 0)	0 (0, 0)
6 h	0 (0, 0)	0 (0, 0)
24 h	0 (0, 0)	0 (0, 0)

Ordinal data are presented as medians and interquartile ranges (given in parentheses).

TAP = transverses abdominis plane; PACU = postoperative anesthesia care unit; PONV = postoperative nausea and vomiting.

* $P < 0.05$; † $P \leq 0.01$; and ‡ $P \leq 0.001$ when compared with control.

the full potential of abdominal wall blockade in patients undergoing major abdominal procedures remains to be realized. An alternative, simple, reliable and effective regional analgesic technique is required.

The skin, muscles, and parietal peritoneum of the anterior abdominal wall are innervated by the lower six thoracic nerves and the first lumbar nerve (2,5) (Fig. 1). The anterior primary rami of these nerves leave their respective intervertebral foramina and course over the vertebral transverse process. They then pierce the musculature of the lateral abdominal wall to course through a neuro-fascial plane between the internal oblique and transversus abdominis muscles. The sensory nerves branch first in the mid-axillary line sending out a lateral cutaneous branch, and continue within the plane to perforate anteriorly supplying the skin as far as the midline (2,5). The transversus abdominis plane thus provides a space into which local anesthetic can be deposited to achieve myocutaneous sensory blockade. Deposition of the local anesthetic dorsal to the mid-axillary line also blocks the lateral cutaneous afferents, thus facilitating blockade of the entire anterior abdominal wall (5). The lumbar triangle of Petit offers an easily identifiable, fixed and palpable landmark, and is located dorsal to the mid-axillary line (5). The transversus abdominis neuro-fascial plane can easily be accessed via this triangle, and local anesthetic deposited into this plane, using the loss of resistance technique as we have described.

In this randomized, double-blind clinical trial, the TAP block produced effective and prolonged postoperative analgesia, when compared with standard therapy, in patients undergoing surgery via a midline abdominal wall incision. The TAP block reduced postoperative pain scores, both at rest and on movement, and reduced postoperative opioid requirements. Overall, during the first 24 postoperative hours, the TAP block reduced mean IV morphine requirements by more than 70%. This reduction in opioid requirement resulted in fewer opioid-mediated side effects. The incidence of PONV was reduced by more than half (69% vs 31%) in the TAP block group. Sedation scores were also modestly reduced in the patients who underwent TAP blockade.

Two potential limitations should be considered. First, the study limited assessment of postoperative analgesia to the first 24 postoperative hours. However, the TAP block has been demonstrated to produce clinically useful levels of analgesia for at least 48 h postoperatively (7). Second, there are difficulties in adequately blinding studies such as these, given that the TAP block produces loss of sensation of the abdominal wall. However, neither the patient nor the anesthesiologist conducting postoperative assessments were aware of the group allocation. The patient's abdomen was not examined during these assessments, and the TAP block sites were covered by dressings in all patients.

We conclude that the TAP block seems to hold considerable promise for patients undergoing surgical procedures involving abdominal wall incisions.

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