Pneumoperitoneum Does Not Influence Spread of Local Anesthetics in Midaxillary Approach
Transversus Abdominis Plane Block
A Descriptive Cadaver Study

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Background and Objectives: The transversus abdominis plane (TAP) block can be used as part of a multimodal analgesia protocol after abdominal surgery. This study investigated whether a pneumoperitoneum during abdominal surgery influences the spread of local anesthetics.

Methods: Nine fresh cadavers were used for the study. Using an ultrasound-guided midaxillary technique, a unilateral TAP block–like injection with 20 mL of methylene blue dye was performed. After the injection, a pneumoperitoneum was immediately installed for 1 hour. After desufflation, this ipsilateral side was dissected, and a TAP block–like injection was performed on the contralateral side. One hour after injection, the contralateral side was also dissected. The anatomical dissection was used to determine the extent of dye spread and the nerves stained by the dye.

Results: In none of the specimens did the dye reach the posterior origin of the transverse abdominal muscle. There was no statistically significant difference in the number of stained nerves and spread of the dye in the insufflated side compared with the noninsufflated side. In 4 of 9 cadavers, we found a variant course of a nerve preventing staining of that nerve.

Conclusions: The stretch of the abdominal wall caused by the insufflation of the abdomen does not influence the spread of dye in the abdominal wall. Because of the absence of posterior spread, regardless of the timing of the midaxillary ultrasound-guided approach, we believe that a posterior approach should be chosen if posterior spread is desired.

Postoperative pain after abdominal surgery is a common problem with both visceral and somatic components. Undertreated postoperative pain negatively impacts patient satisfaction, length of stay, and overall clinical outcome. Various options such as parenteral opioids and epidural analgesia are available to manage postoperative pain. However, with surgical practice changing toward minimal invasive techniques and the increasing popularity of ambulatory surgery, these techniques need a critical reappraisal like in–situations.

The transversus abdominis plane (TAP) block is a regional anesthesia technique where local anesthetics are injected between the internal oblique and transverse abdominal muscles. The ventral rami of the segmental thoracolumbar nerves are situated in this plane, before innervating the hemiabdominal wall. Blocking these nerve branches will thus provide analgesia to the anterior part of the corresponding hemiabdomen. Because the analgesic effect of the TAP block is limited to the abdominal wall and does not cover the visceral pain component, a multimodal pain protocol is imperative for successful postoperative analgesia. Since its first description in 2001 by Rafi, the TAP block has been the subject of extensive research. It has gained widespread popularity as both the blind and ultrasound (US)–guided approaches are easy to perform and have an excellent safety record. A systematic review and meta-analysis by Charlton et al concluded that the TAP block should be considered to be part of the analgesic regimen after abdominal surgery as it is safe and reduces both postoperative morphine consumption and the incidence of postoperative nausea and vomiting. Minimal access surgery is beneficial for clinical outcomes, and abdominal procedures are increasingly performed laparoscopically. For visibility and safety, these procedures require the installation of a pneumoperitoneum. A pneumoperitoneum has important effects on abdominal wall mechanics and on the topography of the abdominal muscle layers. Consequently, a pneumoperitoneum might influence the spread of the local anesthetic mixture deposited between the muscle layers in the abdominal wall. If the installation of a pneumoperitoneum increases spread of local anesthetics, one could expect an improved clinical outcome, as potentially more nerves would be blocked.

To our knowledge, no clinical trials have compared clinical outcomes between preinsufflational and postinsufflational TAP blocks. The timing of TAP block may be critical to success. Transversus abdominis plane blocks performed after laparoscopic hysterectomy were shown not to improve clinical outcome parameters such as Quality of Recovery Questionnaire score, visual analog scale for pain, and opioid requirements compared with a control group, whereas a TAP block performed before laparoscopic hysterectomy improved these outcomes. A recent meta-analysis evaluating the analgesic efficacy of TAP blocks for laparoscopic surgery emphasized the benefits of preoperative TAP blocks over postoperative TAP blocks.

Various mechanisms may explain these differences in clinical outcomes. In a recent meta-analysis, Berghun et al and Abdallah et al have shown that an approach aimed at the posterior TAP (at the level of the triangle of Petit) such as the landmark technique described by McDonnell is generally more successful than an approach aimed at the lateral TAP such as the midaxillary US-guided approach. If changes in abdominal wall geometry caused by the pneumoperitoneum would increase posterior spread, this could at least partially explain the different clinical results reported in the literature.

We conducted a cadaver study to test the primary hypothesis that a TAP block performed before insufflation of the abdomen...
will have an increased posterior spread compared with a TAP block performed after insufflation. Secondary end points were the number of nerves stained by dye, the area of dye spread on the internal oblique muscle, and the impact of anatomical variants on the staining of the nerves.

**METHODS**

**Specimens**

After approval of the local university ethics committee, 9 fresh-frozen cadavers were obtained via the Human Body Donation Program of the University of Leuven in collaboration with the Jan Palfijn Anatomy Lab (Kortrijk, Belgium). Cadavers with external signs of previous abdominal surgery were rejected. The sample included 7 males and 2 females. All specimens were thawed at room temperature 48 hours prior to the experiments.

**Injection Technique**

A unilateral TAP block was performed using a US-guided technique. An S-Nerve US machine with a linear 5- to 12-MHz probe (Nerve S; SonoSite Inc, Bothell, Washington) was used. All blocks were performed by the same experienced investigator (M.D.). With the cadaver in supine position, the US probe was placed at the midaxillary line between the lower costal margin and the iliac crest. At this point, the plane between the internal oblique and transverse abdominal muscles was identified. A needle (18-gauge, Sonoplex Stim cannula; Pajunk Medizintechnologie, Geisingen, Germany) was inserted using an in-plane technique in an anteroposterior direction. An injection with 2 mL normal saline was used to ensure correct positioning of the needle. Then, 20 mL of dye (methylene blue 0.05%) was injected. Without delay, an insufflation needle (Surgineedle; Covidien, Mansfield, Massachusetts) was inserted on the midline 1 cm below the umbilicus. Correct positioning of the needle was ensured using 3 different methods: tactile (loss of resistance when the parietal peritoneum was pierced), ultrasonographic control of correct intra-abdominal position of the needle, and intra-abdominal pressure monitoring during the initial phase of insufflation with a flow of 15 L/min CO\textsubscript{2}. The pneumoperitoneum was installed during 1 hour with an intra-abdominal pressure of 15 mm Hg using a CO\textsubscript{2} insufflator (Stryker, Kalamazoo, Michigan).

After desufflation, this ipsilateral side was dissected. Also, immediately after desufflation of the abdomen, a TAP block–like injection was performed on the contralateral side using the same technique and approach. The dissection of the contralateral side started exactly 1 hour after performance of the TAP block–like injection to exclude any influence of time on the spread of the dye.

**Dissection Technique**

The dissection was initiated with a craniocaudal incision, from the costal margin to the iliac crest, as posterior as possible in a supine position. Then, 2 transverse incisions were made: one along the lower costal margin and one following the iliac crest extending in to the inguinal crease. A U-shaped flap of skin and subcutaneous fat was dissected and folded toward the midline to reach the external oblique muscle. The external oblique muscle was separated and folded back from the internal oblique muscle in an anteroposterior direction. The same process was repeated to separate the internal oblique muscle from the transverse abdominal muscle.

**FIGURE 1.** Anatomical dissection of the abdominal wall with blue staining caused by the injection of methylene blue in the transverse abdominis plane. Green pin: ilioinguinal nerve, black pin: iliohypogastric nerve, yellow pin: T12, blue pin: T11, red pin: T10, white pin: T9. (1) External oblique muscle, (2) internal oblique muscle, (3) transverse abdominal muscle.
abdominal muscle. We carefully dissected the transverse abdominal plane to expose the different nerves (Fig. 1).

Measurement of the Spread of Dye

We identified the segmental/spinal nerve L1 as the first nerve cranial to the iliac crest with its ilioinguinal branch entering the inguinal canal. The first nerve caudal to rib 10 (costal margin) was identified as T10. The T11 and T12 nerves and the iliohypogastric nerve (L1) were identified by counting between the T10 and ilioinguinal nerve (L1). T9 was identified as the first nerve cranial to T10. Dorsally, the dissection was performed as far as the dye spread. Posterior spread was defined as dye observed beyond the junction of the abdominal wall muscles and the quadratus lumborum muscle. The nerves were traced as far dorsally as necessary to detect staining of the nerves with dye. All findings were separately confirmed by an experienced anatomist (E.V.), who was blinded to the preceding procedures.

After the identification of the different nerves, we measured the extent of dye spread. The internal oblique muscle was isolated and excised entirely. A digital photograph of the muscle with the area colored by the injected dye was taken (Lumix; Panasonic Company, Kadoma, Osaka, Japan). The area covered with blue dye was traced on the calibrated, digital photographs, and area calculations were performed using image analysis software (ImageJ, version 1.47v; Wayne Rasband, National Institutes of Health, Bethesda, Maryland).

Statistical Analysis

Statistical analysis was performed using GraphPad Prism 5 (GraphPad Prism Inc, La Jolla, California). Staining of a nerve was considered a categorical variable; proportions of all nerves combined were compared using Fisher exact test. Differences in dye surface area were compared using Wilcoxon signed rank test. $P < 0.05$ was considered statistically significant.

RESULTS

The installation of a pneumoperitoneum was successful in all 9 cadavers. There was zero incidence of insufflation needle repositioning, and subcutaneous emphysema could not be observed in any of the specimens. In all but 1 hemiabdomen, correct deposition of methylene blue dye in the transverse abdominal plane was confirmed during the dissection. The cadaver with the failed TAP block was excluded from the study; 8 cadavers were included in the analysis. The dye typically dispersed in the region between the iliac crest and the costal margin, yet in some hemiabdomens, the dye did not extend cranially until the costal margin. Special attention was paid to ensure that the dyed area was completely dissected in all directions. In none of the specimens did the dye reach the posterior aponeurotic origin of the transverse abdominal muscle. This allowed us to exclude posterior spread toward the lumbar paravertebral space.

In all cadavers, the nerves T9, T10, T11, T12, and L1 were identified during the dissection. In addition, the iliohypogastric and ilioinguinal branches of L1 were separately identified. We could not identify the ilioinguinal nerve in 1 particularly obese specimen with an inguinal hernia. There was no statistically significant difference between the total number of nerves involved in dye in the insufflated (injection before insufflation) sides and noninsufflated (injection after insufflation) sides of each cadaver (Fig. 2). The T11, T12, iliohypogastric, and ilioinguinal (L1) nerves were stained in most of the insufflated sides (IS). In the noninsufflated sides (NISs), only T12 and the iliohypogastric nerve were almost always stained. Nerve T10 was stained in 50% of the cases in the IS; however, in the NISs, nerve T10 was stained in only 25% of the specimens. Nerve T9 was never stained with dye.

In 1 cadaver, the internal oblique muscles were so fragile that a complete excision of the muscles was impossible, impeding quantification of the stained area in this specimen. The distribution of the dye could be analyzed quantitatively in 7 specimens (Fig. 3). Overall, there was no statistical difference in dyed surface area between the preinsufflation and postsufflation injections. In 5 cadavers, the dyed area was greater after the installation of a pneumoperitoneum with an average increase of 25%. In 1 cadaver, the involved area remained unchanged before and after installation of a pneumoperitoneum, and in 1 cadaver, there was a smaller dyed area (~17%) in the IS compared with the NISs (Table 1).

The ilioinguinal nerve had a variant course in 4 of 8 cadavers. In 1 cadaver, it pierced the transverse abdominal muscle at the midaxillary line in the left hemiabdomen and followed a course between the external and internal oblique muscle on the contralateral side. In 3 other cadavers, the ilioinguinal nerve did not follow a course between the 2 fasciae covering the internal oblique and transverse abdominal muscles, but the nerve was trapped between

![FIGURE 2. Percentage of stained segmental nerves for insufflated and noninsufflated sides.](image-url)
the muscle fibers and the fascia of the internal oblique or the transverse abdominal muscle. In 1 cadaver, T12 pierced the internal oblique muscle at the midaxillary line and continued its course in the fascial plane between the internal and external oblique muscle. These anatomical variants had an impact on staining of the nerves; the ilioinguinal nerve was not stained because of its variant course in the hemiabdomens of 2 specimens.

**DISCUSSION**

This anatomical study could not demonstrate a statistically significant effect of a pneumoperitoneum on spread of injectate after midaxillary US-guided TAP block. The efficacy of TAP blocks has not consistently been demonstrated in the literature. Clearly, different approaches to the TAP block and different volumes of injectate lead to a different distribution of local anesthetics. McDonnell and colleagues reported anesthesia in the dermatomes T7 to L1 after a landmark-based TAP block with 20 mL of local anesthetic. However, Bengum et al could not confirm this extended block in volunteers using a single-shot US-guided TAP block at the level of the midaxillary line. Their results showed involvement of dermatomes T10, T11, and T12 after a single-shot TAP block with 30 mL of local anesthetics. Another cadaver study using a midaxillary US-guided approach with 20 mL of aniline dye demonstrated involvement of the segmental nerves T10 to L1. Using magnetic resonance imaging techniques, it was demonstrated that only US-guided posterior approaches and the classic landmark approach lead to paravertebral spread from T5 to L1.

This paravertebral spread might explain the better clinical outcomes with posterior approaches. Along with the difference in analgesic efficacy, there is an increased duration of analgesia with the posterior approach. In a recent-meta analysis, Abdallah and colleagues showed that, in contrast to a lateral approach, posterior approaches reduced morphine consumption with 63% compared with the control groups at 24 to 48 hours postoperatively. In contrast to lateral approaches, posterior approaches also reduced rest and dynamic pain scores with 15 and 22 mm, respectively, compared with control groups.

As the clinical effect of a TAP block depends mainly on its posterior spread, it is important to understand all the mechanisms influencing this spread. Knowledge of the influence of a pneumoperitoneum on the distribution of local anesthetics could guide the clinician to decide on the optimal timing for a TAP block. Our study showed the absence of posterior spread with the midaxillary approach regardless of preinsufflation or postinsufflation injection.

<table>
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<tr>
<th>Specimen</th>
<th>Insufflated Side</th>
<th>Non Insufflated Side</th>
<th>Difference, %</th>
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<tr>
<td>1</td>
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<tr>
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**FIGURE 3.** Resection specimen of the left internal oblique muscle with view with methylene blue spread on the inner surface.
preemptive analgesia, may be offered to explain the clinical benefit of preoperative TAP blocks compared with postoperative TAP blocks. Currently, there are no data available to confirm this hypothesis.

In general, the results of our study indicate that a posterior approach might be clinically more relevant than the exact timing of a TAP block with relation to insufflation of the abdomen.

**Importance of Anatomical Variations in Nerve Distribution**

Our study confirms the high variability of the trajectory of the thoracolumbar segmental nerves (T9–T11). The variation in spinal contribution, emergence, and distribution of the iliouinguinal and iliohypogastric nerves has been well studied. These studies also pointed to the frequent variability of the course of these nerves, which interconnect intensively and form plexuses in their intermuscular and intramuscular extensions and in the (sub)cutaneous region. This emphasizes the necessity of a profound anatomical knowledge to improve block success rate. The variability we observed during our dissections is in line with previous anatomical studies and at least partially explains why patchy blocks are observed even after a perfectly executed midaxillary TAP block.

**Critical Considerations**

Our study has some limitations. First, our study was performed on fresh frozen cadavers. The characteristics of cadaveric tissues, even unembalmed, differ from patients. In the ex vivo situation, the different muscle layers and fasciae are more fragile, and it is possible that nonanatomical connections between muscle planes influence the spread of the dye. In addition, existing anatomical connections between the different muscle layers of the abdominal wall might influence the spread of dye. In fact, some centimeters caudal to the umbilicus, the transverse abdominal aponeurosis ends in the arcuate line. From that point on, the deep rectus abdominis sheath consists only of transversalis fascia lining the parietal peritoneum. This means that at the arcuate line there is a shift from deep to superficial of the deep half of the internal oblique aponeurosis and of the complete transverse abdominal aponeurosis. These anatomical connections combined with the ex vivo tissue characteristics justify to be cautious when extrapolating the results of our study to patients. Other factors might also influence the spread of local anesthetics, which could not be studied in our cadaver experiments, such as respiration, perfusion, previous abdominal surgery, or positioning during surgery.

Second, we used a standard volume of 20-mL injectate, a typical volume in clinical practice and the same volume as used in previous abdominal surgery, or positioning during surgery. In addition, existing anatomical connections between the different muscle layers of the abdominal wall might influence the spread of dye. In fact, some centimeters caudal to the umbilicus, the transverse abdominal aponeurosis ends in the arcuate line. From that point on, the deep rectus abdominis sheath consists only of transversalis fascia lining the parietal peritoneum. This means that at the arcuate line there is a shift from deep to superficial of the deep half of the internal oblique aponeurosis and of the complete transverse abdominal aponeurosis. These anatomical connections combined with the ex vivo tissue characteristics justify to be cautious when extrapolating the results of our study to patients. Other factors might also influence the spread of local anesthetics, which could not be studied in our cadaver experiments, such as respiration, perfusion, previous abdominal surgery, or positioning during surgery.

Third, we used a midaxillary approach. Currently, the US-guided midaxillary approach is the most popular approach due to its simplicity compared with US-guided posterior approaches. Indeed, 8 of 12 randomized controlled trials included in a meta-analysis investigating the analgesic duration of TAP blocks used a midaxillary technique. As such, it was appropriate to choose the technique which is most commonly used. We cannot extrapolate these results to posterior approaches, but as the deposition of local anesthetics with these approaches is farther away from the abdominal field, we believe the influence of a pneumoperitoneum would be minimal.

**CONCLUSIONS**

To conclude, our research showed no influence of a pneumoperitoneum on the spread of dye using a midaxillary US-guided TAP block. On average, 1 or 2 thoracolumbar nerves are additionally stained when the TAP block is performed before the installation of a pneumoperitoneum. However, this was not statistically significant. We did not observe spread beyond the junction of the abdominal wall muscles and quadratus lumborum muscle regardless of the presence of a pneumoperitoneum. As posterior spread of the injectate is lacking with the midaxillary approach regardless of the timing of the injection, we believe that if posterior spread is desired, a posterior approach should be chosen.

**REFERENCES**


