Transversus Abdominis Plane Block

Aidan Sharkey · Olivia Finnerty · John G. Mc Donnell

Published online: 18 September 2013
© Springer Science + Business Media New York 2013

Abstract Regional anaesthesia is a rapidly evolving subspecialty of anaesthesia. Of late, there has been an increasing interest in the use of abdominal plane blocks for post-operative analgesia post-abdominal wall surgery. There are promising data emerging on the efficacy of these blocks. Of particular importance is the transversus abdominis plane (TAP) block, which has proven to be beneficial in reducing post-operative pain scores and opioid consumption when used as part of a multimodal regime in post-operative analgesia. Interest in techniques and applications of the TAP block has expanded exponentially since its introduction over 10 years ago. Clinical trials are continuing to be published examining the role of TAP blocks with various abdominal surgeries, and variants of the TAP block are constantly being conceived to extend the analgesic properties of the block. The choice of techniques and approaches has been assisted by the availability of ultrasound, but the optimal injection sites for different types of surgical incisions remains unclear. The TAP block

continues to evolve and is becoming pivotal to our daily anaesthetic practice.

Keywords Analgesia · Anaesthesia · Transversus abdominis plane block · Regional anaesthesia · Abdominal surgery · Post-operative · Pain

Introduction

First described by Rafi [1], the transversus abdominis plane (TAP) block has been the subject of multiple clinical trials to determine its analgesic efficacy in post-operative analgesia. The TAP block has repeatedly been shown to be effective in reducing post-operative pain scores when used as part of a multimodal analgesic regime in both upper and lower abdominal surgery [2]. The original approach described the insertion of a needle via the lumbar triangle of Petit, using a ‘double pop’ or a ‘loss of resistance’ technique, which resulted in the needle tip being placed within the TAP. It was originally thought that infiltration of local anaesthetic at this point would result in blockade of the somatic nerves supplying the anterior abdominal wall by localized spread, before branching of these nerves throughout the TAP. Our understanding of the TAP block has evolved in recent years thanks to a plethora of studies looking at its effectiveness [2], spread patterns with various needle insertion points [3–5], and the various clinical uses of this evolving regional block [6–14]. With the advent of ultrasound technology, and it becoming fundamental in our daily practice, the ability to visualize the TAP plane and various muscle layers has superseded the landmark approach, and the most recent studies incorporate the use of ultrasound into the delivery of their TAP blocks.

A. Sharkey · O. Finnerty · J. G. Mc Donnell (✉)
Department of Anesthesia, Clinical Sciences Institute, National
University of Ireland, Galway, Ireland
e-mail: johngmcdonnell@gmail.com

O. Finnerty · J. G. Mc Donnell
Department of Anesthesia and Intensive Care Medicine, Galway
University Hospitals, Galway, Ireland

J. G. Mc Donnell
Clinical Research Facility, Galway University Hospitals,
Galway, Ireland

J. G. Mc Donnell
The Centre for Pain Research, National University of Ireland,
Galway, Ireland

Anatomy

The musculature of the abdominal wall consists of the external oblique, internal oblique, and transversus abdominis and muscles. The TAP plane is found between the internal oblique and transversus abdominis (Fig. 1). The landmark approach to the TAP block involves identifying the apex of the triangle of Petit, which is situated between the lower costal margin and iliac crest, bound anteriorly by the external oblique muscle and posteriorly by the latissimus dorsi. Recently, thanks to several cadaveric studies, our understanding of the anatomy and neuroanatomy of the abdominal wall and triangle of Petit has evolved [15–17].

The sensory innervation of the anterolateral abdominal wall arises from the anterior rami of spinal nerves T6–L1 [16, 17]. Branches arising from the anterior rami include the intercostal nerves (T7–T11), the subcostal nerve (T12), and the iliohypogastric and ilioinguinal nerves (L1). They become the lateral and anterior cutaneous branches of the abdominal wall as they become more superficial. The anterior divisions of T7–T11 nerves exit the intercostal spaces and traverse a plane between the internal oblique and the transversus abdominis muscles until they reach the rectus abdominis, which they perforate and supply, ending as anterior cutaneous branches supplying the skin of the front of the abdomen. Along their course, they pierce the external oblique muscle, giving rise to the lateral cutaneous branch, which divides into anterior and posterior branches that supply the external oblique muscle and latissimus dorsi, respectively.

Several cadaveric studies have looked at and described in detail the anatomy of the triangle of Petit. Loukas et al. [15] dissected 80 cadavers and showed the triangle to be

present in 82 % of specimens. Their dissections showed that the area of the triangle was less than 8 cm² in 43.7 % and greater than 8 cm² in 38.7 % of specimens dissected. The triangle was unable to be identified in 17.5 % of specimens; a finding that might be prevalent in a more obese population. Rozen et al. [16] performed thorough dissections on 20 cadaveric hemi-abdominal walls. Their dissections documented the presence of a widespread fascial layer between the internal oblique and transversus abdominis muscles, under which the neurovascular bundles supplying the abdominal wall traverse. They also described the consistent branching and communication of segmental nerves to form multiple plexi running within the TAP. Bands of these plexi are in close proximity to the deep circumflex iliac artery laterally, and the deep inferior epigastric artery posterior to the rectus muscle medially. Adding to our understanding of the anatomy of the triangle of Petit, Jankovic et al. [17] performed dissections of the lumbar triangle of Petit unilaterally on 26 cadavers. In this cadaveric-based study, the center of the triangle was demonstrated to be a mean of 6.9 cm posterior to the mid-axillary line, and a mean of 1.4 cm above the iliac crest, and with a mean area of 3.63 ± 1.93 cm². The intercostal, subcostal, and iliohypogastric nerves followed a consistent course moving antero-medially and always entered the TAP lateral to the triangle of Petit.

Distribution Studies

The TAP block was originally thought of as a local field block or regional abdominal field infiltration (RAFI) block, with its analgesic properties arising due to the spread of

Fig. 1 Ultrasonographic anatomy of the lateral abdominal wall showing muscle layers and the transversus abdominis plane

local anaesthetic within the TAP locally, thus blocking the nerves lying within this plane. And while the method of action of the TAP block is partially associated with localized effects within the TAP, contrast studies have expanded our knowledge of the distribution of injectate within the TAP and to sites distal to the site of injection.

McDonnell et al. [3] injected dye into the TAP at the triangle of Petit using a landmark-based approach on cadaveric specimens. On dissection, they showed that the dye had spread locally from the iliac crest to the costal margin. They also demonstrated consistent spread of radio-opaque contrast in the TAP upon performing landmark-based TAP injections on healthy male volunteers and subsequently following them up with computed tomography (CT) imaging and MRI. These imaging studies showed consistent spread of contrast within the TAP. Volumes used in these studies showed equal spread when using 0.3 and 0.6 ml/kg. Using ultrasound guidance, Tran et al. [4] injected dye into the TAP above the iliac crest in the mid-axillary line in cadavers. On follow-up dissection, dye was seen to have dissipated between the iliac crest, costal margin, and rectus muscle with an average area of 45 cm², and they found the spread of dye to involve the nerves T11–L1. Barrington et al. [5] also injected dye into cadavers under ultrasound guidance to the subcostal TAP region using both single and multiple injection techniques. Fourteen hemi-abdomens were injected with a single 5-ml injection at the linea semilunaris on one side, while on the opposite side they performed four 5-ml injections from the linea semilunaris along the TAP plane from medial to lateral. When the cadavers were dissected, they found that the single injection involved nerves T9 and T10, but that the multiple injection technique involved nerves T8–T11. Murouchi et al. [18] undertook a cadaveric study to evaluate the spread of dye using the ultrasound-guided subcostal and mid-axillary approach. On dissection, they found the spread of dye to involve thoracic nerves (T7–12) and the first lumbar nerve (L1). Segmental nerves T7 (14 %), T8–11 (100 %), T12 (71 %), and L1 (43 %) were involved.

The pattern of dye distribution described in these studies was not consistent with the description of the analgesia profile as seen in the original landmark-based TAP block trials [2•]. Using serial MRI scans, Carney et al. [19•] studied the spread pattern of four blocks: the landmark block, the ultrasound-guided subcostal block, the ultrasound-guided lateral block, and the ultrasound-guided posterior approach described by Blanco [20]. The spread pattern of the subcostal and lateral blocks was confined locally around the point of injection and around the TAP of the anterior abdominal wall, and, thus, was consistent with the cadaveric studies of both Tran et al. [4] and Barrington et al. [5]. What was interesting from the landmark and

posterior approaches was the finding of an extension of the local anaesthetic solution from the TAP to the thoracic paravertebral space. Paravertebral spread between T4 and L1 was consistently demonstrated on subjects who were injected using the landmark and ultrasound-guided posterior approach.

Analgesia

The original landmark-based approach to the TAP block has been shown in randomized, controlled trials to offer analgesic benefit in patients undergoing abdominal and pelvic surgery when compared to placebo in both adult and paediatric populations [2, 13, 21, 22•]. Since these landmark trials, the TAP block has been the subject of numerous studies, meta-analyses, and systematic reviews assessing its analgesic effectiveness, opioid sparing effects, varying analgesia properties with different approaches, and, recently, the use of ultrasound to directly visualize the deposition of local anaesthetic into the TAP plane, and also the placing of catheters into the TAP plane, to further prolong the analgesic effect beyond the pharmacodynamic properties of the local anaesthetic used.

Recent reviews [23, 24•] have reported a trend towards more prolonged analgesia with landmark-based approaches compared with ultrasound-guided TAP blocks. This prolonged analgesia is likely due to the extension of the local anaesthetic into the paravertebral space as described in distribution studies [19•]. The introduction of ultrasound-guided approaches has meant the ability to palpate the triangle of Petit has been superseded by the ability to visualize the muscle and fascial layers using ultrasound technology.

There have been numerous studies [6–14] showing analgesic benefit in patients who received ultrasound-guided TAP blocks in both upper and lower abdominal surgery. Niraj et al. [9] demonstrated significantly reduced post-operative morphine consumption in the patients undergoing open appendectomy who received ultrasound-guided TAP block as compared to those who did not. Aveline et al. [25] showed ultrasound-guided TAP block conferred superior analgesia than blind ilioinguinal/iliohypogastric nerve blocks for day-case open inguinal hernia repair. Niraj et al. [26•] also showed that the ultrasound-guided subcostal TAP block provided beneficial analgesia for upper abdominal surgery. Regarding the application of TAP blocks in laproscopic surgery, there have been mixed results. El-Dawlatly et al. [27] showed substantially reduced peri- and post-operative opioid consumption in patients undergoing laparoscopic cholecystectomy who received an ultrasound-guided TAP block compared to those who did not. Hosgood et al. [28] also showed TAP

block to be beneficial in patients undergoing laparoscopic live-donor nephrectomy. Contrary to these results, Sandeman et al. [29] showed no benefit in patients undergoing laparoscopic appendectomy who received TAP block compared with those who received local anaesthetic port site infiltration. Most recently, Petersen et al. [30•] showed only a minor non-significant benefit in patients undergoing laparoscopic cholecystectomy who received TAP block compared to those who received placebo blocks. The site of deposition of local anaesthetic agent must be remembered when looking at each of these papers, as the pattern of spread is dictated by the needle insertion point, with the optimal site of deposition being in the posterior region (Fig. 2).

Discussion

The current body of evidence supports that TAP blocks confer analgesic benefit to the surgical patient undergoing abdominal surgery, when used as part of a multi-modal analgesic regimen. The majority of the studies to date still compare TAP block to placebo for various abdominal surgeries, and all but one [31•] show analgesic benefit when the TAP block is used as part of a multimodal analgesic regimen. There are limited studies comparing TAP block to central neuro-axial techniques, that is, epidural [26•] or intrathecal opioid [32•]. One study [26•] demonstrated equivalent analgesia when TAP block was compared to epidural analgesia, but the TAP block group used significantly more opioid, supposedly to manage

visceral pain. The studies comparing intrathecal opioid to TAP block are limited to those undergoing Caesarean section, and it has been shown that TAP block is inferior to intrathecal opioid for pain control [32•]. We can extrapolate from these limited studies that, while TAP block provides analgesia for patients undergoing abdominal surgery, the analgesia achieved is not as effective as that offered with central neuraxial techniques, especially where there is significant surgical resection and associated visceral pain.

The advent of ultrasound technology into our clinical practice has resulted in the TAP block evolution, and a variety of approaches being investigated. As demonstrated in recent contrast studies [19•], the landmark and posterior ultrasound-guided approaches to the TAP result in the spread of the local anaesthetic solution to the paravertebral space and may account for the improved and prolonged analgesic profile as seen in the original studies [2•]. One must not forget that the neuro-anatomy of the abdominal wall is derived from the thoracic region, and the ability to block structures such as sympathetic nerves and ganglia in the paravertebral space might improve the analgesic effect and is currently the subject of investigation in research trials [33•]. When thoracic paravertebral spread is achieved, there will invariably be some degree of extension into the epidural space, either through direct spread venous and/or lymphatic drainage systems. From this, we can surmise that the optimal analgesic block is achieved when the block is placed as close as possible to the major site of action of the drugs used, which is either the central neuraxial block or paravertebral block. In certain

Fig. 2 Ultrasound image showing the muscle layers of the lateral abdominal wall with the optimal needle tip position shown

circumstances, this may be neither feasible nor appropriate. It is on these occasions that we must seek suitable alternatives, and the TAP block has been shown to be a reliable alternative in these cases when used as part of a multimodal analgesic regimen.

The TAP block may also have a role to play in rescue analgesia post-abdominal surgery as described by Carvalho et al. [34], who utilized the TAP block to manage suboptimal analgesia post-Caesarean section. Also, the TAP block is increasingly being used for analgesia outside the original scope of the block, as recently described by Gebhardt and Wu [35], who utilized the TAP block to treat abdominal wall cancer pain, and Singh et al. [36], who used bilateral TAP blocks in addition to noninvasive positive pressure ventilation in the management of a patient with impending respiratory failure resulting from excessive pain following emergency laparotomy.

Regarding safety and TAP blocks, there have been some reports in the literature of adverse events regarding its use. Two reports have documented liver trauma occurring during the performance of TAP blocks, one with the landmark-based approach [37] and another under ultrasound guidance [38]. While these injuries may be attributed to human factors, the potential for injury exists just as with any other regional anaesthetic technique even when ultrasound is used. The close proximity of the TAP to internal organs and vasculature must be appreciated, as well as the fact that there are multiple plexi of nerves within the TAP and their associated vascular structures which are possible sites of either injury or access to the systemic vasculature [16]. There have also been reports of potentially and actual toxic doses of local anaesthetic agents being administered to patients [39–41]. While the doses administered have been shown to provide similar serum levels to those obtained from other regional anaesthetic techniques, one must remember to account for the weight, relative size, and clinical state of the patient when calculating the dose of local anaesthetic to be administered.

To date, there have been no randomized controlled trials comparing different local anaesthetic agents, volumes or concentrations. Ropivacaine and bupivacaine are the agents mainly used in various doses and volumes in clinical trials to date. Therefore, there is no evidence base to support one particular regime over another. Currently, there is, however, an on-going trial to determine the influence of increasing local anaesthetic volume.

Conclusion

TAP blocks confer analgesic benefit to the surgical patient undergoing abdominal surgery when used as part of a multimodal regimen, albeit this analgesic benefit does not

seem to be superior to epidural or intrathecal opioids. It is also clear that the characteristics of the block differ with the point of needle insertion, with superior and prolonged analgesia being seen with the more posterior approaches. When central neuraxial analgesia is not possible, a TAP block is a viable alternative in achieving adequate post-operative analgesia, with the option of placing catheters within the TAP to extend the duration of blockade, although it remains unclear whether continuous infusion of local anaesthetic offers any advantage over intermittent boluses when TAP catheters are used.

Compliance with Ethics Guidelines

Conflict of Interest Aidan Sharkey, Olivia Finnerty, and John G. Mc Donnell declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:

- Of importance
- Of major importance

1. Rafi AN. Abdominal field block: a new approach via the lumbar triangle. *Anaesthesia*. 2001;56:1024–6.
2. • McDonnell JG, O'Donnell B, Curley G, Heffernan A, Power C, Laffey JG. The analgesic efficacy of transversus abdominis plane block after abdominal surgery: a prospective randomized controlled trial. *Anesth Analg*. 2007;104:193–197. *Landmark study showing analgesic benefit of the TAP block after abdominal surgery*.
3. McDonnell JG, O'Donnell BD, Farrell T, Gough N, Tuite D, Power C, Laffey JG. Transversus abdominis plane block: a cadaveric and radiological evaluation. *Reg Anesth Pain Med*. 2007;32:399–404.
4. Tran TMN, Ivanusic JJ, Hebbard P, Barrington M. Determination of spread of injectate after ultrasound-guided transversus abdominis plane block: a cadaveric study. *Br J Anaesth*. 2009;102:123–7.
5. Barrington MJ, Ivanusic JJ, Rozen WM, Hebbard P. Spread of injectate after ultrasound-guided subcostal transversus abdominis plane block: a cadaveric study. *Anaesthesia*. 2009;64:745–50.
6. Conaghan P, Maxwell-Armstrong C, Bedforth N, et al. Efficacy of transversus abdominis plane blocks in laparoscopic colorectal resections. *Surg Endosc*. 2010;24:2480–4.
7. El-Dawlatly AA, Turkistani A, Kettner SC, et al. Ultrasound-guided transversus abdominis plane block: description of a new technique and comparison with conventional systemic analgesia during laparoscopic cholecystectomy. *Br J Anaesth*. 2009;102:763–7.
8. Mukhtar K, Khattak I. Transversus abdominis plane block for renal transplant recipients. *Br J Anaesth*. 2010;104:663–4.
9. Niraj G, Searle A, Mathews M, et al. Analgesic efficacy of ultrasound-guided transversus abdominis plane block in patients undergoing open appendicectomy. *Br J Anaesth*. 2009;103:601–5.

10. Aveline C, Le Hetet H, Le Roux A, et al. Comparison between ultrasound-guided transversus abdominis plane and conventional ilioinguinal/iliohypogastric nerve blocks for day-case open inguinal hernia repair. *Br J Anaesth*. 2011;106:380–6.
11. Araco A, Pooney J, Araco F, Gravante G. Transversus abdominis plane block reduces the analgesic requirements after abdominoplasty with flank liposuction. *Ann Plast Surg*. 2010;65:385–8.
12. Araco A, Pooney J, Memmo L, Gravante G. The transversus abdominis plane block for body contouring abdominoplasty with flank liposuction. *Plast Reconstr Surg*. 2010;125:181e–2e.
13. Carney J, McDonnell JG, Ochana A, Bhinder R, Laffey JG. The transversus abdominis plane block provides effective postoperative analgesia in patients undergoing total abdominal hysterectomy. *Anesth Analg*. 2008;107:2056–60.
14. McDonnell JG, Curley G, Carney J, et al. The analgesic efficacy of transversus abdominis plane block after caesarean delivery: a randomized controlled trial. *Anesth Analg*. 2008;106:186–91.
15. Loukas M, Tubbs RS, El-Sedfy A, Jester A, Polepalli S, Kinsela C, Wu S. The clinical anatomy of the triangle of Petit. *Hernia*. 2007;11:441–4.
16. Rozen WM, Tran TMN, Ashton MW, Barrington MJ, Ivanusic JJ, Taylor GI. Refining the course of the thoracolumbar nerves: a new understanding of the innervation of the anterior abdominal wall. *Clin Anat*. 2008;21:325–33.
17. Jankovic ZB, du Feu FM, McConnell P. An anatomical study of the transversus abdominis plane block: location of the lumbar triangle of petit and adjacent nerves. *Anesth Analg*. 2009;109:981–5.
18. Murouchi T, Yamauchi M, Gi E, Takada Y, Mizuguchi A, Yamakage M, Fujimiya M. Ultrasound-guided subcostal and mid-axillary transversus abdominis plane block: a cadaveric study of the spread of injectate. *Masui*. 2013;62(1):60–3.
19. •• Carney J, Finnerty O, Rauf J, et al. Studies on the spread of local anesthetic solution in transversus abdominis plane blocks. *Anaesthesia*. 2011;66:1023–1030. *This study showed the different spread patterns associated with different approaches to the TAP block. It also showed spread of contrast into the paravertebral space with the more posterior approaches.*
20. Blanco R. TAP block under ultrasound guidance: the description of a 'no pops technique'. *Reg Anaesth Pain Med*. 2007;32(1):130.
21. • McDonnell JG, Curley G, Carney J, Benton A, Costello J, Maharaj CH, Laffey JG. The analgesic efficacy of transversus abdominis plane block after cesarean delivery: a randomized controlled trial. *Anesth Analg*. 2008;106:186–191. *Study demonstrating the analgesic benefits of the TAP block in obstetric patients undergoing Caesarean delivery.*
22. • Carney J, Finnerty O, Rauf J, Curley G, McDonnell JG, Laffey JG. Ipsilateral transversus abdominis plane block provides effective analgesia after appendectomy in children: a randomized controlled trial. *Anesth Analg*. 2010;111:998–1003. *Study showing the successful application of the TAP block in a paediatric population undergoing abdominal surgery.*
23. Peterse PL, Mathiesen O, Torup H, Dahl JB. The transversus abdominis plane block: a valuable option for postoperative analgesia? A topical review. *Acta Anaesthesiol Scand*. 2010;54:529–35.
24. •• Abdallah FW, Chan VW, Brull R. Transversus abdominis plane block a systematic review. *Reg Anesth Pain Med*. 2012;37:193–209. *Recently published systematic review looking at the evidence concerning the TAP block and also raising important questions to be answered with future research.*
25. Aveline C, Le Hetet H, Le Roux A, Vautier P, Cognet F, Vinet E, Tison C, Bonnet F. Comparison between ultrasound-guided transversus abdominis plane and conventional ilioinguinal/iliohypogastric nerve blocks for day-case open inguinal hernia repair. *Br J Anaesth*. 2011;106(3):380–6.
26. •• Niraj G, Kelkar A, Jeyapalan I, Graff-Baker P, Williams O, Darbar A, Maheshwaran A, Powell R. Comparison of analgesic efficacy of subcostal transversus abdominis plane blocks with epidural analgesia following upper abdominal surgery. *Anaesthesia*. 2011;66(6):465–471. *Landmark study comparing the TAP block with epidural analgesia in upper abdominal surgery. The authors found no significant difference in median visual analogue scores during coughing at 8 h between the TAP group and epidural group or at 72 h. Opioid consumption was significantly greater in the TAP group.*
27. El-Dawlatly AA, Turkistani A, Kettner SC, Machata AM, Delvi MB, Thallaj A, Kapral S, Marhofer P. Ultrasound-guided transversus abdominis plane block: description of a new technique and comparison with conventional systemic analgesia during laparoscopic cholecystectomy. *Br J Anaesth*. 2009;102(6):763–7.
28. Hosgood SA, Thiagarajan UM, Nicholson HF, Jeyapalan I, Nicholson ML. Randomized clinical trial of transversus abdominis plane block versus placebo control in live-donor nephrectomy. *Transplantation*. 2012;94(5):520–5.
29. Sandeman DJ, Bennett M, Dille AV, Perczuk A, Lim S, Kelly KJ. Ultrasound-guided transversus abdominis plane blocks for laparoscopic appendectomy in children: a prospective randomized trial. *Br J Anaesth*. 2011;106(6):882–6.
30. •• Petersen PL, Stjernholm P, Kristiansen VB, Torup H, Hansen EG, Mitchell AU, Moeller A, Rosenberg J, Dahl JB, Mathiesen O. The beneficial effect of transversus abdominis plane block after laparoscopic cholecystectomy in day-case surgery: a randomized clinical trial. *Anesth Analg*. 2012;115(3):527–533. *Randomized, double-blind study showing beneficial effect of TAP block in patients undergoing laparoscopic cholecystectomy.*
31. • Griffiths JD, Middle JV, Barron FA, Grant SJ, Popham PA, Royse CF. Transversus abdominis plane block does not provide additional benefit to multimodal analgesia in gynecological cancer surgery. *Anesth Analg*. 2010;111:797–801. *Study showing no benefit of TAP block in major gynaecological cancer surgery.*
32. •• McMorro RC, Ni Mhuircheartaigh RJ, Ahmed KA, Aslani A, Ng SC, Conrick-Martin I, Dowling JJ, Gaffney A, Loughrey JP, McCaul CL. Comparison of transversus abdominis plane block vs spinal morphine for pain relief after Caesarean section. *Br J Anaesth*. 2011;106:706–712. *Trial comparing TAP block and intrathecal morphine. Results showed inferior analgesia in the TAP block group compared to those who received intrathecal morphine. This study also showed that the addition of TAP block to ITM added no analgesia benefit.*
33. • McDonnell JG, Finnerty O, Laffey JG. Stellate ganglion blockade for analgesia following upper limb surgery. *Anaesth*. 2011;66:611–614. *Current research looking at the analgesic benefit of blockade of sympathetic nerves and ganglia.*
34. Mirza F, Carvalho B. Transversus abdominis plane blocks for rescue analgesia following caesarean delivery: a case series. *Can J Anaesth*. 2012;60(3):299–303.
35. Gebhardt R, Wu K. Transversus abdominis plane neurolysis with phenol in abdominal wall cancer pain palliation. *Pain Physician*. 2013;16(3):325–30.
36. Singh M, Chin KJ, Chan V. Ultrasound-guided transversus abdominis plane (TAP) block: a useful adjunct in the management of postoperative respiratory failure. *J Clin Anesth*. 2011;23(4):303–6.
37. Farooq M, Carey M. A case of liver trauma with a blunt regional anesthesia needle while performing transversus abdominis plane block. *Reg Anesth Pain Med*. 2008;33(3):274–5.
38. Lancaster P, Chadwick M. Liver trauma secondary to ultrasound-guided transversus abdominis plane block. *Br J Anaesth*. 2010;104(4):509–10.
39. Torup H, Mitchell AU, Breindahl T, Hansen EG, Rosenberg J, Møller AM. Potentially toxic concentrations in blood of total

- ropivacaine after bilateral transversus abdominis plane blocks; a pharmacokinetic study. *Eur J Anaesthesiol.* 2012;29(5):235–8.
40. Griffiths JD, Barron FA, Grant S, Bjorksten AR, Hebbard P, Royse CF. Plasma ropivacaine concentrations after ultrasound-guided transversus abdominis plane block. *Br J Anaesth.* 2010; 105(6):853–6.
41. Griffiths JD, Le NV, Grant S, Bjorksten A, Hebbard P, Royse C. Symptomatic local anaesthetic toxicity and plasma ropivacaine concentrations after transversus abdominis plane block for Caesarean section. *Br J Anaesth.* 2013;110(6):996–1000.