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Non-Epidural Regional Anesthesia Options for the Abdomen.

Robert M Raw, MD.
rob-raw@uiowa.edu

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I. INTRODUCTION

An extreme diversity of surgical procedures gets performed on the abdominal wall, within the abdominal cavity, and or even posterior to the abdominal cavity. There are benefits to be derived from regional anesthesia for any patients undergoing any surgery related to the abdomen. That regional anesthesia may sometimes be used to make fully awake surgery possible, or just be used to reduce the depth of accompanying general anesthesia needed, or also just to provide post-surgical analgesia.

Neuraxial nerve blocks, namely spinal and epidural blocks, are well known, popular, and deserve a large separate discussion. Although the epidural and the spinal block are the common standard and are widely used regional anesthesia techniques for abdominal surgery, they clearly are too invasive, too dangerous or too short acting as single shot procedures for many of the smaller and minimally invasive surgeries. Also, there may be patient contra-indications to neuraxial blocks.

This discussion will cover all the *non-axial regional anesthesia techniques* that can be applied to the abdomen.

Many of the nerve blocks are relatively novel and highly promoted by the claimants to be the ones who first described these techniques. Many of the novel techniques claimed great results that cannot be replicated by other researchers or ordinary anesthesia providers. All novel techniques need to be validated over time by a diverse group of anesthesia providers. A century of experience in anesthesia shows some new technique will become pillars in the profession and others will fade away, forgotten in history. The explosive number of tissue plane blocks described in the last five years, are not always understood as to how they work exactly. Tissue plane blocks are not infrequently personal practice variants under the same name. This lecture will discuss all the new blocks objectively.

Lastly, it is exceedingly important for the anesthesia provider to understand the surgery being done, as well as fully understand abdominal neuroanatomy. Not every block is suitable for every surgery. To obtain best results often, only specific blocks can be paired with specific surgeries. There are also some older blocks that have become forgotten but may prove highly useful still, due they simplicity.   Some blocks also, need subtle features to be executed perfectly for them to achieve best results. All this will be highlighted and pointed out in this lecture.

II. ANATOMY.

The abdominal cavity is the cavity between the diaphragm and the pelvis, including the pelvis. It is lined with parietal peritoneum that share a nerve supply with its overlying muscle and skin. To anterior and the sides are skin and muscles. To posterior is the spinal column with skin and muscles. Ribs cover the upper lateral parts as well as some of the upper front and posterior parts. The cavity is tightly packed without empty spaces. The content are all the intestinal viscera from the distal esophagus to the rectum, as well as the liver, gall bladder and the spleen. Posterior to the peritoneal cavity, in the retro-peritoneal space are the kidneys, adrenal glands large blood vessels and pancreas, ascending colon, descending colon and rectum. Organs having a mesentery are regarded as being intraperitoneal, whilst those without a mesentery and only partly covered by peritoneum are considered retroperitoneal, such as the ascending and descending colons.

The sensory nerve supply of the abdomen is complex. Abdominal surgeries are very variable in their site of surgical access and in very variable in magnitude. Some regional analgesia interventions have serious complications (e.g. epidural hematoma), and some require special skill and training to handle, while others are relatively safe and easy. The key to choosing the best regional analgesia technique is to understand abdominal pain, know the specific surgeries, and know the regional anesthesia technique options available.

The abdomen has a number of components that may need to be specifically included in the nerves blocked for some specific abdominal surgeries;

1) The abdominal wall.
2) The diaphragm.
3) The viscera and visceral peritoneum.
4) The parietal peritoneum that lines the abdominal wall.

a) The abdominal wall nerve supply.

The abdominal wall consists of skin, subcutaneous fat, muscle-fascia layers, and an inner lining of peritoneum. See figure number 1. These tissues all share the same intercostal nerve supply, which is are segmental somatic nerve supply direct from the spinal cord. The spinal cord roots supplying sensation to the abdomen are T6 to L1. In the center at the umbilicus is the T10 dermatome., centered on the umbilicus which has a T10 nerve supply. Any block of an intercostal nerve will block the corresponding segment of abdominal wall in its full thickness from skin to peritoneum. The very lowest part of the abdomen receives it nerve supply from Lumbar root 1 via the ilioinguinal and iliohypogastric nerves.

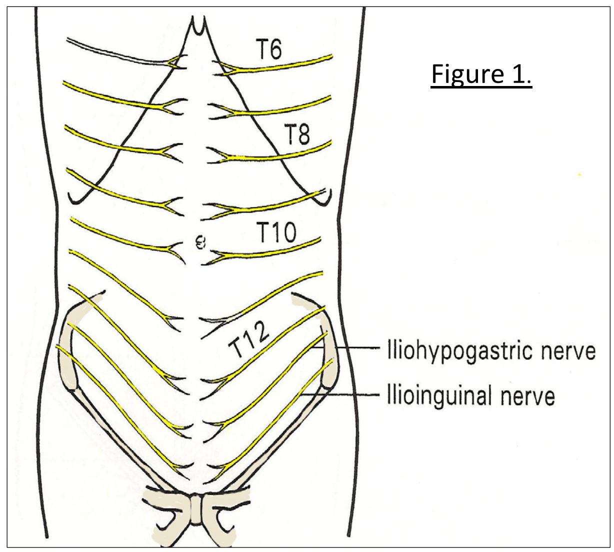


Figure 1.

b) Diaphragm nerve supply.

The peripheral diaphragm receives its nerve supply from intercostal nerves. The central part of the diaphragm, and the crura get their sensation from the phrenic nerves (C3, 4, 5). This arrangement includes the corresponding muscles, fascia, tendinous parts and peritoneal covering of the diaphragm.

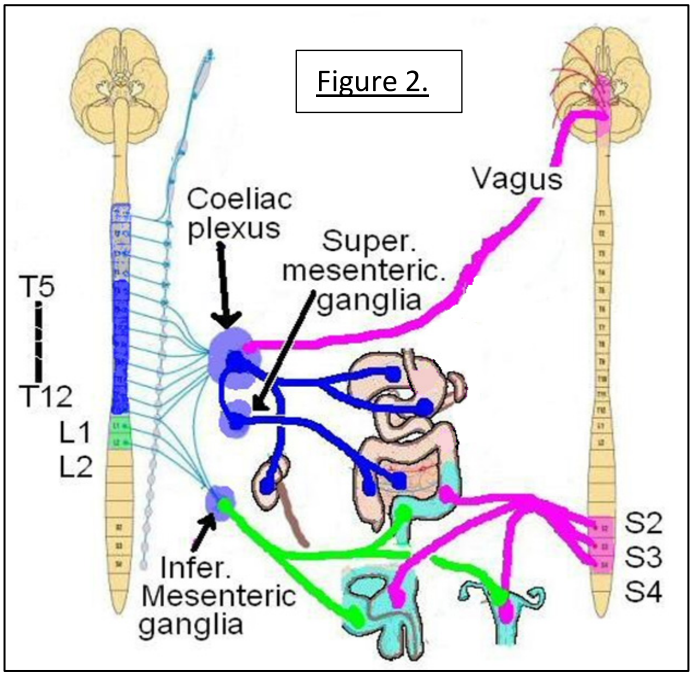
Commonly peritoneal irritation of the peritoneum covered portion of the diaphragm by residual peritoneal gas presents as referred pain in the C5 shoulder dermatomes. That pain can be blocked by performing an ipsilateral phrenic nerve block, if the patient is judged as able to tolerate that. Typically, the shoulder tip pain resolves spontaneously within 4 to 12 hours, although it is highly irritating to the patient. The phrenic nerve, if blocked, ideally should be blocked with motor sparing concentration of bupivacaine such as 0.1% to 0.2% although healthy patients can tolerate a motor phrenic block, as is seen frequently with interscalene blocks.

The phrenic nerve is easily blocked in the neck.

c) The abdominal viscera and visceral peritoneum nerve supply.

Pain signals are carried in both sympathetic and parasympathetic autonomic fibers. Sympathetic fibers for the abdomen originate from spinal cord segments T5 to L2. Those fibers exit the cord as gray rami communicantes to enter the sympathetic chain in the paravertebral position.

Parasympathetic fibers come from two sources; (a) everything in the upper abdomen is supplied via the vagus nerve, except (b) for the colon distal to the splenic flexure and the genito-urinary organs, which receive their parasympathetic fibers from (b) the spinal cord segments S2 to S4 via the inferior hypogastric plexus.



In Figure number 2, the brain and spinal cord are illustrated twice to simplify some concepts, once on the left side and once on the right side of image number 2.

From the brain-and-cord on the right side of the picture, only parasympathetic nerves are shown. It is seen that the top (pink) nerve is the Vagus nerve, which is a Cranial Nerve from the brain. The Vagus nerve, and all afferent (sensory) branches enter the Coeliac plexus. The lower pink nerves exit the spinal cord via roots S2 to S4, and travel via the inferior sympathetic hypogastric ganglion plexus in the pelvis to reach their target organs.

The brain-and-cord on the left side of figure 2, show the sympathetic nervous system outflow to the abdominal contents. The top most sympathetic fibres leave the spinal cord segments T5 to T12 to join the sympathetic chain. Those sympathetic nerve fibers then travel further via the Splancnic nerves to join the vagus parasympathetic fibers. Both nerve systems form the Coeliac Plexus. Some sympathetic fibers then flow direct to some organs whilst others first pass through the superior mesenteric plexus before reaching their target organs, illustrated as the blue nerves in image 2. Next there is a more inferior group of sympathetic nerves, that flow out of spinal cord segments L1 and L2 to pass via the sympathetic chain before meeting the inferior mesenteric ganglion plexus. From the ganglia the sympathetic fibres travel to the bowels distal to the colonic splenic flexure, and genital organs. The testicles and ovaries retain their renal (T10 nerve root) associated nerve supply as they descend during their development.

d) The parietal peritoneum nerve supply.

This is the peritoneum lining the inner aspect of the abdominal wall and is the same as that of the abdominal wall skin and muscles themselves. BELOW: *TABLE:*

ORGAN	Sympathetic sensory supply	Parasympathetic sensory supply
Liver and biliary system	Sensory fibers travel to the **coeliac plexus**, then via splanchnic nerves and paravertebral sympathetic ganglia, to spinal segments T5-10	With blood vessels to the coeliac plexus and then to **Vagus.**
Stomach	Sensory fibers travel to the **coeliac plexus**, then via splanchnic nerves and paravertebral sympathetic ganglia, to spinal segments T7-9	With blood vessels to the coeliac plexus and then to **Vagus**.
Pancreas	Sensory fibers travel to the **coeliac plexus**, then via splanchnic nerves and paravertebral sympathetic ganglia, to spinal segments T6-10	With blood vessels to the coeliac plexus and then to **Vagus**.
Small bowel	Sensory fibers travel to the **coeliac plexus**, then via splanchnic nerves and paravertebral sympathetic ganglia, to spinal segments T9-11	With blood vessels to the coeliac plexus and then to **Vagus**.
Caecum, ascend. Colon, transverse colon	Sensory fibers travel to the **coeliac plexus**, then via splanchnic nerves and paravertebral sympathetic ganglia, to spinal segments T9-L1	With blood vessels to the coeliac plexus and then to **Vagus**.
Descending colon, sigmoid, rectum	Sensory fibers travel with blood vessels to the **inferior hypogastric plexus** and then via the lumbar sympathetic ganglia to spinal segments fibers T9 to T12 for the descending colon, and to spinal segments T11 to L1 for the sigmoid colon and rectum.	Via the pelvic nerves to **spinal segments S2 to S4.**
Kidney and ureters	Sensory fibers travel to the **coeliac plexus**, then via the splanchnic nerves, and paravertebral sympathetic ganglia, to spinal segments fibers T10 to L1	*Upper Ureter and kidneys* = With blood vessels to the coeliac plexus and then to the **vagus** nerves. *Middle and lower Ureters* = Via pelvic nerves to **spinal segments S2-4.**

TABLE: Autonomic sensory nerve supplies (Afferent nerves).

III. SPLANCNIC PAIN

The large extent to which the visceral component of abdominal surgery causes pain, called *splanchnic pain* or visceral pain, had become forgotten in modern times. The severity of visceral pain was rediscovered with modern minimal access surgery. Despite minimal access, surgical pain was as severe with open abdomen surgery. This was due to the *splanchnic pain* being unchanged. Splancnic pain is often worse than the somatic pain.

Figure #3. Frenchman undergoing awake - gastrectomy, under Coeliac Plexus block and bilateral thoracic paravertebral block. The time period was the 1920s.

Splanchnic pain was discovered in early twentieth century surgery of the abdomen performed under regional anesthesia of the abdominal wall[1]. In the 1930s in Europe it was common to perform abdominal surgery under regional anesthesia alone and the surgeons described visceral pain and sensation and pioneered splanchnic analgesia[1,2]. See figure number 3. The surgeons at first operated under bilateral paravertebral block of the abdomen only, and then systematically assessed which handling maneuvers of viscera caused what discomfort and what added nerve blocks, e.g. coeliac plexus blocks, gave pain relief.

Splanchnic pain was rediscovered in 1971 with attempted female sterilizations by fallopian tube ligation awake under local anesthetic failed due to patient pain upon tubal traction and handling[3]. Subsequently in 1972 Intra-peritoneal Regional Anesthesia (IPRA) was used with lidocaine and then awake painless sterilization procedures were first described[4].

Splanchnic pain is typically intense, burning in nature, more unremitting than somatic pain, which finds by comparison, gets some relief with rest and keeping still. Splanchnic pain is only severe for a short duration like 18 to 36 hours. Furthermore, surgery using CO_2 peritoneal insufflation is associated with greater peritoneal inflammation that open surgery causes. That inflammation is partly responsive to NSAIDs. Local anesthetics also have anti-inflammatory effects which may augment the nerve block analgesia effects.

IV. REGIONAL ANESTHESIA OPTIONS.

The following regional anesthesia options could be used in surgery of the abdomen;

1. Neuraxial blocks (spinal and epidural) – *not for discussion here*.
2. Intraperitoneal regional anesthesia.
3. Abdominal wall infiltration.
4. Inguinal hernia field block.
5. Intercostal nerve block.
6. Thoracic paravertebral nerve block.
7. TAP block.
8. Quadratus Lumborum block
9. Rectus sheath block
10. Ultra-Sound Guided (USG) wall blocks
11. USG Transversus Abdominal plane block (TAP block)
12. USG Iliohypogastric nerve block
13. USG Ilioinguinal nerve block
14. USG Transmuscular quadratus lumborum block
15. Coeliac plexus block.
16. Phrenic nerve block.
17. Other abdominal autonomic nerve blocks.

It must be noted that each block here only anesthetizes part of the abdomen. These blocks can only be used in the following two ways; (1) as a single RA procedure for surgery that is largely confined to the tissues that the chosen block anesthetizes, (2) in a combination of two of these blocks that separately block the visceral component and the somatic component of the surgery.

These blocks are mostly used as analgesia blocks for and the patient will still need a general or spinal/epidural anesthetic for the surgery. In a few carefully chosen cases the nerve blocks techniques can be the entire anesthetic and the patient can be kept awake.

It is also important that the anesthesia provider have medical knowledge of what the surgery entails in terms of tissues being handled. For example, an open inguinal hernia that only opens the peritoneal cavity by 3 centimeters and where the surgeon only gently pushes the bowel back with a finger as he/she sutures the internal orifice of the inguinal canal is different from the case where the surgeon has to dissect the bowel off the hernial sack that is large and the bowel was incarcerated, strangulated and necrotic needing resection as well. In the first situation a simple classic inguinal hernia block may facilitate easy awake surgery, whereas in the second situation it will require the appropriate autonomic blockade of the viscera within the hernia sack apart from the somatic block in order to achieve awake surgery. An additional detail for the second case is the specific bowel trapped in the hernia needs to be known as well, in order to select the appropriate autonomic nerves to be blocked.

Thus, the surgeon and anesthesia provider need to be in a true team in order to offer best patient care. The two professionals need to discuss the case needs well prior to the time of surgery.

Examples of inguinal hernia surgery and regional anesthesia, where awake and open surgery is planned. Awake surgery implies that minimal sedatives and, minimal analgesics are used, without a propofol near-general-anesthetic infusion;

1. Small inguinal hernia, not incarcerated, non-obese patient with good musculature:
    - Classic inguinal hernia infiltration block, or
    - T11 ipsilateral thoracic paravertebral block (inject 10 ml local anesthetic), plus a L2 psoas compartment block (inject 15 ml local anesthetic). This will achieve a unilateral T10 to L2 block.
2. Large inguinal hernia, with incarcerated small bowel:
    - Any above inguinal block technique, plus a Coeliac plexus block.
3. Large inguinal hernia with incarcerated sigmoid colon.
    - Spinal block from T10 downwards
    - Epidural block from T10 to S4

1) Intra-peritoneal regional anesthesia (IPRA). (*peritoneal lavage*)

This is done by instilling the peritoneal cavity with local anesthetic and was first reported in 1950[5]. IPRA has also been called peritoneal lavage. IPRA is currently best used in minimally invasive (laparoscopic) intra-abdominal surgery. Minimally invasive surgery usually means surgical access through the abdominal wall is minimal but the "internal" or visceral procedure is the same as before.

IPRA is an old technique that enjoyed varying popularity over the years. Patric Narchi's publication series from 1991 onwards rekindled modern interest in this technique[6]. Published results of Intra-Peritoneal Regional Anesthesia (IPRA) have had variable results probably due to poor case selection and suboptimal technique. A 2000 review of local anesthetic (LA) techniques for laparoscopic surgery found that surgical port site infiltration minimal or zero analgesia benefits[7]. That same study showed *direct tissue injection* of LA into the mesosalpinx during mesosalpinx surgery was very effective but of *short duration*. Little further research on direct visceral injections has been done. All further research has been on free peritoneal instillation of LA.

The 2006 meta-analysis of free peritoneal instillation of LA and review found an overall analgesia benefit, although no consistent analgesia in each trial. They also showed a remarkable *absence of complications and side effects*[8]. The clearest benefit in studies to date has *been reduction in shoulder tip pain* after laparoscopic surgery. Some studies suggest spraying local anesthetic supra-hepatic beneficial for shoulder tip pain only. This author finds instilling large drug volumes (80ml) at the conclusion of surgery and tilting the head down is more effective for this purpose.

This author has personal experience anesthetizing about 1000 cases of laparoscopic cholecystectomy, hiatus hernia repair and gynecologic surgery and using IPRA on all of them. The patient analgesia outcomes were better than what the literature reports. This could be due to an ongoing practice quality review and the systematically changing of the techniques until selection of the best one was found.

The exact mechanism of IPRA is unknown. IPRA has been proposed work one or more of the following mechanisms; (i) by blocking peritoneal nociceptors direct, (ii) by having an anti-inflammatory effect on the viscera, (iii) by blocking the immediate intra-serosal nerves, and or (iv) by blocking of the retro-peritoneal nerve plexuses analogous to how intrapleural local anesthetic blocks intercostal nerves. This author believes the main level of block is dominantly at the level of retroperitoneal plexuses with some lesser anti-inflammatory effects direct on peritoneum. These interpretations are based on reviewing the anatomy, and the speculations of other writers too.

Figure 4.

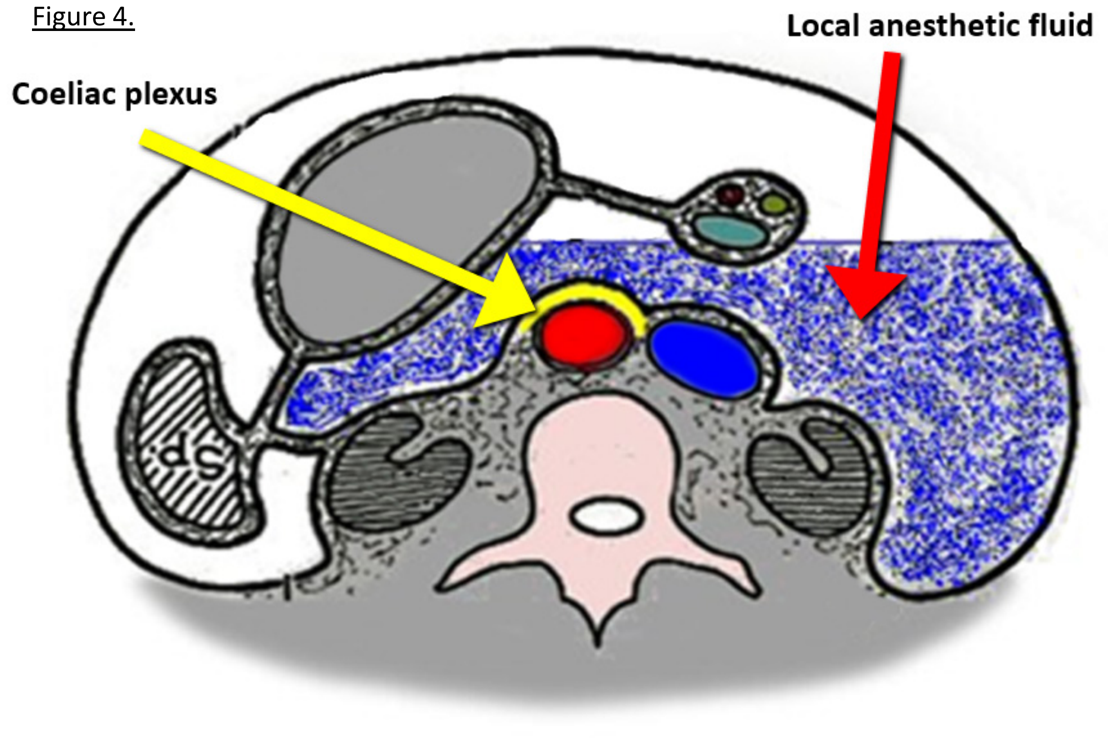


Figure number 4, is of a cross section through the upper abdomen showing the spleen and stomach. Figure number 2 indicates how in the upper peritoneal cavity, local anesthetic will pool behind the stomach and immediately over the coeliac plexus. The Coeliac plexus (colored yellow) is separated only by one layer of peritoneum, and lies anterior to the aorta.

Figure 5.

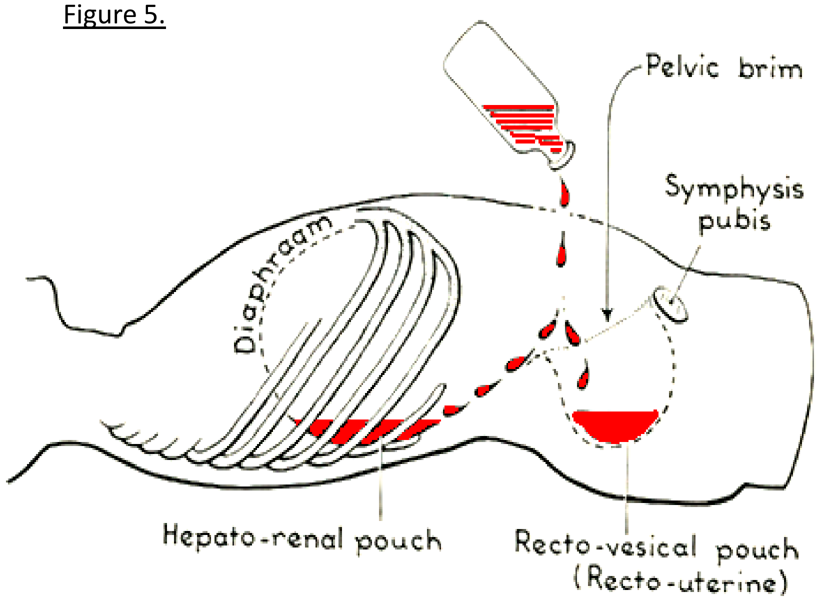


Figure number 5 is a sagittal sectional view through the abdomen. It shows how fluid in the peritoneal space will pool generally towards the head or the pelvis depending on how it is directed.

Figure 5.

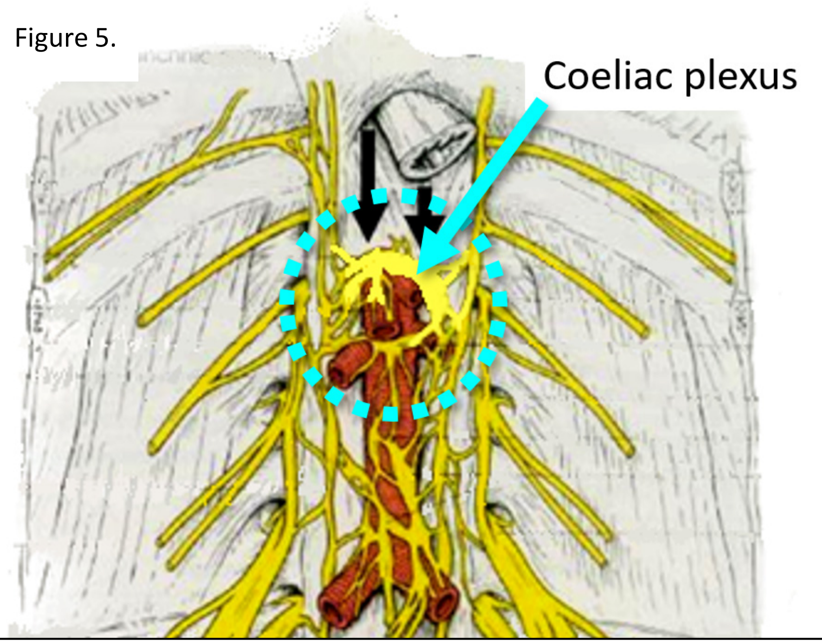


Figure number 5 shows the retroperitoneal pre-aortic autonomic nerve plexuses. The upper black arrow indicates where the terminal vagus nerves (parasympathetic) blend into the Coeliac plexus after passing into the abdominal region from behind the diaphragmatic crura. The blue circle encloses the nerve mass of parasympathetic and sympathetic nerves and ganglia forming the Coeliac plexus. The Coeliac plexus is located anterior to the aorta and around the coeliac artery branches. This all lies under a covering of peritoneum of the lesser peritoneal sac behind the stomach.

Practical technique guidelines for intra-peritoneal blocks.

Injecting larger drug volumes produces better results than injecting small volumes of drugs. Volumes need to be enlarged by dilution, in order to restrict local anesthetic absolute milligram doses to safe amounts. Use volumes of 80 ml for intraperitoneal blocks. Diluting the local anesthetic lot, however makes the block ineffective because of low local anesthetic concentration[9]. That then becomes a good indication to alkalinize the solution, which will increase the UN-IONIZED molecule fraction, which is the local anesthetic molecule portion that enter an axon to produce nerve blockade.

Longer acting drugs work better than shorter acting drugs. The ideal drug to prepare a block solution is *bupivacaine 0.5% with epinephrine 1:200 000*. The epinephrine (adrenaline) has the advantages of slowing down and minimizing the blood absorption peak of local anesthetic, extending the "reservoir effect" of the pool of local anesthetic that remain in the peritoneal cavity thereby extending the block duration to 24 hours. It also enhances the degree of analgesia.

OF NOTE: Alkalinizing full strength local anesthetic solutions for peripheral nerve blocks, in order to increase the active unionized drug portion hardly has any advantage as the non-alkalinized solution perhaps already achieves close to the maximum best block the drug type is capable of. Drug precipitation occurs if the solution is excessively alkalinized, and the solution become milky in appearance. However, alkalinizing a _diluted_ drug solution seems to have a big effect. It makes the drug behave as if were not diluted and is very satisfactory. This achieves large drug volumes with a high concentration of _unionized LA molecules_ while restricting total drug doses in milligrams. If any cloudiness appears in the solution discard and remix. Cloudiness is drug precipitation and is easily seen.

Recommended IPRA mixture (average 75kg adult);

- Take 150 mg bupivacaine with 1:200 000 epinephrine (adrenaline) which is 30 ml of a 0.5% solution. Dilute it to 100 ml with 70 ml 0.9% saline and add 1.25 ml 8.5% Sodium bicarbonate at the last minute.
- If preparing 5 twenty ml syringes admix as follows; (i) 6 ml 0.5% Bupiv.+epi, (ii) 13.75 ml 0.9% saline, and (iii) 0.25 ml 8.5% Sodium bicarbonate at the last minute.
- Use 20 ml for injecting skin incision sites and instill 80 ml into the peritoneal cavity at the end of surgery without drainage.
- Use NASID's and a small amount of morphine (3-5 mg) or similar as multimodal analgesia.

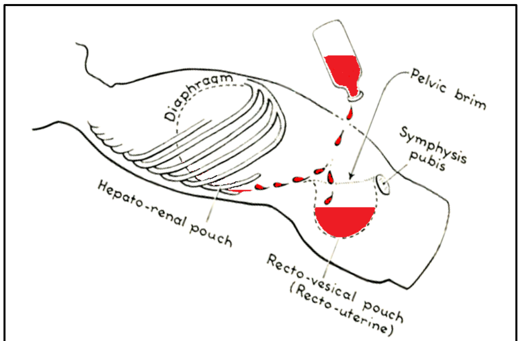


Figure 7. Tilting the head up, to direct the local anesthetic towards the pelvis.

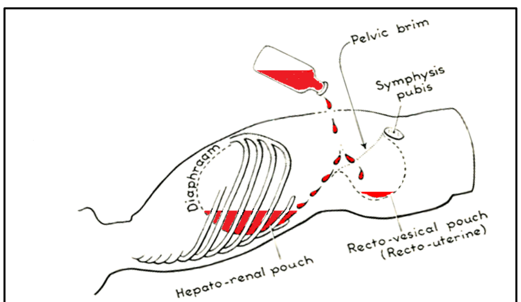


Figure 8. Tilting the head down, to direct the local anesthetic towards the Coeliac plexus.

Shift the IP local anesthetic towards the abdominal part where the surgery was, for 10 minutes. Tilt head 10^0 to 20^0 up for gynecologic surgery, and 10^0 to 20^0 head down for gall bladder and hiatus surgery. With the head down, the drug solution will then form a pool around the Coeliac plexus only separated by a layer of peritoneum. With the head upwards, the solution will fill the pelvis, diffuse out and block the sympathetic and parasympathetic nerves running just under the parietal peritoneum on the sides. See figures 7 and 8.

IPRA can be administered four ways;

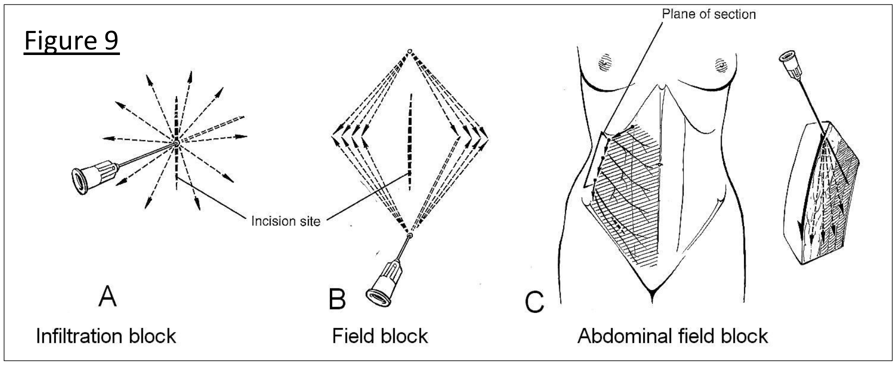
1) By **injection** into splanchnic organs. This is effective where the surgery is small, but the analgesia is very short lasting. The surgeon would do this.
2) By **spraying** the splanchnic organ operated upon with LA. This has been generally unsatisfactory. The surgeon would do that.
3) By **aerosolizing** the LA into the laparoflation gases. This is probably not worth doing. One assessment of the concept, used different CO2 insufflator humidifying systems to vaporize local anesthetic into the peritoneal gas was shown to be ineffective in terms of adding local anesthetic to the gas[10]. It would also be hard to determine the amount of local anesthetic absorbed.
4) By **instillation of a fluid pool** into the peritoneal cavity. This is the recommended method. The local anesthetic can be injected at the conclusion of surgery prior to closure of the peritoneum, or removal of the laparoscopic ports. This the surgeon can do. Where the abdomen was open via long incision, the peritoneum should be closed, then the local anesthetic injected via a canula place into the abdominal cavity. The canula can be removed, upon completion of injection. This is the most studied method and seemingly the best technique presently. Finally tilt the head up or down as needed for about 4 to 20 minutes. The tilting can be repeated in the postoperative period, about every 4 hours. See figures 7 and 8.

The free fluid pools towards the deepest posterior recesses of the abdomen and diffuses through the peritoneum to soak the autonomic nerves. The target nerves in the upper abdomen is the Coeliac plexus. The target nerve for the distal colon and pelvic organs are the various sympathetic and parasympathetic nerves in their assorted paths from spinal cord to the lower abdomen via multiple nerves running posterior and lateral, to the lower peritoneal cavities, and immediately under the peritoneum.

2) Abdominal wall infiltration *(infiltration block, field block, abdominal field block).*

This is one of the oldest local anesthesia techniques for analgesia after abdominal surgery. The best indications are repair of hernias not involving viscera or visceral peritoneum. In general, abdominal wall blocks are futile after intra-abdominal procedures such as bowel resections. The reason is that visceral pain is greater than somatic pain and the absence of the relatively little abdominal pain goes unnoticed. Abdominal wall infiltration after extensive intraperitoneal dissection usually does not produce any measurable analgesia due to the untreated *splanchnic pain* is.

In recent times the device trade has attempted to market disposable infusion devices for wound local anesthetic infusions as if it were a new technique. The block is remains old and only the device is new. The technique is inferior to all other regional anesthesia options for the abdomen generally.



See figure 9. *Infiltration block* is injection into the intended line of incision. *Field block* is injection to the sides of the incision (beforehand or afterwards). *Abdominal field block* is a widefield block exploiting known nerve paths. The abdominal field block has been superseded by the thoracic paravertebral block and the Ultra-Sound guided TAP block now.

Infiltration in the line of incision done before incision is best. Post-incision infiltration into the sides of the open wound (or after closure) is still satisfactory however. The block can also be sustained by continuous infusion of local anesthetic into the wound[11].

In one gynecologic study of 68 patients undergoing surgery with a vertical midline incision and were randomized to receive wound infiltration with 0.5% ropivacaine or 0.9% saline. Injections were done before surgery. There was no difference in pains scores between the groups. This illustrates the futility of abdominal wall blocks if the splanchnic pain is untreated.

In one other gynecology study the patients had transverse (Pfannenstiel) incisions. Infusion catheters were placed into the wounds using either 0.1% or 0.2% ropivacaine by PCA at 9ml per bolus, with a 2-hour lockout, if needed. Both groups used the Local anesthetic PCA equally and both groups needed rescue doses of about 9 mg of morphine in the first 6 hours after surgery.

3. Inguinal hernia field block

Figure 10 is typical right-side inguinal hernia repair (cephalad, top of picture) that this block is ideal for. This block is a classic nerve block, and has been well practiced. It is easy to do. There are a few nuances that need to be known. A surgeon can also do this block if trained and experienced with the block. It is ideal however for the anesthesia provider to do the block ten to 25 minutes prior to preparations for surgery.

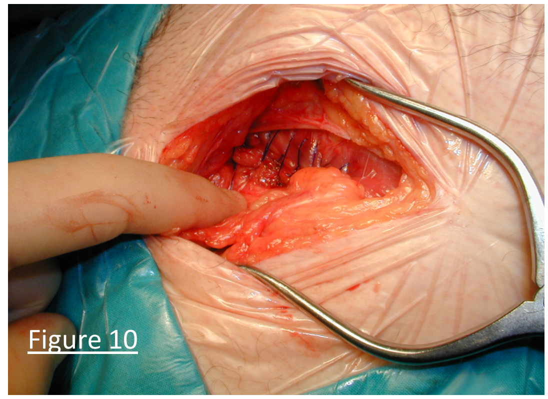


Figure 10

See figure number 11.

Injection #1. Insert a 5 cm needle 1 cm medial to the anterior superior iliac spine (ASIS) and direct it in a plane towards the umbilicus and 45 degrees to posterior. Use a blunt needle (nerve block needle) and advance until a second "pop" is felt. Don't exceed 4 cm. Inject 10 ml of local anesthetic in the tract as the needle is withdrawn. More drug should be injected deep, and in the middle than in the most subcutaneous part. That covers the Iliohypogastric and ilioinguinal nerve branches.

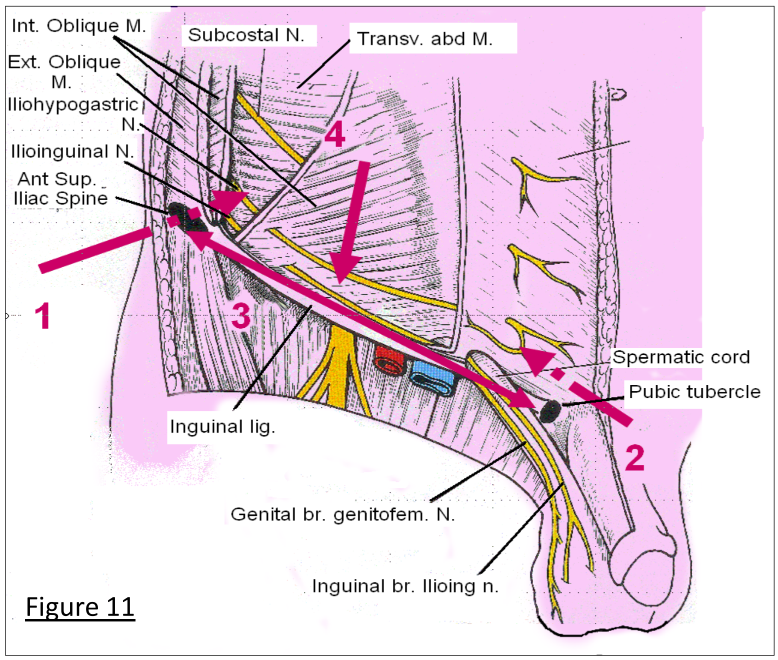


Figure 11

Injection #2. Palpate the pubic tubercle (PT). Inject subcutaneous towards superolateral and deep subcutaneous too (even into the first muscle layer). Inject 5 ml of local anesthetic. A second injection may be made from here direct cephalad for wide surgical incisions. The surgical incision should not cross this vertical injection line.

Injection #3. Use a 22G Quincke point 3½ inch spinal needle and infiltrate subcutaneous for the length of the incision. It is useful if the surgeon can mark this incision before injection. Use 10 ml of local anesthetic.

Injection #4. Palpate the internal inguinal canal ring with a finger. Insert a needle immediately lateral to this point and inject 5 ml of local anesthetic deep at the depth of the palpated ring. The drug spreads and blocks the peritoneum extruding into the hernia canal.

Case management: This block is fully complete for awake surgery provided the surgery does not involve more than insertion of a finger into the abdominal cavity. With very large hernias and extensive bowel handling addition of a light general anesthetic is advised. For healthy younger patients, light general surgery is best. Post operative analgesia will be profound and bupivacaine will last 12 to 18 hours. Warn patients to take oral analgesics at first signs of returning sensation even if still feeling comfortable. Failure to take oral medication early may result in severe pain when the block resolves.

Even if it is not planned to do awake surgery, it is still injecting this block for early post-op analgesia benefits, and the lighter general anesthetic that will result.

Alternate blocks for inguinal hernia are, T12 plus L2 paravertebral blocks together, US guided TAP blocks, US guided ilioinguinal / iliohypogastric nerve blocks. Choice can be based on the anesthesiologist's personal skills.

ANECDOTE: This author once administered this very classic inguinal hernia block, to a surgeon that he worked for regularly. The surgeon had strongly wished to be conscious during the repair of his own inguinal hernia, while being operated upon by a second surgeon. All went well initially. The patient-surgeon was instructed to take a full dose of a NSAID and acetaminophen before going to sleep in the evening. This was to cover the transition period of analgesia between the nerve block phase and the oral analgesia therapy phase. This evening consumption of oral analgesia, even if the pain was zero at that time, is in anticipation of the nerve block wearing off during sleep. The surgeon-patient did not comply with the author's anesthesia instructions and awoke at 2 am in severe pain. He took oral analgesia at that time but it took until the second dose 6 hours later to achieve best analgesia.

The patient-surgeon upon returning to work some time later stated that he would be emphatic telling his future regional anesthesia patient with no pain after surgery to take pain tablets before going to sleep.

If pain, after complete regional analgesia, starts before the evening, the patient should take pain tablets at the very first sign of feeling in the surgical area, even if it is not actually hurting yet.

4. Intercostal block.

This is a historic classic nerve block. The thoracic paravertebral block and the USG T.A.P. block are better blocks for the same indications. Multiple intercostal blocks usually need to be done. This is a useful block for unilateral incisions (e.g. subcostal incisions for splenectomy or open cholecystectomy). The benefit will be maximal, if the viscera also receive an appropriate autonomic nerve block, as a Coeliac plexus block.

Unfortunately, it is one of the nerve blocks with the highest incidences of local anesthetic toxicity. That is probably associated with the fact it has traditionally been performed using sharp hypodermic needles, which readily puncture the subcostal artery and veins. Accordingly, this author strongly recommends, if ever this block is performed, it should be done with a blunt tip nerve block type needle.

See figure number 12. Identify the target rib on the anterior axilla line as in "A". Then advance the needle off the caudad edge of the rib as in "B" advancing exactly 3mm beyond the bone. Aspirate to exclude Intravascular (IV) needle placement before injecting local anesthetic. Inject 5ml of local anesthetic. The Moore technique recommended moving the needle 2 mm back and forth during injection. This likely increases the known risk for IV injection, and this is strongly not recommended. Better inject at only precisely one point and only after safe aspiration. The T12 nerve is the subcostal nerve that is not easily blocked as it runs less closely to the cephalad rib than the other thoracic intercostal nerves do.

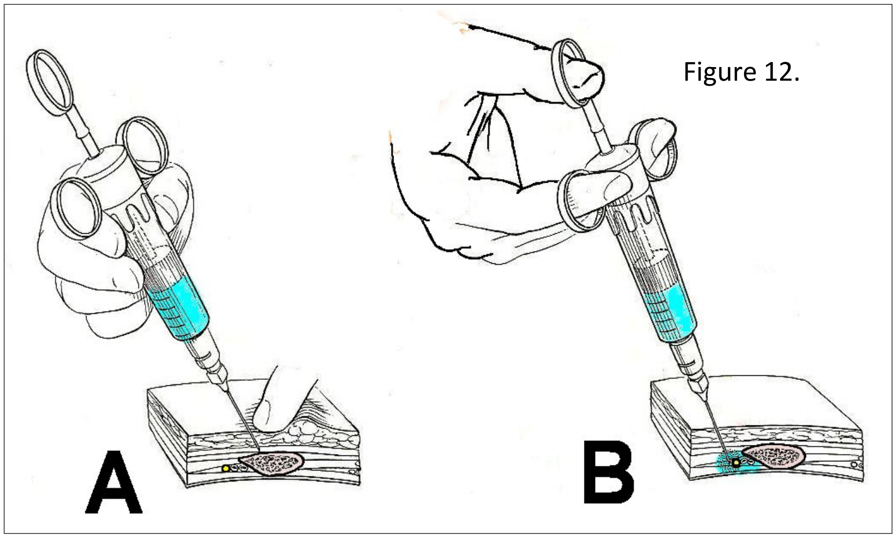


Figure 12.

The intercostal block is limited by its relatively short duration, its highest incidence of LA toxicity, and the need to inject every intercostal nerve requiring blockade, separately. Toxicity is likely due to partial intravascular injection due to using a sharp needle close to arteries and veins. Pneumothorax is a risk.

5. Thoracic Paravertebral block (TPB) - landmark guided technique

There are four advantages of thoracic paravertebral block (PTB) over intercostal block;

i. The *sympathetic roots* to the sympathetic chain are also blocked. This may result in some splanchnic analgesia if the appropriate nerve levels are blocked. Parasympathetic block (Vagus) however is not achieved, nor block of the contralateral sympathetic chain.
ii. The local anesthetic *drug spreads readily up and down to the adjacent nerve roots* from one injection point. A single level injection can achieve a multi-level block.
iii. The paravertebral block has historically been associated with less pneumothoraxes than intercostal blocks.
iv. The paravertebral block has historically been associated with less local anesthetic toxicity

Figure 12

Bilateral paravertebral blocks can be used for awake midline abdominal surgery, if combined with a coeliac plexus block. See figure 12 from Pauchet's French book on Regional anesthesia in 1921. This man underwent a fully awake gastrectomy under paravertebral and coeliac plexus blocks.

This block is a 100-years old, and has been reviewed many times [12], [13], [14], [15], [16], [17], [18], [19], [20], [21].

The landmark based paravertebral block is technically easy to perform, but requires supervised teaching and a fine touch and feel in the hands. It is a tactile block in that one can sense the Loss Of Resistance (LOR) as the needle tip enters the paravertebral space. It is also tactile because one can sense the blunt needle give a "Pop" feeling as it exits the cost-transverse ligament sometimes. In addition, it is a tactile block because with nerve stimulation the *patient* may report paresthesia and muscle twitching in the front abdomen within the transverse band-like zone of the dermatome of the paravertebral level. An assistant may also observe a band of muscle twitch in the abdomen.

The paravertebral block has many subtle technicalities, and should never be attempted unsupervised by a novice to regional anesthesia. It is helpful to already be skilled in the use of ultrasound, as well as be experienced with the "feel" of epidural blocks before attempting one's first paravertebral blocks. It is also best performed if the practitioner has sufficient cases to exceed doing 6 cases per year, or preferably 12 or more cases per year.

The advantages of the landmark technique over the plethora of ultrasound techniques is that the needle tip position is the perfect position to place a paravertebral catheter that will sustain nerve a multi-segment block over a number of paravertebral segments up and down. Drug can spread to adjacent segments with volume needed of 2,5 ml per segment. For example, injection 10 of local anesthetic should block 2 segments up and 2 segments down yielding a 5-segment block including the segment injected at.

Single shot paravertebral blocks are not long lasting and the intervention is barely worth doing unless extended with catheter infusion that will produce a multi-segment block. That perfect position is exactly 2.5cm from the midline. A distance of 3cm from midline may be used with the lowest two paravertebral blocks, namely T11 and T12. Those distances from midline cannot be determined with the majority of ultrasound guided techniques that are promoted. The land-mark technique marks that distance on skin preceding needle insertion. This suggest a combination technique or FUSION technique is best.

- An ultrasound needle tip that is than 2.5 cm from midline will have an excessive epidural block component, and excessive contralateral paravertebral blockade.
- An ultrasound guided needle that ends further than 2.5 cm from midline will not spread well to adjacent ipsilateral paravertebral segments, thus requiring extra injections at each level needing blockade. Alternatively, phrased, a needle further from midline than 2.5 cm acts more like an intercostal block that does not spread to adjacent nerve levels.

The paravertebral space can be also be catheterized allowing continuous infusions. Using manufactured ropivacaine 0.2% solutions, without additives, run at 8 to 12 ml per hour is recommended.

COMPLICATIONS and SIDE EFFECTS of land-mark guided THORACIC PARAVERTEBRAL BLOCK

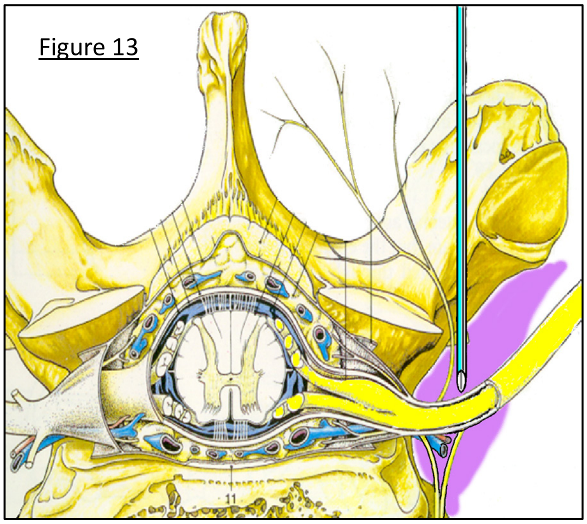
1. NEURAXIAL BLOCK. Spinal, epidural or subdural blocks can occur[22]. The risk for this is increased by a medial direction insertion of needles, as with some ultrasound guided techniques. The risk is operator and technique dependant. Block is then symmetrical on both sides.
2. SHORT SEGEMENT CONTRALATERAL BLOCK. This is not a complication and is a common *side effect*. Evidence suggests that the risk goes up with bigger injection volumes and may approach 10% with single level injections of 20 ml of local anesthetic. This is usually harmless. The short segment contralateral block can be from absorption of some drug into the epidural space via intervertebral foramen diffusion Drug that has diffused into an adjacent space has about a quarter to half the concentration of the first drug injected and a lower grade block result. An alternate mechanism has been demonstrated where the drug spreads prevertebral anterior around the vertebral body sub fascial [16, 23].
3. NERVE INJURY. This theoretical risk has not yet been reported.
4. INTRAVASCULAR INJECTION. This is the same risk as with all regional anesthesia.
5. SEPSIS. This theoretical risk has not yet been reported.
6. HAEMATOMA. This theoretical risk has not yet been reported.
7. BLOCK FAILURE. Block failure can result from inappropriate segment blocking for the surgery. Technical failure is operator dependant and experience dependant.
8. PNEUMOTHORAX. The thoracic paravertebral block (TPB) pneumothorax risk should be less than the risk seen with intercostal nerve block because the needle tip is further from pleura than with an intercostal nerve block and a blunt needle is used with TPB. If with TPB the parietal pleura is penetrated the visceral pleura should not be penetrated as it is firm resisting penetration and also mobile yield to the blunt needle. This means the only access for air to the pleura is via the needle and thus ceases when the needle is removed. Pneumothorax risk is very operator dependant and training dependant.

This author with a memory-based, approximately 1000 case experience, has never had to drain a **paravertebral block associated pneumothorax**. The author has however observed occasional pleural cavity penetration with the nerve block needle. This occurred during the author's own novice period and in the hands of other novice trainees. Six cases are recalled. The penetration of the pleural cavity is strongly suggested if a very clear snap is felt by the fingers gently holding the advancing Touhy needle. The posterior parietal pleural is reinforced by the endothoracic fascia and uniquely produces a "snap'' feeling as it gets penetrated. It is a distinct feeling. This feels different to the feeling of the needle penetrating other costo-cost transverse ligaments or an epidural puncture.
Secondly a drop of fluid hung in the open hub of the needle will suck in fast and instantly. Remove the needle immediately before much air is aspirated. Four cases X-ray showed zero pneumothorax. Two cases revealed 1-2 cm of air in the plural space. In those particular two cases a teaching question was asked just before the hanging drop test was done. That delayed the hanging drop test and the subsequent confirmation of pleural penetration. The delay of about three minutes allowed enough air to entrain to form a visible 1-2cm pneumothorax. The two pneumothoraxes absorbed in

ANATOMY OF THE PARAVERTEBRAL SPACE (PVS)

The paravertebral space (PVS) lies immediately lateral to the intervertebral foramen where the nerve roots exit the spinal canal. See figures numbered 13 and 14.

Figure 13



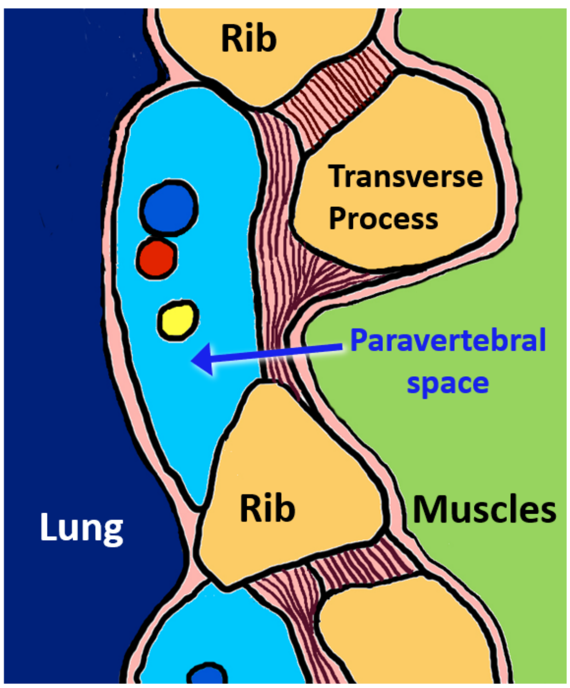


Figure 14. Parasagittal view of the T8 paravertebral space.

The rami communicantes to the sympathetic chain are given off in the paravertebral space. The nerve root divides into (i) a dorsal branch which turns immediately to posterior whilst the (ii) the ventral root runs to lateral to associate with the infero-anterior edge of the corresponding rib. Posterior to the paravertebral space is the anterior surface of the lateral vertebral processes and the dorsal spinal muscles and their anterior fascias in between the lateral processes. Anterior is the Parietal pleura of the chest. This parietal pleura overlying the PVS is thicker than the parietal pleura elsewhere and offers resistance to a blunt Tuohy needle which is palpable as an obvious "pop" or a "snap" if penetrated with a blunt needle. Penetrating the parietal pleura elsewhere, for example when performing interpleural blocks, penetration from anterior is entirely unfelt.

The best description and illustrations of the paravertebral space anatomy, is by Krediet[24]. They studied the paravertebral space using high definition photographs of 0.74 mm slices of frozen cadaver. The photographs were scanned and digitally reprocessed so as to be able to generate additional sectional views of the tissues studied in any plane and orientation desired. The paravertebral space, on its medial side is bordered by the vertebral body, intervertebral disc, and the intervertebral foramen. To superior and inferior the paravertebral space has a bony pair of one rib and one transverse process. The rib's most medial tip, the head, joins the vertebral body with a fibrous joint. The neck of the rib is free as it turns to posterior. Where the rib meets the tip of the transverse process, its tubercle has a second joint securing it to the transverse process. The bone pair of rib and transverse separates each paravertebral space from the paravertebral space above and below.

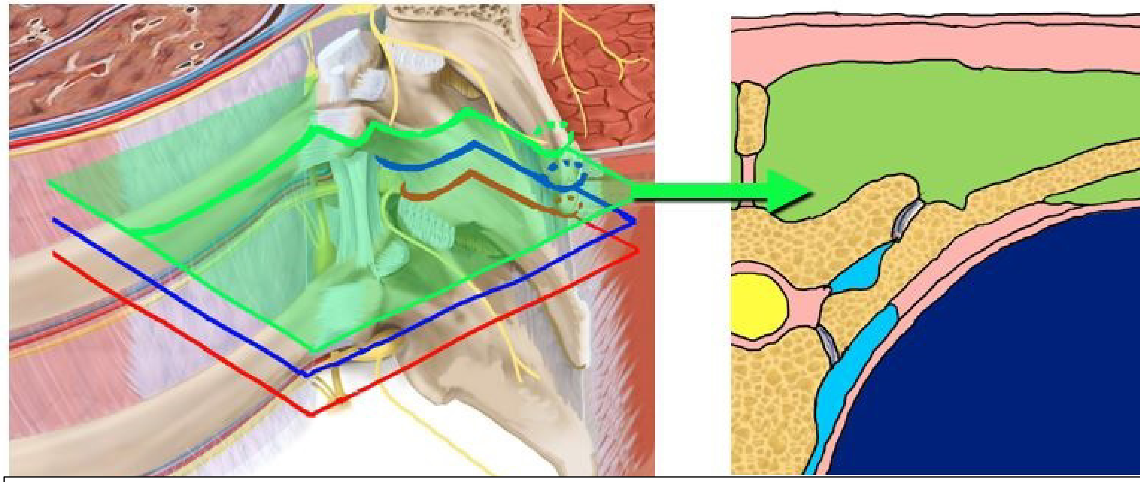


Figure 15. A **top sectional view** of the T8 paravertebral space, at the level of the transverse process.

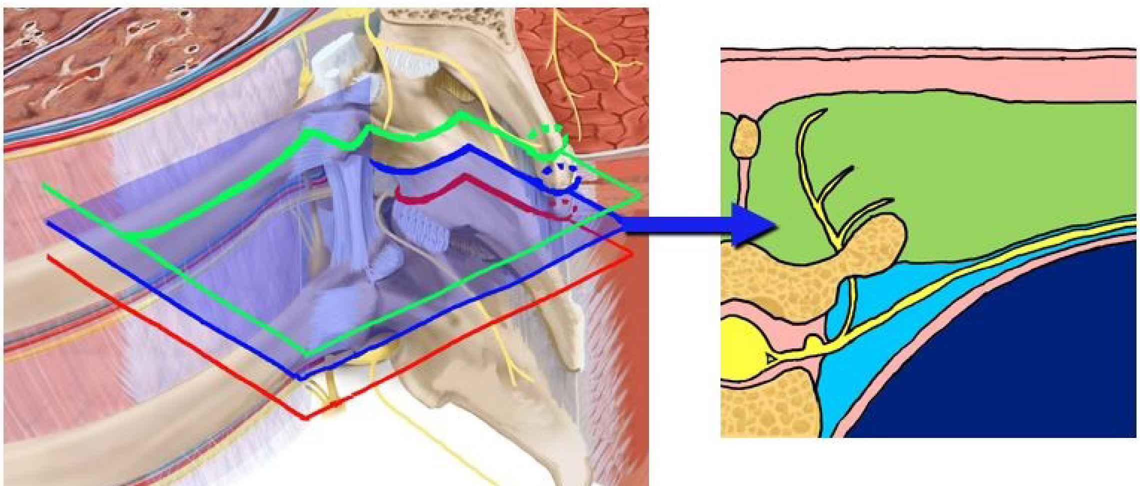


Figure 16. A **mid sectional view** of the T8 paravertebral space, at the level of the transverse process.

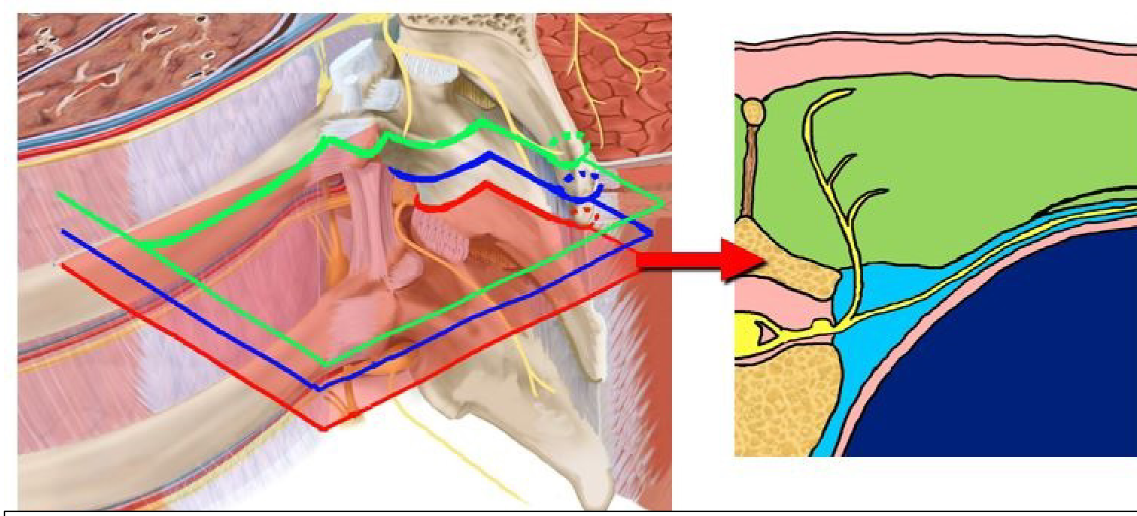


Figure 17. A **bottom sectional** view of the T8 paravertebral space, just above the next rib downwards.

Posterior to each paravertebral space is the rib-transverse bone pair that also turns caudad, and the superior costo-transverse ligament (SCTL). The superior costo-transverse ligament (SCTL) is not a continuous sheet from medial to lateral, and has gaps. A needle inserted into the paravertebral space from posterior, may sometimes be felt to puncture through superior costo-transverse ligament, and other times the needle passes adjacent to it with no feeling of resistance. The SCTL runs from the superior border of the rib to the lower border of the next transverse process lying cephalad, and in a plane more posterior. Lateral to the deepest part of the paravertebral space is pleura. The paravertebral space follows the rib to posterior and curves to lateral with the rib communicating with the intercostal space. The pleura thus lies more anterior, relative to the more lateral paravertebral space.

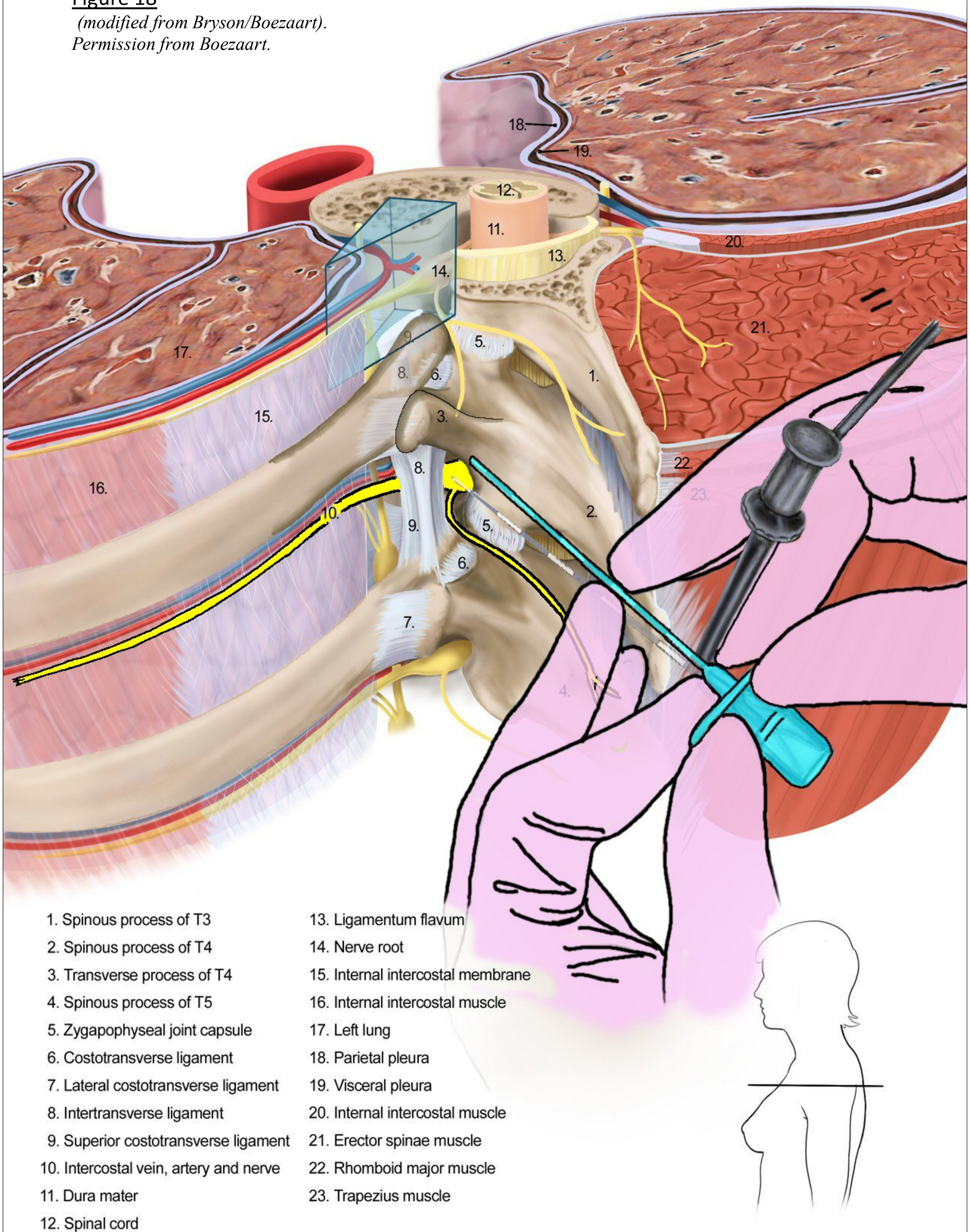
Posterior to the line of the ribs, transverse processes and costo-transverse processes lie the dorsal deep back muscles. The SCTL joins the internal intercostal membrane. The endothoracic fascia lies posterior to the pleura covering the paravertebral space, and is continuous with the prevertebral fascia. If very large drug volume is injected paravertebral sometimes it can spread to the contralateral paravertebral space passing under the prevertebral fascia, anterior to the vertebral body.

The paravertebral space is *filled* with loose small fat globule, blood vessels and nerves. The nerves are the intercostal nerve and the sympathetic trunks connecting to the sympathetic chain. Of great significance, each paravertebral space communicates with the adjacent paravertebral spaces via fat filled channel anterior to the *neck* of the rib against the pleura. Drug injected intercostal cannot communicate with adjacent intercostal spaces as they lack any similar cephalad and caudad channels.

Caudad to the T12 paravertebral space there is no clear communication space towards the psoas muscle, and drug spread is not dependable. Equally, upward drug spread from L1 or L2 psoas block injections only occasionally reaches the T12 paravertebral space and is not dependable. When apparent drug spread across the T12 L 1 barrier is observed, it is likely from small epidural spread due to very large injection volume.

Superior to the PVS is the rib neck and head. The head articulates with the body of the vertebra. The rib shaft runs towards postero- lateral to touch the tip of the transverse process on its anterior aspect and form another joint. Adjacent paravertebral spaces are continuity and injections spread to the spaces above and below.

Figure 18
(modified from Bryson/Boezaart).
Permission from Boezaart.



1. Spinous process of T3
2. Spinous process of T4
3. Transverse process of T4
4. Spinous process of T5
5. Zygapophyseal joint capsule
6. Costotransverse ligament
7. Lateral costotransverse ligament
8. Intertransverse ligament
9. Superior costotransverse ligament
10. Intercostal vein, artery and nerve
11. Dura mater
12. Spinal cord
13. Ligamentum flavum
14. Nerve root
15. Internal intercostal membrane
16. Internal intercostal muscle
17. Left lung
18. Parietal pleura
19. Visceral pleura
20. Internal intercostal muscle
21. Erector spinae muscle
22. Rhomboid major muscle
23. Trapezius muscle

There are also a variety of costo-costo ligaments and costo-transverse ligaments. See figure 14. The ligaments form part of the posterior boundary of the paravertebral space. They are not continuous from medial to lateral and a nerve block needle will mostly pass through one causing subtle pop to be felt, but if passing medial or lateral to the ligaments no pop is felt. The pop is less clear and “snappy” than that offered by the posterior parietal pleura. The Paravertebral space is continuous with the intercostal space laterally. Injections can spread under the pleura to reach the sympathetic chain too. Finally, if thoracic paravertebral drug is injected fast and in large volumes the drug can diffuse partially into the epidural space. This explains the occasion low grade short segmental block seen contralateral.

The LAND-MARK TECHNIQUE of thoracic paravertebral block

Thoracic paravertebral blocks last much shorter than the average peripheral nerve block, but longer than epidural blocks. On average 15 ml at one level provides analgesia as follows; ropivacaine 0.75% 4-5 hours, bupivacaine 0.5% 7-8 hours, and levobupivacaine 8-11 hours. Boezaart and Raw described a continuous catheter technique using nerve stimulators[25].

It can be generally expected that 15 ml at one level can produce a spread of 2 segments up and down each for total of a 5-level block. This is however not very consistent. Many authors favor multiple level injections for this reason. It has also been observed both in published literature and this author’s experience that paravertebral blocks are of much slower onset than that typical of limb peripheral nerve blocks, e.g. a sciatic nerve block. This may be the reason that spread seemed inconsistent in many studies as the assessments were done too early.

The following approach is recommended. For surgery to be done under GA, do a single block at the spinal level of the middle dermatome of the surgery incision. Use a continuous infusion afterwards of 0.2% ropivacaine at 8 to 12 ml / hour. Inject 15 to 20 ml local anesthetic as the loading bolus.

If awake surgery is planned, it is better to do multiple level injections to hasten block onset. Place the catheter as described above, but only inject 5-10 ml, and then do supplementary single shot injections at alternating levels (every second level) above the catheter level, and below the catheter level. This will accelerate speed of onset of surgical grade block. Single shot drug volumes can range from 3 to 5 ml. The single shot supplements will accelerate the onset of surgical usable analgesia. Otherwise a wait in excess of 40 minutes is advised for full block development.

Local anesthetic studied when injected into the paravertebral space was observed to have a biphasic pharmacokinetic response[26]. The authors used a thin gauge (22G) Tuohy needle. The first phase corresponds with that seen with intravascular injections. Adding epinephrine diminished the blood level peaks and delayed it in time. The addition of epinephrine would seem thus indicated.

This author has performed over 400 paravertebral blocks utilizing a variety of techniques and recommends the following method. It combines multiple end points for needle advancement. It is important to accept any clear end point FIRST presenting and not keep advancing the needle.

Use a nerve stimulator set at 1.5 mAmp current, a large blunt Tuohy needle, and a loss-of-resistance to injection of 5DW. This block requires gentle needle advancement, slow movements and understanding that all "endpoint" of needle advancement are usually very subtle. One must see the tissues within one's mind, through the feeling of the needle tip in the tissues as it advances.

METHOD. .

Position the patient. A lateral decubitus position with surgical side upwards is easy for experienced anesthesiologists. If using the sitting position, the patient must only be very lightly sedated. Novices may prefer the sitting position to retain a better sense of the anterior-posterior plane (AP plane). Lateral decubitus patients often roll slightly forward slightly and the AP plane will not be horizontal. The patient must be breathing spontaneously. If the patient is anesthetized and paralyzed cease ventilation during insertion and disconnect ventilator for one minute during the paravertebral nerve block. Reconnect and start ventilation when the catheter has been inserted. The reason for this is that the paravertebral space pressure is partial negative, relative to atmospheric pressure, during apnea or active inspiration and this enhances some of the subtle technique endpoint signs.

Positive pressure ventilation however, makes both the paravertebral space and the intrapleural space have positive pressures and an intrapleural placed catheter may be unrecognized. Identify the level(s) to be blocked. During the moments prior to paravertebral space penetration with the needle, disconnect the ventilator and leave the endotracheal tube open to air. Reconnect when satisfied with the hanging drop test.

Count the dorsal thoracic spines and mark the level(s) to be blocked. Prior ultrasound location of the bony transverse-rib structure is useful, and marking it on the skin prior to needle insertion is very helpful.

Use a large gauge Tuohy needle to maximize the feeling of resistance in the tissues, as well as to perform the Loss-of-Resistance injection technique. Use a maximally soft tip flexible catheter. The Arrow brand Stimucath, is the only very flexible tip catheter. The flexibility assures the catheter will curl up at the needle tip with very little chance of running towards undesired areas, such as to medial towards the epidural catheter. Also ensure when advancing a catheter that the Tuohy needle tip is never facing towards medial. T o enhance the softness of the catheter pull the stiffening stylet back by 2 cm. Also feed the catheter only 2cm beyond the top of the needle.

Infiltrate with local anesthetic, in awake patients. It is not necessary to anesthetize all the way to the transverse process usually.

Place the needle onto the bone of the transverse process. Insert the needle through the dorsal skin exactly 2.5 cm from midline. Successively insert the needle deeper probing systematically in a cephalad-caudad parasagittal arc until the transverse process is located. Advance the needle CAUDAD off the bone staying in a parasagittal plane (deviating neither to medial nor to lateral). Advance slowly while gently injecting 5% DW with a loss-of-resistance syringe.

Stop advancing when ANY one of the following FIVE endpoints is reached.
Loss of resistance to injection of 5% DW is felt. It is subtle and less obvious than with an epidural. A feel of a subtle "pop" after the needle passes through a cost-transverse ligament or other fascia. A pop is not consistently observed as the ligaments are not continuous in medial to lateral plane. It is usually subtle but if it is clear and snapping it is more likely the posterior parietal pleura that has been penetrated. Reaching a distance of 1.25 cm beyond last bony contact. Evidence of intercostal muscle twitching. As the breast and the pectoral muscles conceal the intercostals muscle in the chest it is helpful to have an assistant place a hand against the chest in the axilla to feel for intercostals twitching. In the abdomen the abdominal wall muscle will twitch in the corresponding thoracic dermatomal distribution. Use a current of 1.5 to 2 mAmp and there is no reason to test the needle position with lower currents. Report from the patient of feeling of a tapping paresthesia anteriorly, e.g. in the breast or nipple.

Exclude pleural penetration by placing a saline drop onto the open hub of the Tuohy needle. Asses how the drop behaves;

Responses:

- No drop movement = extremely unlikely pleural. **Insert the catheter.**
- Drop moves in and out with respiration = common = extremely unlikely pleural. **Insert the catheter**.
- Drops sucks in slowly, and same again with each applied new drop = possibly pleural penetration (small chance). Then act as follows;
    - Management of this Possible pleural penetration.
        I. If there was no preceding snapping "pop" and the PVS was identified within 1 cm of the last bony contact LOR, or by nerve stimulation (motor or sensory). Trust the needle position. Pass the catheter.
        II. If the catheter advances with any small resistance, the needle position is perfect in the PVS.
        III. If the catheter advances with zero resistance regard the needle/catheter as intrapleural and redo the block.
- Drops placed in the needle hub suck in vigorously = definite pleural placement. **IMMEDIATELY remove the needle and redo the block**.

FLUOROSCOPY AND CONTRAST

This is only necessary for lytic nerve blocks in pain clinics, and where a very specific level has to be blocked.

POST PROCEDURE CHEST X-RAYS. Not routinely needed.

CONTRA-INDICATIONS FOR PARAVERTEBRAL BLOCK

The standard contra-indications common to all nerve blocks apply, such as allergy to the drugs, lack of patient consent, sepsis at the site of injection, and lack of expertise by the medical practitioner.

Specific contra-indications to thoracic paravertebral block are few, rare and relative.

1. Anti-coagulation therapy or pathological coagulopathy. There are no science-based guidelines, nor case reports of complications attributed to abnormal coagulation. Full anti-coagulation is a risk for bleeding. Partial anticoagulation may become is a relative *indication*, if morphine sparing analgesia is a patient priority and epidural analgesia is more contraindicated.
2. Skeletal anatomical abnormalities, e.g. kyphoscoliosus. Prior X-ray examination is recommended before attempting this the block.
3. Stripping of the pleura surgically.

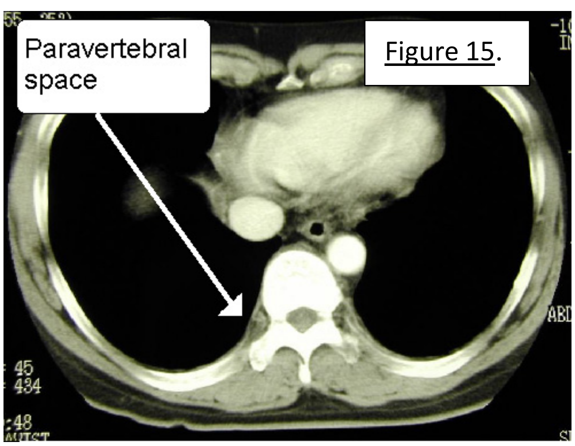
6. Ultrasound guided Thoracic Paravertebral Blocks.

There is no standard or common technique. It is also a fact that simply adding an ultrasound transducer to a technique does not automatically make the nerve blocker, easier, better, safer, or faster.

The one big challenge is ultrasonography cannot display the relatively small nerves of the paravertebral space. So thus, the object of ultrasonography is to indicate the ***space*** occupied by the nerves. This brings the second challenge to the fore. All the relevant bony surfaces and fascial surfaces slope at big angles different to the orientation to the skin, as well as to each other. A structure is only optimally imaged if sonographic waves can impinge on it perfectly vertical so as to reflect directly back to the transducer. Adjusting the transducer angle to the skin to optimize one deeper structures sono-image will make other relevant structure less visible.

The ultrasound guided techniques can be classified as follows:

- **Transverse off-plane FUSION landmark technique**- Recommended as the 2nd best technique.
- **Transverse off-plane K1 technique**- Third best technique.
- **Transverse in-plane K3 technique**. This is a dangerous technique and not a paravertebral block, but a very medial intercostal block. It absolutely requires multiple injections.
- **Paramedian oblique parasagittal in-plane K3** technique. Far too complex for average practitioners. This is not a recommended technique.
- **Parasagittal in-plane technique.** Difficult, dangerous, inconsistent. This is not a recommended technique.
- **Parasagittal off-plane FUSION technique.** This a simultaneous controlled movement of both the needle and transducer as the needle advances. It is readily mastered by technical geniuses with advanced 3-D spatial perceptions, and in-depth anatomy knowledge and experience. It is the 1st best technique.



See figure number Figure 15. It shows the chest in a CT cross section view. The target paravertebral space is shown. Observe that the paravertebral space has a depth of about 2.5 to 3cm, and its breadth is about 1.5 cm in adults. The paravertebral space is located immediately to lateral of the intervertebral foramen from were ta intercostal nerve emerges. There is a rib above the paravertebral space towards cephalad and below a rib below it towards caudad that are not seen on this axial sectional view. Pleura lies both deeper to the paravertebral space, as well as lateral to it.

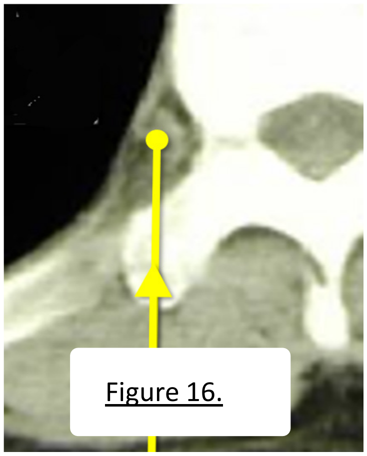


Figure 16.

See figure number 16. It is a CT transverse sectional view through a thoracic paravertebral space. It shows the ideal position for the needle tip to end at. That positon is exactly in the middle of the paravertebral space in all axes.

The pleura lies 1 to 2 cm deeper if the needle were to continue advancing. The pleura however only lies 1 cm towards lateral were the needle to have been directed to lateral f the idel 2.5cm distance from midline. The epidural space and vertebral canal lies 2 cm to medial and is inaccesible by this direction of needle insertion. Ultrasound guided techniques that utilize a lateral to medial shallow approach can easily enter the epidural space.

Never use any technique that has a needle direction from lateral to medial. If the needle imaging is imperfect, and needle tip cut-off occurs it becomes possible to advance the needle into the spinal cord at very worst, or into the vertebral canal still very bad. It is also impossible with the lateral to medial approaches to determine if the needle tip is precisely 2.5 cm from the midline, in the optimal position.

The paramedian in-plane techniques cannot sufficiently define the deep structures if it is held perfectly vertical in a prone patient. Conceptually the transducer could be placed on a skin drawn line that is precisely 2.5cm from midline, and aiming directly towards anterior. If then any side tilting is done with the transducer to improve deep tissue imaging, it will no longer be capable of keeping the needle track all the way at 2.5cm from the midline.

Thus, the recommended techniques are fusion techniques. A line is marked on the skin 2.5 cm lateral to the spinal midline. The ultrasound is used in an off-plane fashion to identify the two boney structures of transverse process and rib jointly. The bony structures position is marked on the skin. The needle is inserted through the 2.5cm line over the bony structures marking. The transducer may then either be held in the transverse or in the parasagittal position, adjacent to the needle already 1.5 cm deep inserted in the flesh. From this time the transducer may be side tilted so as to image the needle tip off-plane as it advances towards the transverse-process-rib structure. Once the needle tip is placed against bone the ultrasound is abandoned. The Tuohy needle is then advanced using tactile feeling, loss-of-resistance, and nerve stimulation. Needle advancement ceases when one of five end points is reached. Often 2 or three end-points are reach simultaneously;

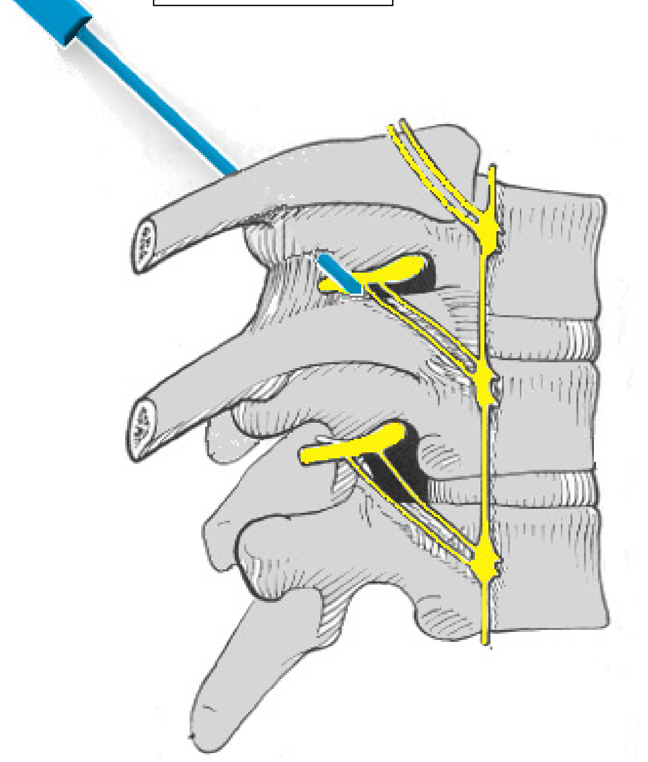
NEEDLE ADVANCEMENT ENDPOINTS;

1. The needle tip is 1.5 cm beyond the last point of bone contact.
2. The patient reports a dermatomal sensation in the distribution the nerve root being stimulated,
3. A subtle loss-of-resistance is felt to have happened.
4. Motor twitching can be seen in band on the abdomen, if the patient is sitting. The band will correspond with the nerve root being targeted.
5. The hanging-drop test passes.
   - A failed test is when the *drops sucks in very fast*, where upon the needle must be withdrawn.
   - A successful test is the drop either (i) does not move at all, (ii) as often, its moves in an out slightly in cycle with the patients breathing.
   - NOTE: If the hanging drops suck in fully and very slowly, and the patient is in the sitting position the needle position can be further tested by

passing a catheter. A catheter being correctly advanced into the paravertebral space will offer resistance of some degree being slight or substantial. If the catheter advances as easily as if it were being advanced into an open space, then consider that as being in the pleural cavity and remove needle and catheter. In this author's personal experience, a very slow-sucking-in drop has only occurred in sitting patients when performing higher paravertebral blocks for breast surgery, and none ever correlated with pleural penetration. The explanation for these general observations is that the paravertebral space is intrathoracic and subject to issues pressure that could potentially fall sub-atmospheric during inspiration particularly if the breath is big. The pressures are however less negative than those actually observed in the pleural cavity itself.

6. The catheter passing test. This test does not have to be done if it is only intended to inject a single shot block at this point, and at least one other block end point has been satisfactorily reached. If a catheter needs to be passed, do observe the degree of resistance that it offers as it leaves the needle.

Figure 17.



See figure number 17. It shows a lateral view of the thoracic vertebral with transverse processes and ribs. The intercostal ribs are seen exiting the intervertebral foramina to enter the paravertebral space. Also see the nerve connections between the intercostal nerves and the sympathetic chain on the sides of the vertebral bodies.

Next observe the nerve block needle inserted from posterior and passing immediately below a transverse process, and penetrating the costo-transverse ligament to enter the paravertebral space.

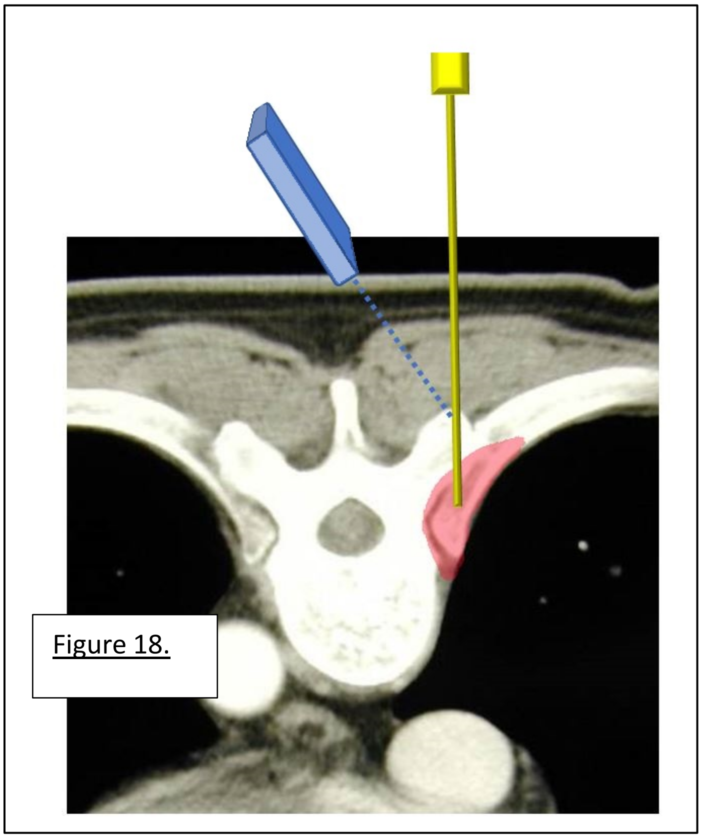


Figure 18.

See figure number 18. It shows at CT sectional view of a thoracic paravertebral space, highlighted in pink. A needle has been passed into the paravertebral space 1cm beyond the last point of bone contact. The needle tip is opposite the intervertebral foramen and dead center in the paravertebral space.

The ultrasound transducer is held parasagittal, and oblique to the nerve block needle on its medial side. The transducer is "looking" at the transverse process, and was used to guide the needle downwards as the needle was inserted. The ultrasound was also used to locate the axial position of the transverse process before the needle was inserted into skin.

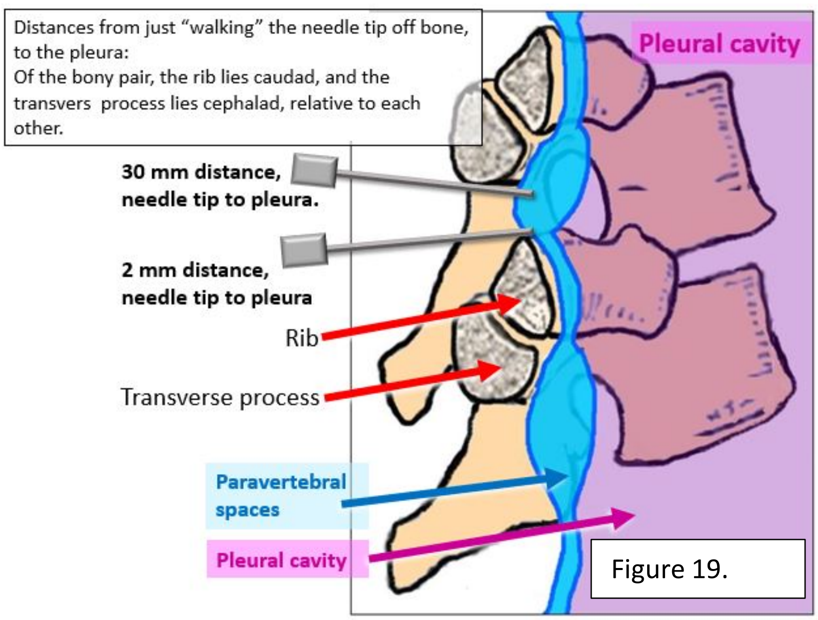


Figure 19.

See figure number 19.

A needle "walked off", cephalad to the lateral bone structures reaches pleura within 2 mm of the last bone contact. A needle walked caudad off the bone pair at 2.5 cm from midline, reaches pleura at about 20mm after last bone contact.

DETAILED DESCRIPTION OF THE ULTRASOUND GUIDED THORACIC PARAVERTEBRAL BLOCK.

Position the patient either fully prone and flat, or more preferably, sitting leaning slightly forward resting their hands on a second support table. Identify the vertebral levels and side to be blocked. The resting inferior angle of the scapula corresponds with the level of the dorsal process of T6. The T1 vertebral process is immediately caudad to the cervical vertebra prominens. If the 12^{th} rib is identifiable below the lateral chest cage, its inferior edge can be palpated and a line along it points back to the dorsal process of the 12^{th} thoracic vertebral dorsal process.

Next mark on the skin, the midline over the dorsal processes. Then precisely measure off a distance of 2.5 cm towards lateral from that mid-line. Draw a line parallel to the first that is consistently 2,5 cm from the midline. Any closer position will place a needle too close to the intervertebral foramen, but a deviation of ½ centimeter more towards lateral is harmless, and acceptable. That is, the ideal distance is 2.5 to 3 cm, with 2.5cm being most ideal.

Now, use a linear ultrasound transducer that is ideally 25 to 400 mm wide and with frequencies as slow as 8 MHz. Place the transducer over the 2.5 cm line, parallel to it, and pointing direct to anterior. Slide the transducer side to side, that is along the body long axis in a parasagittal axis. Seek to see the transverse process. Do not tilt the transducer at all towards medial, or towards lateral. The imaging plane must be 2.5 cm from midline, as indicated by the skin marked line. Aline the bony structure of the transvers process rib cluster with the center of the image. Those structures will not form optimum images, but with understanding and modest experience, the structures will be identifiable. Then, mark on the skin a transverse line aligned with the center of the transducer. Remove the transducer and complete drawing the transverse line so that it intersects with the parasagittal 2.5 cm line. Mark each level to be blocked similarly, and number them per the vertebral body that the intersection represents. Always assume the markings are one level incorrect and nerve block one more vertebral level up and down than what the surgery requires.

Ensure the skin markings are well marked and clear. Do the necessary sterile preparation for the injections. Use sedation and analgesia as indicated, and utilize physiological monitoring with oxygen therapy as is customary.

Use a 17G or 17G Tuohy needle, even if single shot injections alone are to be performed. The needles big advantages are that they are blunt and contribute to good tactile feeling of the tissues it is passed through. Connect a nerve stimulator and set the current to 1.2 mAmp, and a fast twitch. Insert the needle through the skin at a line intersection point. Advance about 2 cm direct towards anterior, and the transverse process. Next pick up the sterile ultrasound transducer

The transducer can now be held medial to the needle in a parasagittal oblique position. Seek the tip of the advancing Touhy needle. As the needle is moved adjust the image plane so that it is just deeper than the needle tip. Then advance the needle until it enters image again. Then readjust the image plane to be a bit deeper, yet again. The degree of obliqueness, or the angle it by which the transducer is tilted away from perpendicular will depend on how deep the needle tip is. At one point the needle will touch the transverse process and rib pair.

The needle's trajectory may at any time be adjusted to aim more to cephalad or more to caudad in order to meet with the target bones. Always however, keep the needle in the parasagittal plane that is 2.5 cm from midline. The needle's trajectory may not be adjusted to more medial or to more lateral.

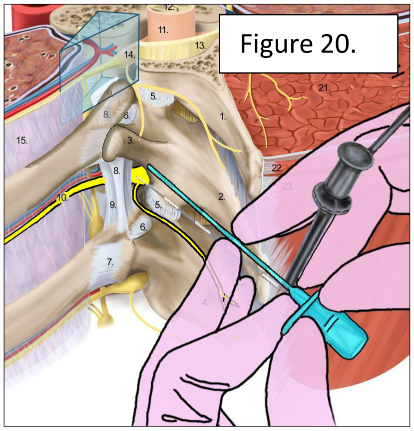


Figure 20.

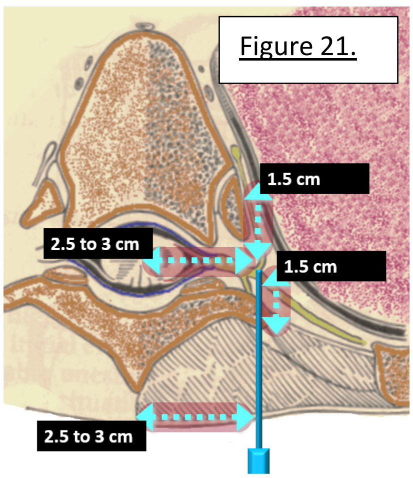


Figure 21.

Put the transducer aside. Connect the nerve stimulator. Attach the loss of resistance syringe containing 5% dextrose water. See figure number 20. Hold the needle in the fashion illustrated. Walk the needle caudad off the bone structure of the paired rib and transverse process. Test the loss os resistance intermittently. Instruct the patient to inform you if they feel any sensation movements or tingling in the abdomen at front. If possible, have someone experienced observe the abdominal wall at front for movements.

Cease advancing the needle if any of the five endpoints is reached, namely: (i) the needle tip is 1.5 cm beyond the last point of bone contact, (ii) the patient reports a dermatomal sensation in the distribution the nerve root being stimulated, (iii) a subtle loss-of-resistance is felt to have happened, (iv) motor twitching can be seen on the abdomen.

See figure number 21. Its shows that a needle inserted in a direct posterior-to-anterior plane not exceeding a distance of 1.5 cm beyond first point of bone contact, and also keeping the distance of 2.5 cm from midline is perfectly centered in the paravertebral space.

Then do the hanging drop test. Follow that, all being well, with insertion of the nerve block catheter, or injection of local anesthetic, using standard safety measures.

THORACIC PARAVERTEBRAL DRUG DOSING.

Single shot block duration is approximately 4 hours for 1% ropivacaine, 3 hours duration for 0.75% ropivacaine, 7 to 8 hours for 0.5% bupivacaine, and 8-9 hours for levobupivacaine. Inject 4 ml per segment level needing to be blocked. Drug spreads up and down to adjacent paravertebral spaces in a ratio of 2.25 to 2.5 ml per segment. For example, if 20 ml of drug is injected at one point, the block will cover the segment injected at and also cover 2 segments up and two segments downwards, at least. Injection at T6 of 10 ml drug should produce an anesthetized area spanning dermatomes T4 to T8, being five levels in total. IF the block is for post-surgical analgesia after recovery from a general anesthetic, there will be sufficient time for the five-segment block to develop. If the block is for awake surgery, block onset can be accelerated by doing a supplementary single injection at alternative levels above and below the level where the catheter was placed. Ensure total doses do not reach unsafe limits. Absorption of drug is relatively fast, ad ropivacaine should be preferably used than bupivacaine if the total volume of all the nerve blocks is reaching near unsafe dose limits. Ropivacaine is the safest of the long acting drugs.

An infusion can be injected in to the catheter after surgery, and generally an hourly flow of ropivacaine 0.2% running at 8 to12 ml per hour will maintain a 4 to 5 segment spread of nerve block. Occasionally, in the evening or on the first morning after surgery, a supplementary repeat main dose may be required to restore the full dermatomal breadth needed from the nerve block.

7. Ultrasound guided abdominal wall nerve blocks

INTRODUCTION

In the last eight years *ultrasound guided abdominal wall* blocks have become very popular. These blocks are best suited for surgeries that have a minimal visceral peritoneal component. These blocks are finding a place in pediatric anesthesia, in ambulatory abdominal surgery in adults, and in very sick ICU patients needing added non-sedating analgesia for abdominal surgery to facilitate weaning from ventilators but where there are contra-indications to epidural anesthesia. Ambulatory abdominal surgery is commonly gynecological. A TAP block is easier and safer than a thoracic paravertebral block.

The blocks are;

1) The TAP block.
2) The Quadratus lumborum block.
3) The Rectus sheath block.

ANATOMY OF THE LOWER ABDOMINAL WALL NERVES.

The nerves of the lower abdominal wall are the following. The abdominal wall is supplied by segmental nerve roots T6 to T12 and L1 derived nerves of the lumbar plexus. See figures 22 and 23.

The genitofemoral nerve (roots L1-2) arises from the lumbar plexus within the psoas muscle. It emerges anterior on the psoas muscle, and runs along it under the fascia iliaca. It next divides with one portion entering the medial inguinal canal and the other entering the femoral triangle passing behind the inguinal ligament and lateral to the femoral artery.

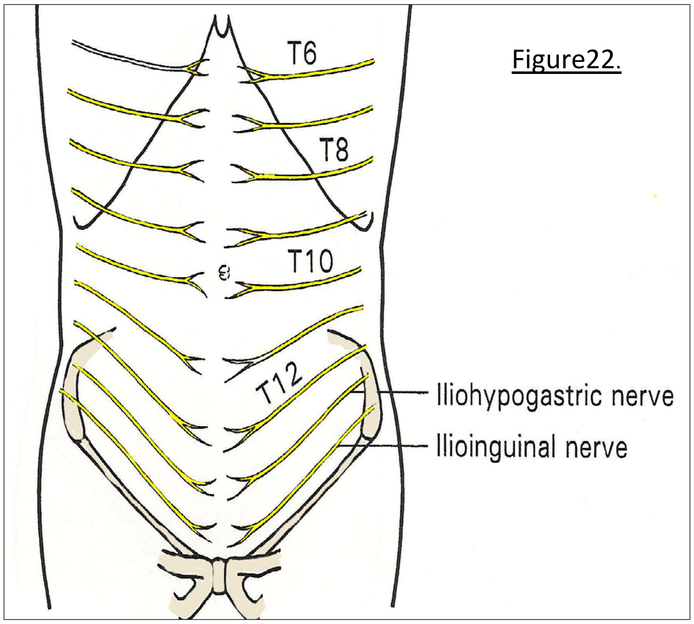


Figure22.

The Iliohypogastric nerve (root L1) arises from the lumbar plexus within the psoas muscle, emerges on the lateral side of the psoas muscle, and runs anterior to quadratus lumborum, to pierce the transversus abdominis fascia deep to the triangle of Petit.

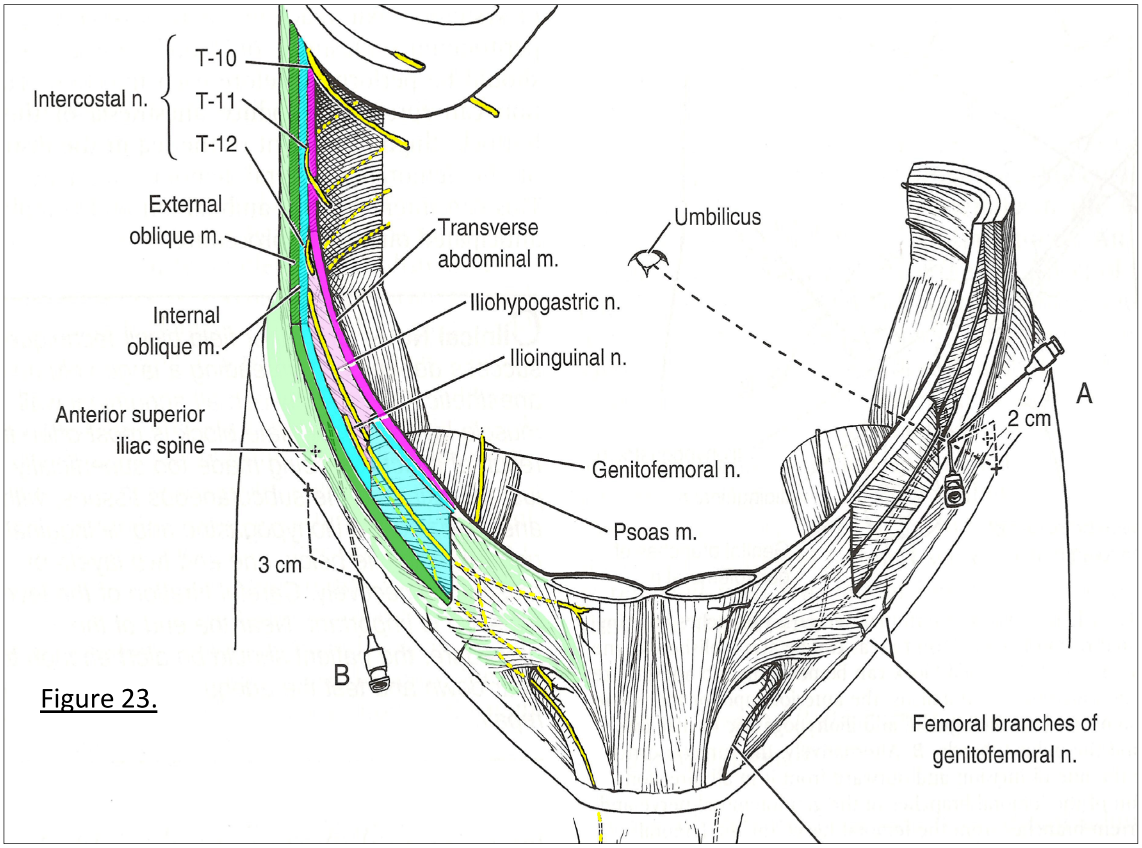


Figure 23.

The TAP Block

The very original **T**ransversus **A**bdominis **P**lane block, or **TAP** block, was a *land-mark based block*. A blunt (shallow bevel) needle was inserted blind, through the skin into the Triangle of Petit and advanced until two fascial "pops" were felt. The local anesthetic was then injected. The Iliohypogastric nerve then runs in this transversus abdominus plane (TAP) and gives off a lateral cutaneous branch 2 cm anterior to the triangle of Petit. The remaining anterior cutaneous branch, remains in the TAP plane until it reaches 2 cm medial to of the Anterior Superior Iliac Spine (ASIS) where it penetrates the internal oblique muscle to run further to infero-anterior between the two oblique muscles before it finally become subcutaneous 3 cm cephalad of the superficial inguinal ring

The Ilioinguinal nerve (root L1) also arises from the lumbar plexus, emerges on the lateral side of the psoas muscle, runs anterior to quadratus lumborum, and pierces the transversus abdominis fascia posterior to the triangle of Petit. Its path is just caudad and similar to that of the Iliohypogastric nerve, and the Ilioinguinal nerve comes to accompany the spermatic cord (and round ligament) in the inguinal canal. See figure 3 where the iliohypogastric and ilioinguinal nerves both pass anterior to quadratus lumborum and lateral to that penetrate transversus obliquus muscle. The MRI section in figure 4 is just cephalad to the triangle of Petit. *The intercostal nerves* similar to the above lumbar plexus nerves run in between internal oblique muscle and transversus abdominis muscle. The abdomen is supplied by the intercostal nerves with roots thoracic 6 to 12 (figures 1 and 11). The umbilicus is supplied by T10 (figures 1 and 11). The intercostal nerves give off lateral branches in the mid-axilla position which supply the skin from immediately latera of the paraspinous muscles to the lateral edge of the rectus sheath. The anterior branch of the "abdominal" intercostal nerve remains in a plane deep to oblique muscles and superficial the Transversus abdominus muscle to finally pass to superficial through the rectus muscle (see figure 12) and supply the entire abdominal wall thickness from midline to the lateral edge of the rectus sheath.

*T*he *transversus abdominis plane* (TAP) is the fascial space between the internal oblique muscle and the transversus abdominis muscle. See figures 12 and 13. It extends from posterior, immediately lateral to Quadratus lumborum muscle, to near midline where the transversus fascia merges with the posterior fascia of the rectus muscle sheath near the midline (figures 14). Superiorly this space is limited by the abdominal wall muscle attachments to the ribs and inferiorly this TAP space is limited by the abdominal wall attachments to the iliac crest and inguinal ligament.

The TAP is readily separated and filled with drug. The TAP contains blood vessels, nerves and a minimal amount of very loose connective tissue and it allows slight sliding movement of adjacent muscles to each other. Under ultrasound guidance a nerve block needle is readily placed into this plane. Note in figure 14, that the anterior intercostal nerves pass through the posterior fascia of the rectus sheath posterior, run through the rectus abdominis muscle and then split into subcutaneous branches superficial to the rectus abdominis muscle. Bilateral blocks of this terminal branches of the anterior intercostal nerve near the rectus sheath blocks the full thickness of the abdominal wall, parietal peritoneum included, from midline to the lateral edge of the rectus muscle. See figure 14.

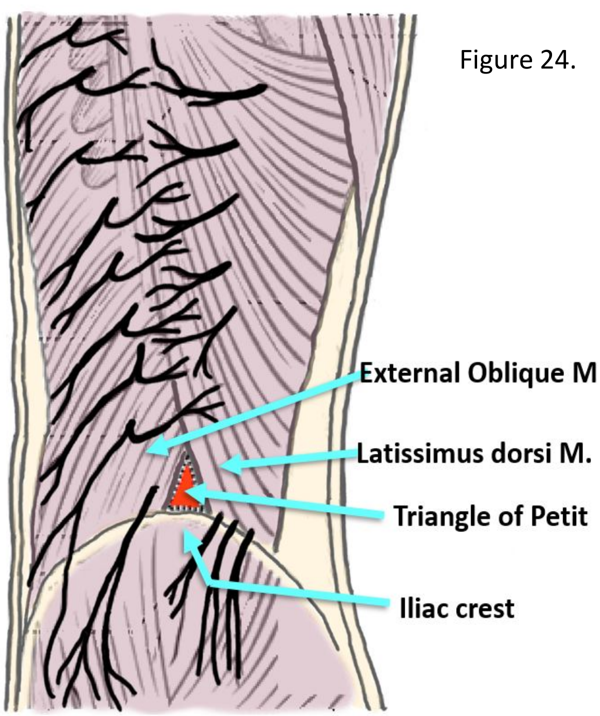


Figure 24.

The *triangle of Petit* is also called the inferior lumbar triangle. See image number 24. It is a view of the lower left abdominal lateral side with the skin dissected off. The triangle of Petit lies in between the muscles latissimus dorsi (posterior), the external oblique (anterior) and the iliac crest (inferior).

1. THE ULTRASOUND GUIDED TRANSVERSUS ABDOMINIS PLANE (T.A.P.) BLOCK

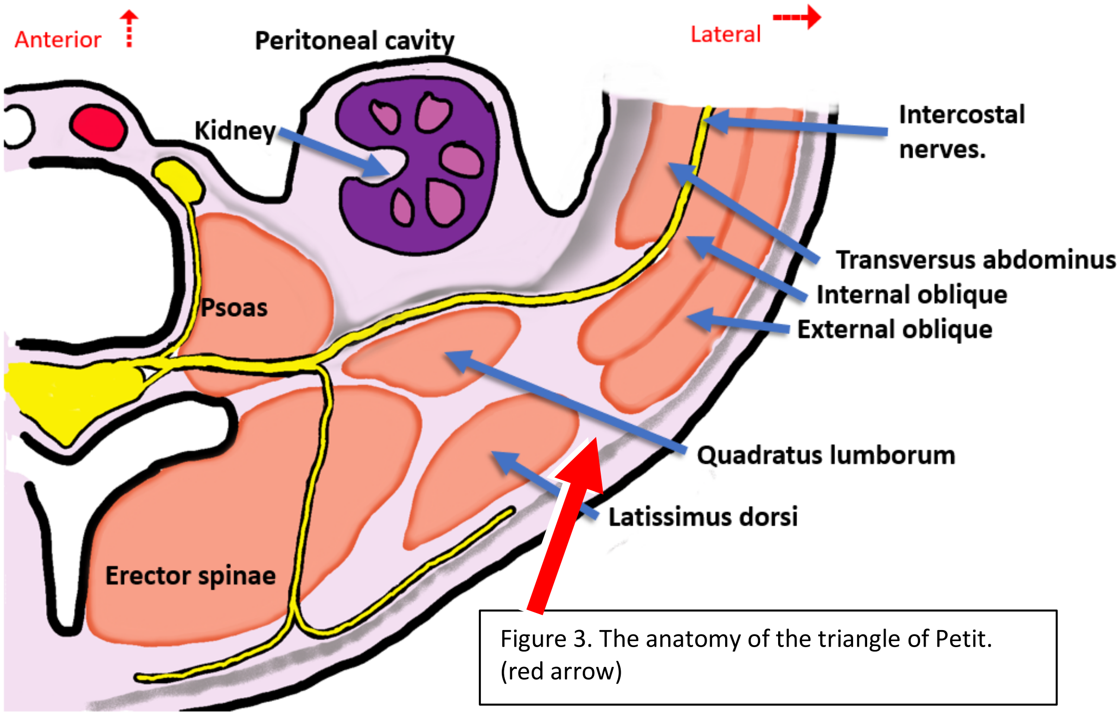
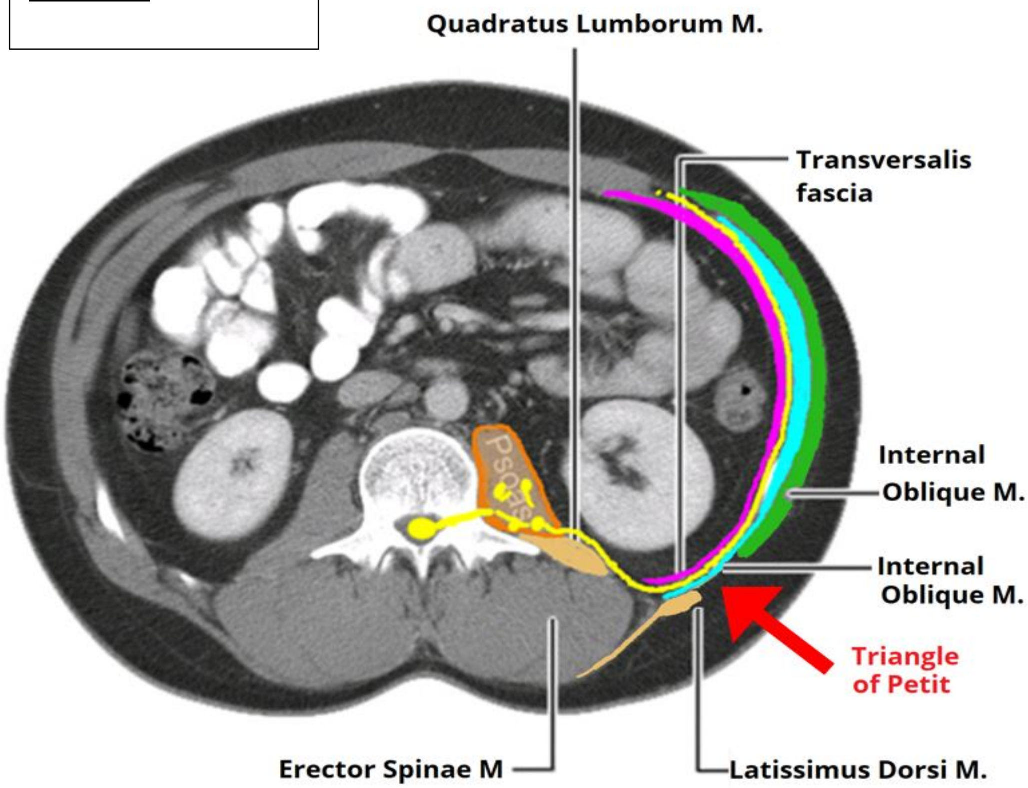


Figure 3. The anatomy of the triangle of Petit. (red arrow)

The land-mark based TAP block was first described in 2001 by Rafi as the “Abdominal field block” injecting into the triangle of Petit[27,28]. The same block was independently described again as the Transversus Abdominis Plane block (TAP block) [27]. McDonnell in 2004 independently re-invented it calling it the Transversus Abdominis Plane block (TAP). The technique involved a tactile feel “two-pops” after inserting a blunt needle inserted blindly through the skin. The great limitation of the block was the immense variability between individuals with respect to the abdominal wall anatomy, and the difficulty of confidently reliably locating precisely the triangle of Petit, especially in obese persons. That hernias can push muscles to the side and emerge through that point is a fact. That the true triangle of Petit can be identified on all individuals clinically and that two “pops” of the needle passing through fascias will precisely deliver a needle tip into the identical fascial compartment as the abdominal wall nerves, is a fallacy. The land-mark tactile technique is advised against being used. Injuries related to insertion of the needle too deep or clinical failure are real risks.

Shortly after the TAP block was described as landmark and tactile technique it was re-described as an ultrasound guided (USG) technique after which it became widely known. It is virtually true that, complications using ultrasound guidance (USG) are so rare as to be un- reported. When a TAP block is used for appropriate indications, it achieves near 100% analgesia in near 100% of patients.

Figure 13



There are some technique variations used by different colleagues. At very first practitioners tried to place the transducer over the supposed true triangle of Petit. Practitioners soon used much more anterior positions closer to midline anterior, and then in addition varied the injections more to cephalad or more to caudad. This author recommends using a position in axial line with the umbilicus, and as far towards posterior as what three formed muscles can be observed in the sonogram. The muscles are Transversus Abdominus, Obliquus Internus, and Obliquus Externus. At some point too far anterior or too far posterior one or more of the muscles loses their fleshy form to become3 only an anchoring fascia that has various fashions of fusing with adjacent fasciae.

Figure 14.

Figure number 14 illustrates a very typical optimum USG transducer and needle position.

Concomitant use of multimodal analgesia (NSAIDs etc.) is generally recommended.
Using ultrasound guidance, the transversus abdominis plane can be accessed more easily slightly anterior to the triangle of Petit and the names of Ultra-Sound Guided (USG) Ilioinguinal, USG iliohypogastric and USG TAP block are interchangeably used to refer to nearly the same block effectively for the lower abdomen. Use a Quincke point 3 ½ inch 22G spinal needle. It penetrates the tissues easier with less distortion of the anatomy. Blunt needles approaching fascias at shallow angles, penetrate fascia with difficulty and distort visual sonographic anatomy.

One only has to be able to recognize the TAP plane in Petit's triangle or just anterior to Petit's triangle or just supero-anterior (subcostal) to Petit's triangle. The slightly more infero-anterior position merges into the Ultra-sound guided (USG) Ilioinguinal / Iliohypogastric block (II/IH block) which also uses the TAP. See figures 8 and 9.

Moving slightly anterior the muscular portions of the oblique muscle are well developed and this may assist ultrasound visualization. It is however important not to move the injection point too anterior as fewer intercostal nerves will be blocked and also the lateral cutaneous branches of the intercostal nerves may be missed. The lateral cutaneous branches penetrate to subcutaneous in the mid axilla line.

METHOD:

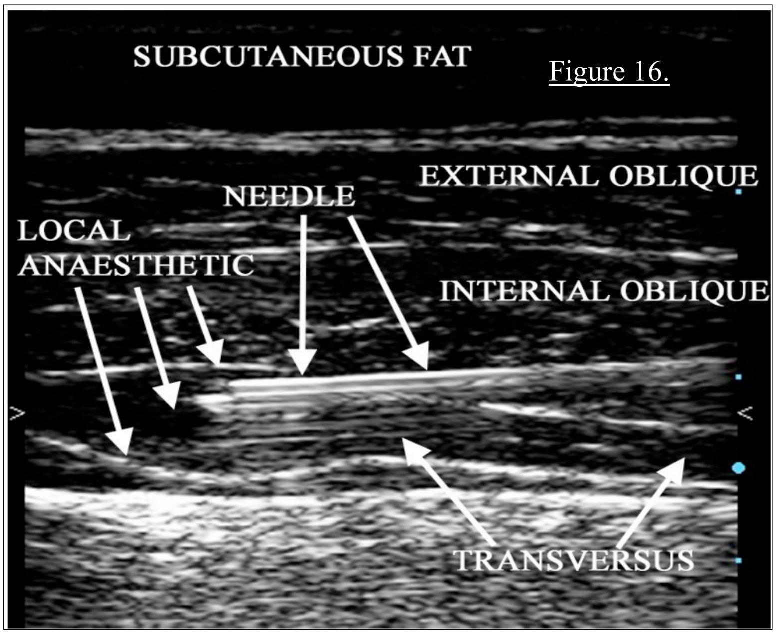


Figure 16.

Place the transducer over approximately where Petit's triangle is expected to be, as in figure 14. Hold the ultrasound transducer so the sound plane is coronal, and insert the needle *in-plane from anterior*. Insert the needle until the tip lies deep to the internal oblique muscle and superficial to the transversus abdominus muscle as in figure 16. Repeated small injections of 0.5 to 2 ml of 5% Dextrose water (5DW) may be made to precisely locate the needle tip visually.

Performing the block fractionally closer to the II / IH position, that is more caudad is well suited for inguinal herniorrhaphy as the lowest nerves receive most drug. Intercostal nerves 12 and 11 would still be reliably blocked. Pediatric practitioners familiar with small juvenile abdomens frequently

Performing the block in Petit's triangle is suitable for lower abdominal surgery pubis to umbilicus because intercostal roots 9 and downwards are blocked. Performing the block superior and anterior to Petit's triangle as in the "Subcostal TAP block" is better suited to upper abdominal surgery but it could NOT be relied on the include T12 and II / IH nerves.

There are two "failure" injection points.

An injection point posterior to the triangle of Petit may find the ilioinguinal and iliohypogastric nerves have not yet entered the transversus abdominis plane

An injection point too medial may miss the lateral cutaneous branches of the intercostal nerves.

Have a 10 to 20 ml syringe of 5DW to inject as ultrasound image contrast and for hydro-dissection to place the needle confidently into the TAP plane, before local anesthetic injection.

Use a linear high frequency ultrasound transducer.

Inject 20 ml of local anesthetic in a typical adult.

2. THE ULTRASOUND GUIDED ILIOHYPOGASTRIC / ILIOINGUINAL NERVE BLOCK

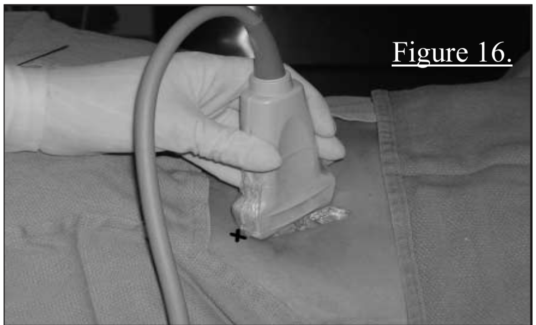


Figure 16.

Ultrasound transducer positioned at the short axis to the nerve course. X marks the needle entry point.

For practical purposes these two nerves can be regarded as if they are blocked as one. Drug spreads to both. The ilioinguinal one is the larger is *sometimes* seen with ultrasound. Actually identifying the nerve, is however not needed for block success. It is only the correct fascial plane that needs identification.

This block is done immediately anterior to the anterior superior iliac spine (ASIS). Hold the transducer on a line from ASIS to umbilicus as in figure 16. Insert the needle from medial towards the umbilicus.

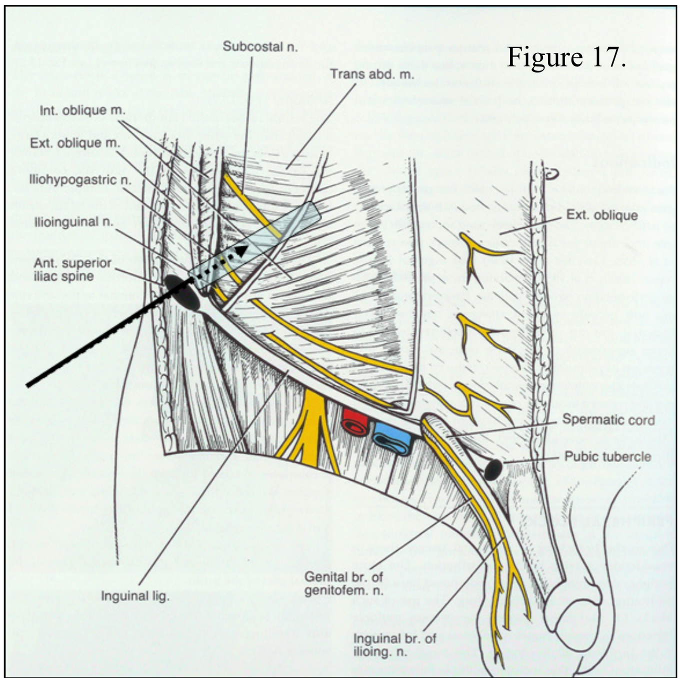


Figure 17.

If an approach is taken due medial of ASIS the Iliohypogastric nerve which penetrates the internal oblique muscle to lie above it and under external oblique, as seen in figure 13 and 14, could theoretically be missed if the drug does not spread sufficiently to posterior. It is best to inject into the TAP plane at a point where all the target nerves lie within it.

Drug injected here spreads cephalad to include the T 11 and T12 intercostal nerves. Inject 20 ml of local anesthetic in a typical adult.

This block is very similar to the TAP block at the triangle of Petit. The only criterion for success is to inject the drug between the transversus abdominis and internal obliquus muscles.

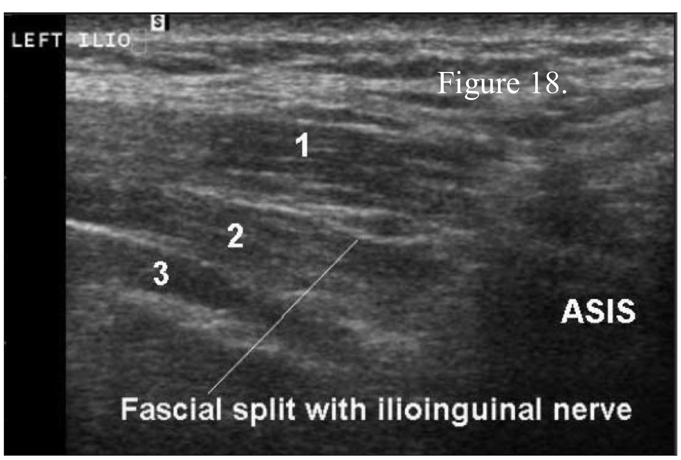


Figure 18.

This ilioinguinal-iliohypogastric nerve block is ideal block for inguinal herniorrhaphies and abdominal wall surgery up to the T11 dermatome. For awake surgery do an extra genitofemoral nerve block (see later).

Special note; In figure 18 the ultrasound transducer was held in a plane caudad to the anterior superior iliac spine (ASIS) and the ilio-inguinal nerve has passed superficial to the internal oblique muscle to lie below the external oblique muscle.

Injection at this point could result in failure to block the iliohypogastric and 12th intercostal nerves. Examine the course of the ilioinguinal nerve in figure 17 to understand this. The best injection point is superomedial to ASIS. In figure 19 a typical ultrasound image is obtained with the ilioinguinal nerve deep to the internal oblique muscle and above abdominis transversus muscle.

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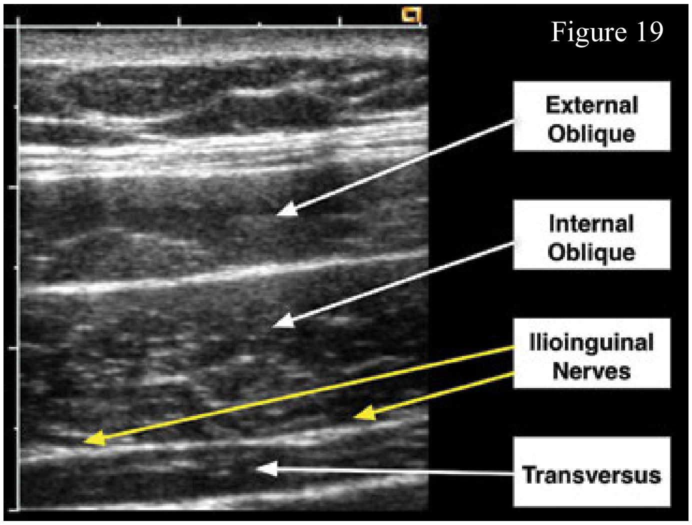


Figure 19

3. SUBCOSTAL T.A.P. BLOCK

This variant is performed by injecting more cephalad than Petit's triangle and immediately anterior to the lowest ribs. It blocks the intercostal nerves of the supra-umbilical abdominal wall. A dose of 10 to 20 ml local anesthetic is recommended per side.

Position the ultrasound transducer parallel to the rib edge. The needle can be inserted in an in-plane view from medial or from lateral. A technique of *hydro-dissection* can be used to inject along the rib margin over a distance and it can be necessary to reposition the transducer as the injection progresses. Hydro-dissection uses small injections (1/2 to 1 ml) to widen the space in front of the advancing needle. The local anesthetic is used here for the hydro-dissection. This assists with longitudinal spread of drug within the fascial plane, and thus across many intercostal nerves.

NOTE: If it seems the drug is spreading poorly, lift the transducer slightly to diminish skin pressure and the drug spread within the image "slice" will improve. Drug spread is however satisfactory outside of the view field regardless.

THE QUADRATUS LUMBORUM BLOCK

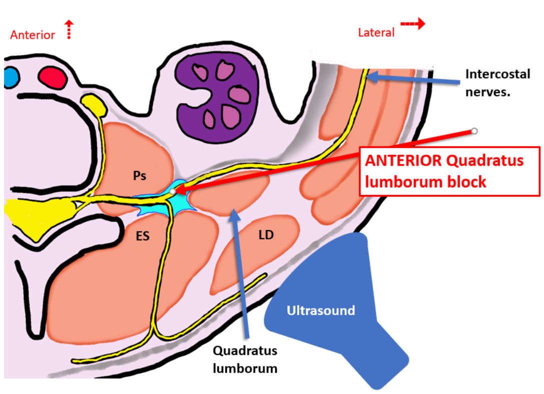
The ultrasound guided quadratus lumborum nerve block (QLB) was first described in 2007. There is some similarity to TAP blocks. In truth Rafi essentially first described the block as a tactile surface anatomy block in 2001, performed in the triangle of Petit**Error! Bookmark not defined.**. Rafi called it the *abdominal field block*, and he injected after feeling the needle "pop" through two fascias. McDonnel described an ultrasound guided block in 2007 which he called the Transversus Abdominis Plane block (TAP)[27]. The exact sonographic views for the triangle of Petit TAP block were variable between different patients. Very soon practitioners of McDonnel's block discovered that an improved view existed slightly more towards anterior (closer to the umbilicus) and over a point where all three abdominal wall muscles were fleshy. This produced a reliable view and that it was easy to inject the local anesthetic drugs to a point between the deepest two of the three muscles for the TAP plane. The name TAP block however was kept.

The quadratus lumborum block (QLB) is simply a return to the original Rafi's abdominal field block, but instead using ultrasound imaging as a guide. The QLB has a different injection point to the TAP block. The quadratus lumborum muscle is used as a visual reference point. It is confusing because there are four basic QLB variants of injecting relative to the quadratus lumborum block. Each variant has many different names, and each with different needle insertion directions. Each variation behaves differently in terms of where the drug spreads to. Each variant has its own "prophet" who travels the world lecturing at conferences claiming their version is best at something. The QLB character is slightly like that of a paravertebral block although displaced slightly more lateral than thoracic paravertebral blocks by the psoas muscles. Also, there are no ribs acting as reference points. The QLB block is more challenging than TAP block which will handicap practitioners making exact precision injections each time.

Complete failure QLB has been described. Complications suggestive of neuraxial spread, and lumbosacral plexus spread have been described. That latter observation is supported by series reports of using it for analgesia for hip arthroplasty cases, although with only modest success. The overall impression is that although analgesia efficacy can be shown for all the variants, the analgesic spread is inconsistent and many individual patients experience disappointing analgesia

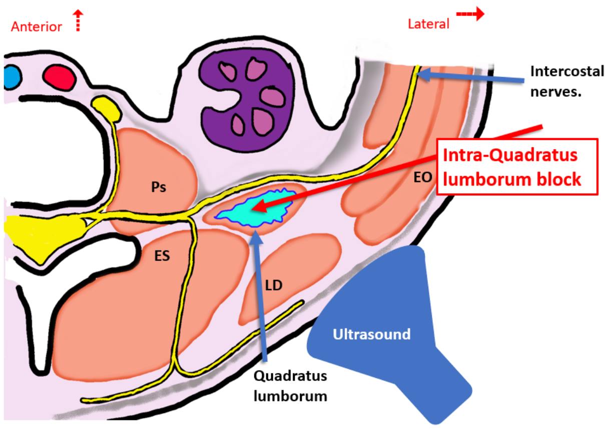
This author will use the classification proposed by Ueshima, for ultrasound guided quadratus lumborum blocks[29]. Persons reading original scientific reports must read the full article and not the abstract, to establish which *Ueshima classification* the article fits.

This author does not recommend the quadratus lumborum block over the TAP block which is uniquely easy and effective for appropriately selected surgeries.



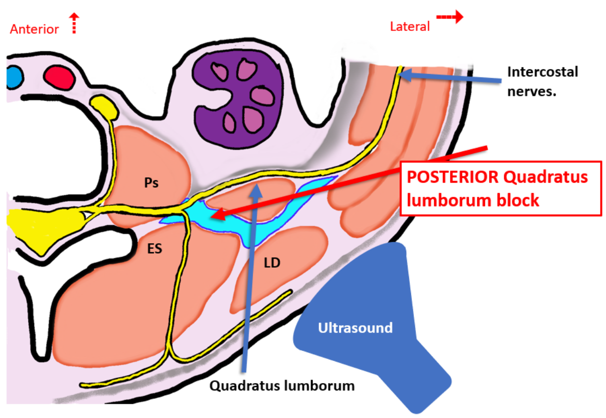
The **Anterior QLB**, labeled improperly by some as a subcostal QLB or the transmuscular QLB, is the deepest variant of the group. It is also the most difficult of the group in adults. The patient is positioned supine with a curved transducer positioned over the tringle of Petit. The needle is inserted from anterior in-plane.

The injection point is between the psoas muscle and the quadratus lumborum muscle. The drug is considered to spread on the anterior surface of quadratus lumborum muscle. That point is reached by inserting the needle through the quadratus lumborum muscle. Because of its proximity, to the psoas muscle local anesthetic drug diffuses into the psoas muscle compartment and some features of a L2 level psoas compartment block can develop. This block is also considered a risk block to penetrate the peritoneal cavity with the needle due to its deepness and the lack of precision sonographic imaging that often occurs. In children with their enhanced ultrasound imaging compared to adults this variant has had more popularity used for acetabular-hip surgery. Efficacy is not 100%. This author prefers using the more specific L3 psoas compartment block supplemented with the simple subcutaneous iliac crest and subcostal nerve blocks for acetabular-hip surgery analgesia.



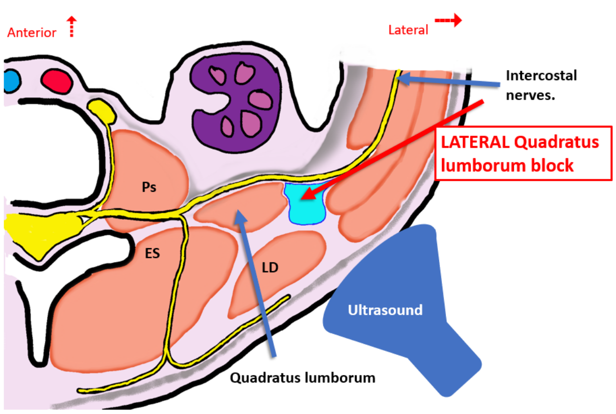
The **Intramuscular QLB** is injected into the middle of the quadratus lumborum muscle. The local anesthetic spreads up and down the muscle, and then diffuses outwards onto adjacent fascial planes and to block a range of passing intercostal nerves in the T10 to L1 range.

The patient is positioned in the supine position. The transducer is placed transverse to the patient long axis, over the triangle of Petit. The needle is inserted from anterior in-plane.
Some proponents prefer a linear transducer.



The **Posterior QLB** is injected in between the erector spinae muscle and the quadratus muscle. The drug is considered to spread posterior to quadratus muscle. The drug ultimately will diffuse onto nerve structures in the region.

The patient is positioned in the supine position. The transducer is placed transverse to the patient long axis, over the triangle of Petit. The needle is inserted from anterior in-plane.



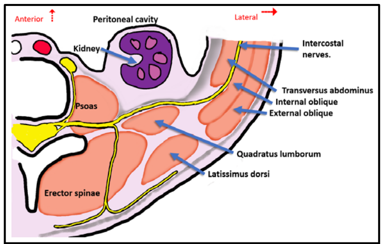
The Lateral QLB is injected with the patient supine and the transducer over the triangle of Petit and held transverse across the patient. The needle is inserted near the upper edge of the transducer in-plane. The tip is positioned at the lateral edge of quadratus lumborum muscle.

The block is considered successful, by its proponents, if sonographically the drug appears to surround the quadratus lumborum muscle.

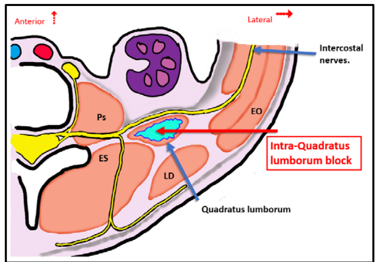
SUMMARISING COMMENTS; The fact that such diverse range of QLB techniques have been shown to all cause some analgesia suggest that within the region, a large volume of injected local anesthetic almost however injected within the triangle of Petit is capable of diffusing far enough to reach some nerves in a large group of patients. It is a fact that drug that primarily baths nerves direct will produce the fasted onset of nerve block with the longest duration in effect. For these considerations, and from experience, the author considers the TAP block superior to the quadratus lumborum group of blocks for (i) reliability of benefit for most patients, and (ii) duration of analgesia.

CLASSIFICATION OF THE QUADRATUS LUMBORUM BLOCK (per Ueshima)

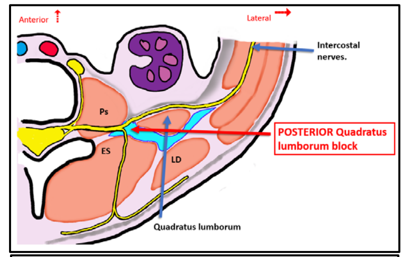
<table>
<tr><th>Ueshima name</th><th>Point of injection</th><th>Technical ease of block</th><th>Safety of block</th><th>Consistency of analgesia</th></tr>
<tr><td>Anterior QLB</td><td>In between psoas muscle and quadratus muscle</td><td>Difficult</td><td>Less safe</td><td rowspan="4">Less consistent</td></tr>
<tr><td>Lateral QLB (QLB1)</td><td>Lateral to the quadratus lumborum muscle.</td><td>Not easy</td><td>Moderately safe</td></tr>
<tr><td>Posterior QLB (QLB2)</td><td>Posterior to quadratus lumborum muscle, in between erector spinae and quadratus muscle.</td><td>Not easy</td><td>Less safe</td></tr>
<tr><td>Intra-QLB</td><td>Within the muscle mass of quadratus lumborum.</td><td>Very easy</td><td>Moderately safe</td></tr>
<tr><td>TAP block</td><td>In between the transversus abdominus and interior oblique muscles</td><td>Very easy</td><td>Very safe</td><td>Very consistent</td></tr>
</table>



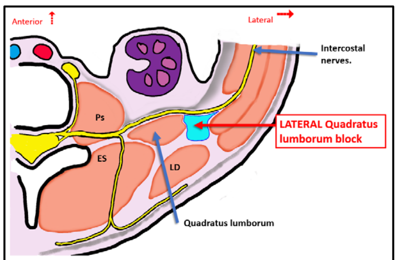
Anatomy of the quadratus lumborum block.



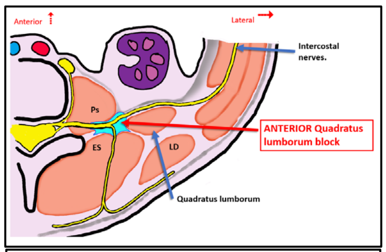
The Intramuscular Quadratus lumborum block.



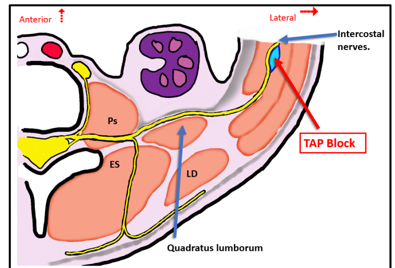
The posterior quadratus lumborum block.



The lateral quadratus lumborum block.



The anterior quadratus lumborum block.



The TAP block.

FREQUENTLY ASKED QUESTIONS ON ULTRASOUND GUIDED ABDOMINAL WALL BLOCKS.

1. Are the ilioinguinal/hypogastric blocks (II/IH blocks) and the TAP block different blocks?
   A= **Virtually no**. They were described independently of each other each for a different patient group. The TAP block was described for adult lower abdominal surgery. The II/IH blocks were described for pediatric inguinal surgery. When it became realized that both are best performed with USG and that approaches could be more anatomically flexible, it was realized that both block II/IH and TAP block are very similar and block the same nerves.
2. When should I do a TAP block and II/IH block?
   A = The II/IH block is best performed for inguinal hernia surgery and as a bilateral procedure for lower abdominal surgery with transverse incisions (e.g. retropubic surgery, and Caesarean sections using the transverse Pfannenstiel incision.).
   The TAP block can be used for all the IH/IH indications but is definitely superior in gaining extra intercostal dermatomes for lower abdominal surgery with incision sup to the umbilicus. With few exceptions another primary anesthetic is still needed (GA or neuraxial block), and these abdominal wall blocks are *analgesia blocks* for post-surgical pain.
3. Do the intercostal nerves of the abdomen supply the peritoneum?
   A = YES, they supply the parietal peritoneum of the abdominal wall but not the visceral peritoneum of the abdominal contents which have an autonomic sensory supply.
4. Are these blocks useful in obese patients.
   A = If the BMW exceeds 40 these blocks are near impossible due to tissue thickness and difficulty acquiring images. With a BMI of 35 or less they are reasonably easy to do
5. Is the USG II/IH or TAP block useable for AWAKE inguinal herniorrhaphy?
   A = NO, not on its own. There are two possible areas of analgesia deficit. One relates to a repair incision impinging on the midline (Typically on the larger hernia on more obese patients). This requires a supplementary subcutaneous infiltration of local anesthetic from pubis upwards for 2 to 4 cm. Second the USG TAP/II/IH block does not include the genito

femoral nerve which needs to blocked separately. It is best blocked by injecting local anesthetic from the pubic tubercle in a supero medial direction from bone and then onwards deep subcutaneous for 2 to 4 cm.

CONCLUSION.

The nerve supply to all of the abdomen and its content is complex, and there are very many nerve blocks that can be used in combinations that will provide optimal analgesia of abdominal surgeries. The TAP block is characterized by its ease of performance, great safety, simplicity, and high level of efficacy when used for the appropriate surgeries. The TAP block is thus a highly recommended nerve block. The user must just understand the surgeries for which it works best.

4. THE RECTUS SHEATH BLOCK

The rectus sheath block is used for midline incisions. Typical best cases would be ventral hernia repairs and umbilical and paraumbilical hernia repairs. It is unsuitable for surgery involving visceral peritoneum resection.

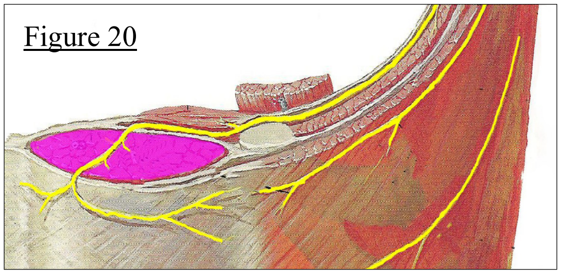


Figure 20

This authors experience has been that if used for peri-umbilical hernia repairs with vertical incisions and the incision could be restricted to under 10 cm long100% analgesia is usually achieved.

Inject in each of four quadrants about the planned incision. It is useful to have the surgeon mark his planned incision on the skin before hand. Analgesia will extend about 2.5 cm further cephalad and caudad from each injection. The injections should be made in the middle of the vertical plane of the rectus abdominis muscle. Each injection on one side should be 5 cm apart. For incisions 10 to 15 cm long a 6 segment (3 per side) bilateral block can be performed for larger incisions alternate blocks (e.g. subcostal TAP block) would be better.

Inject the drug immediately deep to the rectus muscle taking care not to penetrate

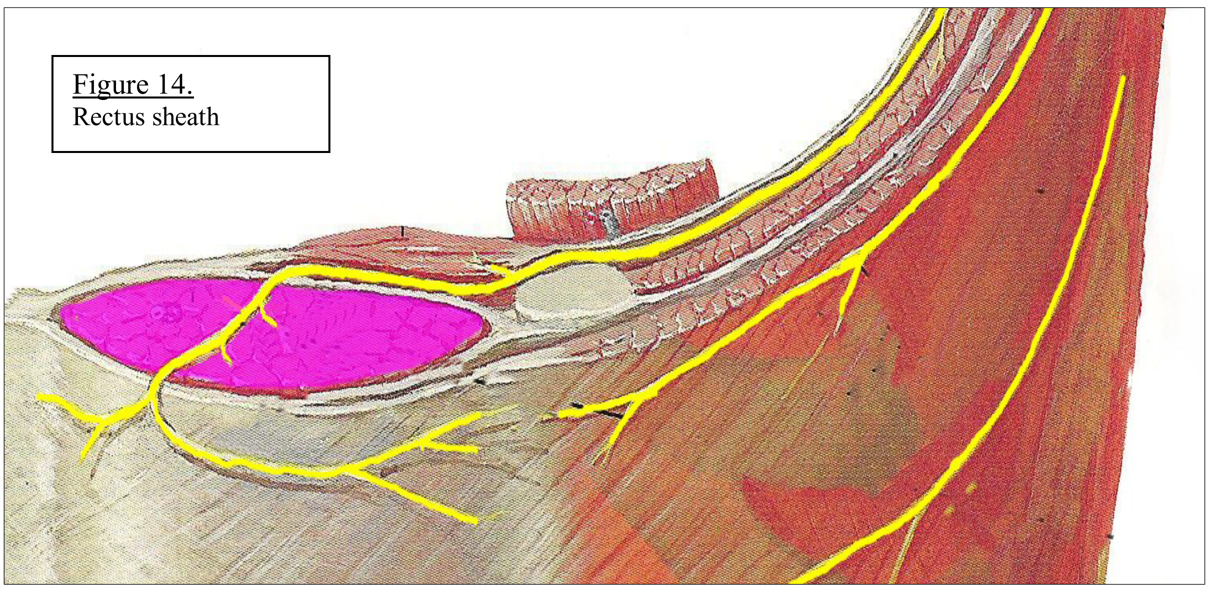


Figure 14.
Rectus sheath

peritoneum. Use a hydrodissection method with 5% DW to continually confirm correct needle tip position. Inject 5 to 8 ml local anesthetic per site in adults.

NERVE BLOCK OF THE GENITOFEMORAL NERVE FOR INGUINAL HERNIA REPAIR.

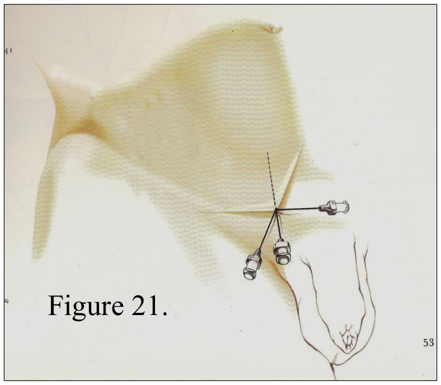


Figure 21.

This is a *supplementary* block needed if the USG Ilioinguinal-iliohypogastric block is to be used for awake inguinal herniorrhaphy. See figure 21. The ultrasound is not used. Insert the needle direct onto the pubic tubercle. Inject 2 ml of local anesthetic then inject the balance of 10 ml total of local anesthetic drug generously in deep subcutaneous fashion aiming cephalad, then latero-cephalad, then fully lateral for about 2 to 3 cm in each direction. If the surgery is to be performed under general anesthesia one can omit this block and use multimodal analgesia afterwards.

ONSET OF ANALGESIA

These are all slow onset blocks compared to specific peripheral nerve blocks in limbs. TAP blocks consistently blocks down to L1 but only to T10 by thirty minutes. It then spreads very slowly and may reach T8 or even T7 by the end of surgery. It is thus important to do this block before surgery starts.

SUGGESTED DRUGS AND DOSES
Levobupivacaine 0.75% (most long acting)
Bupivacaine 0.5% to 0.25% (long acting)
Ropivacaine 0.5% to 0.75% (medium long acting)

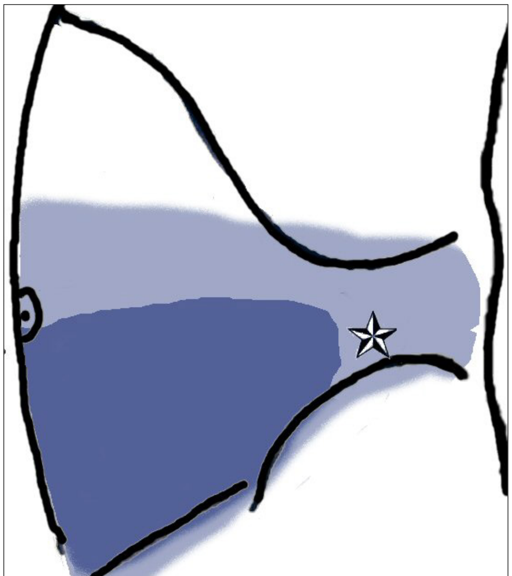
Children under 5 y. with half-strength solutions achieve the same density of nerve block as adults with full-strength solutions.

	USG II/IH block	USG TAP block	Rectus Sheath block
Adults	Inguinal herniorrhaphy; 10 to 20ml Lower abd. surgery to T10; 20ml	20 ml (unilateral) 15 to ml per side (bilateral) Bupiv 0,5%) 20 ml per side (bilateral) (0.75% Ropiv or Levobupiv)	5 – 8 ml per injection.
Children	Inguinal herniorrhaphy 0.25% bupiv @ 0.25ml/kg Lower abd. surgery to T10 .25% bupiv @ 0.33ml/kg	0.25% Bupiv @ 0.25ml/kg (per side)	0.33 ml/kg 0.25% Bupiv. shared between the 4 quadrant injections.

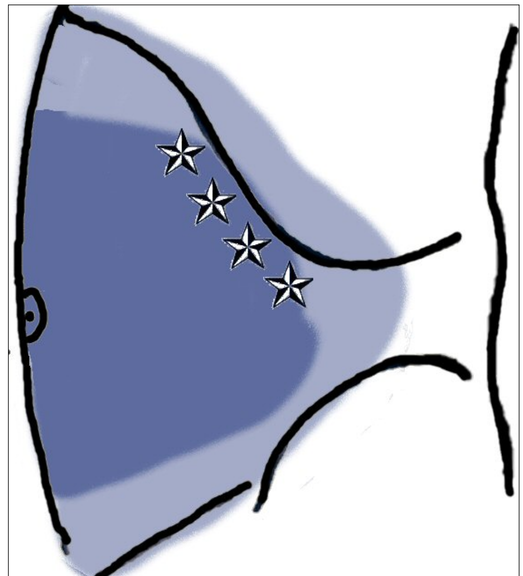
Infusion doses of 0.125% Bupivacaine have been used in unilateral TAP blocks successfully in adults.

SPREAD OF LOCAL ANESTHETIC WITH EACH ABDOMINAL WALL BLOCK

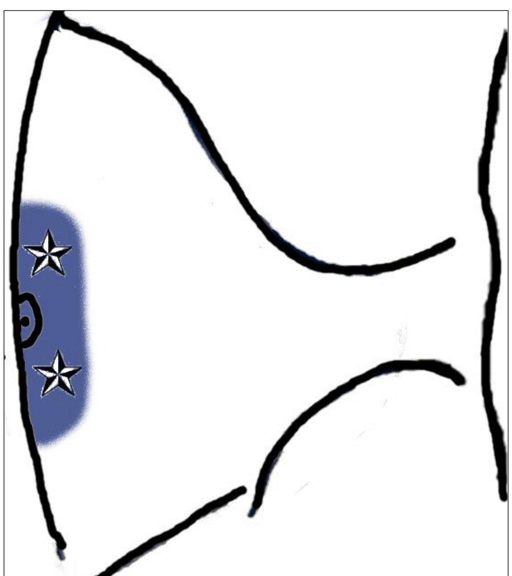
The illustrations below the light gray indicates the best spread of skin analgesia possible and the dark gray indicates the minimum spread of skin analgesia that can be depended upon. The stars indicate the point of injection.



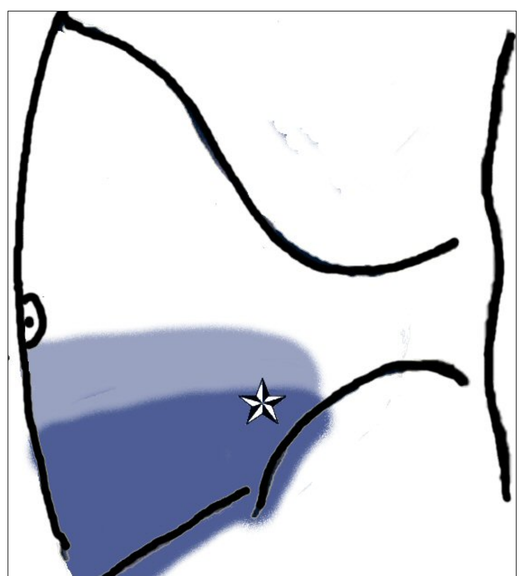
USG TAP block



Subcostal TAP block.



Rectus sheath block. Note; it is a 4-quadrant injection.



USG Ilioinguinal- Iliohypogastric block

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5. Is the USG II/IH or TAP block useable for AWAKE inguinal herniorrhaphy?

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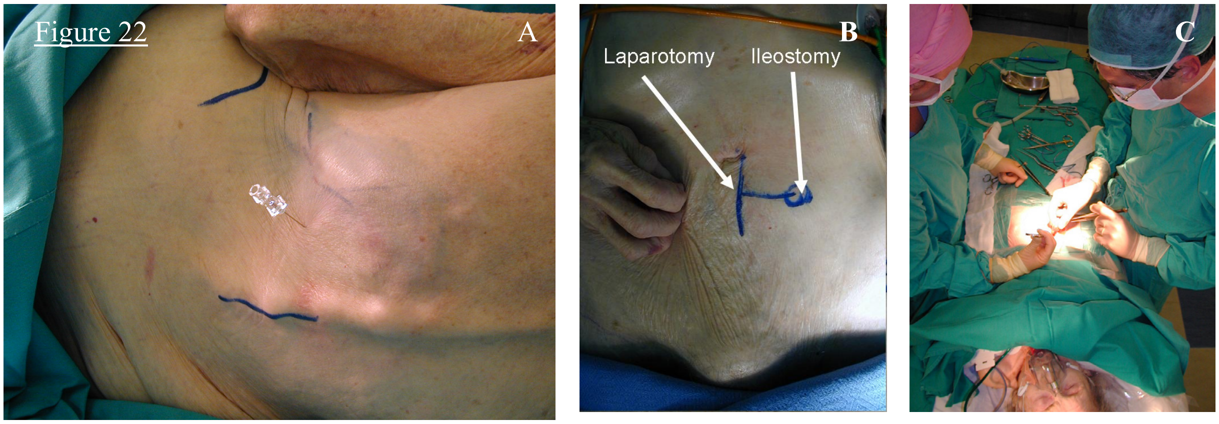
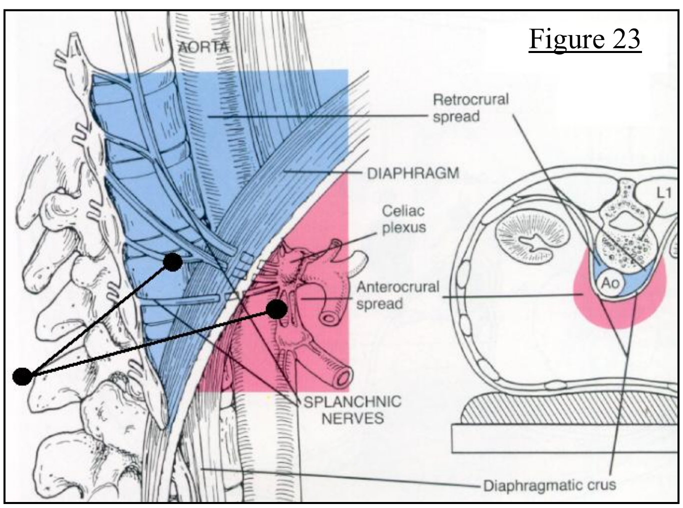
7. Coeliac plexus block.

In figure 22 this emaciated ASA3 38 kg lady underwent a mini-laparotomy and creation of a feeding ileostomy. This was done under abdominal wall field infiltration block, and coeliac plexus block with out sedation or analgesia and without patient discomfort. In image *A* is the coeliac plexus block needle, in image *B* is the surgeons markings for his planned incisions which were then infiltrated and image *C* is the surgery underway.



The “true” Coeliac plexus block is also called the *Trans-crural* Coeliac Plexus block, or *antero-crural* Coeliac plexus block, as opposed to the retro-crural coeliac plexus block or the splanchnic block. This block on its own is insufficient for awake surgery nor for total analgesia after mid-upper abdominal surgery. Other analgesia needs to be provided for the abdominal wall. Also, it is ineffective for any visceral pain or organs “distal” to the colonic flexure and of the genito-urinary tract. Usually light general anesthesia would also be used, but it is possible to omit that if the surgeon could manage without paralysis. Paralysis is not needed if the surgery is “outside” of the abdomen and the patient is frail, as in the illustrated case.



TECHNIQUE.

See figures 23 and 24. There are many approaches but only the *postero-lateral trans-crural* approach shall be described here. As only a one-sided injection is needed the patient may be blocked in the lateral position. Fluoroscopy is not essential for a local anesthetic block, although helpful, but fluoroscopy is essential for lytic blocks. Use anesthesia monitoring and IV access.

Use full sterility for the injections. Infiltrate the skin and anticipated needle tract for 4 cm deep. For the block use a 15 cm 20-22G needle (Chiba needle). Insert the needle through the point marked below the tip of the 12th rib starting on the left side. Aim due medial, 45 degrees from vertical. The desired point of contact is the lateral side of the 1st Lumbar vertebra body at a depth of about 7 to 9 cm deep. If bone is met at 5 cm it is the transverse process. Re-direct the needle slightly caudad. After touching the vertebral body, withdraw the needle nearly fully and re-direct 5-10 degrees more lateral, to slide off the vertebral body 2 to 3 cm deeper than the first bony contact depth. This may take 2 or 3 adjustments. Use a gentle grip on the needle, and if tissue resistance is felt, stop and observe if Aorta pulsations via the needle are present. Stop at that point. It is sufficient for local anesthetic blocks to only insert one needle and only inject from one side. Aspirate on the needles for blood CSF, ascites and urine rotating the needles through all quadrants.

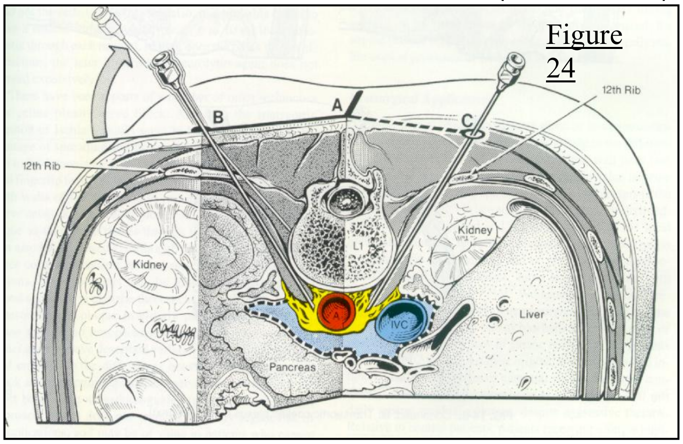


Figure 24

Fluoroscopy is not required for LA injections only nor in relatively normal habitus patients. Then if fluoroscopy is used injection of 3 ml of contrast agent will be seen to spread BELOW to crura of the diaphragm and somewhat anterior to the vertebral column and in a bunched pattern. (The Retrocrural splanchnic block would show contrast more posterior and lateral to the vertebral bodies, with a “V” pattern downwards). Next inject 3ml lignocaine for signs of subarachnoid or epidural block or IV injection. Then inject either 35 ml of bupivacaine with adrenaline (epinephrine), or 40 ml 0.5% levobupivacaine. Aspirate before every injection and after every 5 ml.

COMPLICATIONS
Hypotension. (typically, not as severe as that seen with a high spinal anesthetic)
Epidural or subarachnoid injection.
Interosseus or intra-Psoas injection.
Retroperitoneal hematoma.
Bowel or renal puncture.
Paresthesias in somatic distributions
Sexual dysfunction.

In an unreported series of 75 cases using a Coeliac plexus block with skin incision local anesthetic injection and general anesthesia the following analgesia results were obtained[30]. All patients received 3 mg morphine and 30 mg Ketorolac before awakening from general anesthesia. Two cases were done with retrocrural coeliac plexus blocks and PACU pain scores were “mild to moderate” and 5 mg morphine was consumed over the next 24 hours. It is noted the retrocrural coeliac plexus blocks do not block Vagus, whereas trans-crural coeliac blocks do. Thereafter all cases were done with trans-crural coeliac plexus blocks. Bupivacaine 0.5% with epinephrine (adrenaline was used for the first 35 cases and thereafter levobupivacaine with epinephrine (adrenaline) added was used for the blocks. The 6th case in the series experienced severe post surgical pain which required opiates over the next 24 hours. In that case the coeliac plexus block may have been a technically failure as fluoroscopy was not used. Of the other 32 patients out of the first 35, 75% reported zero pain in the PACU through for 20 hours. The other 25% reported “mild pain” in the PACU but did not request oral or other analgesia for 20 hours. Beyond 20 hours there was slight increase in pain for which oral analgesic were used. Of the last 40 patients (who all received 0.5% levobupivacaine) 75% reported zero pain at no stage in PACU and for 7 days after surgery. No analgesics were used other than the 3mg morphine and ketorolac administered while under anesthesia. Of the remaining 25% of the levobupivacaine group they reported “mild” pain in the PACU but declined analgesics and they never used any other analgesia (oral or parenteral) in the 7 days after surgery. This same surgeon and anesthesiologist team had previously found laparoscopic hiatus hernia surgery to be very painful regardless of abdominal wall local anesthesia. Intraperitoneal regional anesthesia was fairly effective generally but the coeliac plexus block was the most successful analgesia technique used by the team. The only remaining complaints after surgery were shoulder tip pain and that correlated with whether a closing stitch had been placed into the diaphragmatic crura or not. That was subsequently treated with another local anesthetic technique. There were no complications in the series, and only one intravascular injection recognized after 20 ml of drug had been injected when the 5ml aspiration test was done. The heart rate increased at the moment of aspiration (from the likely preceding IV injection of LA with epinephrine). The needle was withdrawn until aspiration became negative, and the block completed.

It is recommended this block be learned under tutored guidance.

VI. SUMMARY OF MAIN POINTS

For each surgery involving the abdominal wall and or also the contents of the abdomen, the anatomical nerve supply can be different. There is seldom one single nerve block that will fully block all of the viscera operated upon, as well as the abdominal walls as well. Neuraxial blocks have capacity to provide full analgesia, sufficient for awake surgery if the surgery is confined to the pelvis and lower abdomen with involvement of viscera caudad to the Splancnic flexure of the colon.

Neuraxial nerve blocks may be contraindicated or undesirable for some particular patients or some particular surgeries. There are fortunately a large number of regional anesthesia alternatives to neuraxial blocks for abdominal surgery.

VII. QUESTIONS AND ANSWERS OF REGIONAL ANESTHESIA FOR ABDOMINAL BLOCKS.

- QUESTION: What is awake abdominal surgery?
  - ANSWER: It is surgery performed under regional anesthesia sufficiently comprehensive to block the afferent nerves of three nerve systems, from all tissues handled during surgery. The three systems are parasympathetic, sympathetic and somatic. For the patient to be considered awake they must be capable of arousal and being able to respond to simple questions with affirmation or denial, at the least. If surgical discomfort requires a deeper level of sedation and analgesia injection, then it is not awake surgery and the regional anesthesia technique has failed. True awake surgery, should allow the patient to be alert and able to converse while being acceptably comfortable in that state.
- QUESTION: Can awake an awake gastrectomy be performed under epidural block reaching the T3 level?
  - ANSWER: No. Although the Splancnic sympathetic nerves spinal cord origins will be blocked, the parasympathetic nerves that also supply pain fibres will be unblocked. The patient will require profound supplementary analgesia that will render them to an unarousable state, and they will be virtually anesthetized with compromised respiration. The parasympathetic nerve fibres are best blocked via a Coeliac plexus block.
- QUESTION: Why can caesarean section be performed fully awake under epidural block?
  - ANSWER: All viscera distal to the large bowel splenic flexure, including the pelvic organs do not get their parasympathetic nerve supply from Vagus and the Coeliac plexus. Their parasympathetic nerves derive from the distal spinal cord and it rootles, which are covered by the epidural block.
- QUESTION: How does and epidural placed at T11 and spreading from T 5 to S2 still provide a comfortable condition for awake Caesarean section if the parasympathetic nerve supply takes origin from S2 to S4? Surely the parasympathetic nerve supply is partly unblocked?
  - ANSWER: Part of the mechanism of an epidural block is that drug diffuses across the dura mater to create a cloud of local anesthetic with the intra-thecal space directly under the sheath of local anesthetic occupying the epidural space. The concentration of local anesthetic in that segment of CSF is between 25% and 50 % of the concentration within the epidural space. That is sufficient to block all sensory nerve fibres within the causa equina that are ascending the cord end at L2. This segmental isobaric half-concentration spinal block explains why epidural blocks always seem to block a longer distance to caudad than to cephalad from the injection point. So, any epidural that reaches as low as L2 will bath all the terminal fibres from the spinal cord that are passaging in the cauda equina to more distal exit

points from the vertebral canal. The grade of nerve block may be too light, or the drug may be too dilute to cause loss of tactile sensation in the toes, or movement in the toes. It will however be a good enough block to cover all autonomic pain fibers and make a caesarean section comfortable during the uterus incision. (References. TEXTBOOK. Epidural Anesthesia. Philip Bromage)

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