

*the
Flying Publisher Guide to*

Ultrasound Blocks for the Anterior Abdominal Wall

2011

Adult and Pediatric Surgery

Mokini, Vitale,
Costantini, Fumagalli, et al.



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Ultrasound Blocks for the Anterior Abdominal Wall
Principles and Implementation for
Adult and Pediatric Surgery

Zhirajr Mokini
Giovanni Vitale
Amedeo Costantini
Roberto Fumagalli

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Ultrasound Blocks for the Anterior Abdominal Wall

**Principles and Implementation
for Adult and Pediatric Surgery**

2011 Edition

Flying Publisher

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Preface

Somatic post-surgical pain is invalidating and distressing to patients and carries the risk of important complications. The anterior abdominal wall is involved in most surgical procedures in general, gynecologic, obstetric, urological, vascular and pediatric surgery. Combined multimodal strategies involving nerve blocks, opiates, and non-steroidal anti-inflammatory drugs for systemic analgesia are necessary for optimal pain modulation.

Anterior abdominal wall blocks, transverse abdominal plexus block, iliohypogastric and ilioinguinal nerveblock, genitofemoral nerve block and rectus sheath block have an important role as components of multimodal analgesia for somatic intraoperative and postoperative pain control. Ultrasound visualization has improved the efficacy and safety of abdominal blocks and implemented the application in the clinical setting.

For this reason, they are a very important tool for all anesthesiologists who aim to treat effectively patients' pain. This guide provides an evidence based comprehensive and necessary overview of anatomical, anesthesiological and technical information needed to safely perform these blocks.

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Abbreviations

ASIS: anterior-superior iliac spine	IOM: internal oblique muscle
EOM: external oblique muscle	LIA: local infiltration anesthesia
gGFN: genital branch of genitofemoral nerve	RAM: rectus abdominal muscle
gGFB: block of the genital branch of genitofemoral nerve	RSB: rectus sheath block
IFB: inguinal field block	TAM: transverse abdominal muscle block
IHN: iliohypogastric nerve	TAPB: transverse abdominal plexus block
IIN: ilioinguinal nerve	TFNB: transient femoral nerve block

Table of Contents

1. Anatomy for Anesthesiologists.....	13
Anterior Abdominal Wall Structure.....	13
Blood Supply to the Anterior Abdominal Wall.....	15
Anterior Abdominal Wall Innervation.....	16
Iliohypogastric and Ilioinguinal Nerves.....	18
Inguinal Canal.....	20
Genitofemoral Nerve.....	20
Rectus Sheath.....	22
Communication Between Anatomical Planes.....	23
2. Ultrasound and Regional Anesthesia.....	24
Sound Waves.....	24
Piezoelectric Effect.....	26
Imaging.....	27
Transducers.....	29
Focus.....	30
Presets.....	30
Time-gain Compensation.....	30
Spatial Compound Imaging.....	30
Ultrasound and the Needle.....	31
Equipment.....	31
3. Transverse Abdominal Plexus Block.....	35
Blind Transverse Abdominal Plexus Block.....	36
Ultrasound-guided Transverse Abdominal Plexus Block.....	37
Spread.....	42

4. Iliohypogastric and Ilioinguinal Nerve Block.....	44
Blind Iliohypogastric and Ilioinguinal Nerve Block.	44
Ultrasonographic Visualization Studies.....	48
Ultrasound-guided Iliohypogastric and Ilioinguinal Nerve Block.....	49
5. Genitofemoral Nerve Block.....	53
6. Rectus Sheath Block.....	60
7. Inguinal Hernia Repair.....	65
Inguinal Field Block/Local Infiltration Anesthesia..	65
Iliohypogastric and Ilioinguinal Nerve Block.....	69
8. Inguinal Surgery in Children.....	71
Iliohypogastric and Ilioinguinal Nerve Block and Wound Infiltration.....	72
Iliohypogastric and Ilioinguinal Nerve Block and Caudal Anesthesia.....	72
9. Obstetric and Gynecologic Surgery.....	75
Obstetric Surgery.....	76
Gynecologic Surgery.....	77
10. Other Abdominal Surgery Procedures.....	79
Lower Abdominal Surgery.....	79
Upper Abdominal Surgery.....	80
11. Abdominal Midline Surgery.....	83
12. Local Anesthetics, Pharmacokinetics and Adjuvants..	84
Dose, Concentration and Volume Correlations.....	84
Long-lasting local anesthetics.....	86
Absorption.....	87
Blood Clearance.....	89

Pediatric Considerations.....	89
Adjuvants.....	90
13. Complications.....	91
Transient Femoral Nerve Block.....	91
Peritoneal and Visceral Puncture.....	93
Complications of Rectus Sheath Block.....	95
Complications of Genitofemoral Nerve Block.....	96
14. References.....	97
15. Index.....	111

1. Anatomy for Anesthesiologists

Zhirajr Mokini

Anterior Abdominal Wall Structure

The abdominal wall and the abdominal organs are involved to a variable extent in general, gynecologic, obstetric, vascular and urological surgery. The extent of involvement of the abdominal wall, of the peritoneum and of the abdominal organs determines the presence and the severity of the somatic and visceral components of post-surgical pain. For this reason, operations selectively involving the abdominal wall or the groin and the spermatic cord are considered surface procedures. They cause prevalently somatic pain to the abdominal wall. Procedures requiring laparotomy and involving the abdominal organs may cause severe somatic and visceral pain. Blocks of the anterior abdominal wall aim at eliminating the somatic component of surgical pain.

The anterior abdominal wall is formed by skin and a musculo-aponeurotic layer in which all muscles are covered by a posterior and an anterior fascia (Figure 1.1, 1.2, 1.3).

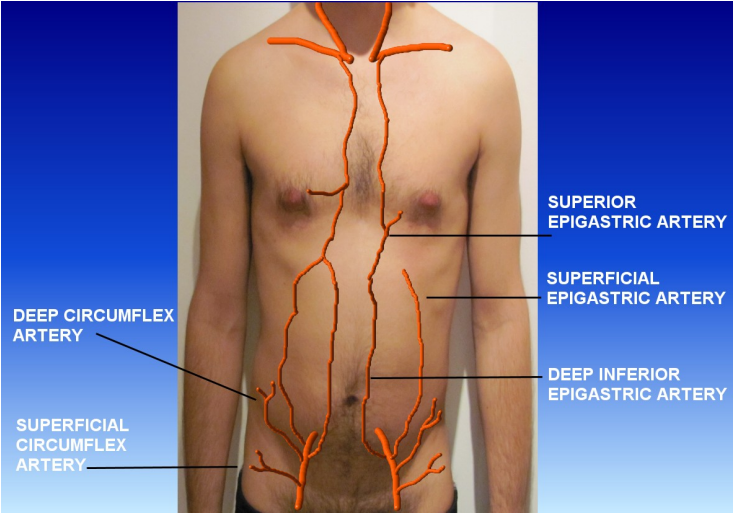


Figure 1.1 - The anterior abdominal wall arteries.

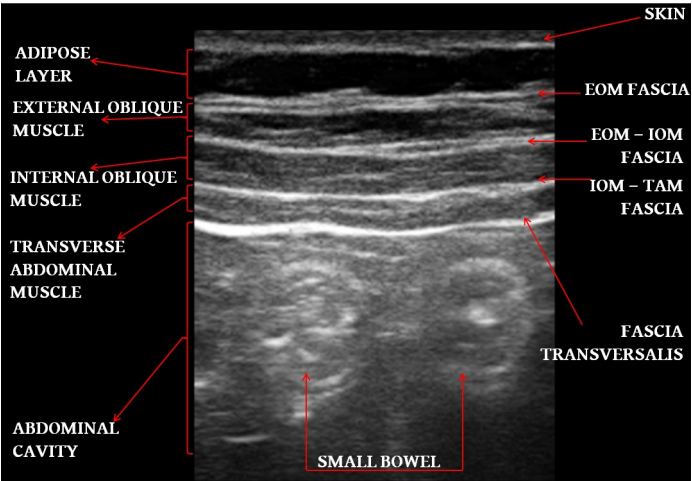


Figure 1.2 - Ultrasonographic view of anterior abdominal wall.

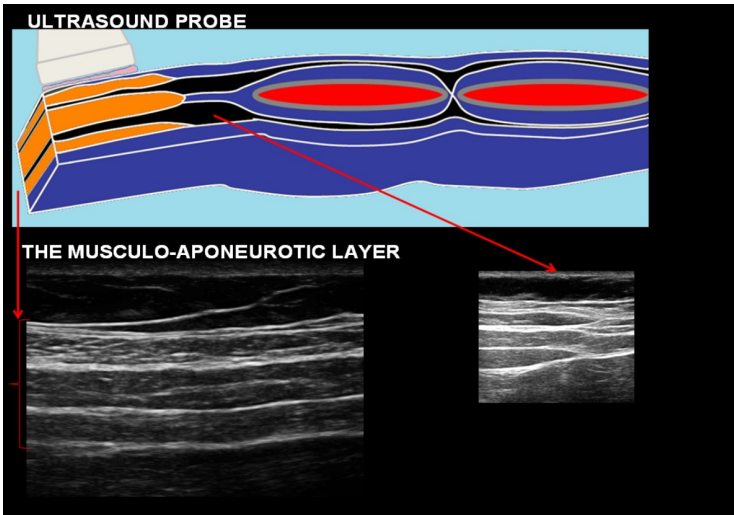


Figure 1.3 – The musculo-aponeurotic layer.

Anteriorly, the rectus abdominal muscle (RAM) lies on both sides of the vertical midline or linea alba. On either side of the RAM, the musculo-aponeurotic plane is made up respectively, from the anterior to the posterior surface, of three flat muscular sheets: the external oblique muscle (EOM), the internal oblique muscle (IOM) and the transverse abdominal muscle (TAM). The pattern of relative abdominal muscle thickness is RAM > IOM > EOM > TAM (Figure 1.4) (Rankin 2006).

The plane between the IOM and the TAM is the target for most of the abdominal blocks (Figure 3.4).

Blood Supply to the Anterior Abdominal Wall

Knowledge of abdominal wall vascularization is necessary for a safe performance of blocks. Three major arterial branches supply blood to both sides of the anterior abdominal wall (Figure 1.1). The deep inferior epigastric artery and vein originate from

the external iliac vessels. A second branch of the external iliac artery, the deep circumflex iliac artery, runs parallel to the inguinal ligament between the TAM and the IOM (Mirilas 2010). The superior epigastric artery (the terminal branch of the internal thoracic artery) and vein enter the rectus sheath superiorly and anastomose with the inferior epigastric vessels (Mirilas 2010).

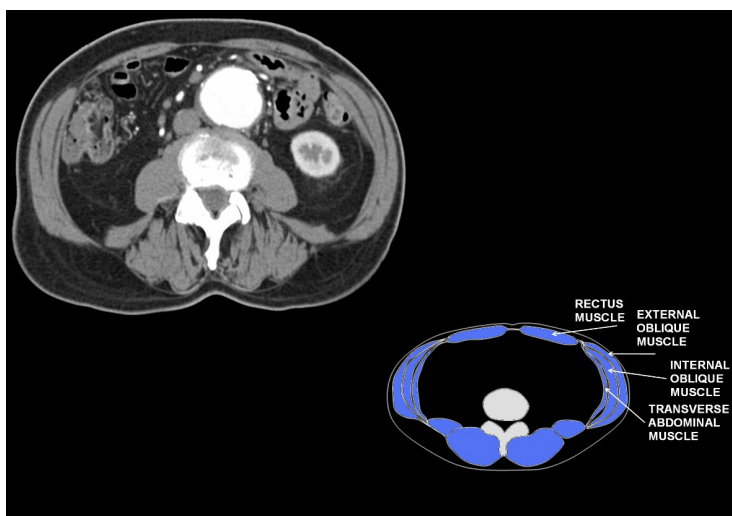


Figure 1.4 - TAC slice of the anterior abdominal wall.

Anterior Abdominal Wall Innervation

The anterior primary roots of T6 to L1 spinal nerves supply the innervation of the anterior abdominal wall. These nerves are the target of abdominal blocks (Figure 1.5).

The intercostal nerves, the subcostal nerves and the first lumbar nerves that emerge from T6 to L1 roots run with their accompanying blood vessels in a neurovascular plane known as the TAM plane (Figure 3.5). This is a virtual anatomical space

between the IOM and the TAM (Rozen 2008). TAM plane is delimited superiorly by the costal margin, inferiorly by the iliac crest, medially by the lateral border of the RAM, posteriorly by the lumbodorsal fascia, superficially by the IOM and deeply by the TAM.

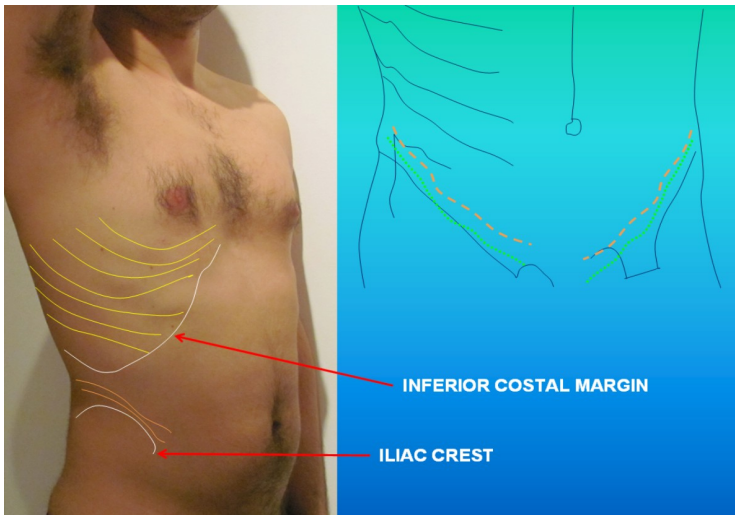


Figure 1.5 – Innervation of the anterior abdominal wall (lines represent T6 to T12 and iliohypogastric and ilioinguinal nerves).

Every segmental origin contributes to at least two nerves that divide into several branches at the level of the anterior axillary line (Barrington 2009). Each nerve gives muscular branches innervating the overlying IOM and EOM and the RAM medially. There is extensive and free branching and communication of nerves within the TAM plane. As a consequence, there is a considerable overlap in the dermal territories of adjacent cutaneous nerves.

The intercostal and subcostal nerves communicate freely in the TAM plane, and constitute a network corresponding to the

intercostal plexus. The nerves from T9 to L1 contribute to a longitudinal nerve plexus, named the transverse abdominal muscle plexus, that lies alongside and lateral to the ascending branch of the deep circumflex iliac artery (Rozen 2008).

The nerves from T6 to L1 form a further plexus into the rectus sheath named the rectus sheath plexus. This plexus runs cranial-caudally and laterally to the lateral branch of the deep inferior epigastric artery (Rozen 2008). A branch of T10 innervates the umbilicus.

Iliohypogastric and Ilioinguinal Nerves

The lumbar plexus, formed by the ventral branches of the spinal nerves from L1 to L4, projects laterally and caudally from the intervertebral foramina. Its roots innervate the lower part of the anterior abdominal wall, the inguinal field, through the iliohypogastric nerve (IHN-greater abdominogenital nerve), the ilioinguinal nerve (IIN-minor abdominogenital nerve) and the genitofemoral nerve (GFN) (Horowitz 1939).

A communication branch from T12 that is called the subcostal nerve may join in 50 to 60% of cases the anterior primary division of L1. More rarely a branch of T11 may also join L1.

The IHN and IIN pass obliquely through or behind the psoas major muscle and emerge from the upper lateral border of the psoas major muscle at the L2 to L3 level (Mirilas 2010). The IHN nerve, the first of the lumbar plexus, and the IIN may be found as a single or divided trunk in the retroperitoneal space. They cross obliquely parallel to the intercostal nerves and behind the lower pole of the kidney towards the iliac crest (which explains the referred pain to genitalia in kidney and ureter affections) (Anloague 2009).

Above the iliac crest, the IHN and IIN pierce the posterior surface of the TAM and run between this muscle and the IOM toward the inguinal region (Jamieson 1952, Mirilas 2010).

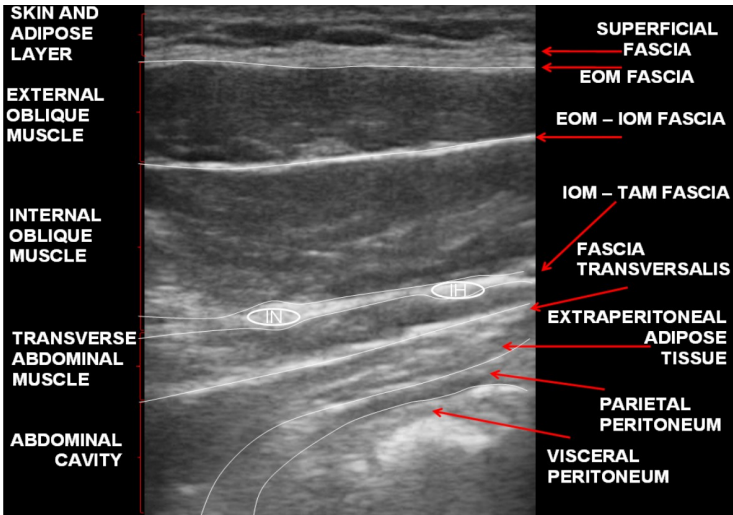
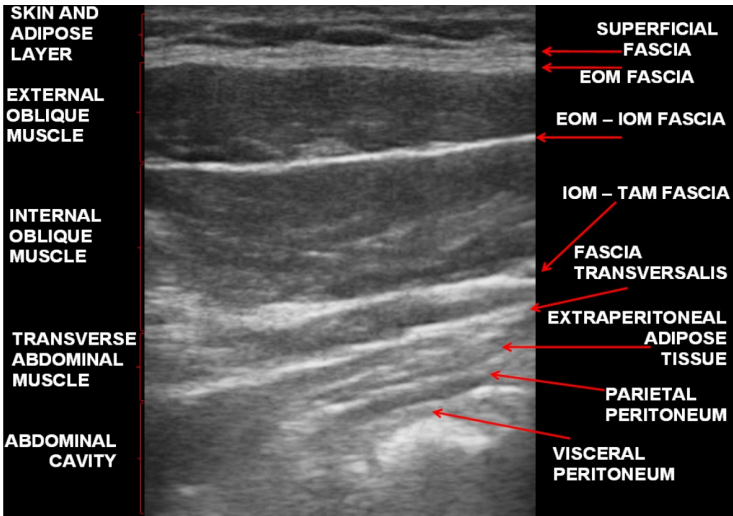


Figure 1.6 – Abdominal wall and iliohypogastric (IH) and ilioinguinal (IN) nerves.

The IHN and IIN have a constant course in the TAM plane in relation to the mid-axillary line. At this point, the nerves have not yet branched extensively (Figure 1.6) (Rozen 2008). Below the anterior-superior iliac spine (ASIS), the IHN and IIN pierce the IOM and are found between this muscle and the EOM.

The IHN pierces the aponeurosis of the EOM above the superficial inguinal ring and continues towards the lower area of the rectus sheath. The IIN continues in most cases in the inguinal canal together with the gGFN, generally at the posterior or at the anterior surface of the spermatic cord (Rab 2001).

The IHN and IIN are also called border nerves because they share a sensitive function to the skin over the inguinal canal, the pubic area, the base of the penis and the medial upper thigh. They share a motor function for the anterior abdominal muscles. They have a highly variable origin, course, distribution, communication between their branches and asymmetry (Mirilas 2010). In some cases they run as a single trunk.

Inguinal Canal

The inguinal canal is an oblique passage containing the testis and the spermatic cord (the round ligament in females) at the lowest border of the anterior abdominal muscles (Figure 1.7).

It extends for about 4 cm downwards and medially from the internal inguinal ring, a deficiency in the transversalis fascia, to the external inguinal ring, a deficiency in the EOM aponeurosis (Mirilas 2010). The wall of the inguinal canal is formed by the EOM aponeurosis, the IOM and the TAM (Mirilas 2010).

Genitofemoral Nerve

The GFN emerges from L1 to L2 roots. It may pierce the psoas major muscle and emerge from its anterior surface near the medial border at the level of L3 to L4 vertebrae. It may emerge both as a single trunk or divided into a genital and a femoral

(called also crural) branch. It runs beneath the transversalis fascia and the peritoneum (Liu 2002).

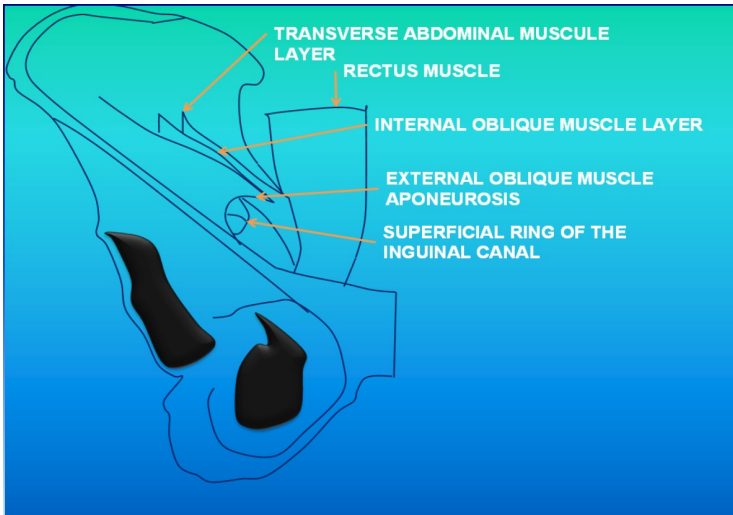


Figure 1.7 – Inguinal canal.

Descending the surface of the psoas muscle underneath the peritoneum, the genital branch crosses over anterior to the external iliac vessels and enters the inguinal canal through the deep ring. It accompanies the cremasteric vessels at the posterior edge of the spermatic cord ensheathed by the cremasteric fascia (Liu 2002). This nerve supplies the cremaster muscle and the skin of the scrotum and thigh. In females, the genital branch accompanies the round ligament of the uterus. The genital branch of the genitofemoral nerve (gGFN) shares a great variability with the IHN and the IIN (Rab 2001).

The femoral branch passes behind the inguinal ligament or the IOM alongside the external iliac artery. It enters the femoral sheath superficially and laterally to the femoral artery. The femoral branch pierces the anterior femoral sheath and fascia

lata to supply the proximal-medial area of the thigh and over the triangle of Scarpa. It may share branches with the genital branch in some cases (Rab 2001).

Rectus Sheath

The rectus sheath is a bilaminar fibrous extension of the aponeurotic layer of the EOM, IOM and TAM (Figure 1.3, 1.8, 6.3).

It encases the RAM on both sides from the costal margin down to the level of the anterior-superior iliac spine, fusing in the midline as the linea alba. The superior and inferior epigastric vessels run longitudinally through the medial portion of the RAM.

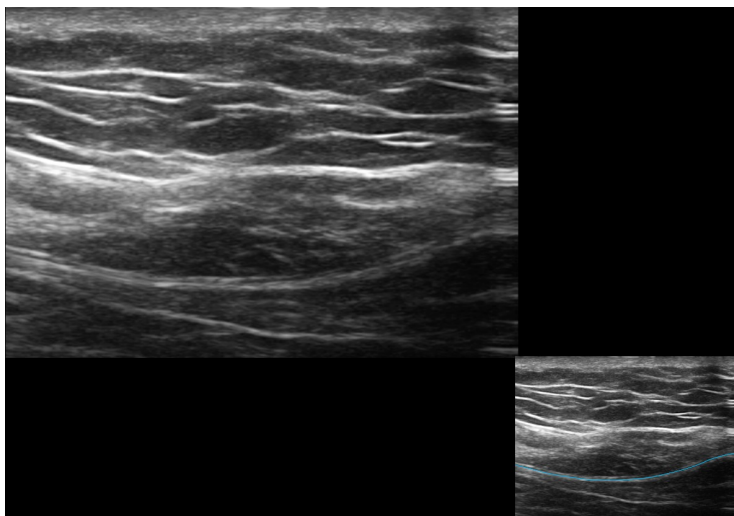


Figure 1.8 - Rectus sheath (line).

A virtual space exists between the posterior rectus sheath and the RAM. Local anesthetic can spread freely in this space in a caudal and cephalic direction.

Communication Between Anatomical Planes

As confirmed by several, although conflicting, anatomical and clinical studies, a virtually communicating plane may exist between the quadratus lumborum muscle, the psoas major muscle and the TAM, the transversalis fascia and the iliac fascia. This communication occurs especially at the inguinal level where the lumbar plexus roots run (Farny 1994, Rosario 1997).

Moreover there may be a communication between the thoracolumbar or lumbodorsal fascia, the paravertebral space, the fascia transversalis and iliac fascia (Mirilas 2010, Saito 1999).

The presented data are important for the performance of safe and effective blocks and to avoid the possible complications of abdominal blocks.

2. Ultrasound and Regional Anesthesia

Gabriele Aletti

Sound Waves

The application of pressure to a medium for a given period of time causes the compression of its molecules that will become closer to the subsequent molecules. The pressure energy will be propagated deeper between adjacent molecules in the direction of the compression. The movement of the molecules will propagate in the form of a pressure wave. A wave is a disturbance in a medium traveling through it at a constant speed. The periodic application of pressure will generate more waves that will travel through the medium.

Sound waves are subsequent and periodic high pressure and low pressure waves of molecular vibration. They travel longitudinally through a physical medium determining high pressure areas (compression) and low pressure areas (rarefaction) along the direction of propagation. Each wave has a frequency (f) of propagation measured as cycles per unit of time. The wavelength (λ) is defined as the geometric distance at an instant between two successive high pressure pulses or two successive low pressure pulses. The wavelength of sound decreases as frequency increases. The speed of propagation of

the wave (c) depends on the physical properties of the medium (Figure 2.1).

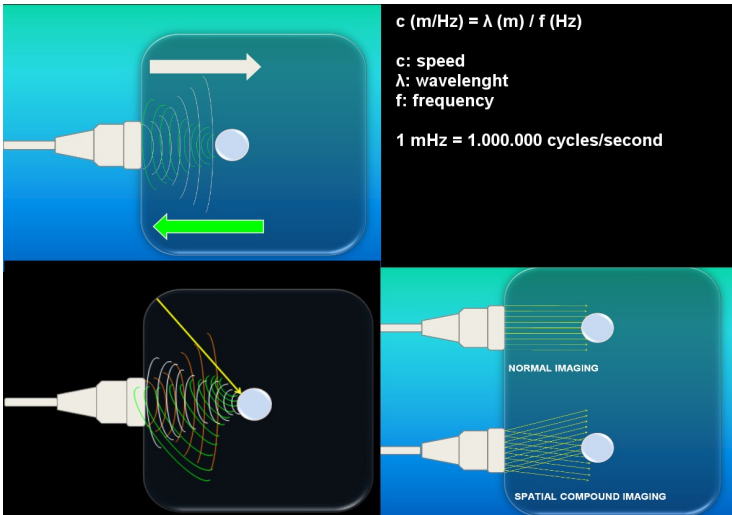


Figure 2.1 - From left to right: Pressure wave and returning echoes. Speed, wavelength and frequency correlations. Scattering effect. Spatial compound imaging.

Ultrasounds are cyclic sound pressures with a frequency above those which humans can hear. The human hearing limit is 20 kHz. Ultrasounds used in the medical setting have a frequency of 1 to 25 mHz. Sound waves are not ionising and are not harmful at the energy levels used for diagnostic purposes. There is to date no epidemiological evidence of harmful effects (Moore 2011).

Ultrasounds travel faster in dense bodies and slower in compressible bodies. In soft tissue the speed of sound is 1540 m/s, in bone about 3400 m/s, and in air 330 m/s. In tissues where the sound travels more slowly, the wavelength decreases.

Piezoelectric Effect

Some materials can produce electric energy in response to a mechanical stress and conversely, produce a mechanical response when an electric current travels through them. This is the so-called piezoelectric effect. Medical ultrasound waves are produced by a piezoelectric crystal as a consequence of the mechanical response to an electric field. The transducer also picks up the reflected waves or “echoes” from the tissues and converts them into electrical signals that are used to form real-time images on a computer. The crystal thus both transmits and receives the sound (Figure 2.1).



Figure 2.2 – Ultrasound system. From top to bottom: linear 10 and 18 and convex 5 MHz transducers.

Each electric signal is registered, amplified, and filtered to reduce noise, and the depth of the tissue that has generated the echo is calculated. The signals are then digitalized and processed in order to produce an image.

Early ultrasound devices used a single crystal to create a one dimension image, called a-mode image. Modern machines generate a b-mode or two-dimensional or gray-scale image created by 128 or more crystals. Each crystal receives a pulse that produces a scan line used to create an image on the screen. This image is renewed several times each second to produce a real-time image. Additional modes, including high resolution real time gray scale imaging, Doppler mode, color-flow Doppler mode, color-velocity Doppler and tissue harmonic modes are now commonly available.

Imaging

Depending on the medium's physical properties and the contact with different interfaces into the medium, the energy of the wave is dissipated, attenuated and reflected. At the interface where one tissue borders another tissue, the wave is refracted and reflected back as an echo. The reflection depends on the tissue density and thus on the speed of the wave. So, as the waves penetrate tissues, they detect where soft tissue meets air, or soft tissue meets bone, or where bone meets air. Instead, some structures will completely absorb the sound waves. Thus, echoic tissues are those tissues that reflect the wave whereas anechoic tissues do not reflect the wave.

Ultrasounds penetrate well through fluids that are anechoic and appear as black on the monitor. Fluids allow ultrasounds to pass through more or less attenuated until they encounter the surface of denser structures. Bone or air are poorly penetrated by ultrasounds and generate a kind of "sound-shadow".

The transverse appearance of nerves is round or oval and hypo-echoic (Figure 2.3). They may appear as honeycomb structures containing hyper-echoic points or septa inside them. Nerves are surrounded by a hyper-echoic border that corresponds to connective tissue. Tendons have a similar appearance. On the longitudinal scan, tendons disappear while

tracking them for some distances whereas nerves do not disappear.

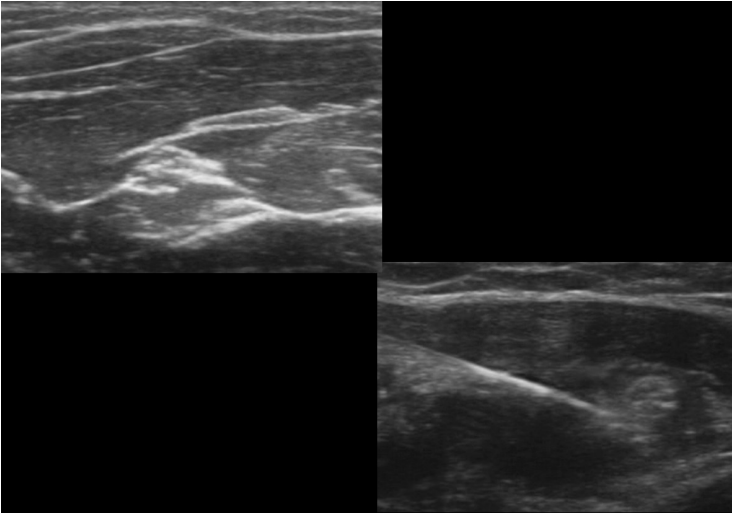


Figure 2.3 – Ultrasound appearance of median nerve and of radial nerve with the needle (in-plane approach).

Blood vessels appear as round hypo-echoic structures with a well defined hyper-echoic border corresponding to the vessel wall. The arteries are not compressible and are pulsating, veins have a thinner border and are compressible (Figure 5.3, 13.3).

Muscles appear as heterogeneous or homogeneous hypo-echoic structures with hyper-echoic septa and a fibrous-lamellar texture (Figure 3.2). The periosteum appears as hyper-echoic as it reflects entirely the echoes. As a consequence, the bone underlying the periosteum appears as black (ultrasound shadow) (Figure 4.1). The knowledge of normal anatomy is essential for the identification of different tissues with ultrasounds.

Since the speed of the wave in different tissues is known, the time for the reflected wave to return back indicates the depth of the tissue.

All this information is converted into a two-dimensional image on the screen. This slice may be directed in any anatomical plane: sagittal (or longitudinal), transverse (or axial), coronal (or frontal), or some combination (oblique).

During an ultrasound-guided nerve block, the left side of the screen should correspond to the left side of the transducer. An indicator on the transducer is used to orient the user to the orientation on the screen. By convention the indicator corresponds to the left side of the screen as it is viewed frontally. The transducer should be placed also in order to have the indicator on the left side of the transducer.

Transducers

Since ultrasound examinations are best suited for investigations of soft tissues, they are indicated for the visualization of the abdominal wall.

Lower-frequency ultrasounds have better penetration and are used for deeper organs, but have a lower resolution. The deeper the structure, the lower the needed frequency.

Higher-frequency ultrasounds provide better resolution, but with a low penetration. So high-frequency ultrasounds are useful in the case of superficial tissues. Depending on the abdominal wall thickness, typical transducers/probes used to visualize the abdominal wall are linear ones from 10 to 20 MHz (Figure 2.2).

Linear compound array transducers allow better visualization of structures poorly visualized by ultrasounds such as nerves. For 0 to 3 cm of depth, linear >10 MHz transducers are necessary. For 4 to 6 cm of depth, 6 to 10 MHz linear transducers are used. Structures which are deeper than 6 cm need 2 to 6 convex transducers. The transducer should be positioned perpendicular

to the anatomical target. The transmission gel is an essential tool for the transmission of echoes.

The transducer and the cable must be covered with a sterile cover. The gel in contact with the skin must be sterile. The skin must be disinfected prior to any contact with the transducer and the needle.

Focus

The focus of the image is usually marked with a point or an arrow at the right side of the screen of the ultrasound device. This arrow should be placed at the same depth of the targeted structure or a bit deeper. It ensures high definition of tissue at that depth.

Presets

Some ultrasound machines offer the possibility to choose between different presets (for muscles, tendons, vessels, soft tissues). Each preset has the best setting of frequency, depth, focus and compound in order to view that tissue.

Time-gain Compensation

Since echoes reflected from deeper tissues are progressively attenuated, time gain compensation is used to amplify echoes from increasing depths to compensate for their progressive attenuation.

Spatial Compound Imaging

Modern piezoelectric crystals can produce echoes that travel in many directions and thus return with more information. The contrast resolution is thus enhanced to provide better tissue differentiation, clearer organ borders, and structure margin

visualization. Tissue layers, nerves and vessels are more clearly differentiated (Figure 2.1).

Ultrasound and the Needle

When inserted to perform a block, the needle may be visualized dynamically with the use of either an “in-plane” or “out-of-plane” approach. An in-plane approach is performed when the needle is parallel to the long axis of the transducer (LOX) (Figure 2.4). An out-of-plane approach is performed when the needle is perpendicular to the long axis of the transducer or parallel to the short axis (SOX). An out-of-plane approach may over- or underestimate the depth of the needle (Marhofer 2010). The needle axis must be parallel and also aligned with the axis of the probe.

When injecting, local anesthetic spread must be monitored. If anesthetic spread is not seen, intravascular injection or poor visualization must be excluded. Needle electrostimulators may confirm the presence of the nerve because of the twitching of the muscles caused by the current. However, in abdominal blocks this effect may not occur.

One of the problems with needle visualization is that depending on the angle of insertion, some echoes are reflected out of the plane of the transducer and thus lost (Figure 2.1). The more the needle is parallel to the transducer, the more the echoes will be captured from the transducer and the needle visualized.

Equipment

Ultrasonography is a safe and effective form of imaging. Over the past two decades, ultrasound equipment has become more compact, of higher quality and less expensive (Figure 2.2). This improvement has facilitated the growth of point-of-care ultrasonography, that is, ultrasonography performed and

interpreted by the clinician at the bedside. Ultrasounds have been used to guide needle insertion, and a number of approaches to nerves and plexuses (groups of nerves) have been reported.

A clear advantage of the technique is that ultrasound produces "living pictures" or "real-time" images. The identification of neuronal and adjacent anatomical structures (blood vessels, peritoneum, bone, organs) along with the needle is another advantage.



Figure 2.4 – Needle parallel to short and long axis of the transducer: out-of-plane and in-plane approaches.

Ultrasounds use has been rated as one of the safest practices for patients. The prevention of intravascular injection during regional anesthesia blocks is best accomplished with a combination of ultrasound technique and epinephrine test dosing (Neal 2010).

Moreover, anatomical variability may be responsible for block failures, and ultrasound technology enabling direct visualization may overcome this problem. Many studies show that complex nerve plexus block as well as single nerve block techniques can be successfully performed with lower volumes of local anesthetics. Sonographic visualization allows for the

performance of extraepineurial needle tip positioning and administration of local anesthetic, avoiding intraepineurial injection. Finally, there may be a reduced need for general anesthesia and reduced inpatient stay.

The performance of peripheral nerve blocks is clearly dependent on technique, and expertise and the use of ultrasounds requires additional skills. Some of the prerequisites for the implementation of ultrasounds in regional anesthesia include excellent understanding and knowledge of human anatomy, understanding of the principles related to ultrasound-guided blocks, having good hand skills and hand-eye coordination (Gonano 2009).

Most ultrasound novices have problems with exact coordination between ultrasound transducer position and needle tip visualization during advancement. The American and European Societies of Regional Anesthesia (ASRA and ESRA) have recently published guidelines for training in ultrasound-guided regional anesthesia, highlighting the encouragement of individual institutions to support a quality-improvement process (Sites 2007, Sites 2009).

Recently a Cochrane review reported that in experienced hands, ultrasound guidance for peripheral nerve blocks has success rates at least as peripheral nerve stimulation. The incidence of vascular puncture or hematoma formation was reduced in some studies. Ultrasounds may improve the quality of sensory and motor block. Many studies assessed block performance time and found a significant reduction with ultrasounds use. No study has assessed trunk blocks and statistical analysis was not possible due to the heterogeneity of the studies. However, the findings are likely to reflect the use of ultrasounds in experienced hands and may not be reproducible by less skilled practitioners (Walker 2009).

In conclusion, the use of ultrasounds may provide a potential standard in regional anesthesia if a responsible, scientific,

structured and careful implementation of such techniques is performed (Marhofer 2010).

3. Transverse Abdominal Plexus Block

Zhirajr Mokini

The block of transverse abdominal plexus (TAPB) provides effective analgesia when used as a part of multimodal analgesic strategies for abdominal surgery and in chronic pain. From the first description, several clinical trials have evaluated the TAPB for postoperative analgesia in a variety of procedures (Rafi 2001)

Conceptually the TAPB is a compartmental block because the local anesthetic is deposited into the fascial plane between the internal oblique muscle and the transverse abdominal muscle. Cadaveric and radiological studies have demonstrated the deposition of the local anesthetic in the TAM plane (McDonnell 2007).

Unlike the rectus sheath block (RSB), which targets only the midline, the TAPB targets the entire anterior-lateral abdominal wall (Rozen 2008). The extent of the block will depend on the puncture site and the volume of local anesthetic. The typical volume used for the TAPB is 20 to 30 ml each side. The maximum block extent is observed after 30 to 60 minutes and residual block may persist after 24 hours (Lee 2008). The block can be achieved both blindly and with the use of ultrasounds. Technical aspects of the TAPB and other blocks are showed in Table 6.1.

The indications for the TAPB are evolving and the technique has been used for postoperative analgesia after general, urological, obstetric, plastic and gynecologic surgery procedures.

Blind Transverse Abdominal Plexus Block

Multiple landmarks for accessing the TAM plane have been described:

- 1- percutaneous loss-of-resistance technique injection through the lower lumbar triangle of Jean-Louis Petit (Rafi 2001),
- 2- the injection between costal margin and the iliac crest at the mid-axillary line,
- 3- subcostal injection under the costal margin.

The landmark-based techniques rely on a two pop feeling. The first “pop”, “click”, “ping” or “ting” occurs when the needle pierces the fascia between the EOM and the IOM. The second occurs when the needle pierces the fascia between the IOM and the TAM.

The inferior lumbar triangle is a triangular area of the dorsal abdominal wall bordered inferiorly by the iliac crest, posteriorly by the anterior edge of the latissimus dorsal muscle and anteriorly by the posterior edge of the EOM (Figure 3.1) (Loukas 2007). The floor of the triangle from superficial to deep is formed by the IOM and the TAM. When the triangle of Jean-Louis Petit is used as a landmark, only the fascia between the IOM and the TAM will be felt in most cases.

At this level, the T6 to L1 afferent nerves are found in the compartment between the IOM and the TAM. Caudal and cephalic spread of local anesthetic occurs when it is injected into this compartment.

However, the triangle of Petit can be difficult to palpate especially in obese persons or children and therefore is of limited use. Since it is found posteriorly, the block through the lumbar triangle is less convenient to perform in supine patients. It varies greatly in its position and its size is relatively small

(Jankovic 2009). The presence of adipose tissue also changes the position significantly. As a result, it is difficult to find the triangle solely on palpation. Ultrasound visualization also is poorly achievable.

Moreover, the lumbar triangle may frequently contain small branches of the subcostal arteries (Jankovic 2009). In an anatomical study, in 17.5% of specimens no triangle was found because the latissimus dorsi was covered by the EOM (Loukas 2007). Finally, unexpected lumbar hernias may be found in 1% of patients (Burt 2004).

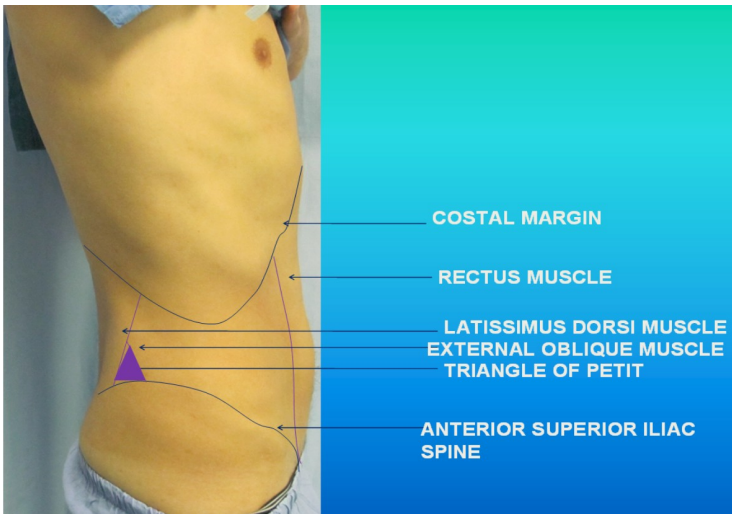


Figure 3.1 - Triangle of Jean-Louis Petit.

Ultrasound-guided Transverse Abdominal Plexus Block

Ultrasounds can overcome the problem of impalpable muscle landmarks because they allow real-time visualization of tissues, of the needle and of the spread of the local anesthetic (Figure 3.2, 3.6) (Hebbard 2008).

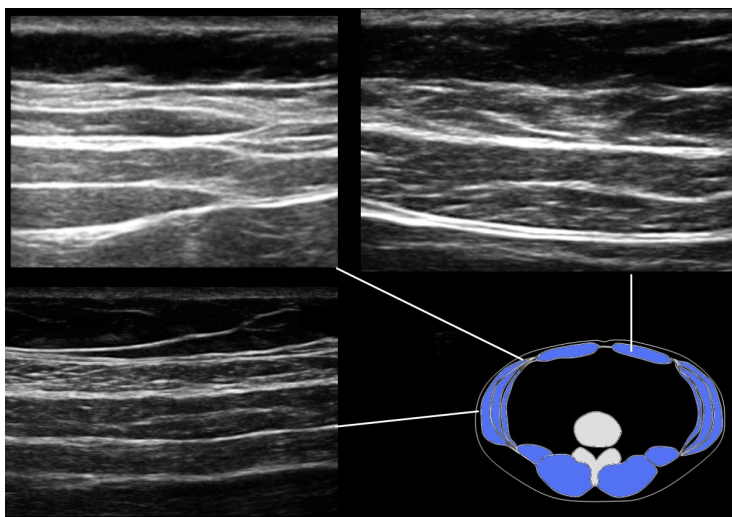


Figure 3.2 – The abdominal wall visualized from different positions.

Preoperative block administration is recommended as tissue visualization with ultrasounds may be impaired after surgery and tissue manipulation. Moreover, late persistence of elevated local anesthetic levels in the plasma after abdominal blocks have been shown.

A traditional or classical TAPB may be performed by injecting the local anesthetic between costal margin and iliac crest at the mid-axillary or at the anterior axillary line (Figure 3.3, 3.4).

When the transducer is positioned between costal margin and iliac crest at the mid-axillary or the anterior axillary line, the three muscular layers of the abdominal wall will be seen on the screen (Figure 3.2). The EOM, IOM and the TAM are seen as hypo-echoic longitudinal bands (Figure 3.5). The IOM is the thickest and the TAM is the deepest. Muscular fascias between the muscles are seen as hyper-echoic and hyper-lucent.

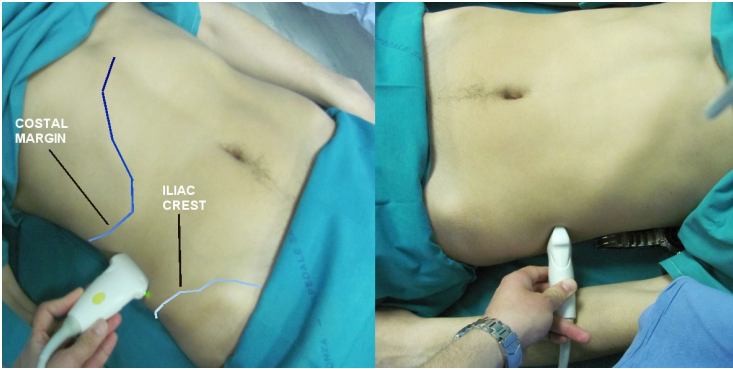


Figure 3.3 – Transducer positioning between iliac crest and costal margin.

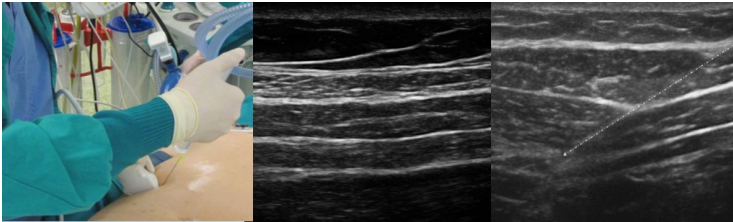


Figure 3.4 – Positioning and ultrasound appearance of classical TAPB procedure.

The needle is inserted and advanced obliquely with an in-plane approach, parallel and aligned to the long axis of the transducer. The in-plane approach would possibly decrease the risk of advancing the needle into the peritoneal cavity. The presence of blood vessels must be always checked on the screen. Aspiration before injection is necessary to avoid intravascular placement.

When the fascia between the IOM and the TAM is reached with the needle, a small volume of local anesthetic may be injected. If the fascia expands, the needle is placed correctly (Figure 3.6). If the muscle expands, the needle must be replaced. The whole

volume is injected while controlling the full dilatation of the fascia on the screen.

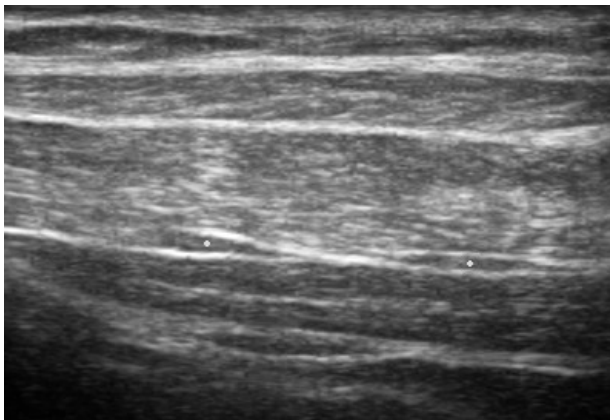


Figure 3.5 - Two nerves seen as fascicular and oval (points) between the IOM and the TAM during a classical TAPB.

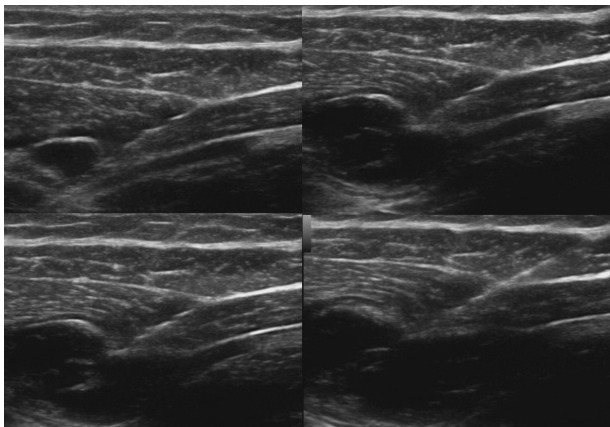


Figure 3.6 - Injection with the needle and dilatation of the fascia during a classical TAPB.

An alternative is the subcostal TAPB (Figure 3.7). In this case the transducer is placed immediately inferior to the costal margin on the anterior abdominal wall (Hebbard 2008). The anesthetic can be injected with an in-plane approach. A good ultrasound landmark may be the TAM plane at the medial edge of the transverse abdominal muscle, near the border with the rectus muscle (Figure 6.2)

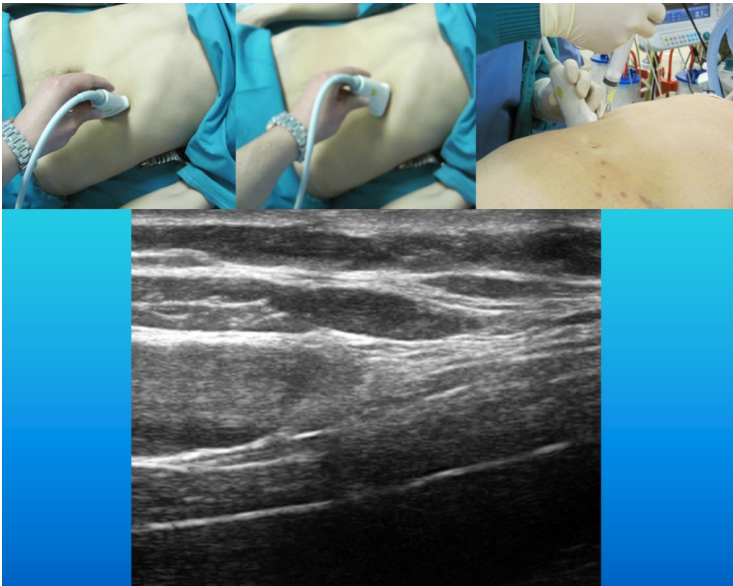


Figure 3.7 – Subcostal transverse abdominal plexus block.

The rationale for the subcostal TAPB lies in the fact that the nerves located between the costal margin and the inguinal ligament at the anterior axillary line have a segmental origin from T9 to L1. Levels more cranial than this, T6 to T8, are not covered with the classical TAPB, limiting its usefulness to lower abdominal surgery. However, a more extensive pattern of nerve involvement may result if an additional injection is made anterior-medial to the costal margin (Rozen 2008). The

difference between the subcostal TAPB and the classical TAPB is the different extent of block.

Spread

The dermatomeric extent of the TAPB and its indications are currently under discussion. It is not clear if the local anesthetic blocks somatic nerves alone or if it also spreads to block autonomic nerves. Radiological computerized tomography and magnetic resonance imaging have evidenced the spread of local anesthetic beyond the TAM plane to the quadratus lumborum and to the intrathoracic paravertebral regions (Carney 2008, McDonnell 2004).

The classical TAPB may not reliably provide analgesia for procedures above the level of the umbilicus that is innervated by T10 endings (Barrington 2009, Tran 2009). The extension is generally from L1 to T10 (Carney 2008, McDonnell 2007 (2)). However, a T7 to L1 extension has been also reported (McDonnell 2007). The subcostal TAPB may produce a T9 to 11 block extent in more than 60% of cases (Lee 2008). In children, ultrasound-guided supra-iliac TAPB with 0,2 ml/kg of anesthetic performed by novice operators, produced lower abdominal sensory blockade of only 3 to 4 dermatomes (Palmer 2011). Only 25% of TAP blocks may have upper abdominal block extension. Thus, the optimal local anesthetic concentration, the duration of effect and utility of these blocks in relation to peripheral and neuraxial blockade in children needs clarification (Palmer 2011).

The clinical application of the transverse abdominal plexus block may be divided between lower abdominal surgery, where the classical posterior approach guarantees an adequate analgesic coverage, and surgery in the upper quadrants of the abdomen, where the subcostal TAPB is preferable to ensure an adequate analgesia (McDonnell 2007 (3), Niraj 2009 (2), Hebbard 2010). A combination of the classical and subcostal approach have been also described.

The TAPB is also indicated for patients unsuitable for epidural analgesia (Niraj 2011).

4. Iliohypogastric and Ilioinguinal Nerve Block

Giovanni Vitale

Blind Iliohypogastric and Ilioinguinal Nerve Block

The block of iliohypogastric and ilioinguinal nerves (IIB) is performed by anesthesiologists and can be achieved blindly or under ultrasound visualization. Aseptic technique and patient security procedures should be strictly observed. Before performing a block on an awake patient, sedation with a benzodiazepine or an opioid together with oxygen may be administered. Midazolam 0.035 mg/kg and/or Fentanyl 1-1.5 mcg/kg can be used for adequate sedation. Blocks can also be administered after general anesthesia induction; in this case the patient will not be able to communicate.

Various injection landmarks have been suggested such as

1. 1 cm inferior-medial to the ASIS (anterior superior iliac spine), 1-2 cm medial to the ASIS, 2 cm superior-medial to the ASIS
2. the junction of the lateral one-fourth on a line from the ASIS to the umbilicus
3. the point just medial and inferior to the ASIS, 5-10 mm in infants and 20 mm in adolescents

4. the point 10–20 mm medial and 10–20 mm superior to the ASIS
5. the point just 10 mm medial to the ASIS
6. one finger-breadth medial to the ASIS, 5 cm above and lateral to the mid-inguinal point

The last approach is mostly used for children and the measure of the finger's breadth is taken at the proximal inter-phalangeal joint of the child's ipsilateral index finger. Single or multiple injections may be done and different puncture sites provide similar effectiveness (Lim 2002).

The fascia between the EOM and the IOM offers a first resistance to the needle felt as a “pop” or “ting” or “ping”, whereas the fascia between the IOM and the TAM provides a second resistance. After the second resistance has been felt, the local anesthetic may be injected.

This ‘resistance’ may be very subtle, particularly in small infants and thin children. A useful tip is to hold a skin fold between the thumb and index of one hand and puncture the skin to reach the subcutaneous tissue. The first ‘pop’ felt is likely to be the aponeurosis of the EOM (Frigon 2006). Another way is to use a sharp introducer to puncture the skin. A 22G Whitacre spinal needle inserted through the introducer into the subcutaneous tissue will provide a good feedback in terms of a distinct ‘pop’ as the EOM aponeurosis and the IOM fascia are penetrated.

However, anatomic and ultrasound control studies on the classical landmarks show that only two muscle layers instead of three may be identified in 50% of the patients. This occurs because the EOM is limited to an aponeurosis in the medial area adjacent to the ASIS (Willschke 2005).

Table 4.1 – Pediatric distances in millimeters (mean ± SD) (modified from van Schoor 2005, Willschke 2005 and Hong 2010).

Neonates	ASIS to left IIN	1.9 ± 0.9, (01 to 0.61)
	ASIS to right IIN	2.0 ± 0.7, (3.44 to 0.49)
Children	ASIS to left IIN	3.3 ± 0.8, (5.31 to 1.52)
	ASIS to right IIN	3.9 ± 1.0, (5.39 to 2.36)
1 months - 8 years	ASIS to IIN	6.7 ± 2.9
	Skin to IIN	8.0 ± 2.2
	IIN to peritoneum	3.3 ± 1.3 (1–4.6)
0-12 months	ASIS to IIN	8.7±2.1
	ASIS to IHN	9.8±2.6
	Skin to IIN	8.7±1.9
	Skin to IHN	9.8±1.9
	IIN to peritoneum	8.5±1.7
	IIN to peritoneum	9.0±1.7
12-36 months	ASIS to IIN	11.6±3.0
	ASIS to IHN	13.2±2.6
	Skin to IIN	9.2±1.7
	Skin to IHN	9.7±2.0
	IIN to peritoneum	6.3±4.1
	IIN to peritoneum	4.1±1.8
> 37 months	ASIS to IIN	15.2±3.7
	ASIS IHN	18.0±4.3
	Skin to IIN	6.5±3.3
	Skin to IHN	3.8±1.5
	IIN to peritoneum	7.3±4.1
	IIN to peritoneum	4.5±1.7

Blind techniques may be confusing because of imprecise description and insufficient understanding. There is also a high potential for complications such as peritoneal or visceral puncture (Weintraud 2008, van Schoor 2005). The reported failure rate remains high and variable, 6 to 43%, even in

experienced hands or when multiple punctures are performed because of the high anatomical and landmark variability (Randhawa 2010). The failure rate may be as high as 6 to 40% especially in infants and children, even when the nerve is exposed at surgery (Weintraud 2008, Lim 2002). Correct administration of local anesthetic around the target nerves occurred in only 14% and 57% of cases in two studies when using a landmark method with a fascial click (Weintraud 2008, Randhawa 2010). The remainder of the injections were deposited in adjacent anatomical structures (iliac muscle 18%, TAM 26%, IOM 29%, EOM 9%, subcutaneous tissue 2%, and peritoneum 2%) (Weintraud 2008).

The data in Table 4.1 show the distances from the skin and the ASIS to the nerves and from the nerves to the peritoneum in children. Table 4.2 show the abdominal muscle size in adults.

Table 4.2 – Adult distances in centimeters (modified from Eichenberger 2006 and Rankin 2006).

Adults	Absolute abdominal muscle size at the mid-axillary line	IIN to bone distance at the ASIS
Males	3.86 (right: 0.64, 95% range 2.58–5.14) 3.88 (left: 0.67, 95% range 2.54–5.22)	0.4–1.1
Females	2.96 (right: 0.46, 95% range 2.04–3.88) 2.94 (left: 0.43, 95% range 2.08–3.80)	0.4–1.1

These data highlight the fact that blind techniques may be imprecise and carry a high risk of bowel, liver or spleen puncture, especially in children. Needle depth should be confirmed by the fascial click, since the risk increases if the needle is introduced too deep when the ‘pop’ is not identified (Hong 2010).

There is a weak correlation between weight and the depth of the IIN (Willschke 2005). These findings emphasize the usefulness of ultrasounds for this block technique and the fact that needle tip visualization is mandatory (Weintraud 2008).

Ultrasonographic Visualization Studies

The IIB is a safe, frequently used block that has been improved in efficacy and safety by the use of ultrasonographic visualization (Willschke 2006). The ultrasound approach increases the safety of this block because the nerves, the surrounding anatomical structures and the needle are visualized. The site of injection is under direct control and the volume of the local anesthetic can be individualized so that it surrounds the nerve structures (Willschke 2006). Preoperative block administration is recommended as tissue visualization with ultrasounds may be impaired after surgery and tissue manipulation. Moreover, late persistence of elevated local anesthetic levels in the plasma after abdominal blocks have been shown.

On long axis scans, the nerves have a fascicular pattern made of multiple hypo-echoic parallel and linear areas separated by hyper-echoic bands. The hypo-echoic structures correspond to the neuronal fascicles that run longitudinally within the nerve, and the hyper-echoic background relates to the inter-fascicular epineurium (Martinoli 2002). On short axis scans, nerves assume a honeycomb-like appearance with hypo-echoic rounded areas embedded in a hyper-echoic background (Martinoli 2002). Color Doppler can help differentiating the hypo-echoic nerve fascicles from adjacent hypo-echoic small vessels (Martinoli 2002). However the IIN and the IHN are small nerves that can generally be seen only as oval hypo-echoic structures embedded in a hyper-echoic border (Figure 4.1).

The IHN and IIN visualization with ultrasounds may be possible in 100% of cases in children between 1 month and 8 years of age and in 95% of cases in adults (Hong 2010, Willschke 2005, Eichenberger 2006). The difficulties that arise because of the smaller anatomical structures in children and the altered anatomy of the abdominal wall in pregnancy, can be

compensated by the greater aqueous consistency and the reduced calcification of tissues.

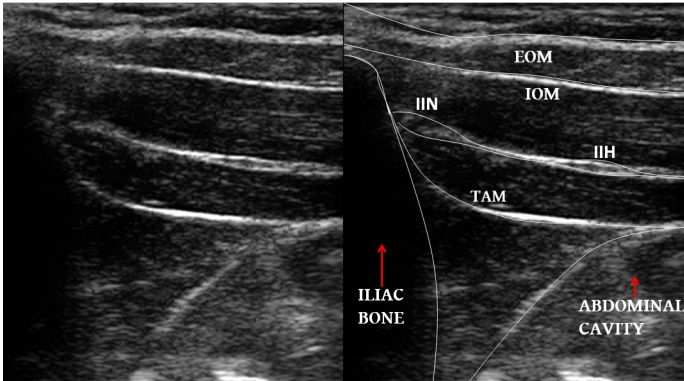


Figure 4.1 – Normal ultrasound anatomy seen above the ASIS.

Ultrasound-guided Iliohypogastric and Ilioinguinal Nerve Block

The transducer is placed over the mid-axillary line and above the iliac crest (Figure 4.2). The best image is tracked by moving the transducer along the course of the iliac crest in the direction of the ASIS (Figure 4.3). When positioning the transducer, the three muscular layers of the abdominal wall will be seen on the screen. The iliac bone will be seen at one side of the screen as black. On the other side of the screen, deeper, the abdominal cavity and eventually peritoneum or the bowel may be seen.

The three abdominal muscles, the EOM, the IOM and the TAM, are seen as hypo-echoic longitudinal bands (Figure 4.1). The IOM is the thickest and the TAM is the deepest. The muscular fascias between them are seen as hyper-echoic and hyper-lucent. Along the fascia between the IOM and the TAM, two oval structures

may be seen corresponding to the IHN and IIN. The IIN is the closest to the iliac bone.



Figure 4.2 – Positioning for ultrasound-guided block performance.

The needle is inserted with an in-plane approach, parallel and aligned to the long axis of the transducer. The needle is advanced obliquely. The in-plane approach would possibly decrease the risk of advancing the needle into the peritoneal cavity. Always control for blood vessels and aspirate before injecting.

Ultrasounds have been shown to decrease local anesthetic volume and improve the success of the block (Willschke 2005, Willschke 2006, Eichenberger 2009). Ultrasound guidance enhances efficacy and safety. The main disadvantages are the cost of equipment and the need for adequate training of

anesthesiologists before clinical application of ultrasound-guided blocks. Anesthesiologists need to develop a good understanding of the anatomical structures involved in the blocks. They need to acquire both a solid knowledge in ultrasound technology and the practical skills to visualize nerve structures.



Figure 4.3 - Transducer positioning for iliohypogastric and ilioinguinal nerve block.

Since IHN and IIN visualization is not always possible because it is operator, patient and equipment dependent, the TAM plane near the ASIS may be a more useful landmark (Ford 2009). A good endpoint for the inexperienced practitioner of ultrasound-guided IIB may be the plane between the TAM and the IOM where the nerves are reported to be found in 100% of cases (Ford 2009). It is important to note that IHN and IIN can not always be reliably identified; this is not a simple block! Ultrasound novices starting to perform IIB should scan the

region at least 14–15 times before performing the block using the muscle planes as an endpoint (Ford 2009). Importantly, the block should be performed above the ASIS. In conclusion, since a lower local anesthetic volume is required for IIB at the ASIS level, selective block of these nerves instead of classical TAPB is advised (Figure 4.4).

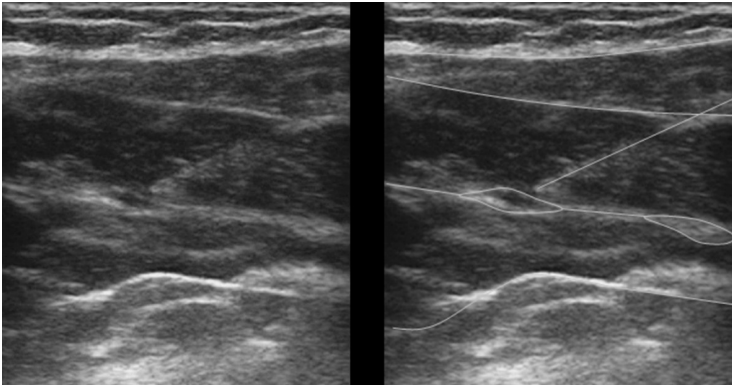


Figure 4.4 - The needle approaching the ilioinguinal nerve under ultrasound guidance.

5. Genitofemoral Nerve Block

Zhirajr Mokini

Occasionally, the inguinal field block (IFB)/local infiltration anesthesia (LIA) (see the detailed discussion in Chapter 7) seem to fail due to pain experienced during spermatic cord manipulation. In these cases, ideally, a block of the genital branch of genitofemoral nerve (gGFB) should be performed because local anesthetic infiltration into the inguinal canal improves the efficacy of the block (Yndgaard 1994).

A selective gGFB is not possible except under direct intraoperative vision (Rab 2001). The IIN and gGFN generally enter the deep inguinal ring and run together into the inguinal canal on the surface of the spermatic cord. In all cases the gGFN innervates the cremaster muscle (Rab 2001).

The blind landmark for the inguinal canal that corresponds to the underlying spermatic cord is the point on the skin, one finger-breadth above the mid-point between the ASIS and the mid-penopubic fold at the symphysis pubis (Hsu 2005). The typical injection site for the gGFB is referred to be superior-lateral to the pubic tubercle in order to inject the anesthetic near the spermatic cord (Peng 2008). Caution should be taken because at the pubis level the inferior epigastric vessels are found respectively at 7.47 ± 0.10 cm on the right and 7.49 ± 0.09 cm on the left side from the midline (Saber 2004).

Recently an ultrasound and non-selective technique with a linear 6-13 MHz transducer has been developed for gGNB. Since it is not possible to achieve gGFN visualization with ultrasounds, the technique includes the injection of the local anesthetic inside and outside the spermatic cord (Peng 2008).

The transducer is aligned to visualize the femoral artery in the long axis and then is moved upwards towards the inguinal ligament where the femoral artery becomes the external iliac artery. The spermatic cord is seen superficially to the external iliac artery just opposite to the internal inguinal ring. It appears as an oval or circular structure with 1 or 2 arteries (the testicular artery and the artery to the vas deferens) and the vas deferens as a tubular structure within it (Peng 2008). The transducer is moved medially away from the femoral artery and an out-of-plane technique is used. The final position is about 2 finger-breadths to the side of the pubic tubercle and perpendicular to the inguinal line.

While with this technique the spermatic cord is likely to be found outside the inguinal canal, anesthetic infiltration into the inguinal canal may provide a greater probability of blocking not only the gGFN, but also the IIN and/or the IHN endings (Rab 2001). Inguinal canal injection would be suitable for inguinal surgery both in the case of local, general or spinal anesthesia.

An ultrasound-guided gGFB with a 10-18 MHz transducer can be performed. The transducer is placed under the inguinal ligament at the intersection between the hemiclavear line and the line between the pubic tubercle and the ASIS (Figure 5.1). The femoral artery is visualized transversely along the short axis (Figure 5.2). Subsequently, the transducer is moved medially towards the pubic tubercle. The pubic bone is seen as anechoic (black). The inguinal canal can be seen between the femoral artery and the pubic bone. It is located more superficial under the aponeurosis of the EOM as an oval shadow containing the

spermatic cord in it. It is useful to ask the patient to cough in order to see tissue movement of the spermatic cord.

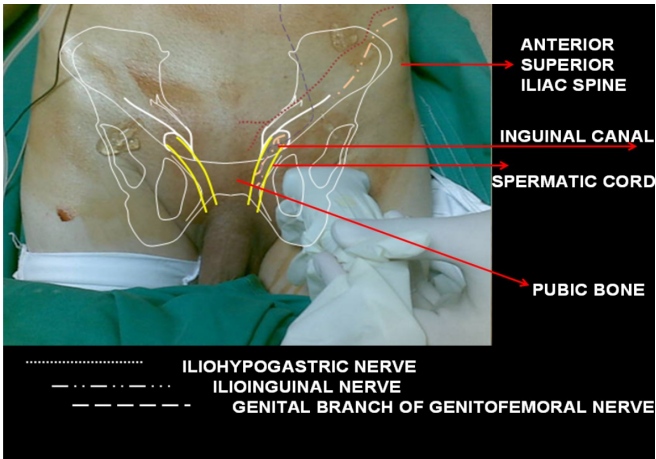


Figure 5.1 – Transducer position for the injection into the inguinal canal.

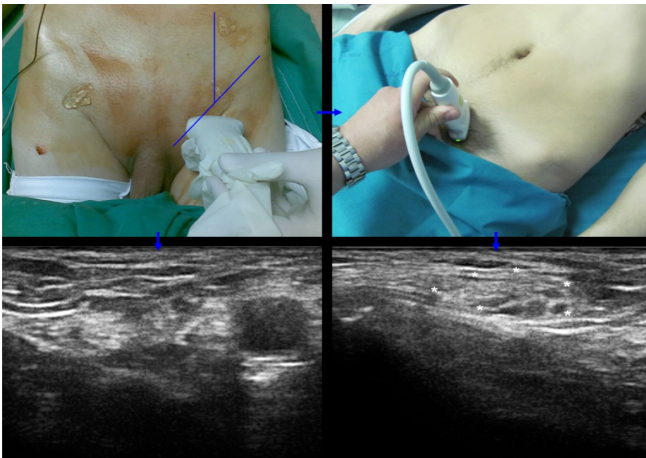


Figure 5.2 – Probe position (left then right) and ultrasound view (stars indicate the inguinal canal).

This movement will be more evident in the case of an inguinal hernia. An in-plane needle is inserted. A 10-20 ml of anesthetic is injected into the inguinal canal just after the needle penetrates the EOM aponeurosis (Figure 5.3). A “pop” is also felt while the needle penetrates the aponeurosis. The spread of the anesthetic will block the gGFN and/or the IIN and IHN. Intracanal tissues will be hydro-dissected and may be observed as gelatinous during surgery at the dissection of the aponeurosis of the EOM (Figure 5.4).

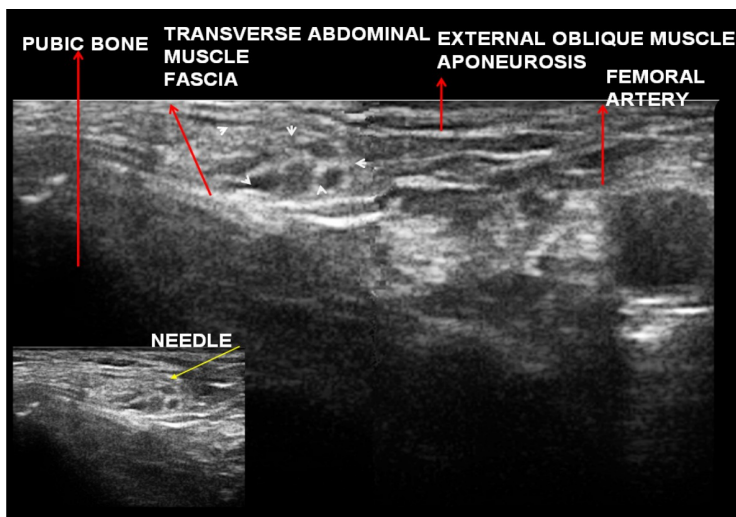


Figure 5.3 – Left inguinal canal injection. The two images of the procedure described in Figure 5.2 have been reconstructed.

If a stimulated needle is used, visible testicle retraction and twitching of the cremaster muscle may be occasionally present. Since the gGFN runs together with the cremasteric vessels ensheathed by the cremasteric fascia, needle aspiration is mandatory (Rab 2001). It is advisable to inject the local anesthetic just under the aponeurosis of the EOM and not to

penetrate the spermatic cord because of the risk of spermatic artery and deferens duct puncture or peritoneal puncture in the case of a hernia.

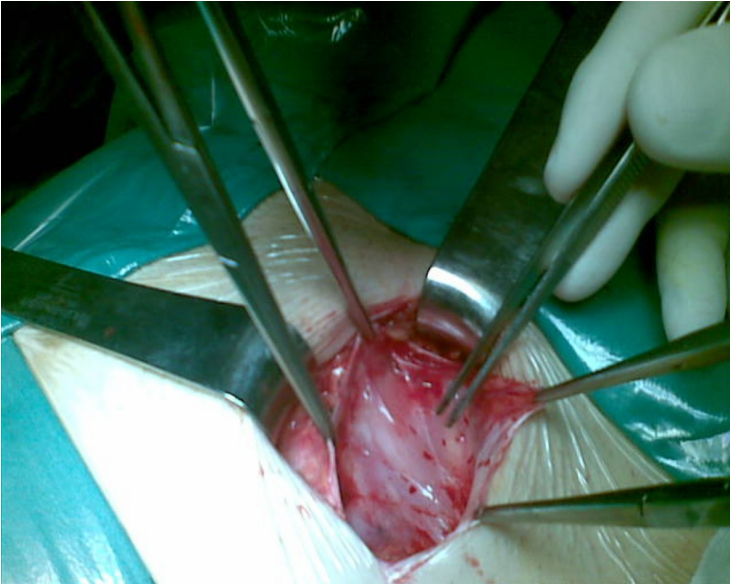


Figure 5.4 – The inguinal canal has been successfully infiltrated.

Also, the use of epinephrine is not recommended because of the possible constrictive effect on the testicular artery (Peng 2008). Bowel presence in the case of inguinal hernia must also be tracked (Figure 7.1).

Triple inguinal block (iliohypogastric, ilioinguinal and genitofemoral) has been reported by some studies in association with general or spinal anesthesia or in the setting of a IFB/LIA technique (Figure 5.5). Ultrasound-guided IIB and gGFB may provide optimal intraoperative and postoperative analgesia with low rates of intraoperative analgo-sedation requirements, quick recovery and quick discharge criteria achievement.

Since complete block may not occur, intraoperative analgo-sedation or local anesthetic supplement by the surgeon may be required for patient comfort. Moreover, subcutaneous injection along the incision line is necessary for a good IFB/LIA because of the variability of innervation of the IHN and IIN and the heterogeneous afferences from other nerves.



Figure 5.5 - From left to right: Iliohypogastric and ilioinguinal nerve block, genitofemoral nerve block and wound infiltration (Triple block).

After ultrasound-guided IIB and gGFB, a 90 mm needle is entirely advanced in the subcutaneous tissue under the incision line. Injection is made while slowly retracting the needle and aspirating from time to time. Depending on the patient's body mass index, 10 to 30 ml are generally required. This block provides optimal operative conditions, almost immediate discharge criteria achievement, low analgesic requirement and high patient satisfaction. The technique has several advantages

especially in the case of patients with severe comorbidities for whom general or spinal anesthesia may be risky.

6. Rectus Sheath Block

Savino Spadaro, Tommaso Mauri

The central portion of the anterior abdominal wall is innervated by the anterior branches of the spinal nerve roots from T6 to L1.

The nerves enter the rectus abdominal muscle near the midline and lie between it and the posterior sheath (Rozen 2008). The superior and inferior epigastric vessels run longitudinally through the medial portion of the muscle (Figure 13.3).

The existence of myofascial intersection points on the anterior border of the rectus muscle limits the spread of a local anesthetic solution. The tendinous intersections of the rectus muscle are not present at the posterior rectus sheath, which allows local anesthetic to spread cephalic-caudally within the ipsilateral compartment from a single injection site (Figure 6.1, 6.2).

The RSB has been used to provide surgical anesthesia as well as postoperative analgesia for laparotomy or laparoscopic procedures involving the abdominal midline (Finnerty 2010). The block appears to be safe and easy to learn and perform. It provides the anesthesiologist with another method of effective and apparently long-lasting analgesia for common day-case procedures. The RSB should be performed bilaterally with relatively large volumes of local anesthetic.

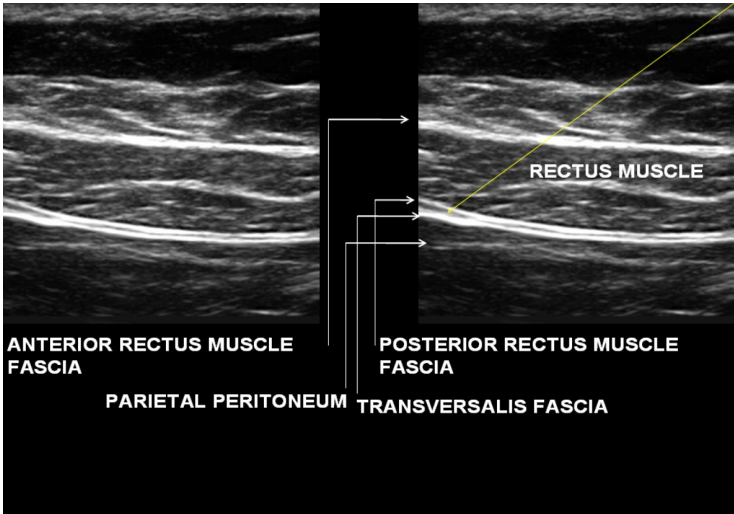


Figure 6.1 – Rectus sheath under ultrasound guidance.

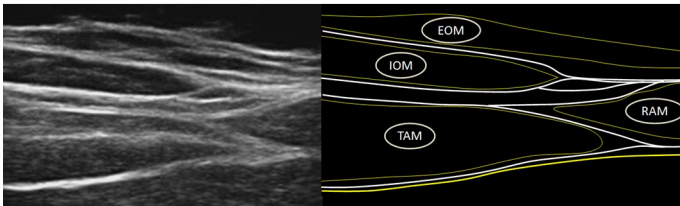


Figure 6.2 – Rectus abdominal muscle (RAM) and the triple musculo-aponeurotic layer.

It can be combined with other blocks, such as the IIB, to achieve wider blockade for transverse incisions below the umbilicus (Yentis 2000). However, in these cases TAPB should be considered.

The blind technique is performed using “pop” sensations to determine the positioning of the needle’s tip. The needle is inserted bilaterally at 1 to 3 cm from the midline. The posterior

rectus sheath is thin - if the peritoneum is inadvertently pierced, bowel perforation may occur.

The advantages of ultrasound guidance for RSB are similar to those for TAPB. A 100% success rate has been reported in the ability to visualize the spread of anesthetic between the RAM and the posterior sheath (Willschke 2006 (2)). In a study, the anesthetic was placed in the correct plane in only 45% of cases using a loss of resistance technique by trainees with no previous experience and in 89% of cases using ultrasound guidance (Dolan 2009). The difference became more pronounced as patient body mass index increased. 21% of injections performed using the loss of resistance technique were intraperitoneal and 35% too superficial.

Ultrasound-guided RSB is carried out with the transducer placed in the longitudinal plane near the lateral edge of the rectus sheath (Figure 6.3). The distribution of the local anesthetic can be monitored under real-time imaging. The local anesthetic is injected between the RAM and the posterior sheath (Figure 6.1). Skin incision can be performed 15 minutes or later after placement of the block.

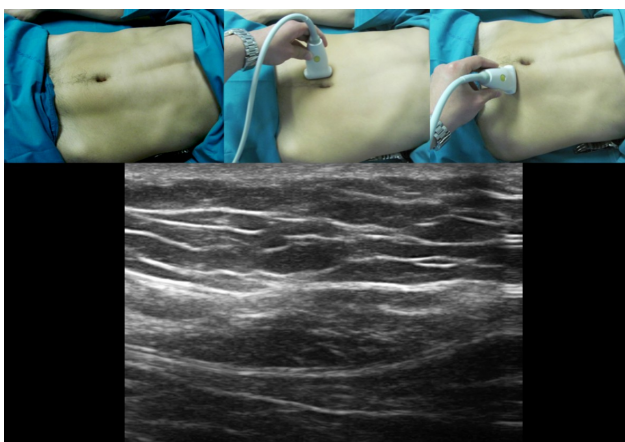


Figure 6.3 – Rectus sheath under ultrasound guidance.

Table 6.1 – Technical aspects of the abdominal blocks.

	IIB	TAPB	RSB	GFB/Inguinal canal
Needle	25-22 G, 35-90 mm, with or without injection line	25-22 G, 35-90 mm, with or without injection line	25-22 G, 35-90 mm, with or without injection line	25-22 G, 35-90 mm, with or without injection line
Transducer	Linear 10-20 mHz	Linear 10-20 mHz	Linear 10-20 mHz	Linear 10-20 mHz
Technique	LOX / In-plane	LOX / In-plane	LOX / In-plane	LOX / In-plane
Local anesthetic volume	10 ml each side	10-30 ml each side	10-30 ml each side	10-20 ml each side

Some important conclusions on the abdominal blocks can be drawn on the basis of the anatomical data which are confirmed by several clinical studies.

1. Landmark techniques may be unclear and inaccurate for positioning the needle tip near the nerves. Moreover they carry a high risk of complications.
2. Ultrasound techniques provide direct visualization and give better results in terms of block efficacy, local anesthetic dose reduction and incidence of complications.
3. The visceral peritoneum, the abdominal organs and testis will not be blocked with TAPB, IIB, RSB and gGFB. Abdominal blocks are only one component of a multimodal analgesic technique and supplemental analgesia with non-steroidal or opiate analgesics is necessary.
4. The classical TAPB is indicated for procedures involving L1 to T10 extent. Subcostal TAPB is indicated for procedures involving T12 to T8 extent.
5. Although the classical TAPB is effective for IIB, a selective IIB is recommended because lower doses of local anesthetic are required.

6. The best site for needle placement for IIB is above the ASIS, at the intersection between the iliac crest margin and the mid-axillary line, at the TAM plane.

7. gGFB can be achieved, although non-selectively. The ultrasound technique is highly recommended.

8. Triple inguinal block is necessary for adequate IFB/LIA in awake and sedated patients undergoing inguinal surgery.

9. The RSB is effective for procedures involving midline incision. Ultrasounds are highly recommended. If large volumes of local anesthetic are used, consider the safer TAPB.

7. Inguinal Hernia Repair

Roberto Fumagalli

Inguinal hernia repair is the most frequent operation in general surgery accounting for 10-15% of all operations (Figure 7.1). At the first day after herniorrhaphy, moderate or severe pain occurs in 25% of the patients at rest and in 60% during activity, and on day 6 the incidence is 11% and 33%, respectively (Callesen 1998). Neither the type of hernia nor the type of repair seem to influence postoperative pain scores, although young patients have more activity-related pain after inguinal herniorrhaphy (Callesen 1998, Lau 2001). Conversely, anesthetic technique may affect pain severity after inguinal herniorrhaphy (Callesen 1998, Song 2000).

Inguinal Field Block/Local Infiltration Anesthesia

Step by step IFB/LIA technique performed by surgeons was first described at the beginning of the previous century and includes a stepwise infiltration with local anesthetic of the skin, of subcutaneous tissue, of muscle and fascial layers, of spermatic cord and of peritoneal sac (Cushing 1900). The procedure is performed by the surgeon while operating. IIB and gGFB can be performed directly in the operative field, although it is very likely that the local anesthetic solution will reach the nerves in

any case (Amid 1994). Some reports have described IIB during laparoscopic hernia repair.

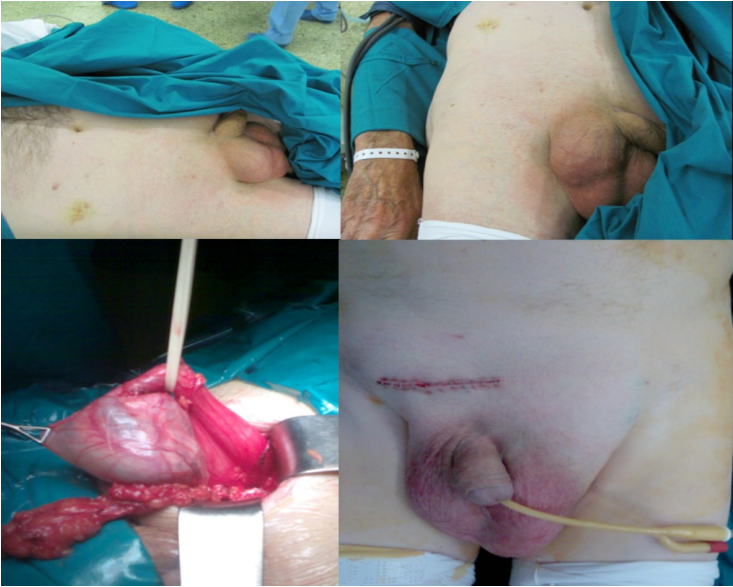


Figure 7.1 - Voluminous bilateral inguinal-scrotal hernia containing bowel.

The use of long acting anesthetics has increased the postoperative pain free period. Use of local anesthesia allows the patient to cough and strain during the procedure, to identify additional hernias as well as test the competency of the repair at the end of the surgery. An anesthesiologist is present to monitor the patient's vital signs and provide supplementary analgesia and sedation.

This technique and its variations seem to be the preferred one for all cases of reducible and even voluminous or bilateral inguinal hernias. The technique is recommended for its safety, intra- and postoperative effectiveness on pain, reduced or absent

complications, low analgesic request, rapid reappraisal of the ability to walk and void, ease of perioperative management, shorter hospital stay, rapid discharge and economical convenience (Kark 1996, Kark 1998, Song 2000, Andersen 2005, Aasbo 2002). During local infiltration anesthesia, there is generally a low sedation requirement and potentially no need for anesthesiologist or nurse presence.

These benefits are useful especially in the elderly and in patients with cardiac or pulmonary disease. IFB/LIA has also been associated with better postoperative pulmonary function tests (Gonullu 2002). High patient satisfaction scores have been reported as well (Callesen 2001).

Despite these advantages, local infiltration anesthesia is rarely performed outside dedicated hernia centers and its use may be as low as 2% (Kettle 2001). Only about 60% of patients undergo this procedure in the ambulatory setting (Callesen 2001, Bay-Nielsen 2001). Limited learning of the technique is one of the most important causes. Another explanation may be intraoperative patient discomfort and pain. The fear of intraoperative pain and significant patient distress is dependent on the operator's ability and affects surgical preferences. The surgeon must handle the tissues more carefully while operating because surrounding tissues, peritoneum and testis are not blocked. Although intraoperative pain is a real problem with the IFB/LIA technique, skilled and experienced surgeons can perform the operation even without the attendance of an anesthesiologist or nurse (Andersen 2005, Callesen 2001, Callesen 2001 (2)). A study referred that the majority of patients who received IFB/LIA experienced mild pain during the operation, though this was not measured, and a minority recorded some anxiety (Teasdale 1982). The problem of intraoperative discomfort may be underestimated because studies refer only the need for intraoperative rescue analgo-sedation and not pain scores. The use of sedation may be associated with increased

patient satisfaction compared with unmonitored anesthesia (Song 2000). Finally, the traditional use of monitored anesthesia care with propofol and opioids or spinal and general anesthesia may have negatively influenced its diffusion (Callesen 2001, Toivonen 2004).

A documented problem of the IFB/LIA is that it may require supplementary local anesthetic and sedation with moderate to high doses of benzodiazepines, requiring the attendance of an anesthesiologist (Ding 1995). IFB/LIA and IIB have not been evaluated in overweight and obese patients, where larger local anesthetic volumes are needed, although they are reported to be safe especially if the mixture is diluted. Moreover, a higher intensity of intra- and postoperative pain and a higher incidence of complications have been reported in obese patients (Nielsen 2005, Reid 2009).

Some authors state that IFB/LIA of triple block performed before surgery is more time consuming, requires larger volume of the local anesthetic solution, does not always result in satisfactory anesthesia because of the blind nature of the procedure, and accidental needle puncture of the inguinal nerves may result in prolonged postoperative pain or neuropathic pain within their innervation field (Amid 1994). However, actual anesthesia block techniques offer selective nerve block achievement with low volumes of local anesthetic, direct visualization if ultrasounds are used, optimal pain control, fast recovery and discharge of patients and low analgesic requirements. A randomized study in children undergoing groin surgery performed to compare postoperative analgesia with IIB performed either percutaneously by the anesthesiologist before surgery or by the surgeon under intraoperative direct vision, revealed no statistical difference in pain scores between the groups (Trotter 1995).

Ilioypogastric and Ilioinguinal Nerve Block

Inguinal hernia is the type of surgery in which the IIB has been mostly practiced and studied. The IIB has been associated to monitored anesthesia care, general anesthesia or spinal anesthesia to decrease the initial pain after inguinal herniorrhaphy (Song 2000, Ding 1995, Andersen 2002, Aasbo 2002, Toivonen 2004, Toivonen 2001).

A combined IIB together with an infiltration procedure may provide improved intraoperative analgesia, decreased requirements for additional sedation and monitoring and increased patient acceptance (Andersen 2005, Kehlet 2005). Many results indicate that IIB should be always performed after a general or spinal anesthesia. Moreover, preemptive IIB may be effective in decreasing postoperative analgesic requirements and prolonging the time to first rescue analgesia (Ong 2005).

Ropivacaine for IFB and IIB under propofol and opioid analgo-sedation compared to general anesthesia with wound infiltration, resulted in a significantly more rapid transfer to the recovery unit and discharge, less need of analgesics during the first postoperative week and significantly faster and less painful reappraisal of normal activities (Aasbo 2002).

The adding of IIB improves pain relief for 4 to 24 hours and reduces analgesic consumption compared to spinal and general anesthesia alone (Tverskoy 1990). Patients require the first opioid or non-steroid analgesic rescue significantly later and start to eat and mobilize sooner (Nehra 1995, Abad-Torrent 1997, Bugedo 1990). These benefits occur in spite of pain score differences at rest or in movement (Harrison 1994). The beneficial effects of IFB/LIA on pain scores, analgesic consumption and return to normal activities may last for 6 hours to up to 10 days (Narchi 1998, Murloy 1999, Bugedo 1990, Toivonen 2001).

The factors contributing to delays in the time-to-home readiness include nausea, vomiting, inability to void, drowsiness,

postural hypotension, post spinal headache, prolonged motor blockage, and administrative and social delays.

General anesthesia is associated with a significantly higher incidence of sore throat, drowsiness, postoperative nausea and vomiting. A higher incidence of postoperative pruritus, urinary retention, lumbar backache and the longest time to achieve home discharge criteria occurs after spinal anesthesia (Song 2000, Toivonen 2004). Patients who receive IIB and spinal anesthesia have faster awakening and orientation times than patients who receive general anesthesia.

Compared with standardized general and spinal anesthesia, IIB has been associated with lower pain scores at discharge, less analgesic requirement, a decreased time-to-home readiness, a lower incidence of side effects and lower total perioperative costs (Song 2000). Block group patients consumed more propofol than general anesthesia patients, but less fentanyl.

In a retrospective study the use of IIB for patients undergoing herniorrhaphy resulted in no need for recovery room care (Yilmazlar 2006). Time to recovery and discharge criteria achievement is significantly lower even when a selective spinal anesthesia technique is performed (that has shorter recovery times compared to non selective spinal anesthesia), or subarachnoid opioid is associated (Poli 2009, Gupta 2003).

8. Inguinal Surgery in Children

Giulio Napoletano

Inguinal surgery comprises inguinal hernia repair, orchidopexy, orchiectomy, removal of cyst of the spermatic cord, ligation of patent processus vaginalis and hydrocelectomy. The blocks of the nerves of the abdominal wall have been evaluated in combination to general and spinal anesthesia and in comparison to multimodal analgesia.

The IIB is among the most common (70% of all peripheral nerve blocks) used mainly for children between 4 and 7 years of age (Ban 2010). Inguinal hernia repair is the most frequent operation in which iliohypogastric and ilioinguinal nerve block is administered together with general anesthesia. The block appears to be safe and effective in reducing pain scores and analgesic request (Dalens 2001). However, the success rate may be as low as 70-80% with blind techniques and complications may occur (Lim 2002, Fell 1987). Intraoperative IIB decreases postoperative pain, analgesic use, and promotes early ambulation, recovery and discharge in children undergoing hernia repair.

Iliohypogastric and Ilioinguinal Nerve Block and Wound Infiltration

Many studies have compared IIB to LIA. Simple infiltration of the wound with local anesthetic solution should be encouraged in pediatric anesthesia as it may become as effective as IIB. IIB has been shown to be more effective than simple wound infiltration for postoperative pain and analgesic request in inguinal surgery (Caetano 2006). Also, IIB associated with LIA may improve analgesia after inguinal surgery.

Ultrasound-guided IIB is effective in reducing intra- and postoperative pain in children undergoing inguinal hernia repair, orchidopexy or hydrocele repair (Willschke 2005). Ultrasounds reduce the required volume of local anesthetic (Willschke 2006). The reduction in the dose is also necessary because of reported higher plasma levels of local anesthetic after ultrasound-guided blocks (Weintraud 2009).

Iliohypogastric and Ilioinguinal Nerve Block and Caudal Anesthesia

The IIB for inguinal procedures may provide analgesia comparable to a caudal injection, possibly with a longer mean duration (Hannallah 1987, Markham 1986). The adverse effects of motor block and urinary retention are eliminated. Heart rate, linear analogues score, total amount of analgesic and time of first administration of analgesics have been evaluated as criteria for the efficacy of the analgesic technique.

The IIB compared to a caudal block revealed similar recovery times and no difference in postoperative pain or discomfort scores after inguinal hernia repair (Hannallah 1987). Both procedures have a similar duration of action of at least 6 hours. No difference in the number of patients without pain for 4 h or in those requiring analgesics by 24 h has been reported compared to caudal block (Fisher 1993). Similarly, children

undergoing herniotomy, orchidopexy or ligation of patent processus vaginalis, show no statistically significant differences between IIB and caudal analgesia (Markham 1986). Patients with caudal anesthesia have prolonged discharge times when compared to patients who receive IIB (Splinter 1995). Earlier micturition and less complications in the IIB group is an important advantage over the caudal block (Markham 1986).

Caudal epidural blocks may be more effective than IIB plus LIA in controlling pain after herniorrhaphy with laparoscopy and result in earlier discharge to home (Tobias 1995).

Pain control with caudal blocks can be improved by increasing the concentration of local anesthetic. This will increase the incidence of adverse effects. The adverse effects associated with caudal blocks may be urinary retention, delayed ambulation and accidental subarachnoid or intravascular injection. However, IIB may also be associated with serious complications, especially in children. (For a detailed discussion of complications please refer to Chapter 13.)

Many authors believe that the complication risk with caudal blocks on children undergoing minor surgical procedures is not justified. The risk of complications is certainly greater in neonates and infants.

Orchidopexy is a procedure usually performed in children through an inguinal incision similar to that of the inguinal herniorrhaphy, but it involves more testicular and spermatic cord traction. It must be remembered that testicular innervation can be traced up to T10 and from the aortic and renal sympathetic plexus (Kaabachi 2005). Moreover innervation of spermatic cord by the gGFN should be taken into account. For these reasons, the IIB alone is unable to prevent either the painful stimulation from traction of the spermatic cord or manipulation of the testis and peritoneum (Jagannathan 2009). In a study, an ultrasound-guided IIB added to a caudal block decreased the severity of pain in inguinal hernia repair,

hydrocelectomy, orchiectomy and orchidopexy, but these data and the time to first rescue analgesic were significant only in inguinal hernia repair patients (Jagannathan 2009). The addition of a spermatic cord block to an IIB may reduce analgesic requirements in orchidopexy (Blatt 2007). Percutaneous IIB + gGFB in children undergoing inguinal herniorrhaphy resulted in lower pain scores for 8 hours and lower analgesic requirements (Hinkle 1987). Conflicting results have been shown by a study in which the benefit of the additional gGFB to IIB was limited only to the time of sac traction without any postoperative effect (Sasaoka 2005).

9. Obstetric and Gynecologic Surgery

Zhirajr Mokini

Anterior abdominal wall blocks have been evaluated in gynecologic and obstetric surgery. The Pfannenstiel section for open gynecologic and obstetric surgery affects the groin territory innervated by ITH and IIN. Obviously, a bilateral block is required in these types of surgery. Multimodal analgesia with anterior abdominal wall regional blocks applied to laparoscopic or open intra-abdominal surgery seem to be particularly useful in reducing postoperative opioid requirements (Bamigboye 2009). A recent survey among obstetric anesthesiologists in the United Kingdom showed that 21.6% of them used TAPB for cesarean sections (Kearns 2011).

It is important however to provide patients with adequate analgesia in relation to the surgical procedure because blocks cannot offer visceral pain control. Objective evaluation in terms of pain reduction may be difficult because the visceral component of postoperative pain may be subjectively described as moderate to severe. This is why many studies report significant reduction in opioid requirements without significant differences in pain scores. Visceral pain can be effectively relieved with neuraxial or systemic opioid administration, but at the price of uncomfortable side effects (Kanazi 2010).

Obstetric Surgery

The IIB has been evaluated after general anesthesia and spinal anesthesia. Overall, the quality of postoperative analgesia was improved compared to placebo with reduced pain reports, an increased time for first rescue analgesic and reduced opioid need. Pain scores and analgesic requirements may be reduced for the first 24 hours (Ganta 1994, Belavy 2009).

These results suggest that the IIB should be always performed after cesarean delivery under general anesthesia or spinal anesthesia when neuraxial opioids are not used (Belavy 2009). However, adverse effects related to opioids have been reported to be not reduced by IIB. A recent Cochrane review indicated that women who undergo cesarean section under regional anesthesia with IIB have decreased opioid consumption but no difference in visual analogue pain scores (Bamigboye 2009).

The block of the transverse abdominal muscle plexus, in which the IIB and the IIN run, provided better analgesia with reduced opioid request and delayed time to rescue analgesic compared with placebo (McDonnell 2008). More patients have been reported to be able to put the babies to the breast at 8 hours (Kuppuvelumani 1993).

Neuraxial opioid is currently the “gold standard” treatment for pain after cesarean delivery. Bilateral ultrasound-guided TAPB in patients undergoing cesarean delivery under subarachnoid anesthesia with fentanyl resulted in significantly reduced total morphine use for 24 h (Belavy 2009, Baaj 2010). TAPB and subarachnoid anesthesia with fentanyl compared to intravenous morphine and regular non-steroidal analgesics reduced total morphine requirements by 60%-70% and postoperative pain in the first 48 hours (McDonnell 2008, Baaj 2010).

Opioid-related, dose-dependent, side-effects including nausea, vomiting, pruritus and sedation, may occur. Delayed maternal respiratory depression due to cephalic spread of hydrophilic

opioids is another risk. Side effects reduce overall patient satisfaction, and techniques that reduce opioid requirements may be of benefit.

Some authors state that IIB or TAPB may offer no benefit on pain control compared to neuraxial morphine (Costello 2009, Kanazi 2010, McMorrow 2011). The addition of morphine to the local anesthetic is easier to perform, is less time-consuming and does not require extra equipment or skills to be performed (Kanazi 2010). However, subarachnoid morphine 0.1-0.2 mg provided better analgesia but with more adverse effects (Costello 2009, Kanazi 2010, Puddy 2010). In a study, patients receiving both subarachnoid anesthesia with 0,1 mg morphine and a TAPB had a higher incidence of pruritus and anti-emetic use. Less pain on movement and later postoperative morphine request were shown by patients receiving subarachnoid morphine compared to saline (McMorrow 2011).

Gynecologic Surgery

Few trials have evaluated abdominal blocks for gynecologic surgery. Bilateral IIB for total abdominal hysterectomy or prolapse repair through a Pfannenstiel incision under general anesthesia has shown to reduce prevalently dynamic pain and morphine need. In a study the reduction of morphine was 51% (21 +/- 9 mg vs. 41 +/- 24 mg) during the first two postoperative days with a more rapid control of early postoperative pain (Oriola 2007).

Bilateral TAPB in total abdominal hysterectomy significantly reduced morphine requirements at all time points for 48 hours. A longer time to first morphine request and reduced postoperative pain scores at rest and on movement were shown compared to the placebo (Carney 2008 (2)).

The reduction in pain scores is often not significant, suggesting the existence of additional pain from deep pelvic dissection and suturing of the vaginal vault during hysterectomy

(Kelly 1996). Recently, a trial on women undergoing pubic to umbilical midline incision for heterogeneous gynecologic malignancy, showed no benefit of ultrasound-guided TAPB on analgesic requirement, pain scores, adverse effects and satisfaction over multimodal analgesia (Griffiths 2010).

10. Other Abdominal Surgery Procedures

Andrea Pradella, Tommaso Mauri

Lower Abdominal Surgery

Lower abdominal surgery includes varicocelelectomy, appendicectomy, open prostatectomy, lumpectomy and intra-aortic procedures with femoral artery cannulation.

Surgical reports on awake varicocelelectomy show the efficacy of local anesthetic infiltration beneath the aponeurosis of the EOM into the inguinal canal to block the ilioinguinal and genitofemoral nerves (Hsu 2005). Recently, an effective ultrasound-guided spermatic cord block was reported (Wipfli 2011).

In the only randomized study in adults undergoing varicocelelectomy under general anesthesia and an IIB before surgery, patients experienced significantly reduced postoperative pain scores at rest and during mobilization, less analgesic consumption, less nausea and vomiting and were all discharged at 6 hours (Yazigi 2002).

The IIB and the TAPB have also been evaluated in the performance of appendicectomy. The IIB performed before surgery in children undergoing appendicectomy showed better

pain scores and less analgesic consumption for 6 hours (Courrèges 1996). The reduced pain and postoperative morphine consumption effects of ultrasound-guided TAPB in appendicectomy may last for 24 hours (Niraj 2009 (2)). TAPB for laparoscopic appendicectomy in children has been shown to offer no important clinical benefit over local anesthetic port-site infiltration (Sandeman 2011).

Bilateral IIB or TAPB has been reported to be effective for pain control in retropubic prostatectomy and femoral artery cannulation at the level of groin (O'Donnell 2006, Serpetinis 2008). Ultrasound-guided TAPB has also been evaluated in patients scheduled for major orthopedic surgery and anterior iliac crest harvest for autologous bone graft, with pain abolished for the first 48 hours (Chiono 2010).

Upper Abdominal Surgery

TAPB is an effective method of blocking the sensory afferents supplying the anterior abdominal wall. However, the classical TAPB may not reliably produce analgesia above the umbilicus (Shibata 2007). The subcostal TAPB involves injection immediately inferior to the costal margin. It has been reported to provide analgesia for incisions extending above the umbilicus (Hebbard 2008). A further development of the subcostal TAPB is the possibility to place a catheter along the oblique subcostal line in the TAM plane for continuous infusion of local anesthetic (Niraj 2011, Hebbard 2010). An ultrasound-guided technique with a Tuohy epidural needle and catheter may be used in this case.

Bowel surgery

TAPB in adults undergoing large bowel resection via a midline abdominal incision resulted in a significant reduction of pain scores and morphine requirements for the first 24 postoperative hours (21.9 ± 8.9 mg vs. 80.4 ± 19.2 mg) (McDonnell 2007 (2)).

TAPB employed for laparoscopic colonic-rectal resections reduces overall postoperative morphine (31.3 vs. 51.8 mg) and hospital stay (Conaghan 2010). In a retrospective analysis of patients undergoing laparoscopic colonic-rectal resection, an ultrasound-guided TAPB significantly reduced time to the resumption of diet and postoperative hospital stay (Zafar 2010).

Ultrasound-guided TAPB in patients undergoing laparoscopic cholecystectomy was associated with a significant reduction in the administration of intraoperative sufentanyl and postoperative morphine (10.5 +/- 7.7 vs. 22.8 ± 4.3 mg) (El-Dawlatly 2009).

Kidney surgery

TAPB may reduce pain scores and morphine requirements in patients undergoing renal transplant (Jankovic 2009 (2)). Pain scores and intraoperative opioid need may be reduced for 12 hours (Mukhtar 2010). Kidney transplant recipients receiving IIB and block of T11 to 12 intercostal nerves show reduced postoperative pain and total morphine consumption (12.7 +/- 10.5 mg vs. 34.9 +/- 5.9 mg) (Shoeibi 2009). Subcostal bilateral TAPB with catheters compared to epidural analgesia in adult patients undergoing elective open hepatic-biliary or kidney surgery, provided no significant differences in pain scores at rest and during coughing at 8, 24, 48 and 72 h after surgery. Tramadol consumption was significantly greater in the TAP group (Niraj 2011). Patients received bupivacaine 0.375% bilaterally every 8 h in the TAM plane and an epidural infusion of bupivacaine 0.125% with fentanyl 2 mcg/ml.

A novel 'semi blind' technique of administering the TAPB through the laparoscopic camera during nephrectomy has been described (Chetwood 2011).

Plastic surgery

Intraoperative TAPB reduces postoperative analgesic consumption in patients undergoing body contouring abdominoplasty with flank liposuction (Araco 2010, Araco 2010 (2)). After the flap resection, the fibers of the EOM and IOM are separated until the TAM is visualized and local anesthetic is injected bilaterally. Similarly, patients receiving a combination of intercostal, iliohypogastric, ilioinguinal and pararectus blocks for abdominoplasty, showed successful long-term relief of pain and a significantly reduced recovery time, allowing the patient to return to normal activities and work much sooner (Feng 2010).

11. Abdominal Midline Surgery

Savino Spadaro, Tommaso Mauri

The rectus sheath block (RSB) is safe, easy to learn and perform, and provides the anesthesiologist with another method for effective and long-lasting analgesia for common day-case procedures.

The RSB has been described both in adults and in children. Although regional anesthesia techniques are commonly used for postoperative pain control in children, there have been few studies investigating the efficacy of RSB. The technique is recommended for midline laparoscopy where it provides effective analgesia. The onset of analgesia is usually evident within five to ten minutes and provides excellent operative conditions with muscular relaxation (Smith 1988). In children, RSB is a simple block that provides intra- and postoperative analgesia for umbilical, paraumbelical and epigastric hernia repair. Another potential use of RSB is for analgesia after pyloromyotomy. In adults, the RSB may be an alternative to epidural anesthesia for some surgical procedures (Azemati 2005).

The RSB has also been described as particularly useful to improve postoperative analgesia after midline laparotomy for umbilical or epigastric hernia repair in high risk patients. However, a pilot study failed to demonstrate the advantage of RSB over infiltration for umbilical hernia repair (Isaac 2006).

12. Local Anesthetics, Pharmacokinetics and Adjuvants

Amedeo Costantini

The action of local anesthetics is elicited through a specific block of the sodium channels in the peripheral and central nervous system. They block both nerve impulse generation and propagation. Local anesthetics have a particularly high level of activity in the central nervous system and the cardiovascular system.

When using local anesthetics for regional anesthesia blocks, patient safety procedures such as a safe vein access, oxygen availability, intensive care equipment, adequate monitoring, immediate availability of general anesthesia, and a sterile procedure should be assured according to national and international guidelines (Bertini 2006). Guidelines for an adequate postoperative pain treatment strategy and management of local anesthetic systemic toxicity must be also taken into account (Savoia 2010, Neal 2010).

Dose, Concentration and Volume Correlations

The concentration is defined as the mass of a constituent (the local anesthetic) divided by the volume of the mixture (volume of solution) (Table 12.1).

Table 12.1 – Dose, volume and concentration correlations.

C = Concentration (mg/ml)	$C = M / V$
M = Mass (mg)	$M = C \times V$
V = Volume (ml)	$V = M / C$

The right approach to a local anesthetic dosing is to calculate the dose per kg of weight and to dilute it in order to obtain the desired volume or concentration. The total dose (the product of volume x concentration) should be tailored to the minimum mass of local anesthetic necessary to achieve the desired clinical effect (Table 12.2, 12.3, 12.4).

Table 12.2 – Recommended doses of the long-lasting local anesthetics.

Recommended doses	Ropivacaine	Levobupivacaine	Bupivacaine
Adults	2-3.5 mg/kg	2-3 mg/kg	2-3 mg/kg
Children dose	1-3 mg/kg	1-2 mg/kg	1-2 mg/kg
Children volume	0.075-0.5 ml/kg	0.075-0.5 ml/kg	0.075-0.5 ml/kg

Table 12.3 - Maximum recommended doses of the long-lasting local anesthetics in adults.

Local anesthetic	Infiltration anesthesia (doses with epinephrin are in brackets)
Ropivacaine	200-225 mg
Levobupivacaine	150 mg
Bupivacaine	150-175 (225) mg

Table 12.4 – Concentration ranges of the long-lasting local anesthetics for infiltration and nerve block anesthesia.

Recommended concentrations	Ropivacaine	Levobupivacaine	Bupivacaine
Adults	2-7.5 mg/ml	1.25-5 mg/ml	1.25-5 mg/ml
Children	1-7.5 mg/ml	1-5 mg/ml	1.25-5 mg/ml

The decision to use larger volumes of a higher concentration to achieve a longer block must be weighed against the potential risks of higher systemic absorption. Special attention should be posed to obese patients in which a dosing on a milligram of local anesthetic-per-kilogram of weight basis would be dangerous. In these patients, a dosing based on the ideal weight may be more correct.

Maximum recommended doses are valid in relation to normal conditions (70 kg healthy persons) and do not constitute a maximum (Rosenberg 2004). They must be varied individually depending on the type and site of block, the weight and the clinical condition of the patient.

Monitoring according to the technique of administration and to the expected plasma concentration is highly advised (Rosenberg 2004).

Long-lasting local anesthetics

The long lasting amide anesthetics, bupivacaine, levobupivacaine and ropivacaine, are highly lipophilic molecules of similar properties and efficacy. Concentrations of 2.5 to 5 mg/ml of the long lasting anesthetics are generally used for IFB/LIA, IIB and TAPB (Bay-Nielsen 1999, Mulroy 1999). The efficacy and block duration is dose dependent (Mulroy 1999).

As reflected by clinical studies, the duration of analgesia after IFB/LIA, IIB and TAPB after a single injection of long lasting local anesthetics typically lasts less than 12 h. However, the benefits on the subjective pain levels at rest and under stress, on the postoperative amount of analgesics and on postoperative mobilization may last for 24 hours to 10 days (Pettersson 1998, Ding 1995, Harrison 1994).

Among the long-lasting local anesthetics, ropivacaine is preferred for abdominal blocks because it is less cardiotoxic than bupivacaine (Knudsen 1997). Ropivacaine (and levobupivacaine,

the levoenantiomer of bupivacaine) causes cardiovascular and CNS toxicity at higher doses than bupivacaine (Bardsley 1998).

Absorption

Pharmacokinetic parameters (for example plasma concentrations of local anesthetics) vary widely between individuals. The pharmacokinetic variables depend on the absorption from the site of injection, the distribution in the tissues and body fluids according to lipid solubility and protein binding, and the metabolism and clearance of the drug.

The amount of fat affects tissue accumulation. The passage of the local anesthetic into the blood will depend on the total dose, the capillarity of the site of injection and on the ratio between the volume of the drug and the surface in contact with it. A smaller absorption surface may counterbalance a high drug concentration whereas the unpredictable spread of a large volume of local anesthetic may become a reason for side effects (Rosenberg 2004).

The pattern of the absorption rate for different blocks is generally intercostal > epidural /caudal > brachial plexus > sciatic block > subcutaneous. The absorption after an IIB or a TAPB may be faster than a caudal block (Ala-Kokko 2000, Ala-Kokko 2002, Stow 1988). Moreover, absorption may be influenced by local or systemic inflammation (Rosenberg 2004). The emergence from anesthesia may be also associated with increased absorption and a second plasma peak (Smith 1996).

Absorption from the abdominal wall

The pharmacokinetics of local anesthetics in the TAM plane is an area of current investigation. The common landmarks are close to important vessels that run through the fascias. The TAM plane has a big surface that requires high volumes of diluted solutions in order to achieve an extended block. Even at a dilute concentration, large volumes of local anesthetics may cause

serious consequences after an intravascular injection or if there is rapid uptake from the tissues. Moreover, it is to be considered that an IFB/LIA involves soft tissue infiltration. Intraperitoneal injection may be also dangerous because of the high absorption rate. Repeated injections may be associated with prolonged systemic absorption and with unexpectedly high and persistent elevations of plasma concentrations during an IFB/LIA (Mulroy 2009). Therefore, it is not recommended to repeat abdominal blocks or supplementary anesthetic injections within the elimination life of the local anesthetic.

Pharmacokinetic studies and the abdominal wall blocks

The plasma levels of the local anesthetics after abdominal blocks rise gradually in a dose-proportional fashion in 15 to 60 minutes and remain near the peak levels for a 60 to 120 minute period (Mulroy 1999, Pettersson 1998, Griffiths 2010 (2)). These data indicate the need for caution when performing supplemental injections of local anesthetic.

Despite the prolonged elevation of plasma levels, no signs of local anesthetic toxicity have been reported even with 300 to 375 mg doses of ropivacaine (Mulroy 1999, Pettersson 1998, Wulf 1999, Wulf 2001, Martin 1987, Pettersson 1999). However, most studies have used premedication with a benzodiazepine and many are conducted under general anesthesia which may have occulted transitory neurological effects. The TAPB performed at the conclusion of surgery for pain relief or for brief operations, may be potentially neurotoxic because of the elevated plasma concentrations in conscious patients.

The ultrasound-guided IIB and TAPB have been associated with a faster absorption and more elevated plasma concentrations in both adults and children due to the great surface of contact (Willschke 2005, Willschke 2006, Kettner 2009). Thus, a reduction of the volume of local anesthetic should be considered when using an ultrasound-guided technique for abdominal blocks in

adults and children (Griffiths 2010). The analgesic effect of the TAPB may partially depend on the rise in serum concentration of the local anesthetic (Kato 2009).

Blood Clearance

In normal healthy persons, the amide local anesthetics are bound to plasma α -1-acid-glycoprotein that effectively prevents the presence of high concentrations of unbound and active local anesthetic. Surgery further stimulates the synthesis of α -1-acid-glycoprotein from the liver, reducing the risk of toxicity (Aronsen 1972, Pettersson 1998).

The clearance of local anesthetics is dependent on the renal and hepatic flow and cardiac function. In advanced heart, kidney and liver failure and therapy with cytochrome isoenzyme inhibitors like antimycotics, the dose of the local anesthetic should be reduced by 10 to 50% (Rosenberg 2004).

Age related changes in blood flow and organ function may increase the nerve sensitivity to a local anesthetic block, and a smaller dose is needed to achieve the same effect. Local anesthetic doses need to be reduced by up to 20% in the elderly (Rosenberg 2004).

The late stage of pregnancy is characterized by a physiologically enhanced sensitivity of nerves to local anesthetics. Blocks should be performed with the lowest possible doses for short periods aiming to reduce the need for other analgesics (Rosenberg 2004).

Pediatric Considerations

Neonates and children up to 4 months of age have low plasma concentrations of α -1-acid-glycoprotein and thus a greater amount of free drug in the blood (McNamara 2002). A more conservative dose should be used when performing an abdominal block in infants and neonates (< 15 kg) because a

higher absorption of local anesthetic has been shown (Smith 1996). The cause may be the increased cardiac output/body mass index ratio, the decreased tissue accumulation and the reduced liver metabolism. When large doses of local anesthetic are used, the dose per kilogram should be reduced by about 15% (Rosenberg 2004).

Children under two years of age have been reported to have significantly higher pain scores than those above this age (Trotter 1995). Ropivacaine as a long-lasting agent for IIB in children may be more effective when used with a high concentration/small volume than when used with a high volume/low concentration (Trifa 2009). If smaller volumes of local anesthetic are used, ultrasounds become a necessary tool in order to improve the chance for a successful block.

Adjuvants

Several studies have evaluated the use of adjuvants to local anesthetics (clonidine, ketamine ecc) for improving postoperative analgesia after the anterior abdominal blocks.

Clonidine added to intermediate or long-acting local anesthetics for single-shot peripheral nerve or plexus blocks prolongs the duration of analgesia and motor block by about 2 h but at the cost of an increased risk of hypotension, fainting, and sedation and with an unclear dose-responsiveness kinetics (Pöpping 2009).

Clonidine used for the abdominal blocks or IFB/LIA has not shown to give a clinically important benefit in adults and children (Beaussier 2005, Kaabachi 2005, Dagher 2006, Elliott 1997). A common adverse effect is orthostatic hypotension during the first postoperative hours. In these types of block, as a consequence of the spread into a wide zone, the accumulation of clonidine near nerves may be decreased. Thus clonidine would not reach the right level to affect nerve conduction or facilitate the action of the local anesthetic (Kaabachi 2005).

13. Complications

Zhirajr Mokini

Transient Femoral Nerve Block

The most frequently described complication after an IIB is the transient postoperative block of the femoral nerve (Rosario 1994, Rosario 1997). It may occur both after selective IIB or TAPB or after an IFB/LIA performed by the surgeon.

The transient femoral nerve block (TFNB) may be partial or complete, sensory and/or motor (Wulf 1999). The transient femoral nerve block includes a reduced sensation of the skin overlying the anterior and lower medial portion of the thigh and weakness of the thigh expressed as a difficulty in standing up and walking (Erez 2002).

Special attention is required, since there may be a 2.5 to 6 hour delay between the injection of the anesthetic and the onset of TFNB (Kluger 1998). Once the TFNB is present, it may persist for up to 36 hours (Salib 2007). Complete spontaneous recovery before 12 hours has been generally reported (Erez 2002, Rosario 1997).

The TFNB is a potential cause of delay in patient discharge and a cause of possible complications like minor injuries or even fractures from subsequent falls (Szell 1994). The awareness of

this complication is important to avoid morbidity, and patients should be informed of the transitory nature of this complication.

The incidence of inadvertent femoral nerve block ranges from 0.27% to 28% in adults and children (Lipp 2000, Lim 2002, Lipp 2004). Most reports are from pediatric patients who seem to have an increased risk of TFNB (Erez 2002). The TFNB may be less likely to occur in females than males because of a different distance between the femoral nerve and the point of injection for the IIB. The TFNB has not been reported yet after an ultrasound-guided nerve block.

The IIB given under direct vision by surgeons appear to have a lower incidence of TFNB. The transient femoral nerve block has been reported also after laparoscopically guided IIB (Lange 2003).

The mechanism involved in the TFNB development may be due to the direct instillation around the femoral nerve or the anesthetic diffusion under the iliac fascia. The local anesthetic may reach the plane deep to the iliac fascia and the femoral nerve when it is deposited between the TAM and transversalis fascia or directly under the iliac fascia around the femoral nerve (Rosario 1994, Rosario 1997, Erez 2002). It is to be remembered that the femoral nerve runs over the iliopsoas muscle in close proximity to the inguinal canal (Erez 2002).

Local anesthetic introduction into the plane between the quadratus lumborum and the psoas major muscle, blocking the lumbar plexus roots, may be also the cause for femoral nerve block (Winnie 1973). Moreover, the injection into the plane of the TAM can increase the risk of this complication (Rosario 1997).

Apart from local anesthetic block, TFNB may follow femoral nerve trauma, suture involvement, entrapment with staples, compression or hematoma both after open or laparoscopic hernia repair (García-Ureña 2005).

Peritoneal and Visceral Puncture

Ultrasonographic studies have confirmed that especially in children, not only the abdominal wall is thinner and body size and the operating area are smaller, but also the IIH and the IIN are very close to the peritoneum in an age-dependent manner (Willschke 2005, Hong 2010).

Intraperitoneal injection has been reported both in children and adults after an IIB or TAPB (Jankovic 2008). An ultrasound control study reported that the local anesthetic solution was deposited into the peritoneum in 2% of cases, emphasizing the considerable risk of peritoneal or visceral puncture (Figure 13.1) (Weintraud 2008).

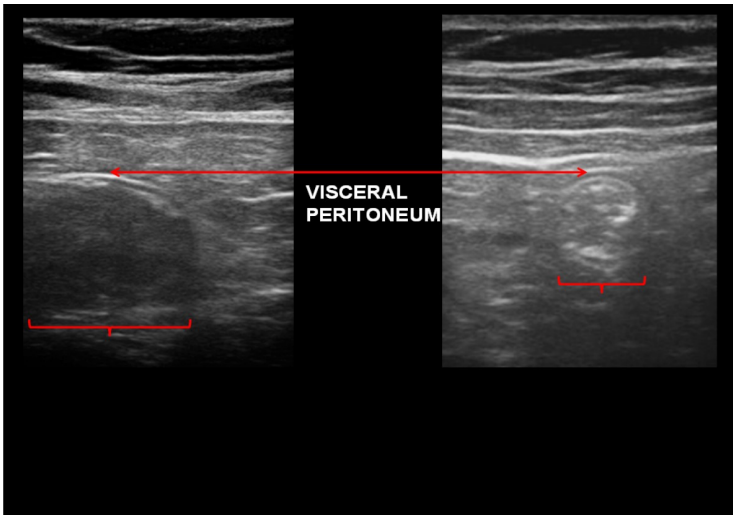


Figure 13.1 – Large and small bowel under the abdominal wall.

Other rarely reported complications are colonic or small bowel puncture and pelvic hematoma (Johr 1999, Frigon 2006, Amory 2003, Vaisman 2001). The presence of visceral puncture may remain undetected if the block is performed for a type of surgery

such as inguinal repair or orchidopexy that do not include bowel exposure. In three children from 6 to 14 years of age, subserosal hematomas of the colon and small bowel have been reported following an IIB under general anesthesia respectively for spermatic vein ligation, appendectomy and left inguinal hernia (Johr 1999, Frigon 2006, Amory 2003).

In one case, small bowel hematoma required resection of a bowel loop. The recovery was uneventful and the child was discharged on day 8 (Amory 2003). Subcutaneous local hematoma at the puncture site has been also reported (Erez 2002).

Liver trauma has been also described after a TAPB (Farooq 2008, O'Donnell 2009, Lancaster 2010). In one case the liver was enlarged and reached the right iliac crest. Hepatomegaly or splenomegaly with the liver or spleen margin reaching the iliac crest may be a risk factor for puncture (Farooq 2008, O'Donnell 2009). It would be prudent to palpate the edge of the liver and spleen before performing the procedure, and this is particularly important in patients of small stature.

Failure to recognize the “pops” may result in needle advancement deeper than the TAM and into the peritoneal cavity (O'Donnell 2009).

Aspiration prior to injection and image check for vascular structures reduces the risk of direct intravascular administration of the anesthetic agent (Figure 13.2).

In order to reduce the risk of puncturing intra-abdominal structures, some authors strongly suggest the routine use of ultrasonography (Weintraud 2008, Fredrickson 2008). Needle tip and correct tissue visualization is advocated in all cases (Lancaster 2010). Moreover, an in-plane approach may allow easier visualization of the muscle layers and needle tip position.

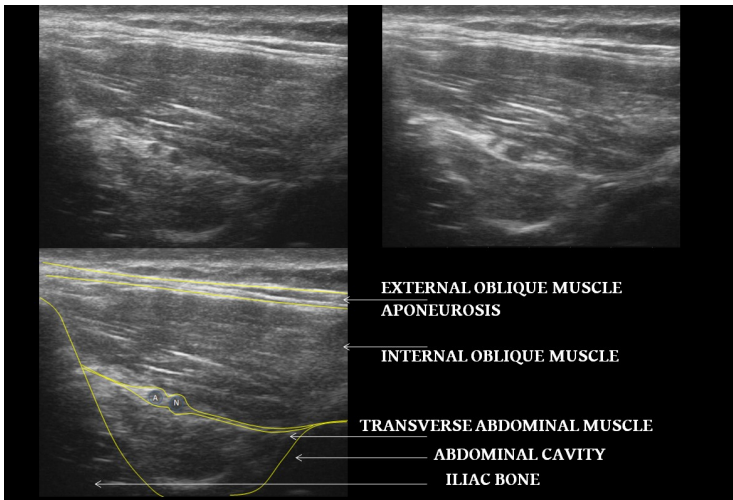


Figure 13.2 – A small artery (A) seen as a pulsating image near the ilioinguinal nerve (N).

Complications of Rectus Sheath Block

Complications are rare but can include puncture of the inferior epigastric vessels and peritoneal injection (Figure 13.3). Peritoneal injection is highly possible with a loss of resistance technique and can be avoided by using ultrasounds. Aspiration prior to injection reduces the risk of direct intravascular administration of the anesthetic agent. The block is thought to be particularly difficult in the obese and those patients with abdominal distension. A retroperitoneal hematoma in the right paraaortic region extending from the level of the umbilicus down to the pelvic brim, has been reported after a blind periumbilical RSB (Yuen 2004).

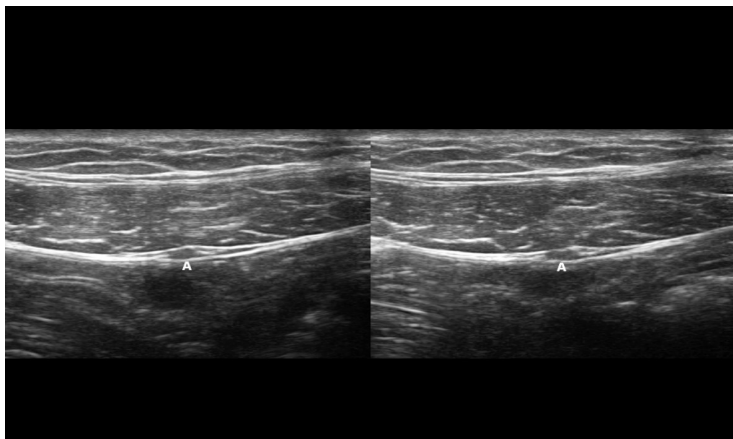


Figure 13.3 – Right and left rectus sheath and deep inferior epigastric artery that was seen as pulsating on real-time image (A).

Complications of Genitofemoral Nerve Block

Because of the presence of multiple vessels in the spermatic cord (pampiniform plexus and testicular arteries), the blind technique is associated with the possibility of an intravascular local anesthetic injection and subsequent systemic intoxication.

The perforation and damage of the testicular artery with the potential of subsequent bleeding and hematoma formation is also a well-described serious side-effect of the blind technique (Goldstein 1983).

The injection should be performed with an ultrasound technique and administered just below the “click” of the external oblique aponeurosis and after aspiration.

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15. Index

Index

- absorption..... 87
- adjuvants..... 90
- anterior abdominal wall
 - innervation..... 16
 - anterior abdominal wall structure 13
- appendectomy..... 79
- blind iliohypogastric and ilioinguinal nerve block..... 44
- blind transverse abdominal plexus block..... 36
- blood clearance..... 89
- blood supply to the anterior abdominal wall..... 15
- bowel puncture..... 93
- caudal block..... 72
- cesarean section..... 76
- communication between anatomical planes..... 23
- complications of rectus sheath block..... 95
- complications of genitofemoral nerve block..... 96
- cyst of the spermatic cord..... 71
- dose, concentration and volume correlations..... 84
- equipment..... 31
- flank liposuction..... 82
- focus..... 30
- genitofemoral nerve..... 20
- gynecologic surgery..... 77
- hydrocelectomy..... 71
- hysterectomy..... 77
- iliohypogastric and ilioinguinal nerve block..... 69
- iliohypogastric and ilioinguinal nerve block and caudal anesthesia 72
- iliohypogastric and ilioinguinal nerve block and wound infiltration..... 72
- iliohypogastric and ilioinguinal nerves..... 18
- imaging..... 27
- in-plane..... 31
- inguinal canal..... 20
- inguinal field block/local infiltration anesthesia..... 65
- inguinal hernia repair..... 71
- inguinal hernia repair..... 65
- intraperitoneal 93
- Jean-Louis Petit..... 37
- long axis of the transducer 31
- long-lasting local anesthetics..... 86
- lower abdominal surgery..... 79
- lumpectomy..... 79
- midline laparoscopy..... 83
- needle..... 31
- obstetric surgery..... 76
- orchidopexy..... 71
- orchiectomy..... 71
- out-of-plane..... 31
- pediatric..... 89
- pediatric considerations..... 89

peritoneal and visceral puncture	time-gain compensation.....	30
.....	transducers.....	29
pfannenstiel.....	transient femoral nerve block..	91
77	transverse abdominal plexus.....	35
pharmacokinetic.....	transverse abdominal plexus	
88	block.....	35
piezoelectric.....	ultrasonographic visualization	
26	studies.....	48
piezoelectric effect.....	ultrasound and the needle.....	31
26	ultrasound-guided iliohypogastric	
plasma concentrations.....	and ilioinguinal nerve block.....	49
87	ultrasound-guided transverse	
presets.....	abdominal plexus block.....	37
30	upper abdominal surgery.....	80
prostatectomy.....	varicocelelectomy.....	79
79		
rectus sheath.....		
22		
references.....		
97		
short axis		
31		
sound waves.....		
24		
spatial compound imaging.....		
30		
spread.....		
42		
technical aspects.....		
63		



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#3



Regional anesthesia techniques are an essential tool in the setting of a multimodal analgesia strategy.

The transverse abdominal plexus block, the rectus sheath block and the iliohypogastric, ilioinguinal and genitofemoral block are among the most promising techniques for somatic pain control in adult and pediatric surgery.

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