Langenbeck's Archives of Surgery
https://doi.org/10.1007/s00423-018-1705-y

REVIEW ARTICLE

Pain management in abdominal surgery

Thomas M. Hemmerling [1,2,3]

Received: 20 May 2018 / Accepted: 26 August 2018

Abstract

Background Abdominal surgery has undergone major changes during the last two decades with a general shift from open, invasive surgery to closed minimally invasive surgery. Accordingly, pain management strategies have also changed, especially with the introduction of ultrasound-guided abdominal wall blocks. Despite laparoscopic abdominal surgery classified as minimal, pain can be quite significant and needs to be addressed appropriately.

Purpose This narrative review focuses on adequate pain strategies for various types of surgery. The respective techniques are described and examples of specific pain management strategies given. Advantages and disadvantages of techniques are discussed. This review can serve as a sort of empirical guideline and orientation for the reader to develop their own strategy as well as bringing surgeons up-to-date with the latest anesthetic techniques.

Conclusion Pain is not less or less relevant in minimally invasive surgery. New hallmarks of a multimodal pain strategy are abdominal wall blocks, either as single shot or continuously. Minor open surgery is best performed under a combination of loco-regional blocks and continuous sedation. Abdominal wall blocks, NSAIDs, and short-acting opioids given by nurses or as PCA present the best multimodal pain strategy in abdominal surgery. Epidural analgesia and spinal anesthesia have become second-line options or are reserved for specific patient morbidities or surgical requirements.

Keywords Abdominal surgery · Pain management · Loco-regional anesthesia

For several decades, abdominal surgery has been mostly open surgery. In the recent two decades, this has shifted towards closed and laparoscopic techniques. This has led to an adjustment of pain relief techniques and the development of new local or regional analgesic techniques. The most important introduction to anesthesia has probably been the development of the transversus abdominis plane block (TAP). Epidural analgesia is still important pain relief for major abdominal surgery; however, its use has been limited by an ever increasing number of drugs used to interfere with blood coagulation: in contrast to orthopedic surgery, where even for emergency interventions, delays might be acceptable until the effect of these drugs has worn off in order to allow for neuraxial techniques, delays of surgery cannot be accepted in abdominal emergency surgery. In the elective setting, this might not necessarily be an issue since surgeons would stop these drugs to allow spontaneous recovery of normal blood coagulation. Even so, the sheer number of drugs available, their often unpredictable effect on blood coagulation and a general tendency for anesthesiologists to look for alternative pain techniques, simply to avoid medico-legal issues, has decreased the use of epidural analgesia and weakened its status as the key analgesic component of pain treatment for major abdominal surgery.

The concept of combining different pain strategies, e.g., epidural analgesia plus non-steroid anti-inflammatory drugs (NSAIDs), has been firmly established in the center of perioperative pain relief. It needs no further justification. However, it has also been confirmed that the combination of pure pain strategies with collective supplementary strategies, such as early food intake, early mobilization, and tight blood sugar control, further enhances these pain strategies. Lastly, preoperative preparation of the patient, physically, medically, and psychologically, also plays into the hands of optimal perioperative analgesia.

✉ Thomas M. Hemmerling
thomas.hemmerling@mcgill.ca

[1] Department of Anesthesia, McGill University, 1650 Cedar Avenue, Montreal, Canada

[2] Division of Experimental Surgery, McGill University, Montreal, Canada

[3] Department of Anesthesia, University of Montreal, CIUSSS Montreal-North, Montreal, Canada

Published online: 03 October 2018

Let us separate this review on pain relief after abdominal surgery into pain relief for minor or major surgery, as well as open or closed surgery.

Pain relief for minor open abdominal surgery

Repair of umbilical or inguinal-femoral hernias, ischiorectal abscess, repair of pilonidal sinus or fistula, and hemorrhoid surgery belong into this category.

It seems that the most appropriate analgesic strategy is to perform these types of surgery under local or loco-regional block.

For some anesthesiologists, a categorical patient's wish "I want to sleep" rules out the feasibility of loco-regional techniques when, in fact, this is not a hindrance at all. It is all about explaining to the patient the possibility of "sleeping" during surgery in the same way as they would sleep at home and reassuring them that the wish to sleep and not hear or feel anything does not necessarily mean general anesthesia, but that this state is very feasible using continuous propofol sedation. In its most sophisticated form, this means target-controlled infusion (TCI) of propofol and establishment and maintenance of the desired sedation level using continuous brain monitoring, e.g., bispectral index monitoring. In addition, explaining to the patient that in case of insufficient analgesia during surgery, the surgeon can add local anesthesia, similar to a dentist when performing dental surgery under local anesthesia, can reassure almost all patients. It is all about explaining in depth the advantage of loco-regional anesthesia—speedy recovery, early discharge, no impact on urinary retention, excellent and long-lasting pain relief after surgery—while assuring that the "block" will be performed under short-term sedation and surgery under continuous sedation.

Using this strategy, most patients will choose this kind of anesthesia. It seems that for this kind of surgery, the combination of loco-regional block and sedation is the best combination of efficiency of analgesia, fast recovery, and risk reduction.

However, it is not without pitfalls.

These pitfalls can be categorized into problematic sedation and problematic loco-regional blocks.

Problematic sedation can occur specifically in young patients as well as in older patients. The right amount of sedation can be difficult to judge and depends a lot on the experience of the anesthesiologist as well as the patient's condition and drug use. In a society where recreational drugs, such as marijuana, have achieved social and legal acceptance, anesthesiologists and surgeons need to question the patient carefully about any regular drug (ab)-use. Daily use of marijuana, for example, will often necessitate higher doses of propofol to achieve a certain level of sedation—but even this is not predictable. Performing these kinds of surgery under sedation can create the following unpleasant scenarios: patients who get confused, patients who get disinhibited, or patients where even little doses of propofol can cause respiratory distress. It is best to start with an empirical dose and adjust it rapidly according to either a clinical level of sedation or a level of sedation as determined using objective brain monitoring. It is often desirable to start the sedation well before the incision, at the time of placing the patient on the operating table, if possible. Also, in order to avoid respiratory distress, oxygen supplementation can avoid respiratory distress and avoid having to lower the sedation level in order to secure proper oxygenation. One of the most important aspects of perioperative analgesia using loco-regional blocks is the cooperation between surgeon and anesthesiologist throughout the procedure. Failure of these techniques are often observed when surgeon and anesthesiologist do not know each other well and have little experience in managing these cases in this way.

The blocks most commonly used are abdominal wall blocks and amongst them mostly transversus abdominis plane blocks (TAP), rectus sheath blocks (RS), or block of ilioinguinal and iliohypogastric nerves. All these blocks are performed using ultrasound guidance, and although commonly referred to as loco-regional blocks, they should not be confused with neuraxial blocks; they are referred to as regional blocks because the analgesia achieved performing them cover a region but are not providing motor blockade. They are easy to perform, show a rapid learning curve, and provide excellent analgesia during and after surgery for up to 24 h. However, the applicability can somewhat be limited in very obese patients, specifically with blocks of the ilioinguinal and iliohypogastric nerves where nerve localization via ultrasound can be difficult or impossible.

Ideally, all blocks should be done outside of the operating room so as to decrease the stress for the patient. They should also be performed under adequate monitoring. Emergency drugs, such as ephedrine or atropine, should be ready to be used in prepared syringes. Obviously, an intravenous cannula should be inserted and sedation for the block should be provided. The most efficient sedation for these blocks is single-shot administration of intravenous midazolam or propofol according to the anesthesiologist's preference; this author either uses 1–2 mg of midazolam or 0.25–0.5 mg/kg of propofol. Oxygen insufflation and mask ventilation should be available.

It is important, both for the anesthesiologist as well as the surgeon, to familiarize himself with the abdominal wall anatomy before performing any of the abdominal wall blocks [1].

Keep in mind that all these blocks need sufficient time to work: in this author's experience, 15–30 min onset time is common after TAP and RS blocks. Therefore, sufficient time should elapse between the completion of the block and the start of surgery.

Specific surgeries

Open repair of umbilical hernia

The appropriate block technique both depends on the surgical technique as well as the amount of defect. Smaller defects and an open surgical technique, which uses small intra-umbilical incision, can best be repaired using rectus sheath (RS) blocks [2].

This block (Fig. 1) provides analgesia of the terminal branches of the 9th to 11th intercostal nerves between the internal oblique and transversus abdominis muscles. These nerves run through the posterior wall of the rectus abdominis muscle towards the anterior cutaneous branch around the umbilical area. Ultrasound guidance shows the various muscle structures. The probe is placed at 5–10 cm lateral of the umbilical area and the internal oblique and transversus abdominis muscles are identified. The needle is advanced in-plane from lateral to medial and superficial deep into the area in-between the muscles. All abdominal wall blocks depend more on volume than on concentration of local anesthetics: usually 20 ml of local anesthetic of a low concentration is sufficient.

This author prefers a combination of 10 ml of bupivacaine 0.25% and 10 ml of lidocaine 1% in a mixture of 1:1 on each side. Also, as a slight modification of the standard technique, 15 ml is injected near the posterior border of the rectus sheath, whereas the remaining 5 ml of the mixture is injected just underneath the anterior border of the rectus sheath.

The skin incision can easily be covered by small amounts of lidocaine 1% either applied by the anesthesiologist or the surgeon immediately before incision. It is important for the anesthesiologist to be familiar with the surgical incision and surgical technical habits. This type of analgesia works best with a small incision and insertion of a mesh graft, which secures itself with few stitches. Surgical techniques, which cut below the umbilical area and necessitate extensive subcutaneous dissection, might be more difficult to perform under loco-regional techniques alone.

Rectus sheath blocks provide analgesia for 12–24 h.

Transversus abdominis blocks might be an alternative, especially if the dissection is more elaborate.

Preparation of the patient is the same, monitoring, intravenous cannula, single-shot sedation for performing the block.

The injection site is between the transversus abdominal muscle and the internal oblique muscle, more lateral than the rectus sheath block (Fig. 2) [3].

This author places the needle in the middle or at level of the intended surgical incision and injects 25 ml of local anesthetic (same mixture as above) per side.

For both techniques, continuous sedation is appropriate during surgery, as well as the availability of additional local anesthesia in form of lidocaine, as a sterile injection given by the surgeon to supplement local anesthesia in areas of newly occurring pain during surgery.

Target-controlled infusion of propofol and brain monitoring seems to be the most sophisticated and precise way of providing adequate sedation; in younger patients, TCI is usually started at 1.5 microg/ml, and adjusted according either to clinical sedation level and/or brain monitoring, with BIS values of 75–85 usually showing adequate moderately profound sedation levels. In older patients, 0.5–1 microg/ml as

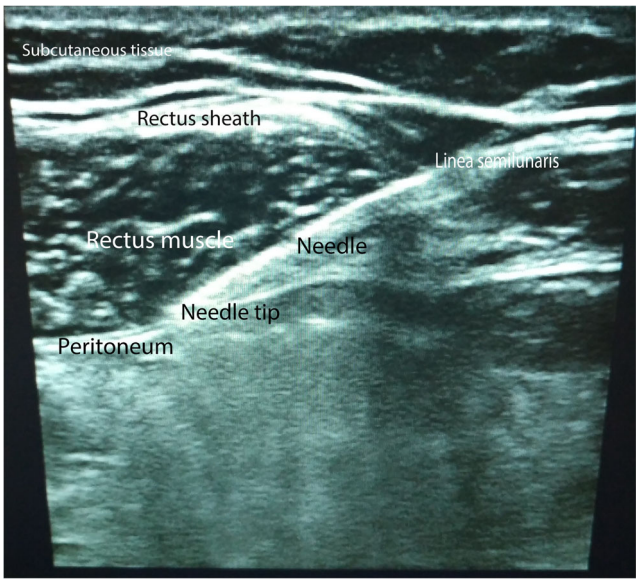

Fig. 1 US-guided RS block. Ultrasound image of the anatomical structures relevant for the rectus sheath block. Local anesthetic is injected so as to lift up the rectus muscle

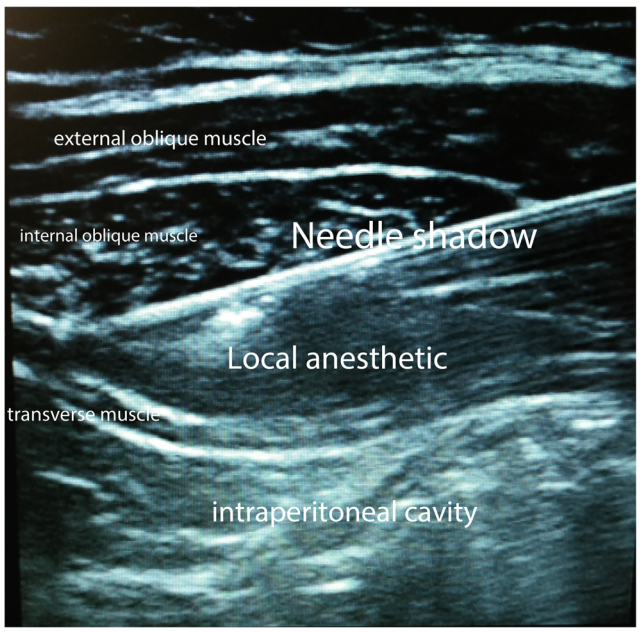

Fig. 2 US-guided TAP block. Ultrasound image of the anatomical structures relevant for the transversus abdominis block. Local anesthetic is injected in-between the internal oblique and transverse abdominis muscle

a target is the safer choice and adjustments are done as described before. It seems important that the sedation is already under way and the desired sedation level achieved before surgery starts.

Usually, these two blocks should provide sufficient pain relief after surgery as well. However, independently from occurrence of intraoperative pain or not, some patients might still experience mild pain after surgery. Short-acting opioids, such as fentanyl in increments of 25–50 microg or ketorolac 30 mg IV, are generally sufficient to provide excellent pain relief. The vast majority of patients, however, do not have pain after umbilical repair under TAP or RS and can go directly to the ward without stopover in the recovery unit. Urination is not impeded and discharge from the hospital is rapid.

In order to avoid prolonged stay in the recovery room due to prolonged sedation, intraoperative sedation with propofol should be stopped well before the end of surgery so that the patient is well awake when surgery is completed.

Open repair of inguinal hernia

There are two possible block techniques for this kind of surgery: TAP block or blockade of the ilioinguinal and iliohypogastric nerves with the former being much more popular recently, being easier to perform, and providing more consistent efficiency. There is still controversy which technique is superior in terms of pain control during surgery and in the immediate postoperative period. Both block techniques in comparison to neuraxial techniques seem to decrease the occurrence of chronic pain after inguinal hernia repair [4].

The efficacy of TAP block for inguinal hernia repair seems to depend as well of the proximity between the TAP block needle insertion site and the surgical site. The needle insertion site should be located as caudal as possible. Also, sometimes 25–30 ml of local anesthetic might not be sufficient and 40 ml of local anesthetic, e.g., bupivacaine 0.25%/lidocaine 1% in a mixture of 1:1 is necessary.

Local skin analgesia can be provided by the surgeon just before surgery.

Initial studies showed a better pain relief of ultrasound-guided TAP versus blind ilioinguinal block techniques. However, recent advances and the use of US guidance have increased the success rate of this block. In comparison to TAP blocks, it needs lower volume of local anesthetics—in general, 15 ml of the mixture described above is sufficient—and now shows more reliable efficacy.

The ultrasound probe is placed obliquely on a line between the anterior superior iliac spine and the umbilicus, superior to the anterior superior iliac spine. The needle is placed in the fascial layer (Fig. 3). It occasionally, when performed too caudally, causes a femoral nerve block; therefore, proper motor function of the leg and the quadriceps should be checked postoperatively in all patients receiving a combined ilioinguinal-iliohypogastric block. This is not a frightening complication as long as the anesthesiologist explains this to the patient—and the surgeon. It obviously can delay discharge from the hospital. This block might be an advantage for bilateral open hernia repair as it provides a bigger local anesthetic toxicity margin than bilateral TAP blocks by the reduced volume necessary to achieve satisfactory analgesia—although practically, local toxicity after bilateral TAP blocks has rarely been described [5].

Hemorrhoid surgery

Open hemorrhoid surgery can easily be performed under local anesthesia only—plus or without sedation [6].

Firstly, sufficient sedation should be achieved since the anal area is very sensitive. Depending on the area, 10–20 ml of a mixture of bupivacaine 0.25%/lidocaine 1% with epinephrine is sufficient; this mixture should be injected around the anus in equal doses. Additional doses of this mixture—generally 5–10 ml—are then also inserted deeper, into the intersphincteric plane on four sides of the anus. Since the anus region is highly vascularized, onset is very rapid and sufficient analgesia can usually be provided within 5 min.

In comparison to spinal anesthesia, this technique carries far less side effects—headaches, dizziness, hypotension, urinary retention—as well as better and longer lasting pain relief after surgery. However, this technique necessitates a cooperative patient or deeper sedation in order to avoid movement during surgery.

Surgery of ischiorectal abscess

This generally is not an ideal surgery for solely local anesthesia; depending on the degree of inflammation, the efficacy of local anesthetics is greatly reduced and therefore surgery cannot easily be performed under local anesthesia only. Spinal anesthesia or general anesthesia is better suited.

Surgery of pilonidal sinus-fistulas

Surgery of pilonidal sinus or fistulas should only be performed under local anesthesia if the patient wishes so, if the layers of fat and muscles are thin, sufficient sedation is provided or contraindications exist for either spinal or general anesthesia. Then, local anesthesia with widespread infiltration around the sinus or fistula should be performed, carefully infiltrating in increments from superficial to deep areas—towards the gluteal muscle fascia—and all around. Larger volumes of local anesthesia are usually needed because of the extensiveness of surgery, generally a total of 40 ml of a mixture of bupivacaine 0.25%/lidocaine 1% mixture of 1:1.

All these blocks demand good collaboration between surgeon and anesthesiologist. It is best performed with teams

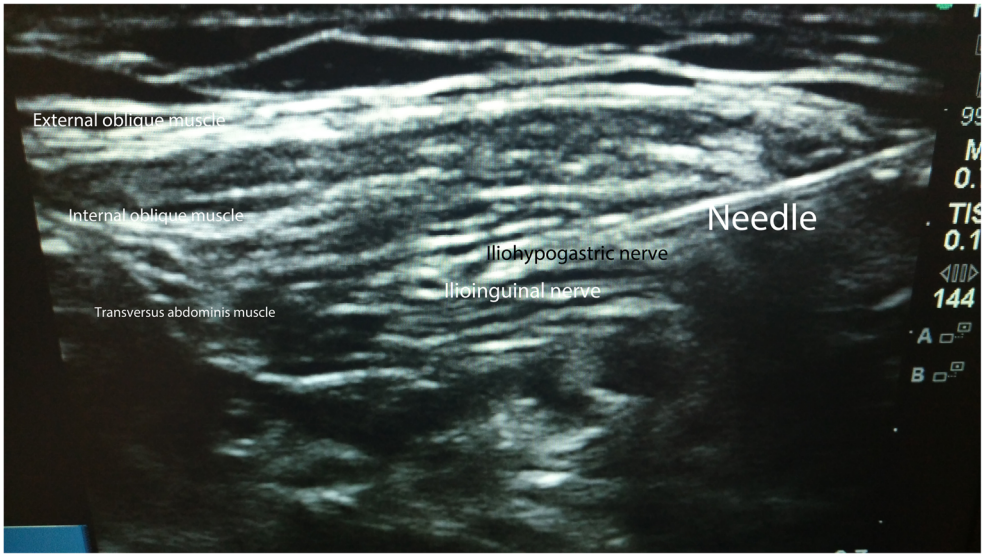

Fig. 3 US-guided ilioinguinal-iliohypogastric block. Ultrasound image of the anatomical structures relevant for the ilioinguinal and iliohypogastric block. The nerves can often be identified as hypoechogenic circular structures between internal oblique and transversus abdominis muscles

who know each other well and have done these procedures under these circumstances before. It is important to create a comfortable OR atmosphere for the patient and/or sufficient sedation. Excellent communication between all heath care providers avoids failure and guarantees best outcome. In these circumstances, loco-regional techniques together with continuous sedation provide optimal pain relief during and after surgery for these kinds of open minor abdominal surgeries.

However, all these surgeries can also be done under general anesthesia, most of them using a laryngeal mask airway. If there are absolute or relative contraindications for the use of the laryngeal mask airway (LMA), then endotracheal intubation can be used, such as for more obese patients or surgery in the prone position. Some might argue that performing general anesthesia in these patients might have a negative impact on them leaving the hospital early or being done on an outpatient basis. This can be true depending on how anesthesia is delivered and how long surgery is. Modern techniques of general anesthesia—total intravenous anesthesia using target-controlled infusion, monitoring of depth of anesthesia, using short-acting drugs, such as remifentanil, reduced, or no muscle relaxation—have greatly reduced not only the most common side effect of general anesthesia in this setting, postoperative nausea, or vomiting, but also shortened significantly the length of stay, both in the recovery room and in the hospital allowing the vast majority of these types of surgery being done as an outpatient.

The most important aspect of early discharge and patient comfort, however, is the combination of general anesthesia with adequate multimodal pain relief strategies, including the combination of local analgesic techniques. The more drugs are used, the higher the risk for having side effects. Not every patient reacts well to receiving ketorolac as pain relief, some suffer from side effects, such as upset stomach, nausea, or vomiting. However, these side effects are less frequent than when opioids are used [7].

If general anesthesia is chosen to provide anesthesia for these patients, great care should be taken to use short-acting anesthetic agents, and reverse the effects of muscle relaxants efficiently, and use multimodal pain relief strategies, including pre-emptive local analgesic strategies, local infiltration by anesthetist or surgeon before incision, or using loco-regional blocks before start of surgery to limit the use of opioids in the postoperative period.

It is a very common practice for surgeons to infiltrate the wound after surgery using longer-lasting local anesthetics. However, this is not the right strategy: local wound infiltration should be performed before incision, with the idea to have optimal local analgesia at the time the incision is performed. Knowledge of the onset profile of a given local anesthetic is important and very often lacking; also, time constraints within the operating room will press the surgeon to cut before the local anesthetic infiltration has not reached its speak effect yet. Onset time, not time to peak effect, for levobupivacaine, for example, is 10–15 min: it would be uncommon to see the surgeon inject preemptively levobupivacaine as a local infiltration and then wait patiently for 15 min before doing the skin incision.

It is therefore preferable if preemptive local anesthesia is performed by the anesthetist, so that there is sufficient time between injection and incision—without wasting expensive time in the operating room [8].

Using preemptive blocks, such as TAP block, RS block, or ilioinguinal and iliohypogastric blocks, is another option, probably providing better postoperative analgesia than local infiltration alone. Since surgery in this case is performed under

general anesthesia, most anesthetists would decrease the concentration of the local anesthesia used, while still using the same volume: however, there is no fixed rule for this.

There are some types of surgeries in this list, pilonidal sinuses and ischiorectal abscess, where local infiltration techniques are not available or of limited or experimental value. Both types of surgeries are usually performed using general anesthesia and multimodal drug pain relief strategies, e.g., a combination of intraoperative opioids, preemptive ketorolac at the end of surgery, and oral pain medication for the postoperative period. It is the opinion of this author that these patients generally benefit from a combination of these strategies with spinal anesthesia rather than general anesthesia, in order to better cover the immediate postoperative period.

Let us summarize a couple of exemplary case studies for the different surgeries under general anesthesia plus local/regional pain techniques and pain drugs.

Umbilical hernia

Induction and maintenance of anesthesia as target-controlled infusion (TCI) of propofol, target-controlled infusion of remifentanil, brain monitoring to provide light level of anesthesia; LMA without or reduced use of muscle relaxants.

Controlled ventilation or spontaneous respiration according to the anesthetic preference

BEFORE incision

Rectus sheath block bilaterally, using 20 ml bupivacaine 0.125%, each side at least 15 min before surgery

AT end of surgery

Injection of ketorolac 30 mg intravenously (immediate onset of peak effect, usually lasting for 6–8 h) [9]

Inguinal hernia

Induction and maintenance of anesthesia as TCI propofol, TCI remifentanil, brain monitoring to provide light level of anesthesia; LMA without or reduced use of muscle relaxants.

Controlled ventilation or spontaneous respiration according the anesthetic preference

BEFORE incision

TAP block, using 20 ml bupivacaine 0.125%, at least 15 min before surgery

AT end of surgery

Injection of ketorolac 30 mg intravenously

Hemorrhoid surgery

Induction and maintenance of anesthesia as TIVA-TCI propofol, TCI remifentanil, brain monitoring to provide light level of anesthesia; LMA without or reduced use of muscle relaxants.

Controlled ventilation or spontaneous respiration according the anesthetic preference

BEFORE incision

Local infiltration using 20 ml bupivacaine 0.125%, at least 15 min before surgery, equally injected around the anal skin

AT end of surgery

Injection of ketorolac 30 mg intravenously

Surgery of ischiorectal abscess

Although there are studies showing a beneficial effect of local anesthesia on pain relief after anal surgery [10], one needs to remember that the efficacy of local anesthetics in areas of infection or inflammation is greatly reduced [11].

Surgery of pilonidal sinus-fistulas

Since the surgical site is usually not highly "inflamed or infected," local anesthesia might be useful [12]. In the literature, there is simply the description of injecting 20 ml of local anesthetics around the pilonidal sinus in the sacrococcygeal region.

Here is a possible alternative technique for general anesthesia with local infiltration using a more *plane type technique*.

Induction and maintenance of anesthesia as TCI propofol, short-acting opioids, brain monitoring to provide light level of anesthesia; endotracheal intubation with reduced use of muscle relaxants (since most of the surgeons prefer a prone position).

Controlled ventilation

BEFORE incision

Plane block using US guidance: deposit of 15 ml bupivacaine 0.125%, at least 15 min before surgery, equally injected on each side, deposited just above the profound glutaeus maximus muscle fascia. In addition, 5 ml bupivacaine 0.125% is injected below the skin, medially and centered along the pilonidal sinus.

AT end of surgery

Injection of ketorolac 30 mg intravenously

Other than umbilical hernias, these open types of minor abdominal surgery are suitable for spinal anesthesia.

One of the main problems of spinal anesthesia, however, is the occurrence of headaches as well as the risk of dural hematoma; hence, the contraindication of its use when coagulation is impaired. Due to the increased and aggressive use of anticoagulant drugs by cardiologists, there is also an increasing number of patients on these drugs. In the elective setting, this might not be a problem since normal coagulation is restored before surgery and therefore spinal anesthesia can be used. In the emergency setting, e.g., incarcerated hernias or ischiorectal abscesses, this is not the case. Spinal anesthesia cannot be used. General anesthesia plus loco-regional techniques are a good choice here.

The advantage of spinal anesthesia in the immediate postoperative period is the complete analgesia in the first hours after surgery. However, since spinal blockade also limits transfer from the recovery room and affects spontaneous urination, discharge from the hospital might also be delayed.

Two main types of spinal anesthesia are available and their use depends on the type and length of surgery, as well as the preference of the anesthesiologist.

Lidocaine, formerly a popular choice for short-acting spinal anesthesia, has lost its place due to the inherent risk of transient neurologic symptoms (TNS). Other more modern short-acting local anesthetics, such as articaine or prilocaine, are not available in all countries for these indications. This leaves the anesthesiologist with the safest choice as spinal anesthesia with isobaric or hyperbaric long-acting local anesthetics, such as bupivacaine or levobupivacaine [13].

Isobaric spinal anesthesia provides the advantage of not wasting OR time before surgery, while hyperbaric spinal anesthesia offers the advantage of faster recovery time, shorter time in the recovery room, and ultimately earlier discharge from the hospital.

Adding about 5 min of "fixation" time when hyperbaric spinal anesthesia is used can easily shorten 1–2 h of time in the recovery room [14].

There is also some debate whether there is less urinary retention with hyperbaric than isobaric spinal anesthesia, and the duration of leaving the patient in a given position is debatable, from 3 to 10 min usually, to as short as 1 min [15].

Generally speaking, hyperbaric spinal anesthesia involves a bit more "timing" and might not offer significant advantages in terms of urinary retention; however, the duration of motor and sensory block is significantly shorter. Some anesthesiologists experience patients to be more prone to hypotension with hyperbaric spinal anesthesia than isobaric anesthesia although not objectively proven [14].

As a rule of thumb, spinal anesthesia can be performed with almost 100% success in terms of sufficient analgesia for all types of minor abdominal open surgery using 2 cc of isobaric bupivacaine 0.5% or equivalent doses of other local anesthetics, or 1 cc of hyperbaric bupivacaine 0.75%.

In the author's experience, a "positioning" time of 5 min is sufficient in the vast majority of patients.

In terms of postoperative analgesia, similar strategies to the ones mentioned in the section of general anesthesia are important. Postoperative analgesia should be provided before the spinal anesthesia has worn off.

Most studies have shown that spinal anesthesia provides better pain relief in the immediate postoperative period versus general anesthesia with no difference in the latter stages after surgery [16, 17].

However, especially in younger patients, this benefit might be outweighed by the risk of post spinal headache.

One particular clinical problem is managing bigger inguinoscrotal hernias, especially in cases where bowel is within the scrotal sac and which then during surgery will then have to be pulled back into the abdominal cavity.

It is this author's experience that both loco-regional techniques as well as spinal anesthesia often are not sufficient and adequate. Pulling on the intestines and reflex activation of the peritoneum can often lead to significant pain more cranially or significant vagal reaction. The author's preference is to perform these big hernias using general anesthesia combined with either TAP or ilioinguinal/iliohypogastric blocks.

Recently, many minor abdominal surgeries are performed laparoscopically, namely the repair of hernias. This presents new challenges for the anesthesiologist as these types of surgery cannot be performed using loco-regional techniques or neuraxial anesthesia alone.

In addition, laparoscopic surgery is prone to cause more often postoperative nausea and vomiting; hence, intraoperative management should focus on trigger-free general anesthesia, e.g., propofol anesthesia without nitrous oxide. The pneumoperitoneum can cause significant postoperative pain in a wide area; very often patients complain postoperatively of pain close to the insertion ports, the bigger the insertion port the more likely it is to cause pain.

The best pain strategy is a multiple regiment pain relief effort given before the end of surgery combined with TAP block right after induction of anesthesia [18].

In the author's experience, it is best to insert the needle at a level of T11–T12 and opt for bigger volume and lower concentrations; e.g., 30 ml bupivacaine 0.125% injected on each side provides analgesia in T10-L1 nerve endings.

However, since pneumoperitoneum covers a wider area than just T10-L1, one should not be surprised that the TAP block alone is not sufficient to cover all postoperative pain, hence the need for an adequate multimodal pain strategy. It is also interesting to note that although classified as "minimally invasive surgery," a great number of patients will experience significant pain as usually experienced after open surgery only.

Some studies have found sufficient analgesia when RS is performed for these types of surgeries, although this author would suggest TAP blocks [19].

Particular laparoscopic surgeries

Laparoscopic appendicectomy

Laparoscopic appendicectomy must be performed under general anesthesia. The new gold standard for appendicectomy presents considerable challenges for the anesthetist: it is usually a short procedure necessitating a rather profound level of muscle relaxation and produces—since it is an inflammatory emergency—significant postoperative pain. Effective pain relief starts with sufficient intraoperative analgesia, with opioid doses generally higher than one would expect for minor laparoscopic procedures. A multimodal postoperative pain strategy is the basis for sufficient pain relief.

Recent studies have focused on efficacy of abdominal wall blocks for pain relief and have been somewhat inconclusive with studies showing no effect of TAP blocks [20–23] over simple port-site local anesthesia. However, there are few studies showing a significant benefit if TAP block is part of a multimodal pain strategy in children undergoing laparoscopic appendicectomy [24] as well as in open appendicectomy, which is rarely performed nowadays [25–27].

As a standard practice, this author would not recommend applying TAP blocks for laparoscopic appendicectomy but for open appendicectomy only. Remifentanil or fentanyl intraoperatively, ketorolac before the end of surgery, and acetaminophen after surgery are all part of a multimodal pain relief strategy.

Laparoscopic cholecystectomy

Similar strategies are necessary for laparoscopic cholecystectomy, which is the gold standard nowadays for elective or urgent cholecystectomy. In fact, open cholecystectomy usually only occurs as a complication of failed laparoscopic attempt and presents a significant challenge for postoperative pain management, usually necessitating either morphine IV or controlled by the patient or even sometimes a high thoracic epidural analgesia for pain control.

In laparoscopic cholecystectomy, most studies have shown no benefit of conventional TAP block as part of a multimodal strategy and no significant advantage over port infiltration [28, 29]. However, subcostal TAP block might actually provide beneficial analgesia [30–34].

The subcostal TAP blocks anesthetizes the intercostal nerves T6–T9 between the rectus abdominis sheath and the transversus abdominis muscle. The approach necessitates oblique positioning of the US probe just beneath the rib cage, on the right side [35].

As in a standard TAP block, 20–30 ml of local anesthetics should be administered before surgery.

In summary, laparoscopic appendicectomy and cholecystectomy present various challenges for the pain management; both are usually emergency surgeries with a strong component of local inflammation or even general septicemia. This implies usually an upregulation of pain receptors, which makes pain management more difficult; surgery time is usually short at less than 60 min. From a perioperative pain management point of view, a key aspect is sufficient intraoperative analgesia—either remifentanil or fentanyl with the majority of the dose given at induction and titrated to the end—with narcotic needs usually more than expected, and a sufficient multimodal pain strategy, including ketorolac or acetaminophen. Standard TAP block might be considered for open appendicectomy only, subcostal TAP block for laparoscopic cholecystectomy, both administered before surgery.

If closed cholecystectomy turns to open, then more elaborate pain strategies might be considered, such as TEA or PCA using opioids since considerable pain can be expected.

Repair of incisional hernia

Incisional hernias cannot easily be classified; depending on the size and location of defect, surgery—and associated pain—can resemble the repair of a simple umbilical hernia or a full median laparotomy. In addition, there is no clear consensus between surgeons which technique to use in which patient [36].

However, there is clearly a tendency towards laparoscopic repair, with it being more cost effective, associated with reduced length of stay, number of outpatient visits, and estimated days off [37].

Therefore, the choice of pain strategy depends on the type of surgery—open versus closed—and size of incision and/or defect. Multimodal pain strategy can therefore be either similar to pain management of an open umbilical hernia or open major abdominal surgery.

Major abdominal surgery

As for minor abdominal surgery, laparoscopic surgery has become more and more popular even for the most complex abdominal surgeries; however, not all surgeons use laparoscopic techniques for major abdominal surgeries, nor is it considered the gold standard. Therefore, pain management needs to be adapted to all types of approaches, be it open or closed, depending on the surgeon's preference.

Open major abdominal surgery

Preferred access is median laparotomy in various degrees of incision lengths and placements depending on the site of surgery and individual surgeon. For many decades, thoracic epidural analgesia has been the gold standard of perioperative pain management [38].

Not only does TEA provide excellent analgesia, but it can also be beneficial for recovery of gut function, reduce pulmonary, cardiovascular, thromboembolic, and gastrointestinal complications occurring after abdominal surgery.

It is important to know that lumbar epidural catheters do not provide these additional benefits. To the contrary, lumbar epidurals can actually impair recovery since it can make mobilization of the patient difficult. Depending on the incision site, TEA should be placed in the lower or middle thoracic region and used perioperatively, as a continuous infusion of local anesthetics, with or without adjuncts such as clonidine or opioids. It is important that TEA is followed either by an anesthesiologist or a dedicated pain service to adjust doses according to the development of pain after surgery, as well as the degree of patient mobilization, and recognize and control possible complications, such as epidural hematoma. The risk of developing such a hematoma is considered to be around 1:6600 [39] but increases if there is insufficient cooperation between the health care providers, e.g., a surgeon would prescribe heparin, without the anesthesiologist's knowledge, and a catheter be removed under heparin—thus creating the risk of an epidural hematoma.

A practical approach would be the following TEA regimen: installation of TEA before surgery, starting of TEA at 10 ml/h of bupivacaine 0.065% with 3 microg/ml of fentanyl for 3–5 days titrated to the pain between 4 and 16 ml/h. If pain is more than 4/10, then the TEA infusion rate is increased by 1 ml/h, if pain is absent, reduce infusion rate by 1 ml/h. Safety instructions and standardized protocols are preeminent for using TEA in safe conditions and all health care providers must be aware of the catastrophic complication of epidural hematoma and how to act in this emergency situation.

Supplemental multimodal pain medication is equally important as enrolment in a fast track program; studies have shown that enrolment in such a program alone can have analgesic effects.

However, epidural analgesia has been associated with longer hospital stay and higher hospital costs, and more urinary tract infections [40]. Also; this might be due to the use of lumbar epidural analgesia rather than thoracic epidural analgesia. This might be the reason for increased postoperative ileus [41].

However, there is an increasing number of recent studies showing difficulties with using epidural analgesia in the scenario of colorectal surgery, mostly in terms of urinary retention, longer hospital stay, and problems of management of anticoagulation therapy [42, 43]. In times, where anticoagulation therapy affects more patients, and is more aggressive, and major abdominal surgery is increasingly performed laparoscopically, the use of TEA is reduced. A meta-analysis from 2018 provided moderate evidence for equally effective analgesia of TAP blocks and epidural analgesia, with fewer episodes of hypotension with TAP blocks [44]. A recent study confirmed this tendency even in esophagectomy [45]. Better overall analgesic efficacy and less hypotension after surgery with TAP blocks in comparison to thoracic epidural analgesia were reported for major abdominal oncologic resections [46].

Laparoscopic major abdominal surgery

This type of surgery differs in terms of "pain" area from the laparoscopic approach described for minor abdominal surgery, such as laparoscopic hernia repair, in such a way that in order to remove the dissected colon, a small incision must be made. So in addition to the small incision holes found in minor abdominal laparoscopic surgery, an additional incision of 5–10 cm is made and the bowel removed.

One experiences that the pain intensity is increased and pain treatment is more difficult.

Studies have shown that bilateral TAP blocks are beneficial in a multimodal pain strategy after laparoscopic colorectal surgery [47]. This author prefers to perform the TAP blocks in close proximity to the intended site of "incision to remove the bowel" to optimize the pain strategy. The usual 25–30 ml of low concentration local anesthetics is sufficient to provide good pain relief within a strategy of postoperative low-dose opioids, NSAIDs, and other supplemental analgesia.

A relatively new technique is continuous TAP blocks via catheters, bilaterally inserted. There is the advantage of providing continuous local anesthesia, both either via continuous infusion of, for example, 8 ml/h ropivacaine 0.2% each site, or as intermittent boli of 20 ml of ropivacaine 0.2% each site every 8 h. The disadvantage of this technique is that the catheter can only be inserted after surgery—because otherwise of being within the surgical sterile field—so sufficient intraoperative analgesia is necessary.

In this author's practice, TAP block—continuously or as single-shot—has almost replaced TEA for colorectal surgery, other than for specific indications, such as chronic pulmonary disease.

One can say that in the last decade, there is a paradigm shift both for open or closed major abdominal surgery from TEA as the gold standard of perioperative pain control towards more modern forms of less invasive techniques, with the main focus on TAP blocks. Studies have shown that continuous TAP blocks can be as efficient in terms of pain control as continuous epidural analgesia [48–50], which leaves us with the

Table 1 (continued)

Most often no additional medication necessary; if yes, fentanyl 25–50 microg IV in the PACU; 650 mg acetaminophen BID

Minor laparoscopic surgery

Inguinal, incisional, or umbilical hernia

TCI-TIVA propofol, fentanyl, full relaxation using rocuronium, controlled ventilation using endotracheal intubation

Bilateral transversus abdominis plane block before surgery

Example: 2 × 20 ml of a 1:1 mixture of lidocaine 0.5%/bupivacaine 0.125%

Ketorolac 30 mg IV at the end of surgery

Postoperatively

Fentanyl 25–50 microg IV in the PACU; 650 mg acetaminophen orally BID

Laparoscopic appendicectomy

TCI-TIVA propofol, fentanyl, full relaxation using rocuronium, controlled ventilation using endotracheal intubation

Note to give sufficiently intraoperative opioids

Ketorolac 30 mg IV at the end of surgery

Postoperatively

Fentanyl 25–50 microg IV in the PACU; 650 mg acetaminophen orally BID

Laparoscopic cholecystectomy

TCI-TIVA propofol, fentanyl, full relaxation using rocuronium, controlled ventilation using endotracheal intubation

Note to give sufficiently intraoperative opioids

After induction of anesthesia, before surgery

Subcostal transversus abdominis plane block before surgery

Example: 20 ml of a 1:1 mixture of lidocaine 0.5%/bupivacaine 0.125%

Ketorolac 30 mg IV at the end of surgery

Postoperatively

Fentanyl 25–50 microg IV in the PACU; 650 mg acetaminophen orally BID

Major open surgery

Colorectal surgery

One choice

Installation of TEA and start of continuous infusion of bupivacaine 0.065% with 2 microg/ml fentanyl at 6–10 ml/h; to be continued for 72 h

TCI-TIVA propofol, fentanyl, full relaxation using rocuronium, controlled ventilation using endotracheal intubation

Ketorolac 30 mg IV at the end of surgery

Postoperatively

650 mg acetaminophen orally QID for 3 days

Alternative choice

TCI-TIVA propofol, fentanyl, full relaxation using rocuronium, controlled ventilation using endotracheal intubation

Installation of continuous bilateral TAP blocks immediately after surgery; continuous infusion of Naropin 0.2% at 8 ml/h each side

Ketorolac 30 mg IV at the end of surgery

Postoperatively

650 mg acetaminophen orally QID for 3 days

PCA fentanyl for 3 days

Major laparoscopic surgery

Colorectal surgery

TCI-TIVA propofol, fentanyl, full relaxation using rocuronium, controlled ventilation using endotracheal intubation

Bilateral transversus abdominis plane block before surgery

Example: 2 × 20 ml of a 1:1 mixture of lidocaine 1%/bupivacaine 0.25%

Ketorolac 30 mg IV at the end of surgery

Postoperatively

650 mg acetaminophen orally QID for 3 days

PCA fentanyl for 3 days if necessary

Table 1 Pain management per type of surgery—an empirical approach

Minor open surgery

Umbilical hernia

1st choice

Bilateral rectus sheath block 20 min before surgery under short-term sedation (midazolam or propofol)

Example: 2 × 20 ml of a 1:1 mixture of lidocaine 1%/bupivacaine 0.25%

Intraoperative sedation using TCI-TIVA propofol titrated to BIS between 75 and 85

Ketorolac 30 mg IV at the end of surgery

Postoperatively

Most often, no additional medication necessary; if yes, fentanyl 25–50 microg IV in the PACU; 650 mg acetaminophen BID

Inguinal hernia

1st choice

Bilateral transversus abdominis plane block 20 min before surgery under short-term sedation (midazolam or propofol)

Example: 2 × 20 ml of a 1:1 mixture of lidocaine 1%/bupivacaine 0.25%

Intraoperative sedation using TCI-TIVA propofol titrated to BIS between 75 and 85

Ketorolac 30 mg IV at the end of surgery

Postoperatively

Most often, no additional medication necessary; if yes, fentanyl 25–50 microg IV in the PACU; 650 mg acetaminophen BID

Hemorrhoid surgery

1st choice

TCI-TIVA propofol, fentanyl, low-dose rocuronium to facilitate LMA placement, controlled ventilation using LMA

After induction of anesthesia

Local anesthesia using 15 ml of 1:1 mixture of lidocaine 1%/bupivacaine 0.25%, injected around anus

Ketorolac 30 mg IV at the end of surgery

Postoperatively

Most often, no additional medication necessary; if yes, fentanyl 25–50 microg IV in the PACU; 650 mg acetaminophen BID

Repair of pilonidal sinus in the prone position

1st choice

Spinal anesthesia

After spinal anesthesia and before surgery

Local anesthesia both sides of the pilonidal sinus: 2 × 20 ml 1:1 mixture of lidocaine 1%/bupivacaine 0.25%

Ketorolac 30 mg IV at the end of surgery

Postoperatively

question when to use single-shot TAP block versus continuous TAP block.

Is there a difference in pain after open versus closed major abdominal surgery [51]?

Pain peaks after laparoscopic surgery occur mostly within the first 24 h; pain peaks after open surgery occur during the first 72 h, mostly during mobilization.

Single-shot TAP blocks are therefore sufficient for patients undergoing laparoscopic major abdominal surgery with an

expected analgesia of up to 24 h, whereas continuous TAP blocks are used in open abdominal surgery where significant pain is expected to occur for several days after surgery.

Both techniques are combined with a multimodal analgesia strategy, ketorolac 30 mg IV at the end of surgery, and orally administered acetaminophen or paracetamol QID for 2 days. In addition, PCA with a short-acting opioid such as fentanyl can be used if necessary.

Patients treated with TAP blocks undergoing laparoscopic colon surgery showed lower postoperative nausea and vomiting, lower rates of postoperative ileus, and paresthesia when compared with patients with thoracic epidural analgesia [52].

Conclusion

The basis of efficient pain relief during abdominal surgery is a multimodal strategy, a combination of loco-regional analgesic techniques combined with short-acting opioids, NSAIDs, and supplemental drugs, such as acetaminophen.

Thoracic epidural analgesia has lost its status as the gold standard for major abdominal surgery with the introduction of alternative local techniques, specifically abdominal wall blocks, and the trend towards laparoscopic surgery. In addition, recent advancement and developments of aggressive anticoagulation medication used for a variety of indications as well as recent studies questioning the overall benefit of TEA both in terms of superior pain relief but also its negative impact on mobilization—patient and bowel—and spontaneous urinary output have shifted the risk-benefit balance away from TEA.

Minor open abdominal surgery, from open inguinal hernia repair to hemorrhoid surgery, can easily be performed under a variety of abdominal wall blocks and local field blocks, TAP, RS, ilioinguinal-iliohypogastric blocks only with efficient continuous sedation, best titrated to a given objective state of sedation (brain monitoring). These strategies guarantee the best risk-benefit ratio, allowing surgery with optimal analgesia and early hospital discharge. Collaboration between all health care providers is essential for the success of these strategies.

Spinal anesthesia can no longer be considered as the first anesthesia choice for open minor abdominal surgery. Abdominal wall blocks can be used as an efficient and probably main component of a multimodal strategy for pain relief when general anesthesia is necessary for minor laparoscopic surgery. Laparoscopic appendicectomy does not benefit from abdominal wall blocks; a standard conservative multimodal strategy consisting of NSAIDS and opioids is efficient.

Subcostal TAP blocks have shown to be beneficial for laparoscopic cholecystectomies as part of a multimodal strategy.

Major laparoscopic abdominal surgery, such as laparoscopic colon resections, will mostly benefit from a combined strategy of bilateral single-shot TAP blocks before surgery, sufficient opioid administration during surgery—e.g., continuous remifentanil or fentanyl with the majority of fentanyl given in the beginning and tailoring off towards the end of surgery—administration of IV ketorolac before the end of surgery and oral NSAIDs plus PCA fentanyl after surgery. Most of the pain will be gone within 24 to 48 h postsurgery.

Major open abdominal surgery will benefit from a multimodal pain strategy including continuous TAP block installed after surgery. Thoracic epidural analgesia should be reserved for specific indications such chronic pulmonary disease.

Spinal anesthesia should be reserved for anal surgery if patient or surgeon does not accept local techniques. It also still has a place in repair of ischiorectal abscesses or pilonidal sinus surgery, where postoperative immediate pain can be severe, local anesthesia tends to fail due to the significant inflammation.

Pain management in abdominal surgery needs to be adjusted for each type of surgery to find the best possible option (Table 1).

Acknowledgements The author thanks the Department of General Surgery at Fleury Hospital for their precious collaboration during the development of a modern multimodal pain strategy. He is also grateful to his colleagues Drs Chaveron and Errouissi for their enthusiasm and creativity to implement these strategies. Lastly, many thanks to the nurses of the PACU of Fleury Hospital for their dedication and help.

Compliance with ethical standards

Conflict of interest The author declares that he has no conflict of interest.

Ethical approval This article does not contain any studies with human participants performed by any of the authors.

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