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The Tissue Plane

Philip Cornish

Abstract

In recent times, terms such as 'interfascial plane block' and 'fascial plane block' have become common in describing regional anaesthesia blocks such as transversus abdominis plane (TAP), serratus anterior plane (SAP) and erector spinae plane (ESP). In fact, none of these names accurately describes the applied anatomy involved in each named technique, as the acronym is only one part of the anatomic jigsaw puzzle. The correct term is 'tissue plane block', which derives from surgical terminology. The tissue plane is not new to regional anaesthesia, as it has been the endpoint of 'loss of resistance' and 'pop' techniques for many decades. However, the game-changer is that now we can see the tissue plane courtesy of ultrasound. The purpose of this chapter is to review the history of the tissue plane in relation to its use in regional anaesthesia, and to see how ultrasound has further advanced the regional anaesthesiologist's options in this regard. The chapter will also review how an understanding of tissue dynamics can further enhance our clinical results by manipulating the characteristics of the tissue plane.

Keywords: tissue plane, ultrasound-guided regional anaesthesia, applied anatomy, TAP block, ESP block, SAP block, rectus sheath block, tissue plane dynamics, dye studies, injectate, hydrodissection, nerve block

1. Introduction

> *'something old, something new, something borrowed, something blue…'*
>
> *18th Century English Rhyme*

'Something old' – it may have evolved over geological time, it may distort with congenital, surgical, traumatic or other influences, but fundamentally anatomy has been around for a long time. This was wittily expressed by Harrop-Griffiths and Denny [1] in relation to the introduction of ultrasound to regional anaesthesia when they suggested that there are 'no new blocks, just old anatomy'. These authors would undoubtedly agree though that how we look at anatomy can change, and indeed should change as study and scholarship advances our understanding.

'Something new' – the ability of ultrasound to visualise tissue planes provides a new, or more accurately, a newly appreciated target. The explosion of named techniques using ultrasound guidance in the last several years bears testimony to this development in regional anaesthesia practice.

'Something borrowed' - The 'tissue plane' is a concept borrowed from surgical practice [2–4] and it forms the foundation of modern surgical dissection technique. An alternative term for the same idea is the 'plane of dissection'. Surgeons also talk about 'creating' a plane of dissection or 'getting into the correct (tissue) plane' [4]. The key idea which surgeons are emphasising is that of dissecting between

structures, and it matters little whether this is with a sharp (e.g., scalpel) or blunt (e.g., finger) instrument. In regional anaesthesia practice, the dissection occurs solely with a blunt (injected fluid) instrument and is termed 'hydrodissection'.

'Something blue' – it has been routine for many years in cadaveric anatomic studies in the regional anaesthesia literature to use methylene blue as a marker to track nerve block placement. These have in effect been studying spread of fluid along tissue plane/s. Once again, we find that this is not so much a new as an under-appreciated phenomenon. A note of caution however – early post-mortem changes in collagen change the structure of connective tissues [5, 6] and therefore the cadaveric model has an inherent flaw when it comes to assessing the dynamics of the tissue plane.

This chapter is divided into the following 10 sections: The tissue plane defined, History of the tissue plane in regional anaesthesia, The modern era of the tissue plane in regional anaesthesia, Tissue plane dynamics and some misunderstandings, Dye studies on tissue plane dynamics, High-definition ultrasound studies and the tissue plane, Tissue plane blocks versus compartment blocks, Systematic reviews, Research opportunities, and Conclusion.

2. The tissue plane defined

A tissue plane is defined as a potential space separating structures such as organs, muscles, nerves and blood vessels [7]. It frequently but not exclusively contains fine loose areolar tissue which is easily divided by both sharp and blunt dissection [2, 8]. The finer quality of these connective tissues contrasts to the much denser connective tissue that forms fascial boundaries, e.g. the prevertebral fascia. This is an important distinction as local anaesthetic will not diffuse across a fascial boundary.

Tissue planes are located throughout the body [2]. Examples include; providing a conduit for nerves, blood vessels and lymphatics from one body region to another e.g., within the femoral canal, [8]; dividing elements of a structure into its component parts, e.g., the brachial plexus [8, 9]; or where structures can be easily separated, e.g., between the fascicles of rectus abdominis muscle and the posterior rectus sheath [10].

The surgeon divides these tissues with scalpel, scissors, probe or finger and in so doing creates the plane of dissection in order to excise tissue or access an anatomic area. In surgical practice there is also a plane of dissection which creates less bleeding, the so-called 'avascular plane' [2]. By contrast the regional anesthesiologist injects a bolus of fluid which spreads along and through the tissue plane/s, not so much dividing as separating the tissues and then diffusing into the nerve/s to create a conduction block.

It is important to keep reminding ourselves that the tissue plane is a concept, not actual anatomy. It points towards tissues which are easily dissected/divided vs. tissues which are not. In regional anaesthesia the tissue planes of interest contain nerves. In this respect it is required to know which nerves may be blocked, where and what they innervate, how and where to access the tissue plane safely and how the tissue plane/plane of dissection will spread the injected solution.

3. History of the tissue plane in regional anaesthesia

While the tissue plane concept is fundamental to surgical dissection technique [2–4], the lack of emphasis on its importance in regional anaesthesia is perhaps

ironic given the number of publications in the literature which have in fact related to it prior to the introduction of ultrasound [11–34]. Indeed, the terms 'loss of resistance' and 'pop' refer to techniques accessing tissue planes, although they have not traditionally been described in that fashion.

The lack of acknowledgement of the tissue plane concept changed abruptly in 2007 with the publication of TAP (transversus abdominis plane) block [35]. In this paper the authors described the tissue plane between the fasciae of internal oblique and transversus abdominis muscles as a 'fascial plane' and then called it the 'transversus abdominis plane'. The fascial plane label stuck as did the name TAP and the search was on for others which surfaced in quick succession [36–43]. This pursuit for new targets was undoubtedly promoted by the emerging use of ultrasound and it is fair to say that subsequently there has been an explosion of interest across the spectrum of practice [44–83]. The terms 'fascial plane block' and 'interfascial plane block' have been further promoted [84] although more recently 'tissue plane' has been used [9].

The common theme of course is that all of the above involves the study of tissue planes and their dynamics of solution spread. As in surgical practice the tissue plane concept has been and is fundamental to the practice of regional anaesthesia.

4. The modern era of the tissue plane in regional anaesthesia

In the modern era, the rules have changed with the introduction of ultrasound. Now we are able to directly visualise tissue planes and at least in theory, manipulate them to our clinical advantage. While we now have a significant advantage with this development, a greater need for understanding the concept and its relevance to regional anaesthesia has arisen. A headlong rush to discover and name new blocks has often preceded the basic scientific work that should have underpinned the practice. Soft endpoints (e.g., 'we have done 20 and they worked well') and generic terms (e.g., 'multimodal analgesia') have the potential to hide the fact that a particular technique does not achieve the intended effect.

Added to this is a confused nomenclature. Surgical specialties have long used the term 'tissue plane' with a clear understanding of its meaning and it would seem odd to borrow this concept and claim it for regional anaesthesia under revised names. That being said, this author would also argue that for historic reasons it is important to retain the original name of individual techniques since these are the names given by authors to their techniques and which have been accepted through a peer-review process.

In the following paragraphs, we examine several of these techniques through the lens of intended clinical application versus anatomic scientific foundations.

PECS block was originally published as a technique to provide analgesia following breast surgery [37]. The name refers to the tissue plane between pectoralis major and pectoralis minor muscles, and the aim is to block the medial and lateral pectoral nerves which derive from the brachial plexus. This creates somewhat of a dilemma as the pectoral nerves do not innervate the breast. There have been modifications since, possibly reflecting that fact and correcting the record somewhat.

The pecto-intercostal fascial block was first published as an analgesic technique for breast surgery [52] and anterior chest wall trauma [53]. It aims to block the anterior cutaneous sensory branches of the intercostal nerves where they penetrate the chest wall near the edge of the sternum. Whilst the cutaneous termination of the intercostal nerves T2-T6 do innervate the skin over the medial aspect of the breast, these same cutaneous sensory nerves do not innervate the bony structures of the anterior chest wall. Further study of the relevant tissue planes is awaited.

By contrast, the superior cluneal nerve block was first published as a very different type of anatomic study [85]. These nerves derive from the first three lumbar dorsal rami and innervate the skin over the buttock area. This technique creates a plane of dissection just deep to the superficial layer of the thoracolumbar fascia in its inferolateral aspect. The authors of that paper first studied a cadaveric model, but then in recognition of the inherent flaws of such modelling repeated the block in volunteers with accompanying mapping of sensory loss against potential surgical incisions. The accompanying editorial suggested that new techniques required similar basic science study so that in the clinical environment, we know exactly what we are doing and what we can expect to achieve [86].

Erector spinae plane block (ESP block), an injection into a tissue plane deep to the erector spinae group of muscles, has quickly become one of the most popular techniques since its first description [60]. It was almost immediately accompanied by multiple case reports with dramatic claims of efficacy [87–90]. There followed several quite different randomised controlled trials with claims of efficacy [91–94], and the indications for the technique have multiplied almost exponentially [95]. The source of greatest debate has seemed only related to the mechanism of action. A cadaveric study [65] disputed the theory that there was adequate spread of local anaesthetic to the ventral rami and instead suggested local anaesthetic spread to the lateral cutaneous branches of the ventral rami through the lateral aspect of the tissue plane. The original authors then followed up with their own cadaveric study [66] showing spread to the ventral rami and hence providing a mechanism of action for their observed results. The tie breaker in this debate was a volunteer study [96] which demonstrated inconsistent spread of injectate to the ventral rami. Hence the enthusiasm to use ESP block has far outrun our understanding of the technique. Can this enthusiasm cause harm? Yes, by lack of effect or failure to use alternative techniques of known efficacy. Some hospitals now run programs using continuous ESP block for rib fractures – one wonders how they work when the ribs are innervated by the ventral rami, and the lateral cutaneous nerves neither pass through the erector spinae group of muscles nor innervate the ribs. Hence the exact role of ESP block remains uncertain.

Continuous rectus sheath block has re-emerged as an option for analgesia post-midline laparotomy. The modern version of placement is a surgical technique, where a plane of dissection is developed between the rectus abdominis muscle and the posterior rectus sheath with a catheter placed in the ensuing compartment for upper abdominal procedures [10], and a plane of dissection developed between the rectus abdominis and the anterior rectus sheath for lower abdominal procedures [97]. It took little time for ultrasound-guided versions of the same technique to emerge [38, 39], although for the majority of placements there is little logic in placing the catheters percutaneously after the wound has been surgically closed [98]. It is suggested that an approach with ultrasound might be indicated if there is intraabdominal sepsis or adhesions making surgical access to the tissue plane unwise or impossible. In this scenario, avoidance of lateral approaches to the rectus sheath is recommended due to the risk of perforation of the epigastric vasculature. There have now been two dye studies confirming the spread of local anaesthetic throughout the developed tissue planes for rectus sheath block [99, 100]. One study demonstrated that inferior to the arcuate line where the posterior rectus sheath is less distinct, a tissue plane containing the relevant abdominal wall nerves lies between rectus abdominis muscle and the transversalis fascia [99], while the other demonstrated the importance of volume to ensure spread of solution across the tissue plane [100]. It is important to note that both of these studies used boluses and this has management implications for continuous systems.

Pericapsular nerve group (PENG) block is a recently published tissue plane block. First described in 2018 [69] it has been accompanied by multiple clinical

reports and recently a randomised controlled study in the hip fracture population [101]. Whilst it appears remarkably effective for analgesia for hip fractures, the reasons for this are yet to be fully answered. It purports to block just the sensory branches to the hip joint from the femoral and obturator nerves [69]. Could there also be spread further posteriorly to include the superior gluteal nerves? A dye study [102] sheds some light on the characteristics of spread in this tissue plane deep to iliopsoas muscle. In this study, the needle was slightly more caudad to the site of PENG block but in the same plane and suggested that restriction of spread of injectate was only possible with small volumes. Larger volumes could spread to reach the femoral nerve, defeating the purpose of the technique. In this respect, is this tissue plane limited anteriorly by iliopsoas muscle fascia or by fascia iliaca, the latter being suggested by the spread characteristics of the larger volume in the study?

The IPACK block (infiltration between the popliteal artery and the capsule of the knee) for analgesia post-total knee joint replacement was introduced in 2019 as a cadaveric study [103] although there had been keen interest in this area in the years prior but without an accepted name for the technique [104–106]. A plane of dissection is developed deep to the popliteal artery with the intention to bathe the articular sensory branches of the knee joint in local anaesthetic as they traverse this area to reach the joint capsule. Since 2019 there have been over 10 randomised controlled trials [107–118] and 3 meta-analyses [119–121] reflecting widespread interest in techniques which might provide pain relief without hindrance to ambulation post-total knee joint replacement. There has also been widespread adoption of the IPACK block as reflected by reports of programmes in the literature [122, 123]. It is therefore somewhat concerning that the meta-analyses are not supportive of the technique, at least in its current format. Has enthusiasm outweighed clinical realities in this particular circumstance? Is this a technique that has yet to find its real indication? Or could the literature somehow not be accurately reflecting current effective clinical practice?

5. Tissue plane dynamics and some misunderstandings

In 2006 we published a paper in Anesthesiology which was provocatively entitled 'The Sheath of the Brachial Plexus: Fact or Fiction?' [7]. It may have been better entitled 'The Sheath of the Brachial Plexus: Actual Anatomy or Concept?', as negative reaction to the title may have distracted from what we believed to be the importance of the paper. This was a discussion about tissue planes and their significance to the practice of regional anaesthesia and to our knowledge the first time this had been directly addressed in the literature.

The notion of the brachial plexus 'sheath' has been attributed to various authors [124–126]. Two of these authors were in fact referencing the brachial fascia which is the deep investing fascia of the arm [125, 126], and one also referenced the intermuscular septum of the arm [126]. This is confusing as neither fascia is in intimate relationship with the neurovascular bundle.

Winnie [11] subsequently suggested that the 'sheath' was merely the final part of a tubular prolongation of the prevertebral fascia and promoted the concept of a continuous fascia-enclosed space extending from the cervical transverse processes to several centimetres into the arm. He likened brachial plexus anaesthesia to epidural anaesthesia where, once the space had been entered only a single injection was needed, an analogy intended to stop practitioners performing multiple injections which thereby increased the chances of neural injury. Various publications subsequently presented findings which significantly modified his concept [14, 16, 18, 20, 23, 28, 68].

The discussion section in our paper addressed tissue planes and their dynamics. The tough tissues of the prevertebral fascia give way rapidly to much thinner, softer and translucent connective tissues which encircle and entwine the brachial plexus and blood vessels [8]. As a collective, these thin and translucent connective tissues form the tissue planes of the brachial plexus. Indeed, in the current age of ultrasound-guidance the presence of these tissue planes is well accepted [9].

Within the tissue planes there may be minimal room for expansion at any one point and therefore flow has to occur along the tissue planes according to resistances encountered along the way [7]. The layers of connective tissue are not homogeneous, do not necessarily interconnect, and can hinder or prevent diffusion. Injection at one point does not guarantee spread elsewhere [8]. At the level of the trunks and divisions of the brachial plexus, the neural elements reorganise significantly and their associated tissue planes interconnect. This is readily observable during surgical dissection [8]. This arrangement allows for a more even spread of solution, a feature which has indeed been observed clinically [9, 127–130]. The belief that supraclavicular blocks are more effective because the neural elements are closer together [131] is better explained by the interconnection of tissue planes at this level. By contrast, at axillary level where the nerves do not interconnect and the tissue planes containing each nerve are largely separate [14, 16, 18], efficacy is lower unless each nerve was blocked separately. Side effect profiles can also be explained by spread of injectate via tissue planes, e.g., phrenic paresis with subomohyoid suprascapular nerve block [132].

The sheath concept also does not take into account the impact that surrounding rigid anatomy has on flow dynamics. Our work on the 'axillary tunnel' [133] calculated the dimensions of the tunnel and explained the significant impact of the varying dimensions. The injected dye did not spread as in a cylindrical tube but followed the contours of the rigid anatomy. The volume of the axillary tunnel at any one point was less than 10 ml, and so flow inevitably occurred along the tunnel. The tunnel had two constrictions and flow of injectate from the needle tip could be anterograde, bidirectional or retrograde depending on where the point of injection occurred in respect of these constrictions. The more lateral constriction was clearly the obstruction to flow at this lower level [133] rather than the head of the humerus as previously described [134]. Historic dye studies of the brachial plexus [11, 134] fitted with our predictions of flow patterns based on the contours of the rigid anatomy.

The CT dye studies from the axillary tunnel work also revealed the reason we were able to avoid the phrenic nerve during anaesthesia and analgesia for shoulder surgery [135]. We were manipulating the tissue planes of the brachial plexus by injecting into the tissue planes posterior to the artery, with retrograde spread restricted to these same tissue planes, well away from the anteriorly situated phrenic nerve. This phenomenon has subsequently been demonstrated by another group [136].

Given that brachial plexus regional anaesthesia had been based for many years on the concept of the sheath, it was unsurprising that a cadaveric study was subsequently published demonstrating apparent macroscopic evidence of the brachial plexus sheath [137]. We had significant issues with this evidence, including: 1. a significant connective tissue structure was demonstrated covering the emerging nerve roots in the root of the neck, but this was the prevertebral fascia. There were difficulties with calling this the brachial plexus sheath, partly because it already had an anatomic name. 2. the brachial plexus, as revealed prior to disappearing from view under the clavicle, was covered by a thin layer of opaque connective tissue. It was agreed by both sets of authors that this was what had been identified as the enveloping tubular structure called the sheath. This opaque connective tissue enveloping

the plexus in the cadaver was remarkable for its difference to the equivalent tissue in a patient undergoing surgical dissection of the plexus [8], and we believe that this most likely reflected post-mortem changes in connective tissues [5, 6]. Interestingly, not all investigators using cadaveric specimens have encountered an opaque layer of connective tissue surrounding similar major nerves or plexuses. Indeed, they have echoed our words of 'thin, transparent and fragile' when describing such connective tissues [138].

We concluded that tissue planes, in conjunction with the influence of surrounding rigid anatomy, provided a better explanation for outcomes in brachial plexus regional anaesthesia than the concept of a sheath.

6. Dye studies on tissue plane dynamics

The regional anaesthesia literature already has a reasonably large number of dye studies [11–34, 44–51, 54–68, 70–83] and they encompass most of the techniques in current common usage. One could be forgiven for believing that we now have most of the answers, but this is an area where for various reasons there is still room for improvement. Our work on the axillary tunnel raised some generic questions to be answered in other areas – under what conditions do flow characteristics change, can flow characteristics be manipulated to clinical advantage and what anatomic features can be disadvantageous in terms of flow characteristics? These questions infer that the tissue plane is a dynamic environment and that this can be used to clinical advantage.

It has been unusual in this type of research work to use any model other than cadavers but for various reasons these cannot provide an accurate replication for clinical application. Connective tissue changes in quality and appearance very soon after death [5, 6]. As pointed out by Ivanusic et al. [65] it is also not possible to investigate for any block-related phenomenae that may be linked to physiological occurrences such as breathing in a dead body. Specific block-related positioning is not possible in cadaveric specimens. At best, with carefully planned and executed dissection, cadaveric models provide a sort of basic static road map of where fluid may spread and what nerve/s might be blocked.

In the above context a dye and latex study by Mayes et al. [139] investigated serratus anterior plane block (SAP) as a potential analgesic technique for rib fractures. It demonstrated a clear plane of dissection between serratus anterior and the external intercostal muscle/ribs, bathing the lateral cutaneous branches of the intercostal nerves in solution as per the description in the original publication [42]. This means that the technique will not provide analgesia for rib fractures, a conclusion framed by the authors in subtle language [139], because the intercostal nerves which innervate the ribs will not be blocked. Does trauma to the chest wall provide a pathway to these nerves? This is unlikely and not a dependable mechanism in this author's opinion. Can solution track along the lateral cutaneous branches to the intercostal nerves of origin? This again is unlikely as it requires the passage of these nerves through the muscle layers of the chest wall to be the path of least resistance as the injected fluid flows through the tissue plane. It is up to those who wish to prove any of these mechanisms to create the models and test their hypotheses.

Another technical issue at play in dye studies relates to where the tip of the catheter is located when injections are made. In a study on continuous parasacral sciatic nerve block [31], the investigators used 8 ml of dye for confirmation of location of their perineural catheters. In our work on the axillary tunnel [133], we realised that we could only locate the tip of the catheter by using a much smaller volume of injectate of 2 ml, a larger volume obscuring the location.

Adductor canal block [54] has gained popularity as an analgesic technique post-total knee joint replacement due to less motor block than femoral nerve block [140] albeit with some accompanying loss of pain relief [140, 141]. There have been several dye studies examining this technique [142–145], with ensuing cautions about volume used, where the injection is placed to limit spread of injectate beyond the adductor canal, and consideration of the impact of tourniquets on the spread of solution. However, there has been no work directly measuring the potential volume of the canal, nor how this might change with application of a tourniquet, nor what flow restrictions if any are present, all of which would require 3-dimensional imaging. This is a more costly investigative modality but provides much more information.

The cadaveric dye studies of ESP block [64, 65] and the subsequent volunteer study of ESP block [96] have been discussed earlier in this chapter. Perhaps this illustrates the peril of having cadaveric studies as stand-alone evidence of efficacy. The volunteer study certainly seems to be one potential bridging option to clinical practice but may not always be possible due to safety considerations. Some authors do combine their cadaveric studies with a clinical case series as additional evidence, but is this practice consistent with the current ethical standards in human research? Multiple pathways are probably likely required to establish efficacy and safety across the range of techniques and indications prior to widespread adoption in clinical practice. In this respect, randomised controlled trials are only as good as the science which underpins them.

7. High-definition ultrasound studies and the tissue plane

There have now been several studies examining nerves of the upper and lower extremities and the soft tissues which surround and envelope these nerves [146–149]. These have given rise to the term 'paraneural sheath' of the sciatic nerve [146] and brachial plexus [149] respectively. In one recent study, the sonographic imaging was correlated with histologic specimens [149] to demonstrate what the authors described as 'fascial tissue planes' within the paraneural sheath.

It is to be noted on the images of the brachial plexus [149] that the pectoral fascia is much more visible, i.e., it exhibits greater anisotropy, than the tissues within the plexus complex. This is not artefactual – fasciae such as the pectoral or prevertebral are much sturdier connective tissue structures than the relatively fragile connective tissues surrounding the brachial plexus. The imaging also demonstrates both the tissue planes of the plexus and the phenomenon of injected fluid separating the tissue planes as it flows through the length of the plexus complex. The 'paraneural sheath' has the same anisotropy as the tissue planes within the neurovascular bundle, i.e., the same type of tissue, which is quite distinct from fascial tissue. This study demonstrates very well some characteristics of the dynamics of the tissue planes of the brachial plexus.

8. Tissue plane blocks versus compartment blocks

In some literature it has been suggested that the local anaesthetic fills a compartment to achieve its effect, particularly where the injection is made within the fascia enclosing muscles such as rectus abdominis or perhaps even the erector spinae plane block [150]. The actual phenomenon can be viewed on ultrasound in real time as the injected solution can be seen to develop a plane of dissection between the muscles and the fascia or bone. Once again, the concept of the tissue plane becomes the focus of our attention.

9. Systematic reviews

There have been a number of systematic reviews over the last few years which have not specifically mentioned tissue planes in the context of regional anaesthesia but which clearly relate to that concept [151–164]. These have all been procedure specific and, despite apparent clinical enthusiasm for the different techniques, are quite often neutral or negative in their recommendations. This may reflect the difficulties in the development phase of various techniques to which the author has alluded earlier in this chapter.

10. Research opportunities

There is a wealth of opportunity for further research in this area. Regional anaesthesia in some respects is in its infancy in understanding and manipulating tissue planes. Ultrasound allows novel tissue plane targets to emerge and the challenge is to fit these new techniques into practice in a scientifically sound fashion. Now more than ever we are required to learn anatomy from a different perspective; what nerve/s innervate this area/region? how do they get there? where can I access them? does this raise safety issues, and how are these overcome? how will the tissues spread the fluid I inject? are there potential complications from this? how do I answer these questions in a scientifically meaningful fashion? do I need to create a new technique when one already exists for my purposes?

I would venture to suggest that after the initial idea comes thoughtful reading, basic science preparation and careful analysis. This is all before consideration is given to conducting randomised controlled trials.

11. Conclusion

Although it has been suggested by many to be the era of ultrasound in regional anaesthesia, it could equally be termed the era of the tissue plane. This of course is courtesy of ultrasound, but the technology alone will not get us the results we want. It has been suggested that 'if we can see it, we can block it' [84], but this invites invocation of the old adage 'primum non nocere'. Was the block necessary? Did it add real benefit? All interventions risk harm. Perhaps we could change the saying to 'now that we can see it, how do we better understand what we are seeing, and how can this aid our practice?' The challenge is to methodically and responsibly work our craft so that it helps us as well as our patients.

Conflict of interest

The author declares no conflict of interest.

Notes/thanks/other declarations

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References

[1] Harrop-Griffiths AW, Denny NM. Eponymity and the age of ultrasound: how should new blocks be introduced into clinical practice. Reg Anesth Pain Med 2006;31:492-5

[2] Whalan C. Tissue planes: traction and counter-traction. In: Whalan C, ed. Assisting at surgical operations. A practical guide. Cambridge University Press; 2006. p 51-53

[3] Carlson GW. Surgical anatomy of the neck. Surg Clin North Am 1993;73: 837-52

[4] Jamieson GG, Game PA. Abdominal incisions: the anatomy of abdominal muscles and fascia. In: Jamieson GG, ed. The Anatomy of General Surgical Operations. Churchill Livingstone; 1992. p 3-8

[5] Achla BY, Punnya VA, Alka DK, Sumit KY. Histological assessment of cellular changes in postmortem gingival specimens for estimation of time since death. J Forensic Odontostomatol 2015;33:19-26

[6] Mazzotti MC, Fais P, Palazzo C, Fersini F, Ruggeri A, Falconi M, Pelotti S, Teti G. Determining the time of death by morphological and immunohistochemical evaluation of collagen fibers in postmortem gingival tissues. Leg Med (Tokyo) 2019;39:1-8

[7] Cornish PB, Leaper C. The sheath of the brachial plexus: fact or fiction? Anesthesiology 2006;105:563-5

[8] Cornish PB, Greenfield LJ. Brachial plexus anatomy. Reg Anesth 1997;22:106-7

[9] Siddiqui U, Perlas A, Chin K, Reina MA, Sala-Blanch X, Niazi A, Chan V. Intertruncal approach to the supraclavicular brachial plexus, current controversies and technical update:

a daring discourse. Reg Anesth Pain Med 2020;45:377-380

[10] Cornish P, Deacon A. Rectus sheath catheters for continuous analgesia after upper abdominal surgery. ANZ J Surg 2007;77:84

[11] Winnie AP, Collins VJ. The subclavian perivascular technique of brachial plexus anesthesia. Anesthesiology 1964;25:353-363

[12] Winnie AP, Radonjic R, Akkineni SR, Durrani Z. Factors influencing distribution of local anesthetic injected into the brachial plexus sheath. Anesth Analg 1979;58:225-34

[13] Moore DC, Bush WH, Burnett LL. Celiac plexus block: a roentgenographic, anatomic study of technique and spread of solution in patients and corpses. Anesth Analg 1981;60(6):369-79

[14] Thompson GE, Rorie DK: Functional anatomy of the brachial plexus sheaths. Anesthesiology 1983;59:117-22

[15] Murphy DF. Continuous intercostal nerve blockade. An anatomical study to elucidate its mode of action. Br J Anaesth. 1984;56:627-30

[16] Vester-Andersen T, Broby-Johansen U, Bro-Rasmussen F: Perivascular axillary block VI: The distribution of gelatine solution injected into the axillary neurovascular sheath of cadavers. Acta Anaesthesiol Scand 1986;30:18-22

[17] Crossley AW, Hosie HE. Radiographic study of intercostal nerve blockade in healthy volunteers. Br J Anaesth 1987;59:149-54

[18] Partridge BL, Katz J, Benirschke K: Functional anatomy of the brachial

plexus sheath: Implications for anesthesia. Anesthesiology 1987;66:743-7

[19] Bösenberg AT, Bland BA, Schulte-Steinberg O, Downing JW. Thoracic epidural anesthesia via caudal route in infants. Anesthesiology. 1988;69:265-9

[20] Pashchuk AIu, Shtutin AA: Topographical and anatomic substantiation of sheath block of the brachial plexus. Ortop Travmatol Protez 1990;5:13-7

[21] Hord AH, Wang JM, Pai UT, Raj PP. Anatomic spread of india ink in the human intercostal space with radiographic correlation. Reg Anesth 1991;16:13-6

[22] Hanna MH, Peat SJ, D'Costa F. Lumbar plexus block: an anatomical study. Anaesthesia. 1993;48:675-8

[23] Pippa P, Rucci FS. Preferential channelling of anaesthetic solution injected within the perivascular axillary sheath. Eur J Anaesthesiol 1994;11:391-6

[24] Vloka JD, Hadzić A, Kitain E, Lesser JB, Kuroda M, April EW, Thys DM. Anatomic considerations for sciatic nerve block in the popliteal fossa through the lateral approach. Reg Anesth. 1996;21:414-8

[25] Saito T, Den S, Tanuma K, Tanuma Y, Carney E, Carlsson C. Anatomical bases for paravertebral anesthetic block; fluid communication between the thoracic and lumbar paravertebral regions. Surg Radiol Anat 1999;21:359-63

[26] Pfirrmann CW, Oberholzer PA, Zanetti M, Boos N, Trudell DJ, Resnick D, Hodler J. Selective nerve root blocks for the treatment of sciatica: evaluation of injection site and effectiveness – a study with patients and cadavers. Radiology 2001;221:704-11

[27] Saito T, Tanuma K, Den S, Tanuma Y, Miyakawa K, Carney E, Carlsson C. Pathways of anesthetic from the thoracic paravertebral region to the celiac ganglion. Clin Anat 2002;15:340-4

[28] Klaastad O, Smedby O, Thompson GE, Tillung T, Hol PK, Rotnes JS, Brodal P, Breivik H, Hetland KR, Fosse ET. Distribution of local anesthetic in axillary brachial plexus block: A clinical and magnetic resonance imaging study. Anesthesiology 2002;96:1315-24

[29] Vas L, Kulkarni V, Mali M, Bagry H. Spread of radioopaque dye in the epidural space in infants. Paediatr Anaesth. 2003;13:233-43

[30] Pandit JJ, Dutta D, Morris JF. Spread of injectate with superficial cervical plexus block in humans: an anatomical study. Br J Anaesth. 2003;91:733-5

[31] Gaertner E, Lascurain P, Venet C, Maschino X, Zamfir A, Lupescu R, Hadzic A. Continuous parasacral sciatic block: a radiographic study. Anesth Analg 2004;98:831-4

[32] Naja MZ, Ziade MF, El Rajab M, El Tayara K, Lönnqvist PA. Varying anatomical injection points within the thoracic paravertebral space: effect on spread of solution and nerve blockade. Anaesthesia 2004;59:459-63

[33] Koo BN, Hong JY, Kil HK. Spread of ropivacaine by a weight-based formula in a pediatric caudal block: a fluoroscopic examination. Acta Anaesthesiol Scand 2010;54:562-5

[34] Luyet C, Siegenthaler A, Szucs-Farkas Z, Hummel G, Eichenberger U, Vogt A. The location of paravertebral catheters placed using the landmark technique. Anaesthesia 2012;67:1321-6

[35] McDonnell JG, Laffey JG. Transversus abdominis plane block. Anesth Analg 2007;105:883

[36] Hebbard P, Fujiwara Y, Shibata Y, Royse C. Ultrasound-guided transversus abdominis plane (TAP) block. Anaesth Intensive Care. 2007;35:616-7

[37] R. Blanco. TAP block under ultrasound guidance: the description of a 'non pops technique'. Reg Anesth Pain Med 2007;32:130

[38] Sandeman DJ, Dilley AV. Ultrasound-guided rectus sheath block and catheter placement. ANZ J Surg 2008;78:621-3

[39] Webster K, Hubble S. Rectus sheath analgesia in intensive care patients: technique description and case series. Anaesth Int Care 2009;37:855

[40] P. D. Hebbard. Transversalis fascia plane block, a novel ultrasound-guided abdominal wall nerve block. Canadian J Anesth 2009;56:618-620

[41] Blanco R. The 'pecs block': a novel technique for providing analgesia after breast surgery. Anaesthesia. 2011;66:847-8

[42] Blanco R, Parras T, McDonnell JG, Prats-Galino A. Serratus plane block: a novel ultrasound-guided thoracic wall nerve block. Anaesthesia 2013;68:1107-13

[43] Børglum J, Jensen K, Moriggl B et al. Ultrasound-guided transmuscular quadratus lumborum blockade. BJA—Out of the blue E-letters, 2013

[44] Eichenberger U, Greher M, Kirchmair L, Curatolo M, Moriggl B. Ultrasound-guided blocks of the ilioinguinal and iliohypogastric nerve: accuracy of a selective new technique confirmed by anatomical dissection. Br J Anaesth 2006;97:238-43

[45] Tran TM, Ivanusic JJ, Hebbard P, Barrington MJ. Determination of spread of injectate after ultrasound-guided transversus abdominis plane block:

a cadaveric study. Br J Anaesth 2009;102:123-7

[46] Luyet C, Eichenberger U, Greif R, Vogt A, Szücs Farkas Z, Moriggl B. Ultrasound-guided paravertebral puncture and placement of catheters in human cadavers: an imaging study. Br J Anaesth 2009;102:534-9

[47] Barrington MJ, Ivanusic JJ, Rozen WM, Hebbard P. Spread of injectate after ultrasound-guided subcostal transversus abdominis plane block: a cadaveric study. Anaesthesia 2009;64:745-50

[48] Gofeld M, Bhatia A, Abbas S, Ganapathy S, Johnson M. Development and validation of a new technique for ultrasound-guided stellate ganglion block. Reg Anesth Pain Med 2009;34: 475-9

[49] Paraskeuopoulos T, Saranteas T, Kouladouros K, Krepi H, Nakou M, Kostopanagiotou G, Anagnostopoulou S. Thoracic paravertebral spread using two different ultrasound-guided intercostal injection techniques in human cadavers. Clin Anat 2010;23:840-7

[50] Hebbard P, Ivanusic J, Sha S. Ultrasound-guided supra-inguinal fascia iliaca block: a cadaveric evaluation of a novel approach. Anaesthesia 2011;66:300-5

[51] Milan Z, Tabor D, McConnell P, Pickering J, Kocarev M, du Feu F, Barton S. Three different approaches to transversus abdominis plane block: a cadaveric study. Med Glas (Zenica) 2011;8:181-4

[52] De la Torre PA, Garcia PD, Alvarez SL, Miguel FJ, Perez MF. A novel ultrasound-guided block: a promising alternative for breast analgesia. Aesthet Surg J 2014;34:198-200

[53] Lopez-Matamala B, Fajardo M, Estebanez-Montiel B, Blancas R,

Alfaro P, Chana M. A new thoracic interfascial plane block as anesthesia for difficult weaning due to ribcage pain in critically ill patients. Med Intensiva 2014;38:463-465

[54] Albokrinov AA, Fesenko UA. Spread of dye after single thoracolumbar paravertebral injection in infants. A cadaveric study. Eur J Anaesthesiol. 2014;31:305-9

[55] Andersen HL, Andersen SL, Tranum-Jensen J. The spread of injectate during saphenous nerve block at the adductor canal: a cadaver study. Acta Anaesthesiol Scand 2015;59:238-45

[56] Desmet M, Helsloot D, Vereecke E, Missant C, van de Velde M. Pneumoperitoneum does not influence spread of local anesthetics in midaxillary approach transversus abdominis plane block: a descriptive cadaver study. Reg Anesth Pain Med 2015;40:349-54

[57] Hong J, Jung SW. Fluoroscopically guided thoracic interlaminar epidural injection: a comparative epidurography study using 2.5 mL and 5 mL of contrast dye. Pain Physician 2016;19:E1013-8

[58] Mayes J, Davison E, Panahi P, Patten D, Eljelani F, Womack J, Varma M. An anatomical evaluation of the serratus anterior plane block. Anaesthesia. 2016;71:1064-9

[59] Carline L, McLeod GA, Lamb C. A cadaver study comparing spread of dye and nerve involvement after three different quadratus lumborum blocks. Br J Anaesth 2016;117:387-94

[60] Forero M, Adhikary SD, Lopez H, Tsui C, Chin KJ. The erector spinae plane block: a novel analgesic technique in thoracic neuropathic pain. Reg Anesth Pain Med 2016;41:621-7

[61] Piracha MM, Thorp SL, Puttanniah V, Gulati A."A tale of two planes": deep versus superficial serratus plane block for postmastectomy pain syndrome. Reg Anesth Pain Med 2017;42:259-262

[62] Dam M, Moriggl B, Hansen CK, Hoermann R, Bendtsen TF, Børglum J. The pathway of injectate spread with the transmuscular quadratus lumborum block: a cadaver study. Anesth Analg 2017;125:303-312

[63] Elsharkawy H, El-Boghdadly K, Kolli S, Esa WAS, DeGrande S, Soliman LM, Drake RL. Injectate spread following anterior sub-costal and posterior approaches to the quadratus lumborum block: a comparative cadaveric study. Eur J Anaesthesiol 2017;34:587-595

[64] Yang HM, Park SJ, Yoon KB, Park K, Kim SH. Cadaveric evaluation of different approaches for quadratus lumborum blocks. Pain Res Manag 2018;2368930. doi:10.1155/2018/2368930

[65] Ivanusic J, Konishi Y, Barrington MJ. A Cadaveric study investigating the mechanism of action of erector spinae blockade. Reg Anesth Pain Med 2018;43:567-571

[66] Adhikary SD, Bernard S, Lopez H, Chin KJ. Erector spinae plane block versus retrolaminar block: a magnetic resonance imaging and anatomical study. Reg Anesth Pain Med 2018;43:756-762

[67] Yang HM, Choi YJ, Kwon HJ, O J,Cho TH,Kim SH. Comparison of injectate spread and nerve involvement between retrolaminar and erector spinae plane blocks in the thoracic region: a cadaveric study. Anaesthesia 2018;73:1244-1250

[68] Brenner D, Mahon P, Iohom G, Cronin M, O'Flynn C, Shorten G. Fascial layers influence the spread of injectate during ultrasound-guided

infraclavicular brachial plexus block: a cadaver study. Br J Anaesth 2018;121:876-882

[69] Girón-Arango L, Peng PWH, Chin KJ, Brull R, Perlas A. Pericapsular nerve group (PENG) block for hip fracture. Reg Anesth Pain Med 2018;43:859-863

[70] Sabouri AS, Crawford L, Bick SK, Nozari A, Anderson TA. Is a retrolaminar approach to the thoracic paravertebral space possible?: a human cadaveric study. Reg Anesth Pain Med 2018;43:864-868

[71] Vermeylen K, Soetens F, Leunen I, Hadzic A, Van Boxtael S, Pomés J, Prats-Galino A, Van de Velde M, Neyrinck A, Sala-Blanch X. The effect of the volume of supra-inguinal injected solution on the spread of the injectate under the fascia iliaca: a preliminary study. Anesth 2018;32:908-913

[72] Elsharkawy H, Ahuja S, De Grande S, Maheshwari K, Chan V. Subcostal approach to anterior quadratus lumborum block for pain control following open urological procedures. J Anesth 2019;33:148-154

[73] Tran J, Giron Arango L, Peng P, Sinha SK, Agur A, Chan V. Evaluation of the iPACK block injectate spread: a cadaveric study. Reg Anesth Pain Med 2019:rapm-2018-100355. doi: 10.1136/rapm-2018-100355

[74] Aponte A, Sala-Blanch X, Prats-Galino A, Masdeu J, Moreno LA, Sermeus LA. Anatomical evaluation of the extent of spread in the erector spinae plane block: a cadaveric study. Can J Anaesth. 2019;66:886-893

[75] Elsharkawy H, El-Boghdadly K, Barnes TJ, Drake R, Maheshwari K, Soliman LM, Horn JL, Chin KJ. The supra-iliac anterior quadratus lumborum block: a cadaveric study and case series. Can J Anaesth 2019;66:894-906

[76] Dautzenberg KHW, Zegers MJ, Bleeker CP, Tan ECTH, Vissers KCP, van Geffen GJ, van der Wal SEI. Unpredictable injectate spread of the erector spinae plane block in human cadavers. Anesth Analg 2019;129:e163-e166

[77] Kampitak W, Tansatit T, Tanavalee A, Ngarmukos S. Optimal location of local anesthetic injection in the interspace between the popliteal artery and posterior capsule of the knee (iPACK) for posterior knee pain after total knee arthroplasty: an anatomical and clinical study. Korean J Anesthesiol 2019;72:486-494

[78] Ruscio L, Renard R, Lebacle C, Zetlaoui P, Benhamou D, Bessede T. Thoracic paravertebral block: comparison of different approaches and techniques. A study on 27 human cadavers. Anaesth Crit Care Pain Med 2020;39:53-58

[79] Shibata Y, Kampitak W, Tansatit T. The novel costotransverse foramen block technique: distribution characteristics of injectate compared with erector spinae plane block. Pain Physician 2020;23:E305-E314

[80] Harbell MW, Seamans DP, Koyyalamudi V, Kraus MB, Craner RC, Langley NR. Evaluating the extent of lumbar erector spinae plane block: an anatomical study. Reg Anesth Pain Med 2020;45:640-644

[81] Robinson H, Mishra S, Davies L, Craigen F, Vilcina V, Parson S, Shahana S. Anatomical evaluation of a conventional pectoralis II versus a subserratus plane block for breast surgery. Anesth Analg 2020;131:928-934

[82] Termpornlert S, Sakura S, Aoyama Y, Wittayapairoj A, Kishimoto K, Saito Y. Distribution of injectate administered through a catheter inserted by three different approaches to ultrasound-guided

thoracic paravertebral block: a prospective observational study. Reg Anesth Pain Med 2020;45:866-871

[83] Bonvicini D, Boscolo-Berto R, De Cassai A, Negrello M, Macchi V, Tiberio I, Boscolo A, De Caro R, Porzionato A. Anatomical basis of erector spinae plane block: a dissection and histotopographic pilot study. J Anesth 2021;35:102-111

[84] Elsharkawy H, Pawa A, Mariano ER. Interfascial plane blocks. Reg Anesth Pain Med 2018;43:341-346

[85] Nielsen TD, Moriggl B, Barckman J, Jensen JM, Kolsen-Petersen JA, Søballe K, Børglum J, Bendtsen TF. Randomized trial of ultrasound-guided superior cluneal nerve block. Reg Anesth Pain Med 2019:rapm-2018-100174. doi: 10.1136/rapm-2018-100174

[86] Cornish P. Ultrasound-guided superior cluneal nerves block: raising the bar. Reg Anesth Pain Med. 2019:rapm-2019-100619. doi: 10.1136/rapm-2019-100619

[87] Ahiskalioglu A, Alici HA, Ari MA. Ultrasound guided low thoracic erector spinae plane block for management of acute herpes zoster. J Clin Anesth 2018;45:60-1

[88] Ueshima H, Otake H. Cinical experiences of erector spinae plane block for children. J Clin Anesth 2018;44:41

[89] De la Cuadra-Fontaine JC, Concha M, Vuletin F, Aran-cibia H. Continuous erector spinae plane block for thoracic surgery in a pediatric patient. Paediatr Anaesth 2018;28:74-5

[90] Forero M, Rajarathinam M, Adhikary SD, Chin KJ. Erector spinae plane block for the management of chronic shoulder pain: a case report. Can J Anaesth 2018;65:288-93

[91] Krishna SN, Chauhan S, Bhoi D, Kaushal B, Hasija S, Sangdup T, et al. Bilateral erector spinae plane block for acute post-surgical pain in adult cardiac surgical patients: a randomized controlled trial. J Cardiothorac Vasc Anesth 2019;33:368-75

[92] GürkanY,Aksu C,Kuş A, Yörükoğlu UH, Kılıç CT. Ultrasound guided erector spinae plane block reduces postoperative opioid consumption following breast surgery: a randomized controlled study. J Clin Anesth 2018;50:65-8

[93] Tulgar S, Kapakli MS, Senturk O, Selvi O, Serifsoy TE, Ozer Z. Evaluation of ultrasound-guided erector spinae plane block for postoperative analgesia in laparoscopic cholecystectomy: a prospective, randomized, controlled clinical trial. J Clin Anesth 2018;49: 101-6

[94] Nagaraja PS, Ragavendran S, Singh NG, Asai O, Bhavya G, Manjunath N, et al. Comparison of continuous thoracic epidural analgesia with bilateral erector spinae plane block for perioperative pain management in cardiac surgery. Ann Card Anaesth 2018;21:323-7

[95] De Cassai A, Bonvicini D, Correale C, Sandei L, Tulgar S, Tonetti T. Erector spinae plane block: a systematic qualitative review. Minerva Anestesiologica 2019;85:308-19

[96] Byrne K, Smith C. Human volunteer study examining the sensory changes of the thorax after an erector spinae plane block. Reg Anesth Pain Med 2020;45: 761-762

[97] Cornish PB, Pullar P, Rhondeau S, Southwick A, Malcolm A, Meffan P. A pilot study of rectus sheath catheters for radical retropubic prostatectomy. Anaesth Int Care 2006;34:5319[A]

[98] Cornish P, Deacon A. Rectus sheath analgesic catheters – some issue of

placement and anatomy. Pain Med 2011;12:1836

[99] Chedgy ECP, Lowe G, TangR, Krebs C, Sawka A, Vaghadia H, Gleave ME, So AI. Surgical placement of rectus sheath catheters in a cadaveric cystectomy model. Ann R Coll Surg Engl 2018;100:120-124

[100] St James M, Ferreira TH, Schroeder CA, Hershberger-Braker KL, Schroeder KM. Ultrasound-guided rectus sheath block: an anatomic study in dog cadavers. Vet Anaesth Analg 2020;47:95-102

[101] Lin DY, Morrison C, Brown B, Saies AA, Pawar R, Vermeulen M, Anderson SR, Lee TS, Doornberg J, Kroon HM, Jaarsma RL. Pericapsular nerve group (PENG) block provides improved short-term analgesia compared with the femoral nerve block in hip fracture surgery: a single-center double-blinded randomized comparative trial. Reg Anesth Pain Med 2021;46:398-403

[102] Nielsen ND, Greher M, Moriggl B, Hoermann R, Nielsen TD, Børglum J, Bendtsen TF. Spread of injectate around hip articular sensory branches of the femoral nerve in cadavers. Acta Anaesthesiol Scand 2018;62:1001-1006

[103] Niesen AD, Harris DJ, Johnson CS, Stoike DE, Smith HM, Jacob AK, et al. Interspace between popliteal artery and posterior capsule of the knee (IPACK) injectate spread: a cadaver study. J Ultrasound Med 2019;38:741-745

[104] Kardash KJ, Noel GP. The SPANK block: a selective sensory, single-injection solution for posterior pain after total knee arthroplasty. Reg Anesth Pain Med 2016; 41:118-119

[105] Thobhani S, Scalercio L, Elliott CE, Nossaman BD, Thomas LC, Yuratich D, et al. Novel regional techniques for total knee arthroplasty promote reduced

hospital length of stay: an analysis of 106 patients. Ochsner J 2017;17:233-238

[106] Runge C, Bjørn S, Jensen JM, Nielsen ND, Vase M, Holm C, et al. The analgesic effect of a popliteal plexus blockade after total knee arthroplasty: a feasibility study. Acta Anaesthesiol Scand 2018;62:1127-1132

[107] Sankineani SR, Reddy ARC, Eachempati KK, Jangale A, Gurava Reddy AV. Comparison of adductor canal block and IPACK block (interspace between the popliteal artery and the capsule of the posterior knee) with adductor canal block alone after total knee arthroplasty: a prospective control trial on pain and knee function in immediate postoperative period. Eur J Orthop Surg Traumatol 2018;28: 1391-1395

[108] Kim DH, Beathe JC, Lin Y, YaDeau JT, Maalouf DB, Goytizolo E, Garnett C, Ranawat AS, Su EP, Mayman DJ, Memtsoudis SG. Addition of infiltration between the popliteal artery and the capsule of the posterior knee and adductor canal block to periarticular injection enhances postoperative pain control in total knee arthroplasty: a randomized controlled trial. Anesth Analg 2019;129:526-535

[109] Eccles CJ, Swiergosz AM, Smith AF, Bhimani SJ, Smith LS, Malkani AL. Decreased opioid consumption and length of stay using an IPACK and adductor canal nerve block following total knee arthroplasty. J Knee Surg 2019. doi:10.1055/s-0039-1700840

[110] Kampitak W, Tanavalee A, Ngarmukos S, Tantavisut S. Motor-sparing effect of iPACK (interspace between the popliteal artery and capsule of the posterior knee) block versus tibial nerve block after total knee arthroplasty: a randomized controlled trial. Reg Anesth Pain Med 2020;45: 267-276

[111] Patterson ME, Vitter J, Bland K, Nossaman BD, Thomas LC, Chimento GF. The effect of the IPACK block on pain after primary TKA: a double-blinded, prospective, randomized trial. J Arthroplasty. 2020;35:S173-S177

[112] Fan R, Xu G, Wang B, Hong H, Guo X. Comparison of analgesic effect of adductor block combined with iPACK and periarticular injection after total knee arthroplasty. Minerva Med 2020. doi:10.23736/S0026-4806.20.06848-2

[113] Tak R, Gurava Reddy AV, Jhakotia K, Karumuri K, Sankineani SR. Continuous adductor canal block is superior to adductor canal block alone or adductor canal block combined with IPACK block (interspace between the popliteal artery and the posterior capsule of knee) in postoperative analgesia and ambulation following total knee arthroplasty: randomized control trial. Musculoskelet Surg 2020. doi:10.1007/s12306-020-00682-8

[114] Ochroch J, Qi V, Badiola I, Grosh T, Cai L, Graff V, Nelson C, Israelite C, Elkassabany NM. Analgesic efficacy of adding the IPACK block to a multimodal analgesia protocol for primary total knee arthroplasty. Reg Anesth Pain Med 2020;45:799-804

[115] Vichainarong C, Kampitak W, Tanavalee A, Ngarmukos S, Songborassamee N. Analgesic efficacy of infiltration between the popliteal artery and capsule of the knee (iPACK) block added to local infiltration analgesia and continuous adductor canal block after total knee arthroplasty: a randomized clinical trial. Reg Anesth Pain Med 2020;45:872-879

[116] Li D, Alqwbani M, Wang Q, Liao R, Yang J, Kang P. Efficacy of adductor canal block combined with additional analgesic methods for postoperative analgesia in total knee arthroplasty: a prospective, double-blind, randomized controlled study. J Arthroplasty 2020;35:3554-3562

[117] Kertkiatkachorn W, Kampitak W, Tanavalee A, Ngarmukos S. Adductor canal block combined with iPACK (interspace between the popliteal artery and the capsule of the posterior knee) block vs periarticular injection for analgesia after total knee arthroplasty: a randomized noninferiority trial. J Arthroplasty 2021;36:122-129

[118] Akesen S, Akesen B, Atıcı T, Gurbet A, Ermutlu C, Özyalçın A. Comparison of efficacy between the genicular nerve block and the popliteal artery and the capsule of the posterior knee (IPACK) block for total knee replacement surgery: a prospective randomized controlled study. Acta Orthop Traumatol Turc. 2021;55: 134-140

[119] Albrecht E, Wegrzyn J, Dabetic A, El-Boghdadly K. The analgesic efficacy of iPACK after knee surgery: a systematic review and meta-analysis with trial sequential analysis. J Clin Anesth 2021;72:110305. doi:10.1016/j.jclinane.2021.110305

[120] Hussain N, Brull R, Sheehy B, Dasu M, Weaver T, Abdallah FW. Does the addition of iPACK to adductor canal block in the presence or absence of periarticular local anesthetic infiltration improve analgesic and functional outcomes following total knee arthroplasty? A systematic review and meta-analysis. Reg Anesth Pain Med 2021:rapm-2021-102705. doi:10.1136/rapm-2021-102705

[121] D'Souza RS, Langford BJ, Olsen DA, Johnson RL. Ultrasound-guided local anesthetic infiltration between the popliteal artery and the capsule of the posterior knee (IPACK) block for primary total knee arthroplasty: a systematic review of randomized controlled trials. Local Reg Anesth 2021;14:85-98

[122] Kandarian B, Indelli PF, Sinha S, Hunter OO, Wang RR, Kim TE, Kou A, Mariano ER Implementation of the IPACK (infiltration between the popliteal artery and capsule of the knee) block into a multimodal analgesic pathway for total knee replacement. Korean J Anesthesiol 2019;72: 238-244

[123] Biehl M, Wild L, Waldman K, Haq F, Easteal RA, Sawhney M. The safety and efficacy of the IPACK block in primary total knee arthroplasty: a retrospective chart review. Can J Anaesth 2020;67:1271-1273

[124] Reding M. Nouvelle methode d'anesthesie du membre superieur. Presse Medicale 1921;29:294-296

[125] Eather KF, Burnham PJ. Axillary brachial plexus block. Anesthesiology 1958;19:683-5

[126] De Jong RH. Axillary block of the brachial plexus. Anesthesiology 1961;22:215-25

[127] Lanz E, Theiss D, Jankovic D. The extent of blockade following various techniques of brachial plexus block. Anesth Analg 1983;62:55-58

[128] Cornish PB. Supraclavicular regional anaesthesia revisited – the bent needle technique. Anaesth Intensive Care 2000;28:676-679

[129] Cornish PB. Ultrasound-guided axillary tunnel block – the 'comet tail' block. Anaesth Intensive Care 2015;43:130-131

[130] Soares LG, Brull R, Lai J, Chan VW. Eight ball, corner pocket: the optimal position for ultrasound-guided supraclavicular block. Reg Anesth Pain Med 2007;32:94-95

[131] Pham-Dang C, Gunst JP, Gouin F, Poirier P, Touchais S, Meunier JF, et al. A novel supraclavicular approach to

brachial plexus block. Anesth Analg 1997;85:111-116

[132] Sehmbi H, Johnson M, Dhir S. Ultrasound-guided subomohyoid suprascapular nerve block and phrenic nerve involvement: a cadaveric dye study. Reg Anesth Pain Med 2019;44:561-564

[133] Cornish PB, Leaper CJ, Hahn JL. The 'axillary tunnel': an anatomic reappraisal of the limits and dynamics of spread during brachial plexus blockade. Anesth Analg 2007;104: 1288-1291

[134] Winnie AP, Radonjic R, Akkineni SR, Durrani Z. Factors influencing distribution of local anesthetic injected into the brachial plexus sheath. Anesth Analg 1979;58:225-234

[135] Cornish PB, Leaper CJ, Nelson G, Anstis F, McQuillan C, Stienstra R. Avoidance of phrenic nerve paresis during continuous supraclavicular regional anaesthesia. Anaesthesia 2007;62:354-358

[136] Cros Campoy J, Domingo Bosch O, Pomés J, Lee J, Fox B, Sala-Blanch X. Upper trunk block for shoulder analgesia with potential phrenic nerve sparing: a preliminary anatomical report. Reg Anesth Pain Med 2019:rapm-2019-100404 doi: 10.1136/rapm-2019-100404

[137] Franco CD, Rahman A, Voronov G, Kerns JM, Beck RJ, Buckenmaier CC. Gross anatomy of the brachial plexus sheath in human cadavers. Reg Anesth Pain Med 2008;33:64-69

[138] Anderson HL, Anderson SL, Tranum-Jensen J. Injection inside the paraneural sheath of the sciatic nerve: direct comparison among ultrasound imaging, macroscopic anatomy and histologic analysis. Reg Anesth Pain Med 2012;37:410-414

[139] Mayes J, Davison E, Panahi P, Patten D, Eljelani F, Womack J, Varma M. An anatomical evaluation of the serratus anterior plane block. Anaesthesia 2016;71:1064-1069

[140] Mariano ER, Perlas A. Adductor canal block for total knee arthroplasty: the perfect recipe or just one ingredient? Anesthesiology 2014;120:530-532

[141] Schnabel A, Reichl SU, Weibel S, Zahn PK, Kranke P, Pogatzki-Zahn E, Meyer-Frieβem. Adductor canal blocks for postoperative pain treatment in adults undergoing knee surgery. Cochrane Database of Systematic Reviews 26 October 2019;doi. org/10.1002/14651858

[142] Runge C, Moriggl B, Børglum J, Bendtsen TF. The spread of ultrasound-guided injectate from the adductor canal to the genicular branch of the posterior obturator nerve and the popliteal plexus: a cadaveric study. Reg Anesth Pain Med 2017;42:725-730

[143] Nair A, Dolan J, Tanner KE, Kerr CM, Jones B, Pollock PJ, Kellett CF. Ultrasound-guided adductor canal block: a cadaver study investigating the effect of a thigh tourniquet. Br J Anaesth 2018;121:890-898

[144] Johnston DF, Black ND, Cowden R, Turbitt L, Taylor S. Spread of dye injecte in the distal femoral triangle versus the distal adductor canal: a cadaveric study. Reg Anesth Pain Med 2019;44:39-45

[145] Tran J, Chan VWS, Peng PWH, Agur AMR. Evaluation of the proximal adductor canal block injectate spread: a cadaveric study. Reg Anesth Pain Med 2019;rapm-2019-101091. doi: 10.1136/rapm-2019-101091

[146] Karmakar MK, Shariat AN, Pangthipampai P, Chen J. High-definition ultrasound imaging defines the paraneural sheath and the fascial compartments surrounding the sciatic nerve at the popliteal fossa. Reg Anesth Pain Med 2013;38:447-51

[147] Míguez-Fernández M, Miguel-Pérez M, Ortiz-Sagristà JC, Pérez-Bellmunt A, Blasi-Cabus J, Möller I, Martinoli C. Ultrasound and anatomical study of accessing the nerves in the knee by fascial planes. Pain Pract 2020;20:138-146

[148] Karmakar MK, Pakpirom J, Songthamwat B, Areeruk P. High definition ultrasound imaging of the individual elements of the brachial plexus above the clavicle. Reg Anesth Pain Med 2020;45:344-350

[149] Areeruk P, Karmakar MK, Reina MA, Mok LYH, Sivakumar RK, Sala-Blanch X. High-definition ultrasound imaging defines the paraneural sheath and fascial compartments surrounding the cords of the brachial plexus at the costoclavicular space and lateral infraclavicular fossa. Reg Anesth Pain Med 2021;46:500-506. doi: 10.1136/rapm-2020-102304

[150] Hamilton DL, Manickam B. The erector spinae plane block. Reg Anesth Pain Med 2017;42:276

[151] Abrahams M, Derby R, Horn JL. Update on ultrasound for truncal blocks: a review of the evidence. Reg Anesth Pain Med 2016;41:275-88

[152] Guay J, Johnson RL, Kopp S. Nerve blocks or no nerve blocks for pain control after elective hip replacement (arthroplasty) surgery in adults. Cochrane Database of Systematic Reviews 31 October 2017. doi. org/10.1002/14651858

[153] Weinstein EJ, Levene JL, Cohen MS, Andreae DA, Chao JY, Johnson M, Hall CB, Andreae MH. Local anaesthetics and regional anaesthesia versus conventional analgesia for preventing persistent postoperative pain

in adults and children. Cochrane Database of Systematic Reviews 21 June 2018 doi.org/10.1002/14651858

[154] Guay J, Suresh S, Kopp S. The use of ultrasound guidance for perioperative neuraxial and peripheral nerve blocks in children. Cochrane Database Syst Rev. 2019 Feb 27;2(2):CD011436

[155] Liang SS, Ying AJ, Affan ET, Kakala BF, Strippoli GFM, Bullingham A, Currow H, Dunn DW, Yeh ZY-T. Continuous local anaesthetic wound infusion for postoperative pain after midline laparotomy for colorectal resection in adults. Cochrane Database of Systematic Reviews 19 October 2019 doi.org/10.1002/14651858

[156] Schnabel A, Reichl SU, Weibel S, Zahn PK, Kranke P, Pogatzki-Zahn E, Meyer-Frieβem. Adductor canal blocks for postoperative pain treatment in adults undergoing knee surgery. Cochrane Database of Systematic Reviews 26 October 2019 doi. org/10.1002/14651858

[157] Yu S, Valencia MB, Roques V, Aljure OD. Regional analgesia for minimally invasive cardiac surgery. J Card Surg 2019;34:1289-1296

[158] Jin Z, Li R, Gan TJ, He Y, Lin J. Pectoral Nerve (PECs) block for postoperative analgesia - a systematic review and meta-analysis with trial sequential analysis. Int J Physiol Pathophysiol Pharmacol 2020;12:40-50

[159] Osborn S, Cyna AM, Middleton P, Griffiths JD. Perioperative transversus abdominis plane (TAP) blocks for analgesia after abdominal surgery. Cochrane Database of Systematic Reviews 09 April 2020. doi. org/10.1002/14651858

[160] Qiu Y, Zhang TJ, Hua Z Erector spinae plane block for lumbar spinal surgery: a systematic review. J Pain Res. 2020 Jul 1;13:1611-1619

[161] Jack JM, McLellan E, Versyck B, Englesakis MF, Chin KJ. The role of serratus anterior plane and pectoral nerves blocks in cardiac surgery, thoracic surgery and trauma: a qualitative systematic review. Anaesthesia 2020;75:1372-1385

[162] Chhabra A, Chowdhury AR, Prabhakar H, Subramanian R, Arora MK, Srivastava A, Kalaivani M. Paravertebral anaesthesia with or without sedation versus general anaesthesia for women undergoing breast cancer surgery. Cochrane Database of Systematic Reviews 25 February 2021. doi.org/10.1002/14651858

[163] El-Boghdadly K, Desai N, Halpern S, Blake L, Odor PM, Bampoe S, Carvalho B, Sultan P. Quadratus lumborum block vs. transversus abdominis plane block for caesarean delivery: a systematic review and network meta-analysis. Anaesthesia 2021;76:393-403

[164] Roofthooft E, Joshi GP, Rawal N, Van de Velde M; PROSPECT Working Group* of the European Society of Regional Anaesthesia and Pain Therapy and supported by the Obstetric Anaesthetists' Association. PROSPECT guideline for elective caesarean section: updated systematic review and procedure-specific postoperative pain management recommendations. Anaesthesia. 2021;76:665-680