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Carline, L.; McLeod, G. A.; Lamb, C.

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A cadaver study comparing spread of dye and nerve involvement after three different quadratus lumborum blocks

Lydia Carline
MSc Student
Centre for Anatomy & Human Identification
University of Dundee, DD1 5EH
lydia.carline@network.rca.ac.uk

Graeme A McLeod
Consultant & Honorary Clinical Professor in Anaesthesia
Institute of Academic Anaesthesia
Ninewells Hospital & Medical School, DD1 9SY
g.a.mcleod@dundee.ac.uk

Clare Lamb
Senior Lecturer in Anatomy (Teaching and Scholarship)
Centre for Anatomy & Human Identification
University of Dundee, DD1 5EH
c.z.lamb@dundee.ac.uk

Corresponding Author
Graeme A McLeod
Institute of Academic Anaesthesia
Ninewells Hospital & Medical School, DD1 9SY
g.a.mcleod@dundee.ac.uk
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Running head
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Background: Posterior variants of abdominal wall block include the quadratus lumborum type I, quadratus lumborum type II and quadratus lumborum transmuscular blocks. Our objectives were to compare the spread of injectate and nerve involvement after conducting blocks using ultrasound guidance in soft embalmed cadavers.

Methods: After randomisation, an experienced anaesthetist conducted three quadratus lumborum 1, three quadratus lumborum 2 and four transmuscular blocks on the left or right sides of 5 cadavers. All cadavers were placed in the lateral position and the quadratus lumborum muscle visualised using a 3 to 9MHz ultrasound probe placed in the flank. For each block, a 20ml mixture of 17.75ml water, 2mls latex and 0.25ml India ink was injected. The lumbar region and abdominal flank were dissected 72 hours later.

Results: We conducted 10 blocks. Two quadratus lumborum 1 and two quadratus lumborum 2 blocks were associated with spread of dye within the TAP plane. One quadratus lumborum 1 block spread to the deep muscles of the back and one quadratus lumborum 2 block dispersed within the subcutaneous tissue surrounding the abdominal flank. All transmuscular quadratus lumborum blocks spread consistently to L1 and L3 nerve roots as well as within psoas major and quadratus lumborum muscles.

Conclusions: Consistent spread to lumbar nerve roots was achieved using the transmuscular approach through the quadratus lumborum.

Introduction

Transversus abdominis plane (TAP) block is commonly used to provide analgesia of the abdominal wall. Although initially described as a landmark technique[1], it is generally conducted under ultrasound guidance[2, 3]. Best results have been gained using posterior approaches to abdominal wall blocks because local anesthetic preferentially spreads to lower thoracic and lumbar nerve roots[4 5] rather than spreading anteriorly within the TAP plane[5]. Posterior injection through the angle of Petit in cadavers[4] was associated with spread of dye in the TAP plane from the costal margin to iliac crest, and in volunteers associated with paravertebral spread from T5 to L1 nerve roots using MRI imaging[5].

Posterior modifications of ultrasound guided TAP blocks include: (1) the quadratus lumborum 1 (QL1) whereby local anesthetic is deposited at the antero-lateral aspect of the QL muscle[6]; (2) the quadratus lumborum 2 (QL2) block[6], injecting local anesthetic at the postero-lateral aspect of quadratus lumborum; and (3) the quadratus lumborum transmuscular (QL-TM) block[7] inserting a needle through quadratus lumborum and injecting local anesthetic between quadratus lumborum and the psoas muscle. Two randomized controlled studies (RCTs) have demonstrated better pain relief using quadratus lumborum block compared to femoral block for fractured neck of femur surgery[8] and and compared to placebo for caesarean section[9]. Several reports have shown benefit for paediatric renal surgery[10 11] and adult laparoscopy[12]

However, for posterior abdominal wall blocks, the ideal regional anaesthesia technique is not known. Therefore, our primary objective was to compare the spread of a 20ml solution of India ink and latex when conducting ultrasound guided QL1, QL2 and QL-TM blocks in soft embalmed cadavers. We chose this model because it provides realistic conditions for simulation of ultrasound guided regional anaesthesia (UGRA); tissue is soft, has life-like strain[13] and stiffness[14] characteristics, and is used for UGRA, difficult airway and surgical training[15]. Our secondary objectives were to document the extent of nerve involvement.

Methods

Following approval by the University of Dundee Thiel Advisory Group, ten quadratus lumborum blocks were conducted on soft embalmed cadavers independently chosen by the scientific officer of at the Centre for Anatomy and Human Identification (CAHiD), University of Dundee. Cadavers were randomised by computer to QL1, QL2 and QL-TM blocks. All cadavers were placed in the lateral position and blocks performed by a single experienced anaesthetist using an 18 gauge, 100mm PlexoLong Sono Tuohy needle (Pajunk, Geisingen, Germany) and linear 3 to 9 MHz ultrasound probe and a Zonare Ultra ultrasound machine (Zonare, PaloAlto, CA). The block needle was connected to a syringe containing a 20ml mixture of 17.75ml water, 2mls latex and 0.25ml India ink. The injectate was chosen from results of a cadaver pilot project conducted by the principal author. The Tuohy needle was chosen for ease of injection of the solution. For all blocks, the ultrasound probe was placed transversely in the abdominal flank above the iliac crest. In this position, the external oblique, internal oblique, transversus abdominis muscles and aponeurosis were identified. The probe was then moved posteriorly in order to visualize the quadratus lumborum antero-lateral to the apex of the L3 and L4 transverse processes and superficial to the psoas muscle.

Block procedure

Each block is illustrated in Fig 1. The QL1 block was performed by inserting the needle in-plane from the anterior edge of the probe, depositing 20ml of the latex and ink mixture onto the anterolateral surface of quadratus lumborum. The QL2 block was conducted in a similar fashion to the QL1 block but dye was injected more superficially onto the posterolateral surface of quadratus lumborum. QL-TM blocks were performed according to the technique described by Borglum et al[7]. The needle was inserted in-plane from the posterior edge of the probe through quadratus lumborum in an anteromedial direction. When the tip lay between quadratus lumborum and psoas muscles, anterior to the transverse process, 20ml of solution was injected. All blocks were video recorded onto the hard disk of a Zonare z.one ultrasound machine (Zonare, Mountain View, CA). The lumbar region and abdominal flank were dissected 72 hours later in order to observe the spread of injectate. Stained regions were documented and their relationship to fascial planes recorded and photographed.

Results

In all, 10 blocks were performed - 4 transmuscular QL blocks, 3 QL1 blocks and 3 QL2 blocks. Two of three QL1 (Fig 2) and two of three QL2 blocks (Fig 3) were associated with spread of dye within the TAP plane. One QL1 block and one QL2 block spread to subcutaneous tissue surrounding the abdominal flank and into the deep muscles of the back. One QL1 block spread to the T3 transverse process. All transmuscular QL blocks (Fig 4) spread consistently to L1 and L3 nerve roots and also within psoas and quadratus lumborum. A summary of block characteristics is given in Table 1.

Discussion

Our dissection showed that ultrasound guided QL-TM blocks consistently blocked lumbar nerve roots. In contrast, two out of three QL1 and QL2 blocks spread anteriorly to the TAP plane between the internal oblique and transversus abdominis muscles and posteriorly to subcutaneous tissue surrounding the abdominal flank over latissimus dorsi.

Our results confirm the findings of Borglum et al[7] that transmuscular QL block consistently extends to nerve roots. However, restriction of spread to the lumbar region conflicts with reports from dye studies in cadavers and MRI studies in volunteers that have demonstrated thoracic spread using the landmark technique[5], QL1[5], QL2[9] and transmuscular QL blocks[7].

In order to explain the limited spread seen in our study, it is important to discuss the physical characteristics of our soft embalmed cadavers, and the importance of injection accuracy when conducting QL blocks.

Soft embalmed cadavers are embalmed with a solution consisting of ammonium and potassium nitrate, sodium sulphite, boric acid and propylene glycol ethanol, but only very small amounts of formaldehyde[18]. Thereafter, they are kept in sealed plastic bags in the mortuary for up to 3 years before cremation. The Anatomy Act 2006 (Scotland) provides the governanace framework. Embalming softens tissues, providing full limb flexibility and a realistic model for ultrasound, ventilation and surgical intervention. Our recent work has shown that cadaver soft tissue stiffness or Young's modulus is approximately 20% greater than age matched volunteers[14], but that relative stiffness between nerves and surrounding tissue is maintained. Analysis of strain patterns[13] secondary to UGRA using elastography indicates flow of embalming fluid along tissue planes and paths of least resistance similar to patients. Nevertheless, cadavers have a functionless cardiorespiratory system and do not experience changes in cavity pressures that may contribute to spread through tissue planes. Moreover, cadavers are kept at room temperature, and we would expect the density of embalming fluids to be higher and tissues to be less elastic than in patients at body temperature.

Our study highlights that the success of QL blocks is highly dependent on the exact position of the needle tip at injection. Despite using an expert anaesthetist with 9 years UGRA experience and 6 years Thiel cadaver regional anaesthesia experience, one QL1 and one QL2 block was misplaced and would not have provided postoperative analgesia if administered in patients. B-Mode images on the cadaver are slightly more difficult to interpret than in patients, but using retrospective ultrasound video analysis we were satisfied that needle tips had been placed as accurately as possible.

The exact position of the needle tip relative to the thoracolumbar fascia is crucial. Transversus abdominis and internal oblique form an aponeurosis of thoracolumbar fascia that divides into three fascial layers anterolateral to quadratus lumborum. Quadratus lumborum lies between the anterior and middle layers and the erector spinae muscles enclosed between the middle and posterior layers. We would hypothesis that our QL1 block failed despite placing the tip of the needle accurately anterolateral to the quadratus lumborum due to preferential spread occurring along the posterior fascial layer towards latissimus dorsi and subcutaneous tissues. Our failed QL2 block may be explained by accurate needle placement but preferential spread back to the TAP and posterior fascial plane. Our results suggest that it is very difficult to guarantee spread with QL1 and QL2 blocks, even with accurate injection, because the anatomical configuration of connective tissue and relative resistance to flow of injectate is not known in each cadaver, or indeed patient. We need to conduct a larger cadaver study using both dye and MRI scanning in order to offer guidance on precise postioning of needle tips for QL1 and QL2 blocks.

Transmuscular injection is effective because it is not dependant on the vagaries of connective tissue anatomy in this region. Needle tip penetration of the postero-medial surface of quadratus lumborum provides a distinct end point and spread of injection both lateral and posterior to the psoas muscle is visible on B-Mode images.

The QL-TM block potentially offers several safety advantages compared to lumbar plexus block. The quadratus lumborum muscle, transverse process of L3 and psoas muscle are seen using ultrasound placed in the flank, and injection beyond the anterior thoracolumbar fascia spreads circumferentially around the psoas muscle. Thus, QL-TM block is less invasive than a lumbar plexus block because anaesthesia is reliant on medial spread rather than injection within the psoas muscle[16] adjacent to the roots of the lumbar plexus. However, application to obese patients is restricted as with all ultrasound imaging because of poorer resolution of vital anatomy and needle tip.

Our results, albeit in a soft cadaver model, suggest a benefit to patients undergoing surgery in regions innervated by the lumbar plexus, but not to patients having operations on the abdominal wall. Questions remain as to how the transmuscular quadratus lumborum block extends in patients to the thoracic nerve roots and provides good pain relief after surgery. We would surmise that slight changes in needle tip placement may alter the distribution of injectate. For example, penetration of quadratus lumborum and anterior thoraco-lumbar fascia more antero-laterally may be associated with a more extensive cephalad distribution. Imaging studies are needed to determine how fluid spreads relative to the position of the needle tip on the anterior border of quadratus lumborum, and what type of surgeries would benefit. The relatively antero-medial position of our needle tips and spread to lumbar nerve roots suggests a potential application in surgical sites innervated by the lumbar nerve roots.

We propose that the efficacy and safety of the QL-TM block is investigated further in patients with fractured neck of femur because patients tend to be small and thin, anatomy is distinct and local anaesthetic can be readily observed spreading to lumbar nerve roots anterior to the lumbar transverse processes. In this population, we would regard the QL-TM block as more superficial than a lumbar plexus block, and easier to perform. Reliance on spread to the nerve roots rather than injection around nerve roots within the psoas muscle suggests a potentially safer block in the presence of altered coagulation. Studies are needed to determine the balance of efficacy and safety of the QL-TM block.

In conclusion, the transmuscular QL approach consistently blocked lumbar nerve roots. The QL1 and QL2 blocks were unreliable. Further research is needed in order to correlate needle tip position with spread using the transmuscular QL block.

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Contributions

Lydia Carline designed and conducted the study and contributed to writing the paper

Graeme McLeod designed the study and contributed to writing the paper

Clare Lamb supervised Lydia Carline's MSc, designed the study and contributed to writing the paper

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Table 1. Needle placement, dispersion of the dye and the success of the blocks performed in all studies.

Fig 1. Schematic diagrams of quadratus lumborum 1 block (left), quadratus lumborum 2 block (centre), and transmuscular quadratus lumborum block. The yellow dot represents the needle tip position during injection.

Fig 2. Quadratus lumborum 1 block. Dye visualized as dark staining and nerve involvement highlighted by coloured paper. All needles pierced the external and internal oblique muscles. Dye spread in block 1A to the TAP plane and around the iliohypogastric nerve. Block 1B spread over the ilioinguinal nerve but mainly to the postero-medial and posterolateral surfaces of quadratus lumborum to the deep muscles of back. Spread associated with block 1B was insufficient for postoperative pain relief. Block 1C spread within the TAP plane but predominantly within the subcutaneous tissue surrounding the antero-lateral abdominal wall muscles and latissimus dorsi.

Fig 3. Quadratus lumborum 2 block. Dye visualized as dark staining and nerve involvement highlighted by coloured paper. All needle tips were placed appropriately. In block 2A dye dispersed predominantly within the subcutaneous tissue and was insufficient for postoperative pain relief. In contrast, blocks 2B and 2C spread within TAP plane and around the subcostal nerve.

Fig 4. Transmuscular quadratus lumborum block. Dye visualized as dark staining and nerve involvement highlighted by coloured paper. All blocks (3A to 3D) penetrated quadratus lumborum and dispersed medially towards the lumbar nerve roots. Extensive nerve involvement in all blocks.

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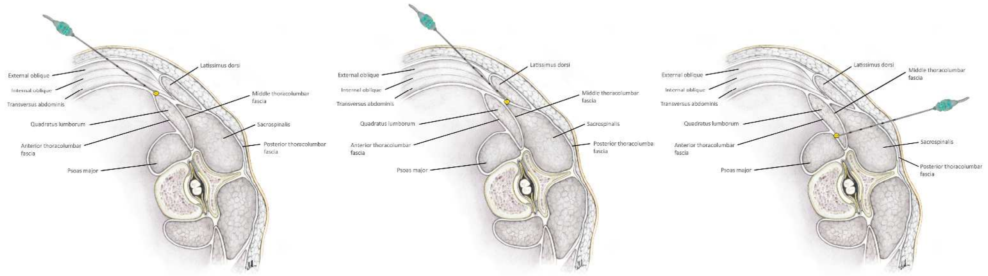
Block	Figure	Needle passage and spread of dye	Nerve block	Successful block
QL1	1A	Needle pierced external, internal oblique and transversus abdominis. Dye spread within TAP, subcutaneous tissue and minimally on the posterior surface of quadratus lumborum Spread laterally to the upper border of 11^{th} rib and cranio-medially to the upper border of 12^{th} rib	liohypogastric nerve on antero-lateral surface of quadratus lumborum Subcostal nerve at distal attachment of quadratus lumborum to the iliac crest on its postero-lateral border	Yes
QL1	1B	Needle passed through external and internal oblique and transversus abdominis to pierce quadratus lumborum. Spread to postero-medial and posterolateral surfaces of quadratus lumborum to deep muscles of back	Ilioinguinal nerve	No
QL1	1C	Needle pierced external and internal oblique. Dye dispersed predominantly within the subcutaneous tissue surrounding the antero-lateral abdominal wall muscles as well as within TAP and latissimus dorsi	Nil	Yes
QL2	2A	Needle tip pierced posterior surface of quadratus lumborum,. Dye spread anteriorly within subcutaneous tissue with a small amount dispersed around external oblique superficial to the thoracolumbar fascia of internal oblique	Nil	No
QL2	2B	Needle tip pierced postero-lateral surface of quadratus lumborum Dye spread within TAP and subcutaneous tissue	Subcostal nerve	Yes
QL2	2C	Needle pierced external, internal oblique and transversus abdominis) Dye spread within TAP and subcutaneous tissue.	Subcostal nerve	Yes
TMQL	3A	Needle pierced the postero-medial aspect of quadratus lumborum and psoas major Most dye dispersed within psoas major from its postero-medial aspect to its postero-lateral surface. Some dye dispersed medially towards the medial aspect of psoas major and to the lumbar vertebrae	L1 to L3 nerve roots	Yes

TMQL	3B	Needle pierced lastissimus dorsi, intrinsic muscles of the back, postero-medial aspect of quadratus lumborum and psoas major. Small amount of dye observed on the postero-medial aspect quadratus lumborum around the postero-medial fibres of psoas major. Majority of dye dispersed cranially and caudally within latissimus dorsi and the intrinsic muscles of the back and medially towards the lumbar vertebral bodies and transverse processes	L1 to L3 nerve roots	Yes
TMQL	3C	Needle pierced latissimus dorsi and the intrinsic muscles of the back, the postero-medial aspect of quadratus lumborum and psoas major. Small amount of dye observed within the postero-medial fibres of psoas major from its cranial attachment at L1 vertebral disc and transverse process to below the iliac crest caudally. Most dye observed within the body of quadratus lumborum, from its cranial to caudal attachments but located mainly within its antero-medial aspect to surround the transverse processes of L1 to L4.	L1 to L3 nerve roots	Yes
TMQL	3D	Pierced latissimus dorsi and the intrinsic muscles of the back, the postero-medial aspect of both quadratus lumborum and psoas major. LAS observed within psoas major surrounding its postero-lateral surface through to its antero-lateral aspect. The majority of the LAS had dispersed within the body of quadratus lumborum.	Subcostal nerve root Genitofemoral, femoral and obturator nerves Nerve roots of L1 to L3	Yes



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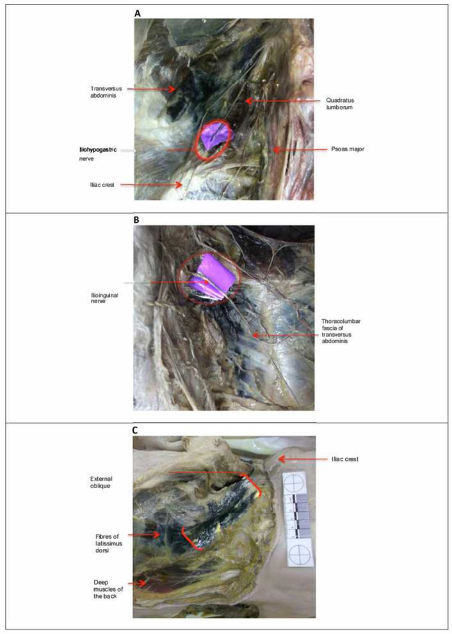

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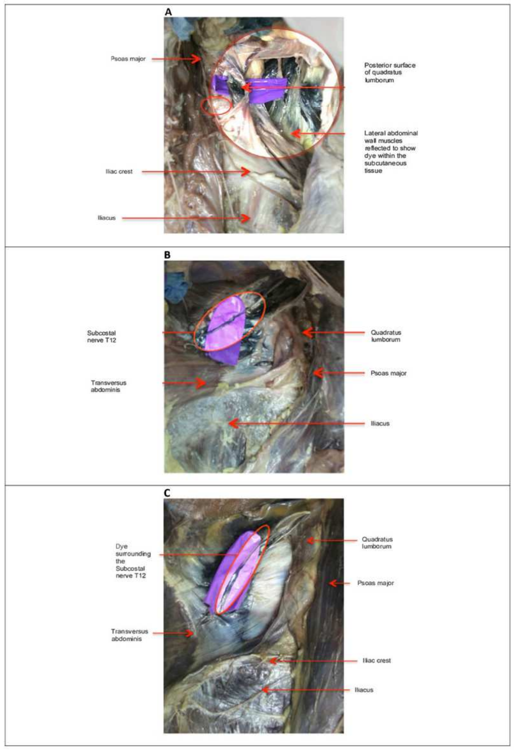

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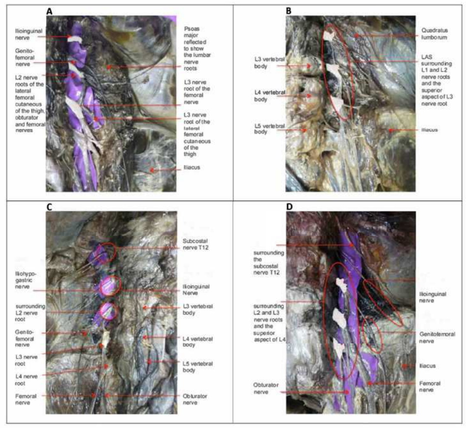

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