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Ultrasound-guided infrapatellar nerve block in human volunteers: description of a novel technique†

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Background. Despite the use of various treatment strategies arthroscopic knee surgery is still associated with clinically important postoperative pain. As the infrapatellar nerve (IPN) innervates vital anterior knee structures we decided to investigate the feasibility of a novel ultrasound-guided IPN block technique as a potential therapeutic option for out-patient arthroscopic knee surgery.

Methods. The IPN was blocked under ultrasonographic guidance in 10 adult volunteers using 5 ml of levobupivacaine 5 mg ml^{-1}. Success rate, time to maximum cutaneous distribution of the block, distribution of cutaneous analgesia and time until full recovery of cutaneous sensation was noted as was the incidence of concomitant blockade of the saphenous nerve (SN).

Results. The IPN was successfully blocked in 9/10 subjects. However, a varying degree of concomitant SN block was observed as part of all blocks. The time to maximum cutaneous distribution of the block was 8.4 (SD 3.6) min and the duration until complete recovery of cutaneous sensation was 27.5 (19.1) h.

Conclusion. Reliable blockade of the IPN can be achieved with ultrasonographic guidance. Because of the very close anatomical relationship between the IPN and the SN it appears inevitable to also get a variable degree of concomitant SN block. The duration of the IPN block was in the majority of subjects greater than 16 h, a finding that may make this block useful for postoperative analgesia in out-patient arthroscopic surgery.

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Introduction

Arthroscopic knee surgery has to a large extent come to replace traditional open techniques both for minor (e.g. meniscectomy) and more major (e.g. anterior cruciate ligament repair) surgical interventions of the knee joint. Despite being minimally invasive and, thus, associated with less surgical exploration and tissue trauma, postoperative pain is still a clinical concern. Various analgesic regimens have been used in order to improve the situation[1–4] but postoperative pain can still be a problem in up to 60–90% of cases during the first 24-postoperative hours.[4] Thus, further improvement of pain relief after arthroscopic surgery is warranted, especially as a large number of such patients currently are handled as out-patients and therefore cannot benefit from more advanced and potent analgesic techniques that are possible to use in hospitalized patients (e.g. patient-controlled analgesia or epidural analgesia).

The infrapatellar nerve (IPN) is a purely sensory nerve that innervates the antero-medial aspect of the knee, as well as the anterior inferior part of the knee capsule, and is a branch of the saphenous nerve (SN).[5] Selective neural blockade of the IPN could, thus, have the potential for providing clinically significant supplemental analgesia in this context as the majority of arthroscopic surgery involves manipulations within the territory that is supplied by this nerve. However, because of the complex anatomical route of this nerve it has previously not been possible to reliably block this nerve based on traditional landmark-based techniques and the use of regular nerve stimulation is also not an option as the nerve is purely sensory in nature.

†*Declaration of interest.* Professors Marhofer, Kapral and Lönnqvist have acted, and will continue to be paid invited speakers, at the Sonosite workshops in ultrasound guided nerve blocks.

The introduction of ultrasound-guided nerve blockade (USNB) has now added the possibility to in fact visualize nerve structures and thereby facilitate various types of regional anaesthetic blocks.[6]

Thus, the aim of this descriptive volunteer study was to attempt selective ultrasound-guided IPN blockade in order to determine success rate, onset time, area of cutaneous anaesthesia and the duration of the block as well as the incidence of concomitant blockade of the SN before applying this new regional anaesthetic technique for further clinical study.

Materials and methods

Following ethics committee approval and informed consent 10 adult volunteers of both sexes were enrolled in the study. The blocked knee should have been considered fully normal by the volunteer and should have been without previous significant trauma (e.g. major accident or surgical intervention).

Equipment

Nerve structures were visualized with a portable ultrasound machine (Titan, Sonosite, Bothell, WA, USA) with a linear 38 mm wide 5–10 MHz probe. The nerve blockade was performed with a 35 or 55 mm 25 G needle with extension tubing (Stimulplex, B Braun, Melsungen, Germany) and 5 ml of levobupivacaine 5 mg ml^{-1} (Chirocaine, Abbott Scandinavia AB, Solna, Sweden).

Procedure

Initially the probe was placed in a transverse direction in relation to the femoral artery and the major branches of the femoral nerve at a mid-femoral level, just medial to the sartorius muscle. At this point the settings of the ultrasound machine were adjusted (frequency, depth, contrast) to optimize the ultrasonographic picture. The femoral artery was then visualized together with the different branches of the femoral nerve, including the SN. The course of the femoral artery was subsequently followed distally in order to define the level at which the artery deviates posteriorly (deep on the US picture) towards the femoral slit. At this level the nerve structures were once again searched for (at a more superficial tissue level compared with the artery). At this location the SN structure was identified and was then followed distally and medially until the division of the IPN could be identified (Fig. 1). The probe was further adjusted at this level so that the IPN could be seen as a distinctive nerve, separated from the SN by at least 1–2 cm (Fig. 2). At this point the injection of local anaesthetic was performed (see below). All blocks were performed by the same experienced anaesthesiologist (SK).

The appearance of multiple vessel structures, considered to be part of an extended rete vascularis genu, made it in certain individuals difficult to visualize the adequate nerve structures at a more distal level or made it impossible to find an acceptable point of injection in order to avoid haematoma formation. In these cases the nerve block was performed at a more cephalad level where only the SN was possible to identify, thus, accepting a block of both the saphenous and IPN fibres.

When the optimal position and US picture of the nerve had been obtained the skin distal to the probe was prepared in an aseptic manner. A transverse view was used during the entire injection procedure and the probe was adjusted to keep the target structures in the middle of the US picture. A small skin wheal was raised with an intradermal injection of lidocaine 0.3 ml (10 mg ml^{-1}, AstraZeneca, Södertälje, Sweden). The nerve block needle was then inserted and manipulated into a position immediately adjacent to the nerve. When the localization of the needle tip was considered optimal an aspiration manoeuvre was performed in order to rule out inadvertent vascular puncture. The position was checked with a small injection (0.25 ml) of local anaesthetic. If the position of the injectate was not considered perfect in relation to the nerve further minor manipulation of the needle tip was performed and the position was rechecked by a further small injection of local anaesthetics. When the needle position was found acceptable 4.75 ml of levobupivacaine 5 mg ml^{-1} was injected (total volume injected at the nerve=5 ml).

Data collection

Data regarding sex, age, weight, height and BMI were registered.

Performance of the block

The skin–nerve depth (mm) was measured by the calliper function of the US machine. The visibility of the nerve was scored according to a 4-graded scale: 0—not visible; 1—can be identified with difficulty; 2—clearly visible but unable to visualize internal nerve structures; 3—clearly visible+possible to visualize internal nerve structures. Based on a US picture taken immediately after the injection of the local anaesthetics the spread of the injected solution was judged as follows: 0—no direct contact between the injected solution and the nerve; 1—the nerve was only partially surrounded by the injectate; 2—the nerve was completely enveloped by the injectate. The distance between the medial joint line of the knee and the injection point was measured with a regular measuring tape.

Characteristics of the infrapatellar nerve blockade

Testing of cutaneous sensation within the innervated area of the IPN was performed immediately after the end of the blocking procedure and then every 3 min until no further extension of the block could be detected compared with the previous assessment. Assessments were continued for a maximum of 30 min and if no effect of the block was noted at this time the block was considered as a failure. Cutaneous

Fig 1 Probe position at the level of injection.

Fig 3 Cutaneous analgesia following infrapatellar nerve block. Circles represent mean values (for numerical values and SD please see Table 2).

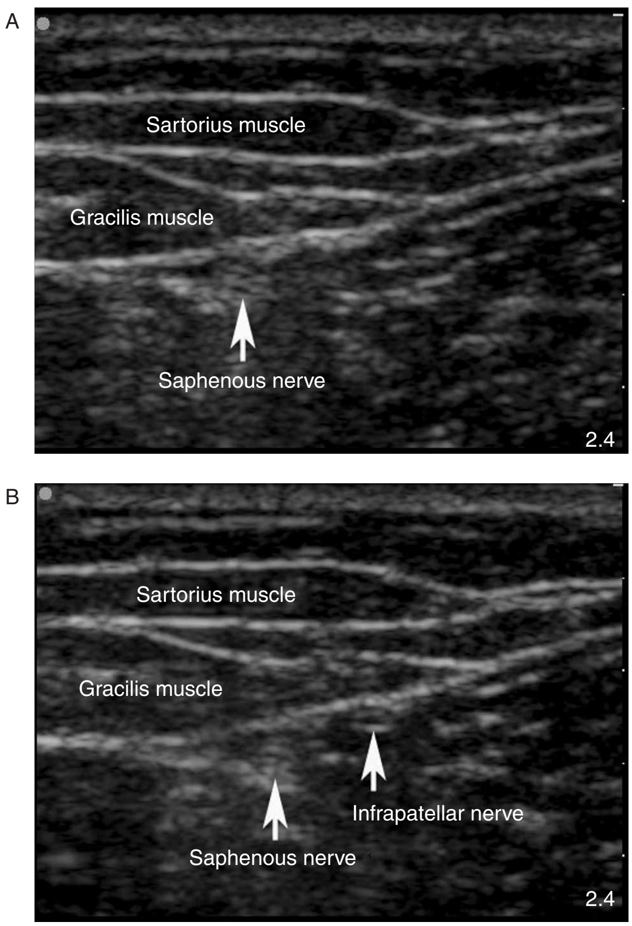

Fig 2 Ultrasonographic pictures of the relevant anatomy. (A) Saphenous nerve, (B) saphenous and infrapatellar nerves.

analgesia was determined by light touch followed by skin pinching. The border for pain on skin pinching was marked on the skin and was subsequently measured (area of cutaneous anaesthesia, see below).

The onset time of the block (min) was defined as the time from the end of the injection of the local anaesthetics to the first sensation of changed cutaneous sensation within the innervated area of the IPN. The time from the end of the injection to maximum extension of cutaneous anaesthesia (min) was defined as the time until two subsequent assessments of the extension of the block generated the same result at which point the time of the last assessment was registered as the time to maximum extension of the block.

After the registration of the time to maximum extension of the block or after 30 min no further assessments were performed and the subject was allowed to leave the hospital. Subjects were instructed to register the time until cutaneous sensation had completely returned to normal within the previously blocked area. If this happened during sleep the time registered was the time when the patient had gone to bed. The time between the time point of maximum extension of the block and the return of complete cutaneous sensation was defined as the duration of the block (h).

The area of cutaneous anaesthesia was determined in a stellate manner using the most cephalad part of the tibial tuberosity as the reference point (Fig. 3). The maximum border of cutaneous analgesia to skin pinching was, thus, marked on the skin in eight different directions (Table 1). The assessments were made with the knee flexed at 90° (Fig. 3).

Characteristics of the saphenous nerve blockade

In order to detect a possible concomitant block of the SN the skin slightly above and anterior to the medial malleolus was tested in a similar manner to what is described above for the IPN in order to detect involvement also of the SN. The following data were recorded: quality of sensory block (0—no block, 1—slight block of cutaneous sensation, 2—dense block), time to onset (min) and duration of the block (h). However, contrary to the IPN block no assessments of either time to or area of maximum cutaneous

Table 1 Cutaneous distribution of the block

Distance from tibial tuberosity (cm)	Mean (SD)
Superior	4.9 (4.0)
Superior–medial	8.2 (4.5)
Medial	8.2 (3.1)
Medial–inferior	9.7 (5.3)
Inferior	9.7 (7.5)
Inferior–lateral	5.6 (4.8)
Lateral	3.2 (2.1)
Lateral–superior	3.7 (2.3)

Table 2 Patient and block characteristics

	Mean (SD)	Median (range)
Subject data		
Sex (m/f)	7/3	
Age (yr)	44 (6.9)	42.5 (35–60)
Body weight (kg)	76.7 (17.0)	79.5 (54–97)
Height (cm)	174.6 (9.7)	174.5 (160–190)
BMI (kg m^{-2})	24.9 (3.7)	24.4 (19.4–30.8)
Block characteristics		
Skin–nerve distance (cm)	2.0 (0.6)	1.9 (1.2–3.2)
Medial joint line-puncture distance (cm)	14.0 (3.1)	14.0 (8.5–18.0)
Nerve visibility (0–3)	2.7 (0.5)	3 (2–3)
Spread of injectate (0–2)	1.8 (0.4)	2 (1–2)
Infrapatellar nerve		
Time to onset (min)	2.2 (1.7)	1 (1–6)
Time to maximal spread (min)	8.4 (3.6)	9 (1–12)
Duration of block/time to return of full sensibility (h)	27.5 (19.1)	30.5 (2.0–58.5)
Saphenous nerve		
Degree of saphenous nerve block (0–2)	1.6 (0.5)	2 (1–2)
Time to onset (min)	4.4 (5.7)	2.0 (1–15)
Duration of block/time to return of full sensibility (h)	27.1 (21.3)	23.5 (2.0–58.5)

spread of the SN block was performed as this was not the focus of the study.

Results

Data concerning patient and block characteristics are shown in Table 2 and area of maximum cutaneous block to skin pitch is displayed in Figure 3.

In 9 out of 10 patients neural blockade of the IPN, with or without significant concomitant blockade of the SN, was registered. In one patient no evidence of neural blockade of the IPN could be observed, for more details, see below. The block failure patient has not been included in the descriptive statistical analysis of the block.

In four subjects a predominant infrapatellar block was achieved with only minimal associated block of the SN. In another four cases the saphenous block was more predominant than the infrapatellar block and in one subject both nerves appeared to be blocked approximately to the same extent.

In four cases an extensive rete vascularis genu necessitated a more cephalad approach compared with what can be considered the optimal injection level, including the subject with the failed block.

In the failed block subject the tissue visualization was considered very favourable and at the more cephalad level of the block four different nerve structures were visible. The slightly larger of these structures was designated the SN and was subsequently blocked. However, as described earlier no IPN block could be noted in this case, only a slight and short lasting block of the SN was noted (duration<2 h). Interestingly the subject on closer questioning did describe that the knee had felt slightly ‘funny’, perhaps best described as being marginally weaker than the unblocked knee. This sensation had been felt during the afternoon and evening after the block but she had been able to bicycle home without any problems.

Discussion

The main finding of the study was that the IPN can successfully be blocked with the use of ultrasonographic guidance but a varying degree of concomitant block of the SN appears inevitable. The duration of the block was in the majority of subjects more than 16 h, a finding that may be clinically useful for postoperative analgesia following arthroscopic out-patient surgery.

Despite being minimally invasive, arthroscopic surgery of the knee can be associated with postoperative pain in as many as 60–90% of patients.[4] A number of different approaches have been attempted in order to improve postoperative pain relief but have only been associated with limited success.[1–4] As the IPN supplies a large proportion of the surgical field,[5] blockade of this nerve could potentially further improve postoperative analgesia in the context of arthroscopic knee surgery. As this nerve is purely sensory in nature it appears well suited for this type of out-patient surgery as its blockade will not influence the possibility for early ambulation.

Because of the complex innervation of the knee joint and its surrounding tissues IPN block may not provide complete postoperative analgesia on its own, especially after more major procedures such as anterior cruciate ligament repair, but may be a nice complement to common postoperative analgesics (e.g. paracetamol and non-steroidal anti-inflammatory drugs).

Furthermore, injury to the more distal parts of the IPN is not uncommon following both conventional and arthroscopic knee surgery, later resulting in infrapatellar neuralgia.[7 8] It can be speculated that prolonged blockade of the nerve with local anaesthetics may reduce the risk for the development of neuralgic problems as some evidence point to a certain degree of protection against long-term neuralgia or chronic pain when peripheral nerve blocks are used.[9]

Selective blockade of the IPN is frequently not described in major textbooks and one of the authors (PAL) clinical experience with this block, using a landmark-based technique, has been erratic. This is most likely attributable to the quite complex and varied anatomical course of this peripheral nerve.[10 11] However, with the aid of ultrasonography it

was possible to visualize the relevant nerve structures in all subjects. Despite good visualization it was only possible to achieve a more selective block of the IPN in <50% of the blocks mainly because of extensive vascularization in the knee area. A certain degree of concomitant block of the SN, thus, appears almost inevitable and is most likely attributable to the close proximity of the IPN to the SN even at more distal levels. However, as the SN is also a purely sensory nerve that supplies a limited part of the lower leg, such a concomitant block of the SN would perhaps not be of any major concern for the patient, especially seen in the context of potentially improved postoperative analgesia.

The fact that USNB will allow for controlled injection of the local anaesthetic immediately on the nerve has previously been found to produce a prolongation of the duration of the block.[12] This was further corroborated by our findings of surprisingly long durations of action (16–58 h) in the majority of subjects despite the limited volume of local anaesthetic used. A long duration of action would obviously be of benefit in out-patients, especially if it does not affect muscle function or ambulation. To use a smaller volume (<3 ml) and a higher concentration of levobupivacaine (7.5 mg ml^{-1}) may reduce the risk for a spillover effect on the SN and may also further prolong the duration of action.

The observations made in the subject with a failed block are interesting. Because of an extended rete vascularis genu a more cephalad approach was necessary. As the subject is a marathon runner the anatomical conditions were excellent and allowed for the identifications of four separate nerve structures at this more cephalad level. It is apparent that the wrong nerve structure was designated to be the SN as there was no block of the infrapatellar and only a very brief and partial block of the SN. Based on the history of a slightly 'funny' feeling in the knee during the rest of the day, best described as slight weakness, we believe that we mistakenly did block the motor branch of the femoral nerve going to the vastus medialis muscle. A motor block of this muscle in this highly fit and muscular individual would most likely not have been noted other than as a marginal weakness.

Against this background it appears to be a useful strategy to combine the use of ultrasound guidance with conventional nerve stimulation if the block, as a result of anatomical circumstances, which would have to be performed at a more cephalad level than expected. This would allow for better discrimination between motor and sensory nerves, something that is not possible using ultrasonographic guidance alone.

In conclusion, reliable blockade of the IPN can be achieved with ultrasonographic guidance. Because of the very close anatomical relationship between the infrapatellar and the SN it appears inevitable to also get a variable degree of concomitant SN block. The duration of the IPN block was in the majority of subjects >16 h, a finding that may make this block useful for postoperative analgesia in out-paitent arthroscopic surgery.

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