Comparison of the Fascia Iliaca Compartment Block with the 3-in-1 Block in Children

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DALENS B, VANNEUVILLE G, TANGUY A. Comparison of the fascia iliaca compartment block with the 3-in-1 block in children. Anesth Analg 1989;69:705–13.

A new single injection procedure, the fascia iliaca compartment block, is described for blocking the femoral, lateral cutaneous, and obturator nerves. The technique consists of injecting a local anesthetic immediately behind the fascia iliaca at the union of the lateral with the two medial thirds of the inguinal ligament, and forcing it upward by finger compression. This block was prospectively evaluated in 60 pediatric patients aged 0.7 to 17 years undergoing surgery of the lower limb, and then compared with a similar group of 60 children given a 3-in-1 block. Adequate analgesia was only obtained in 20% of the patients given 3-in-1 blocks (group 1), whereas the fascia iliaca compartment block proved to be easy, free of complications, and effective in more than 90% of patients (group 2). Such a high failure rate in group 1 was not due to misplacement of the needle since a femoral nerve block developed in all patients. Therefore it is unlikely that the local anesthetic can spread rostrally towards the lumbar plexus then return peripherally along the issuing nerves, and this was, indeed, not confirmed by radiological findings. In the authors' opinion, a multieffective block can only develop when the local anesthetic is introduced behind the fascia iliaca, which circumscribes a potential space where the femoral, lateral cutaneous, and obturator nerves run for a considerable part of their course. This report shows that deliberately injecting this space almost always results in an easy and effective block of these three nerves. The fascia iliaca compartment block can be recommended for use in children.

Key Words: ANESTHETIC TECHNIQUES, REGIONAL—lumbar plexus block, femoral nerve block. ANESTHESIA, PEDIATRIC.

The intraoperative and postoperative courses of numerous operations on the upper extremity are improved by using regional anesthetic techniques, especially axillary and supraclavicular brachial plexus blocks. The same improvements can be expected for operations on the lower extremity. However, due to the complexity of the sensory supply to the lower limb, either a central block or multiple peripheral blocks are necessary for providing adequate anesthesia. On the one hand, epidural or spinal anesthesias are unnecessary and even undesirable for unilateral operations; on the other, the performance of several peripheral blocks is time-consuming and increases the dangers of inaccurate injection and systemic toxicity.

Winnie et al. (1) renewed general interest in regional anesthesia for operations on the lower extremity by describing a multieffective block of the lumbar plexus nerves supplying the thigh with a single injection of reasonable amounts of local anesthetic, the "3-in-1" block. In a number of patients, however, the block fails to provide adequate anesthesia in areas supplied by the lateral cutaneous nerve of the thigh and the obturator nerve. Furthermore, this block procedure has not gained wide acceptance in pediatrics, since most children are unable to grasp the concept of paresthesia. We expected that the use of electrical stimulation and insulated needles might allow the application of the 3-in-1 block procedure in children, and even with improved results, but this was not confirmed by our clinical experience.

We then reevaluated the gross anatomy of the lumbar plexus nerves and fascias of the groin and thigh in children. Our anatomical findings supported the hypothesis that sufficient amounts of a solution injected immediately posterior to the fascia iliaca could spread at the inner surface of this fascia and contact the femoral, lateral cutaneous, genitofemoral, and obturator nerves that run, at least in part, immediately posterior to the fascia. We then developed a new blocking procedure, referred to as the "fascia

Received from the Department of Anesthesiology and the Department of Pediatric Surgery, Hôtel-Dieu Hospital, Clermont-Ferrand, France. Accepted for publication June 8, 1989.
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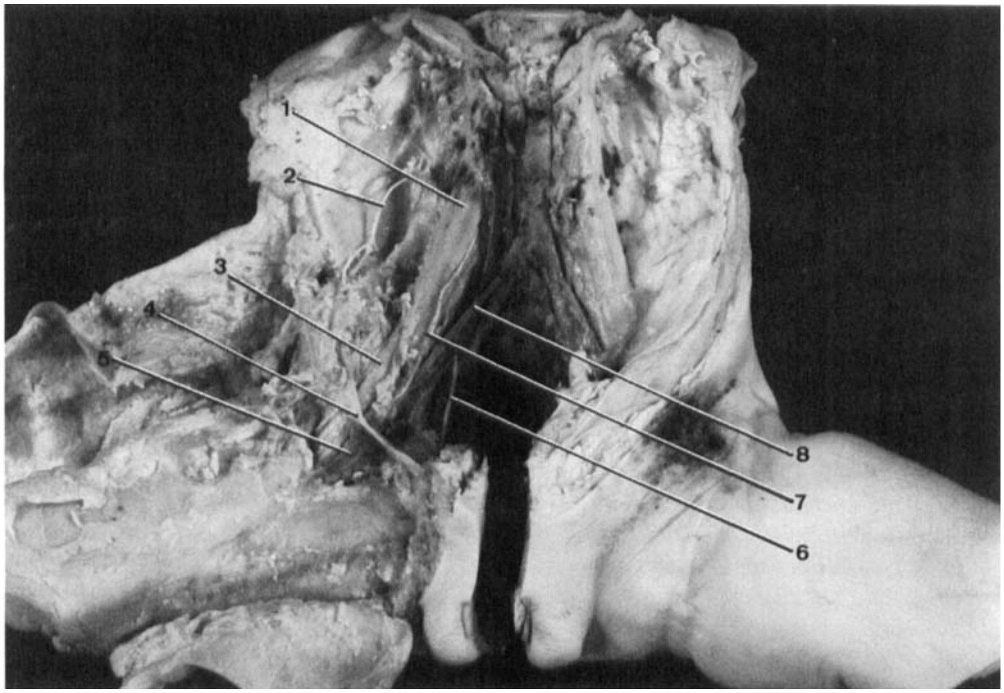

Figure 1. Gross anatomy of the lumbar plexus nerves supplying the lower extremity.
1. Psoas muscle
2. Lateral cutaneous nerve of the thigh
3. Femoral nerve
4. Inguinal ligament
5. Femoral vessels (within their specific sheath)
6. Obturator nerve
7. Genitofemoral nerve
8. Iliac vessels

iliaca compartment" block. The present study was designed to evaluate prospectively the efficacy and reliability of this new technique and to compare it with the 3-in-1 block procedure in 120 pediatric patients. The study protocol received institutional approval as well as informed consent from parents. To reduce interindividual factors, all blocks were performed by the same anesthesiologist.

Material and Methods

Anatomic Considerations

The lower extremity is supplied by three nerves originating from the lumbar plexus which lies in the psoas compartment (3), within the substance of the psoas muscle. The *lateral cutaneous nerve of the thigh* (a sensory nerve) emerges at the upper part of the lateral border of the psoas muscle (Figure 1). It obliquely crosses the iliacus muscle, immediately posterior to the fascia iliaca, passes behind (or through) the inguinal ligament, and then divides into two terminal branches, which supply sensory innervation to the lateral aspect of the thigh. The *femoral nerve* (a mixed nerve) also emerges at the lateral border of the psoas muscle, runs posterior to the fascia iliaca in the groove formed by the psoas with the iliacus muscles, passes behind the inguinal ligament, and then enters the groin in the femoral triangle lateral to the femoral vessels (Figure 1). It supplies both sensory innervation to the ventral aspect of the thigh and the periosteum of the femur and motor innervation to the muscles of the front of the thigh. The *obturator nerve* (mixed, but mainly a motor nerve) emerges at the medial border of the psoas muscle (Figure 1), behind the common iliac vessels, from which it is separated by the fascia iliaca. It then reaches the obturator foramen, where it divides into two terminal branches that are then distributed to the thigh. An accessory obturator nerve may occasionally accompany the obturator nerve.

Two other lumbar plexus nerves also contribute sensory fibers to the upper part of the anterior aspect of the thigh: 1) the *ilioinguinal nerve*, which emerges at the lateral border of the psoas muscle, then crosses the quadratus lumbarum muscle obliquely, immediately posterior to its covering fascia until it reaches the iliac crest, where it pierces the transversus abdominis and the oblique muscles in the direction of the spermatic cord (in the male) or the round ligament of the uterus (in the female); and 2) the *genitofemoral nerve*, which perforates the psoas muscle, then runs on its anterior aspect (Figure 1), posterior to the fascia iliaca, in the direction of the inguinal ligament, where it divides in two terminal branches, genital and femoral, the latter supplying sensory innervation to the skin covering Scarpa's triangle.

Thus, the femoral, lateral cutaneous, obturator, and genitofemoral nerves run a considerable part of their course close to the inner aspect of the fascia iliaca. This complex fascia (3) is attached medially to the vertebral column and the upper part of the sacrum (Figure 2). Rostrally, it covers the psoas muscle and blends laterally with the fascia covering the quadratus lumbarum muscle. Caudally, it covers the iliacus muscle and is tightly attached to the inner lip of the iliac crest, and, medially, to the pelvic brim. The external iliac vessels are anterior to it, whereas the lumbar plexus nerves are posterior to it. At the groin, the fascia iliaca is continuous with the posterior margin of the inguinal ligament. Medially, it passes behind the femoral vessels (which are enclosed in a common sheath limiting a perivasculary space often referred to as the *lacuna vasorum*) and blends with the pectineal fascia which attaches to the pecten pubis (Figure 3). At this level, it also derives fibers towards the capsule of the hip: these fibers form a septum, usually incomplete, which reinforces the division between the femoral nerve (wrapped in its specific sheath) and the lacuna vasorum within which run the femoral vessels.

More caudally, at the level of the femoral triangle the fascia iliaca becomes narrow. Laterally, it attaches to the anterior superior iliac spine and then blends with the fascia covering the sartorius muscle. Medially, it is continuous with the pectineal fascia. It is covered by the fascia lata and it forms the roof of a fat-filled space, sometimes referred to as the *lacuna musculorum* (adjacent to the lacuna vasorum).

Finally, the fascia iliaca delimits a potential space, the "fascia iliaca compartment," triangular in shape (Figure 2). The limits of this compartment are:

1) anteriorly, the inner aspect of the fascia iliaca, which covers the iliacus muscle and reflects medially, thus covering the dorsal, then lateral, then ventral, and then medial aspects of the psoas muscle;
2) posteriorly, the outer aspect of the iliacus muscle;
3) medially, the vertebral column and the upper part of the sacrum; and
4) rostrally and laterally, the inner lip of the iliac crest to which the fascia is tightly attached (rostrally and medially, the space is continuous with that comprised between the quadratus lumbarum muscle and its covering fascia).

Below the inguinal ligament this space is continuous with the lacuna musculorum, covered by the fascia iliaca, the fascia lata, and then the skin covering the femoral triangle. Injecting a sufficient amount of a solution in the lacuna musculorum and favoring its upward migration towards the iliacus muscle should result in a spread of the solution within the entire fascia iliaca compartment, thus allowing all the structures (especially the nerves) traversing this space to be contacted by the solution.

Patients

One hundred twenty patients, 78 males and 42 females, were included in this study after informed consent had been obtained from parents and, as often as possible, from the children themselves. The patients ranged in age from 0.7 to 17 years and in weight from 7.3 to 79 kg. They all underwent surgery of the lower extremity, including 43 emergency procedures (Table 1). They were randomly allocated to one of two equal groups differing from one another in the blocking procedure used: 3-in-1 block in the 60 patients of group 1, and fascia iliaca compartment block in the 60 patients of group 2.

Methods

Anesthetic methods. All procedures were carried out in operating rooms after insertion of a peripheral venous line. Twenty-six patients were kept alert and were given no drugs other than local anesthetics. Children given general anesthesia in addition to regional anesthesia were given 0.02 mg/kg atropine and 0.1 mg/kg diazepam; as usual in our pediatric unit (4,5), anesthesia was then induced using either halothane in 35% O_2/65% N_2O or intravenous thiopental (4 mg/kg) as preferred by the patients, and maintained using halothane 0.25% to 0.5% in 35% O_2/65% N_2O.

Two needles connected to a plastic extension catheter ("immobile" needles [6]) were used: 1) 50-mm-long 22-gauge insulated needles (Top needles) in group 1, and 2) 50-mm-long 24-gauge short bevel needles (Plexufix from Braun) in group 2. A nerve stimulator (Myotest from Datex), adjusted to deliver 1 mA impulses every second, was used in all patients in group 1. All patients were given the same anesthetic solution consisting of a mixture of 1% lidocaine with 0.5% bupivacaine, both with 1:200,000 epinephrine. The volumes of local anesthetic injected were

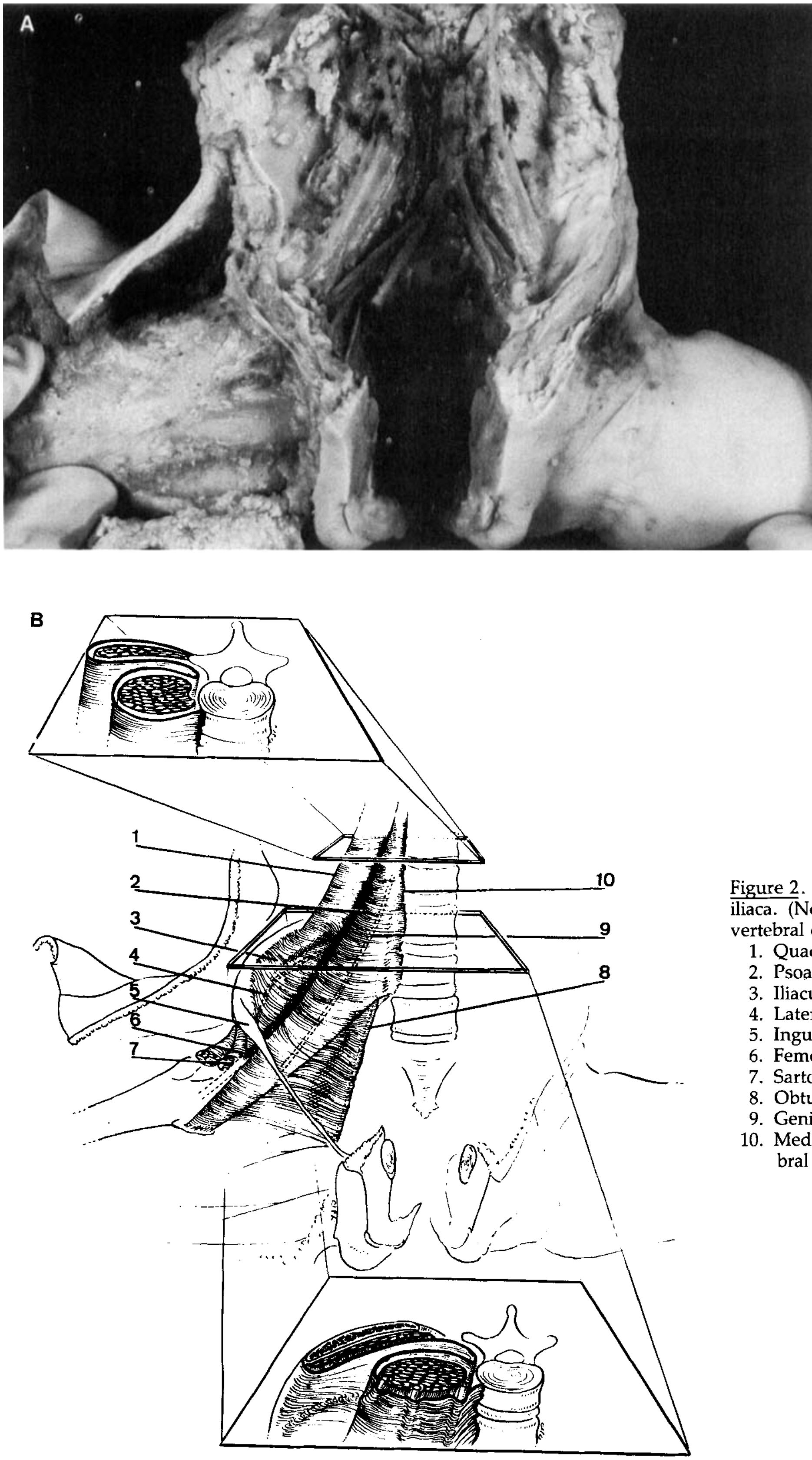

Figure 2. Diagrammatic representation of the fascia iliaca. (Note the reflection of the fascia close to the vertebral column.)
1. Quadratus lumbarum muscle
2. Psoas muscle
3. Iliacus muscle
4. Lateral cutaneous nerve of the thigh
5. Inguinal ligament
6. Femoral nerve
7. Sartorius muscle
8. Obturator nerve
9. Genitofemoral nerve
10. Medial attachment of the fasia iliaca to the vertebral column and upper part of the sacrum

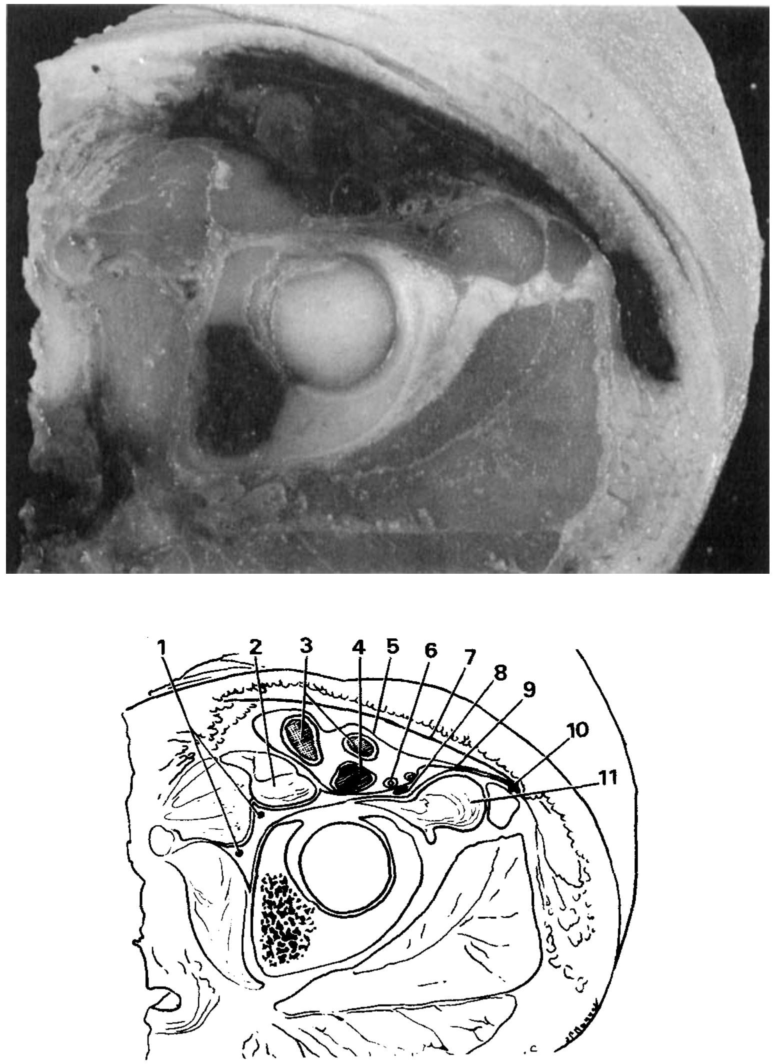

Figure 3. Transverse section at the root of thigh.

1. Division branches of the obturator nerve
2. Pectineal muscle
3. Femoral vein
4. Femoral artery
5. Fascia lata
6. Lacuna vasorum
7. Division branches of the lateral cutaneous nerve of the thigh
8. Femoral nerve
9. Psoas muscle
10. Lacuna musculorum

Table 1. Surgical Indications in Two Groups of Patients Anesthetized by 3-in-1 Block (Group 1) or Fascia Iliaca Compartment Block (Group 2)

Indication	Group 1	Group 2
Fracture of the femur	19	17
Surface operations of the thigh (wounds, skin grafts, abscesses)	11	9
Removal of implants and biopsies of the femur	15	10
Operations necessitating the placement of a tourniquet at the thigh	11	21
Slipped capital femoral epiphysis	4	3

calculated on weight basis in both groups: 0.7 mL/kg for children weighing less than 20 kg, 15 mL for those weighing 20 to 30 kg, 20 mL for 30 to 40 kg children, 25 mL for those 40 to 50 kg in weight, and 27.5 mL for those weighing over 50 kg.

Blocking procedures. A modification of the 3-in-1 block (1) using electrical stimulation for precise nerve location was used in group 1. With the patients in the supine position, the site of puncture was marked on the skin 0.5 to 1 cm below the inguinal ligament and lateral to the femoral artery. The block needle was advanced in a sagittal plane at a 30° angle to skin, pointing rostrally, until muscle twitches were elicited in the quadriceps femoris muscle. Then finger pressure was applied "gently but firmly just distal to the needle" (1) before injection, to force the anesthetic upwards. After the needle had been withdrawn, the finger pressure was maintained for a few minutes while the area was massaged to favor upward diffusion.

The technique of the fascia iliaca compartment block used the same dorsal recumbent position for the patients. A projection of the inguinal ligament was drawn on the skin from the pubic tubercle to the anterior superior iliac spine and divided in three equal parts. The site of puncture was marked 0.5 cm caudal to the point where the lateral joined the two

Table 2. Distribution of Anesthesia

Anesthesia	Femoral nerve		Lateral cutaneous nerve		Obturator nerve		Genitofemoral nerve[a]	
	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2
Complete								
Sensory	60	60	9	55[b]	8	53[b]	10	55
Motor	8	1	[c]	[c]	[d]	[d]	[a]	[a]
Incomplete								
Sensory	0	0	3	4	1	5	1	2
Motor	39	22[b]	[c]	[c]	[d]	[d]	[a]	[a]
Absent								
Sensory	0	0	48	1[b]	51	2[b]	49	3
Motor	13	37[b]	[c]	[c]	[d]	[d]	[a]	[a]

[a]Femoral branch of the genitofemoral nerve providing sensory supply to Scarpa's triangle.
[b]Significant difference when compared to group 1.
[c]The lateral cutaneous nerve of the thigh is a sensory nerve.
[d]The clinical test used for testing motor blockade did not allow definitive conclusions regarding the obturator nerve.

medial thirds of this line. The needle was inserted at a right angle to the skin while gentle pressure was exerted on the barrel of a syringe filled with the local anesthetic and connected to the block needle. A first "give" followed by a loss of resistance was felt as the tip crossed the fascia lata. The needle was advanced further until another "give" and another loss of resistance was felt as the fascia iliaca was pierced: the anesthetic solution was then injected, at the same time exerting a firm compression immediately caudal to the needle to favor the upward spread of the anesthetic. After the needle had been withdrawn, the swelling in the groin was firmly massaged to improve rostral diffusion of the local anesthetic within the fascia iliaca compartment.

Monitoring procedures and evaluation of anesthesia. Electrocardiogram tracings, respiratory rate, and blood pressure (Dinamap) were monitored during all procedures. Tidal volume, end-tidal CO_2, and halothane concentration were continuously monitored in patients given general anesthesia.

The blocking procedure was considered successful when the lateral, ventral, and medial aspects of the thigh were anesthetized permitting the scheduled surgical procedure to be completed on a motionless patient without any additional treatment. The extent of analgesia was evaluated in both groups at the end of the surgical procedure by skin pinching. Anesthesia was considered complete when no reaction or complaints of pain occurred during application of the nociceptive stimulus. It was considered incomplete if the patient either complained a little of pain or had motor responses not observed after pinching of adjacent areas.

Motor blockade was evaluated at the end of the operation in both groups, either by asking the patient to move his or her leg and/or by applying nociceptive stimuli aimed at eliciting withdrawal movements. (This crude evaluation was suitable for testing the quadriceps femoris muscle, supplied by the femoral nerve, but it did not permit conclusions regarding the function of the adductors of the thigh, supplied by the obturator nerve.)

The duration of the sensory block was measured as the time between injection and the first evidence of pain (complaints of pain; crying; grimacing; restlessness; or autonomic responses such as tachycardia, hypertension, or sweating) occurring either spontaneously or with hourly assessments using skin pinching of the ventral aspect of the thigh (supplied by the femoral nerve).

Statistical methods. Data from the two groups were compared using both parametric (Student's *t*-test) and nonparametric (Mann–Whitney test) tests. Qualitative parameters were evaluated using chi-square test. Differences were considered statistically significant at level $P < 0.05$.

Results

Patients in the two groups did not differ significantly with regard to age, weight, surgical indications, or gender. The same 2:1 predominance of males was seen in both groups.

Group 1 (3-in-1 Block)

The femoral nerve was located in every case on the first attempt in 51 procedures. In nine patients, a second attempt had to be made due to reflux of blood into the syringe (arterial in three, venous in two)

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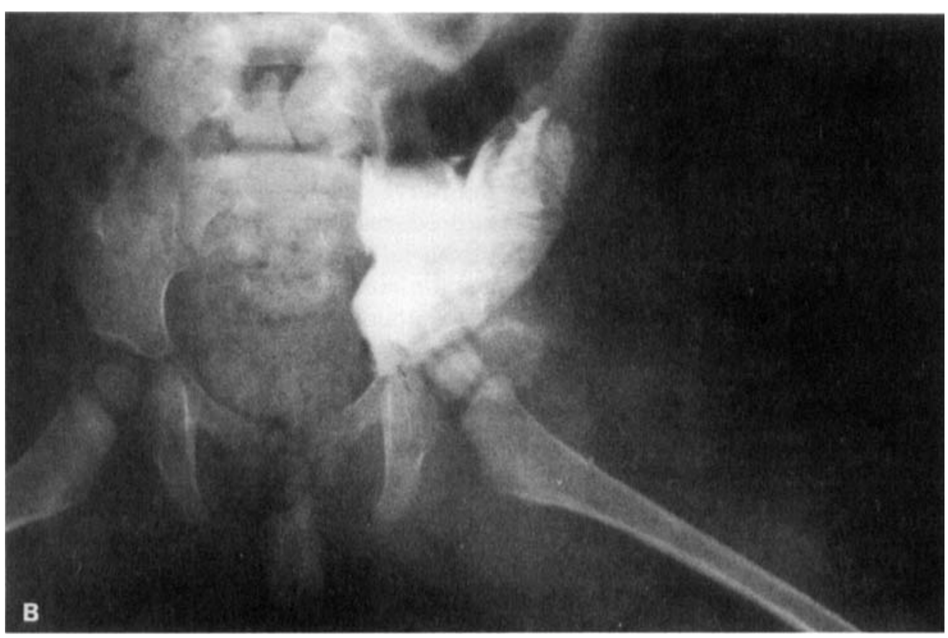
Figure 4. Spread of a solution containing contrast media (data from patients not included in the study protocol). (**A**) 3-in-1 block. Note that the solution does not reach the psoas compartment where the lumbar plexus lies. (**B**) Fascia iliaca compartment block. Note the spread of the solution along the anterior aspect of the iliacus muscle and the medial increase in opacity, probably due to superimposition resulting from the reflection of the fascia iliaca compartment covering successively: 1) the anterior aspect of the iliacus muscle, then 2) the posterior, and 3) the anterior aspects of the psoas muscle.



upon initial insertion of the needle or misplacement of the needle (absence of muscle twitches in four). During injection, swelling in the groin occurred in 11 patients. All patients developed a femoral block, but the procedure was totally successful only in 12 children, including the 11 individuals who developed swelling in the groin. The spread of the anesthetic solution when no swelling had occurred is shown in Figure 4A. The distribution of sensory and motor blockades is shown in Table 2. There were no complications, and postoperative pain relief lasted 6.2 ± 1.4 hours.

Group 2 (Fascia Iliaca Compartment Block)

The two characteristic "gives" resulting from the crossing of the needle through the fascia lata and then through the fascia iliaca were felt on the first attempt in 59 patients, and on the second attempt in one child. Swelling in the groin occurred in 59 patients, and the block procedure was successful in 55. The spread of the local anesthetic is shown in Figure 4B. The one patient who did not show any swelling in the groin developed a femoral nerve block only. The distribution of anesthesia is shown in Table 2: motor blockade of the femoral nerve developed less often in group 2 than in group 1 (a statistically significant difference [$P < 0.05$]), whereas sensory blockade of the lateral cutaneous, obturator, and the femoral branch of the genitofemoral nerves occurred more often (also statistically significant [$P < 0.05$]). No complications were observed and postoperative pain relief lasted 5.0 ± 1.3 h (significantly less than in group 1 [$P < 0.05$]).

Discussion

The fascia iliaca compartment block proved to be easy and free of adverse effects. The technique resulted in blocking the three main lumbar plexus nerves supplying the thigh in more than 90% of procedures and did not require expensive materials or unusual skills. On the other hand, the use of a nerve stimulator did not improve, and even worsened, the results of the 3-in-1 block procedure (1). These poor results were not due to misplacement of the needle since a femoral block developed in all patients, as confirmed by the spread of the local anesthetic within the perifemoral nerve sheath (Figure 4A). While suspecting the importance of the fascia iliaca, Winnie et al. (1) suggested that the local anesthetic injected within the femoral nerve sheath could spread upward, thus reaching the lumbar plexus, within the psoas compartment, and then spreading backward along the lateral cutaneous and obturator nerves. In their paper, the authors included radiographs taken after the injection of contrast material, but as seen in Figure 4A, the local anesthetic does not extend out of the pelvis and does not reach the psoas compartment. Furthermore, in our experience of lumbar plexus blocks (7), we did not observe any spread of anesthetic solution from within the psoas compartment, where the solution was directly introduced, towards either the femoral, lateral cutaneous, or obturator nerve. Thus, the hypothesis of Winnie et al. (1) is not supported even by their own data, and another explanation has to be found to explain why, in a number of patients, three separate nerves can be blocked by a single injection of a local anesthetic. In our group 1, 11 of the 12 patients with a block of the lateral cutaneous nerve developed swelling in the groin during injection. Our hypothesis is that these patients were, in fact, actually given a fascia iliaca compartment block and we think that at least in most cases, the 3-in-1 block is successful when the tip of the needle does not lie within the perifemoral nerve sheath, but outside of it (even if still very close to it), within the fascia iliaca compartment. Confirmation of this hypothesis can be found in the development of inadvertent 3-in-1 blocks following various peripheral nerve blocks at the thigh, such as lateral cutaneous nerve blocks (8,9). Since using a nerve stimulator improves the accuracy of the location of the femoral nerve, it may be expected that the tip of the block needle is inserted in and stays within the perifemoral nerve space (limited by the femoral nerve sheath) more often than after a blocking procedure eliciting paresthesias only. This may explain why the use of a nerve stimulator did not improve the distribution of anesthesia in group 2 but even worsened it.

Whereas the distribution of analgesia was significantly improved by using the fascia iliaca compartment block technique, the duration of postoperative pain relief was significantly reduced (by approximately 1 h). This may be due to the more extended spread of the local anesthetic to the vicinity of highly vascularized tissues (especially the iliacus muscle) as compared to the spread following a 3-in-1 block within the perifemoral nerve space, a space with a relatively poor venous drainage. Thus, the probably higher vascular uptake after fascia iliaca compartment blocks may account for the decrease in duration of postoperative analgesia.

In conclusion, the fascia iliaca compartment block technique is easy, reliable, and provides a high degree of sensory blockade of the lumbar plexus nerves that supply the thigh using reasonable amounts of local anesthetic. This technique requires neither unusual skills nor expensive devices, and it does not threaten any vital organ. We believe that this technique can be recommended for use in children.

We thank Professor Ven Murthy, Laval University, Québec, Canada, for considerable help in reviewing the manuscript, and J.P. Monnet and Y. Harmand for technical assistance in the preparation of illustrations.

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