

## **Intraosseous Regional Anesthesia as an Alternative to Intravenous Regional Anesthesia**

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**A series of 109 orthopedic operations was performed under intraosseous regional anesthesia on the upper and lower limbs. Anesthesia was satisfactory in 106 of the cases; in the other three, inadequate anesthesia was caused by faulty technique. The spread of lidocaine into the bone and venous network was demonstrated by radiography, and the blood levels after tourniquet release were below the toxic level. Intraosseous regional anesthesia proved to be a valuable technique to be used whenever intraosseous anesthesia fails or is not feasible. Injection into cancellous bone (osteoclysis) is easily and quickly performed under aseptic conditions, and there were no systematic complications.**

The intraosseous regional anesthesia technique (IRAT) is an accepted and useful method of anesthesia in operations of the upper and lower limbs. This method is especially useful in some elective surgeries, emergencies, nonfasting patients, and other cases in whom general anesthesia is not possible, as well as the known advantages of regional anesthesia that bypass the advantages and dangers of general anesthesia.<sup>1-3</sup> It is important for patients to be fasting before general anesthesia, and it is advisable to postpone the operation if the patient is not fasting, if possible. There are, however, urgent cases that cannot be postponed, and in these cases regional anesthesia is preferable.

The IRAT is especially difficult to perform in operations of the lower limbs, but also in injuries to the upper limbs. As an alternative method, we found that the intraosseous regional anesthesia (IORA) (i.e., a drip of lidocaine to the epiphysis or metaphysis of the bones) causes the anesthetic material to disperse into the tissues, similarly to intravenous perfusion. Using a small trocar, such as a sternal stabbing needle or the bone injection gun (T.E.I.C., Science Park, Technion-Nesher Ltd.) (Fig. 1), it is possible to infuse fluids into spongy bone in the epiphysis or the metaphysis of the upper and lower limbs in adults.

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Experiments on five dogs, weighing 8 to 10 kg, were conducted. They were anesthetized with halotane for practical experimentation in intraosseal saline infusion at the epiphysis of the tibia. Three adult cadavers were used for practical purposes of intraosseal infusion. Contrast media was injected to demonstrate, on x-ray film, the mode of distribution of the fluids from the metaphyseal spongy bone through the

intraosseal venous sinusoids to the venous network of the limb, draining to the systematic circulation.

We found that the best sites for intraosseous infusion were: the *upper limb* – the distal radial metaphysis; and the *lower limb* – the proximal tibial epiphysis or metaphysis, the medial malleolus, and the distal epiphysis of the first metatarsus.

**FIG 1. Use of the IORA technique before arthroscopic surgery.**

## MATERIALS AND METHODS

Patients were adequately sedated according to their medical condition. In cooperative patients, light sedation with midazolam (0.075 mg/kg) was used. In other patients complaining of pain, morphine (0.1 mg/kg, IV body weight) was added. In our opinion, other kinds of sedation can be used successfully, such as propofol drip (100 to 200 µg/kg/minute) after an initial bolus of 2.5 mg/kg. After choosing the site for injection, the skin is disinfected with povidone-iodin solution and, using surgical gloves, 2 to 4 mL of 1% lidocaine is infiltrated in the skin and subcutis (including the periosteum). After several seconds, the skin is stabbed with the edge of a blade for insertion of the trocar needle, without contact with the skin. The trocar is inserted using rotating movements, and the needle can be left passing through the cortical bone and reaching a soft and hollow area, the spongy bone area. In case of using the bone injection gun, an impact insertion of the trocar needle through the skin is performed.

Impact insertion of a needle into a spongy bone is almost painless, although initiation of the injection of the anesthetic fluid causes pain (intraosseal pain receptors) that passes after 1 minute. It is therefore recommended to withdraw 2 to 4 mL of bone marrow by aspiration and to inject 2 to 4 mL of 1% lidocaine slowly into the bone marrow. Immediately after this procedure, the trocar needle is covered with a sterile napkin. The limb is lifted and an elastic Esmarch bandage is rolled to exsanguinate the blood from the limb vessels in a distal-proximal direction. A tourniquet is then inflated in adults to 250 to 300 mm Hg pressure to the upper limb and 350 to 400 mm Hg pressure to the lower limb. The elastic bandage is removed, and injection of the anesthesia is commenced. At first, there is a certain resistance to the flow of the fluid, but this eases rapidly, and the flow becomes swift. After injection of the anesthetic material, the trocar can be removed after several minutes, but it can also be left in place for the addition of anesthetic material in cases of “continuous IORA”.

It is recommended that 40 to 50 mL of 0.5% lidocaine be injected into the bone of the upper limb in cases using a proximal tourniquet on the arm and 20 mL in cases using a distal tourniquet on the forearm. To the lower limb, 40 to 50 mL of 0.5% (3 mg/kg body weight of a 0.5 solution) lidocaine was injected in cases using a distal tourniquet on the leg and 140 mL of 0.25% lidocaine in cases using a proximal tourniquet above the knee.

In operations wherein a tourniquet was in place on the arm or thigh, a double tourniquet was necessary; if the proximal part of the tourniquet causes problems after 20 to 30 minutes, it could be replaced with the distal part of the tourniquet. In cases wherein the tourniquet was placed on the forearm or calf, there was no need for a double tourniquet, and the single tourniquet caused no discomfort.

In control tests of this tourniquet, the lidocaine level 5 minutes after release of the

tourniquet was 1.97  $\mu\text{g}/\text{mL}$  [i.e., below the toxic level of lidocaine (8  $\mu\text{g}/\text{mL}$ )]. There were no immediate or late complications, either local or general, in any of the cases where we used IORA.

In four cases of IORA, blood samples were taken to measure the lidocaine level before injection, during the operation, and after release of the tourniquet (1, 5, 30, and 60 minutes). The curves obtained were similar to those observed in four cases of IRAT that was performed for comparison.

## Results

One hundred and nine orthopedic procedures (Table 1) were performed on limbs using IORA, 84 of which were elective procedures and 25 were urgent cases.

We conclude that, in adults, 40 to 50 mL of 0.5% lidocaine supplies full anesthesia and good relaxation of the upper limbs. In the lower limbs, the IORA should be conducted with a large amount of 0.25% lidocaine (140 mL), an approximate total of 300 to 350 mg lidocaine, including the initial subcutaneous and periosteal injection in the lower limbs. For knee joint operations, such as arthroscopy or meniscectomy, it is essential to inject 10 mL of 0.25% lidocaine into the knee joint, to the IORA injection.

Among the 109 patients in whom we used IORA, there were three failures, all in the lower limbs, for the following reasons:

1. In one patient, lidocaine was injected extraosseously. This was proven in lidocaine levels in the blood after removal of the tourniquet, which was 0 after 5 minutes and 0.7  $\mu\text{g}/\text{mL}$  after 30 minutes. This curve is similar to subcutaneous or intramuscular injection.
2. The other failures were one in diagnostic arthroscopy and one in arthroscopic meniscectomy, in which the tourniquet was on the thigh and only 80 mL of 0.25% lidocaine was injected.

These failures were not noted in our cases, in which we diluted the lidocaine in a large quantity of fluids (140 mL saline) in low concentration (0.25%) so they would not reach a toxic dose in the case of absorption of lidocaine into the blood stream.

**TABLE 1. Limb surgery classification**

Type of operation	Number of	Average	Male	Female
	Patients	Age		
Colles' fracture (ORIF)	13	54	2	11
Hand surgery	21	35	10	11
Fracture-dislocation of the forearm And elbow (ORIF)	7	42	3	4
Arthroscopic surgery of the knee	24	33	19	5
Hallux valgus, hallux rigidus Surgery	33	58	9	24
Fracture-dislocation of the foot (ORIF)	4	32	3	1

Fracture-dislocation of the ankle (ORIF)	7	49	2	5
Total	109			

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ORIF, open reduction-internal fixation.

## DISCUSSION

There is no need to stress the preference for IRAT over general anesthesia in limb surgery.<sup>4-6</sup> The IRAT is easy to administer, achieves full muscular relaxation that allows any surgical procedure to be performed, provides a nonbleeding operation field, and produces rapid limb recovery after release of the tourniquet, especially lack of the many complications that are observed in general anesthesia. Although this technique cannot be used in many nonelective procedures (such as injuries with tissue swelling, burns, and cases in which it is difficult to locate veins in the limbs in suitable locations), this is a problem that is more pronounced in the lower limbs.

In the anatomic search for suitable locations for osteoclysis (intraosseous infusion), several locations were found in which the insertion of a small trocar was performed without undue effort, in which infusion of fluids into the spongy bone was performed relatively easily (Fig. 2 and 3). Spread of the fluids was conducted from the spongy bone and bone marrow via the venous system that drains from the bone to the venous network of the entire limb.

The experiments were performed on dogs and cadavers; contrast material was injected and x-ray films were taken to prove dispersal of the material to the body tissues (Fig. 4 and 5). Bone marrow injection of anesthetic material is possible even at a broken bone (closed fracture), provided the needle is inserted distally or proximally from the fracture. Surprisingly, the benefit of the lidocaine spreads easily to the venous network of the limb and less to the hematoma around the fracture as well (Fig. 6). We achieved an adequate anesthesia before surgery in the entire limb, including the fractured bone, up to the tourniquet, in all of our trauma cases in the same mode of action as the IRAT (Table 1). The selected bone metaphysis or epiphysis for intraosseal anesthesia injection must be distal to both the tourniquet and the least one articulation. In several cases of excruciating pain at the fracture site, the limb was partially exsanguinated by elevation for 3 minutes only before inflation of the tourniquet.

The phlebography intraosseous technique is well known in the orthopedic literature for the purpose of diagnosis and prognosis in healing of fractures of the long bones.<sup>7-9</sup>

Since the introduction of the IRAT by Holmes<sup>10</sup> in 1963, after modification of Bier's<sup>11</sup> original technique (in 1908), only two changes have been made to improve the technique: introduction of the double tourniquet by Hoyle<sup>12</sup> in 1964; and introduction of a catheter into the suitable vein through which anesthetic material is added in extended surgical procedures of the limbs (continuous IRAT), which was described by Beown and Weissman<sup>13</sup> in 1966.

The anesthetic technique for limbs by introsseous novocaine injection was familiar in Russia.<sup>14, 15</sup> After the experience and knowledge we acquired with osteoclysis, we used the regional anesthetic technique in the injection of lidocaine into the spongy bone by the IRAT principles. In elective surgery, it is desirable for the patient to be fasting, well-sedated, and fully monitored before the use of this technique.

We believe that the IORA method will have a place of honor in the limb surgery in the near future. The method is especially suitable in lower limb surgery, not only in traumatology, but also in elective surgery, such as foot surgery, arthroscopies, plastic surgery, oncologic surgery, and in cases where it is difficult to perform IRAT to the upper limbs.

**FIG 2. Recommended locations for intraosseous injection into the upper limb: distal end of the radius, distal head of the ulnar bone, and the distal head of the second metacarpus.**

**FIG 3. Recommended locations for intraosseous injection of the lower limb: medially to the tibial tuberosity, distal head of the first metatarsus, and proximally to the medial malleolus.**

**FIG 4. Injection of contrast material to the distal head of the ulnar bone that demonstrates immediate distribution of the material via the spongy bone into the venous blood vessels and portrayal of the venous network of the upper limb.**

**Fig. 5 Injection of contrast material to the distal head of the first metatarsus, showing immediate distribution of the material via the spongy bone to the venous blood vessels and portrayal of the venous network to the lower limb.**

**Fig. 6 Closed fracture of the radius (Colles' fracture). Spread of the anesthetic fluid is demonstrated by "urografin"-schering (diatrizoate methylglucamine solution; 10 mL, 60%) injection into the bone marrow in the metaphysis of the same broken bone.**

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