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Review article

Surgical technique and indications of the induced membrane procedure in children

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ABSTRACT

The induced membrane technique is now quite adaptable to segmental bone reconstruction in children. This technique is much the same as the technique used in adults. A cement spacer is interposed, and in a second operating phase, occurring 6 weeks after the interposition of the spacer, the cement is removed and a morselized corticocancellous graft is installed in the induced membrane that had formed around the cement. Graft expansion using allograft chips should not exceed 30% of the total volume. An additional autograft strut is useful in the reconstruction of long femoral or metaphyseal–diaphyseal tibial defects. Despite the apparent simplicity of this technique, it requires rigorous technique during cement sleeving and to stabilize the defect to prevent nonunion, stabilization device loosening, or resorption of the graft, the main complications. This technique is now becoming the gold standard for bone reconstruction in trauma and septic bone surgery. In pediatrics, the Masquelet technique is now mainly used in the context of cancer surgery reconstructions. Constraints related to chemotherapy have led to deferral of the graft, which is therefore empirically performed 8 weeks after the last course of chemotherapy. Congenital anomalies, including congenital pseudarthrosis, may now be treated using this technique, replacing long and difficult conventional treatment. A longer follow-up would be necessary to assess and confirm the superiority of this pediatric reconstruction technique.

1. Introduction

The induced membrane technique, initially described in adults by Masquelet [1,2], has become a reference technique in children in segmental bone reconstruction [3] and makes it possible to reconstruct long bone substance loss up to 30–50% of the total bone length. The ease of shaping bone in children and their bone union capacity has made this a first-choice technique in the classic indications of septic pseudarthrosis and traumatology. However, it is in cancer surgery reconstruction and in congenital pathology that the induced membrane technique has found its greatest utility in pediatrics [3–6]. Despite its apparent simplicity, it requires rigorous surgical technique to prevent a certain number of now well-known complications that can occur, most importantly junctional pseudarthrosis. This article presents the induced membrane technique adapted to children as well as the considerations to be taken into account to prevent the usual complications encountered. Finally, the main indications in children are discussed.

2. Surgical technique

Whatever the indication and despite its apparent facility, the induced membrane technique requires technical rigor, the guarantee of success. This technique allows reconstruction of segmental bone loss in two surgical stages (Fig. 1). A thick membrane reacting to a foreign body forms around the cement spacer interposed during the first surgical procedure. This membrane acts as a true biological chamber that will contain and protect the graft from resorption and stimulate bone regeneration (second surgical phase).

2.1. First surgical phase

The conditions for performing the first surgical procedure depend on the pathology treated. This initial stage of the induced membrane technique can be performed in urgent care in traumatology or within prescheduled management in children who sometimes present a weakened state, most particularly in cancer surgery. This first stage should respect a certain number of rules that condition the success of the reconstruction planned.

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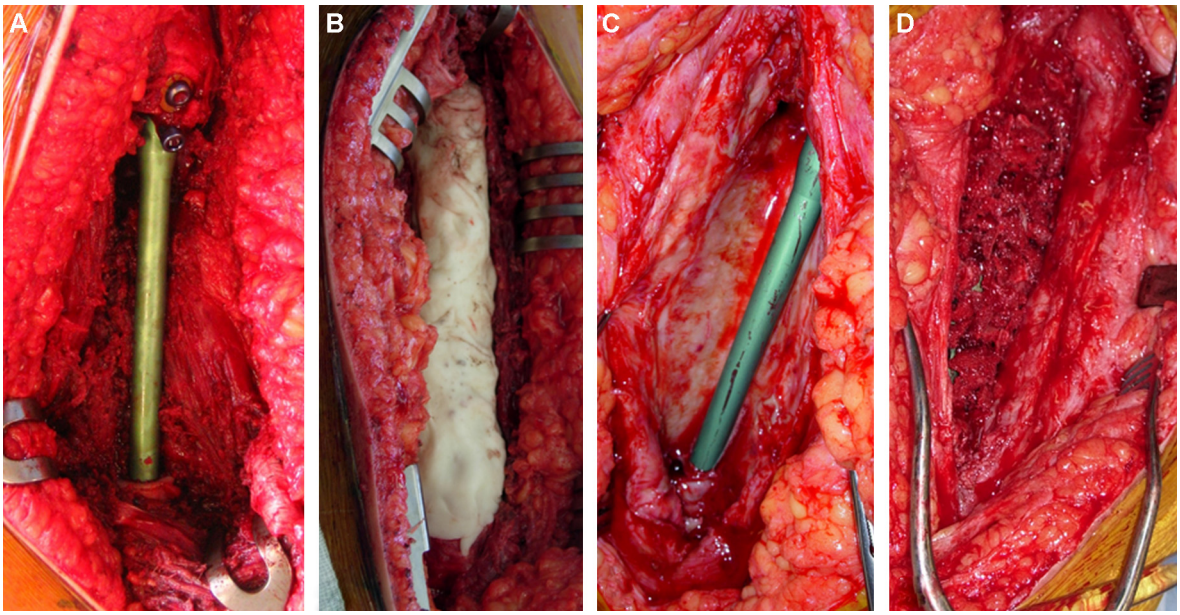

Fig. 1. Induced membrane technique in two surgical phases. Reconstruction of 11.5 cm of bone loss in a course of treatment for Ewing sarcoma of the femur. Subtrochanteric tumor resection and stabilization with intramedullary nailing (A). Interposition of surgical cement spacer (B). Second surgical phase consisting of removal of cement, leaving a cavity covered with an induced membrane (C) forming a true biological chamber ready to receive the morselized graft material (D).

2.1.1. Bone loss

The surgeon is sometimes confronted with bone loss. The bone loss area should in all cases be cleaned of any necrotic or infected component. Any devascularized bone should be excised. The residual bone extremities should be within a healthy and well-vascularized area. Careful attention must be paid to the muscle and fasciocutaneous environment: it would be inconceivable to consider segmental reconstruction if the coverage and environment are not optimal. The first surgical procedure is not so much a debridement procedure as the initial phase of the multi-tissue reconstruction. It will therefore be necessary to add a local flap or free flaps to this stage to optimize the reconstruction conditions.

2.1.2. Bone stabilization

Mechanical stability is an essential factor in successful reconstruction. It depends of course on the bone segment and the length of bone to reconstruct. The most advantageous is plate stabilization with interlocking screws in most locations, assuming that skin coverage is sufficiently thick and healthy so that no risk of material exposure is taken. This type of stabilization is particularly indicated in metaphyseal and epiphyseal bone using a T-plate. For more substantial bone loss, particularly in the tibia or the distal humerus, double stabilization using a medial and lateral plate can be provided. In adolescents, when the growth plates are closed, interlocking intramedullary nailing is undoubtedly the most rigid stabilization method and in the long term will allow weight-bearing more quickly. Stabilization in the very young child remains problematic [3] and can be entrusted to intramedullary nailing or sometimes telescopic transphyseal nailing. Nevertheless, the fixation method is not sufficiently stable for reconstruction in good conditions and adding immobilization in a cast is recommended after the second surgical phase. The cement installed in bone loss around the nails provides sufficient primary stability for the assembly after the first surgical procedure, thus making cast immobilization unnecessary between the two procedures.

The local conditions or urgent care management sometimes require external fixation. The choice of the type of external fixation is of course sometimes imposed by the fracture, i.e., the damage to the diaphyseal or metaphyseal-epiphyseal area of the bone segment involved. Nevertheless, it seems that a circular external fixator, which fosters compressive stresses and prevents shear stresses, is more favorable for an induced membrane reconstruction technique than a single-plane external fixator [3,7]. Shear stresses do not foster union of the proximal or distal bone graft junctions. On the other hand, it is possible to modify the type of external fixator when grafting is undertaken or during bone union if restructuring bone and densification of the graft are insufficient.

2.1.3. Placement of the cement spacer

The cement spacer cannot be placed until after adapted bone stabilization. From the beginning, the surgical cement available in all orthopaedic operating rooms has been used. It is composed of several substances: the main one, polymethylmethacrylate, is a powder and a solvent, which, when mixed, give a malleable paste within a few minutes, which can be molded on demand and hardens in approximately 10 min through exothermic polymerization. In Masquelet's experience in septic bone surgery, the cement used is not impregnated with antibiotics. The cement spacer thus plays the role of bacteriological surveillance where antibiotics would conceal a rampant infection [8]. Others use a cement with gentamycin in the same indications [9] or to protect the surgical site from infection, most particularly in weakened patients who have undergone chemotherapy.

The site should be prepared before interposing the cement. One should plan for a cement placer that is more voluminous than the bone to reconstruct, covering the bone extremities as smoothly as possible so that the future membrane can be detached easily. An interface between the soft tissues and the area to reconstruct is put in place. This can be a piece of a surgical glove [8] or, even better, a half 50-cc syringe cut longitudinally and opened, which will provide a true mold for the cement [3,10]. This mold should extend beyond the bone extremities to facilitate cement coverage. Several half-syringes sutured together can be placed in cases of substantial bone loss (Fig. 2). Finally, these molds can be opened out for metaphyseal reconstruction. Assistance can be provided by screws placed on the plate in the bone loss area to maintain the molds open. These screws will remain encased in the cement [3].