TECHNICAL NOTE

Harvest of cortico-cancellous intramedullary femoral bone graft using the reamer-irrigator-aspirator (RIA) ∗

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Summary The “Reamer-Irrigator-Aspirator” (RIA) is a device that provides continuous irrigation and aspiration during intramedullary reaming of long bones. The RIA system is first used to collect the reaming material from medullary cavities, a thick paste of finely morselized osseous particles containing significantly elevated levels of stem cells and growth factors as reported by quantitative analyses. The volume of bone graft material available from an adult femur corresponds to the amount of cancellous bone graft obtained from both the anterior and posterior iliac crests. The assembly and technicalities of the RIA system require a training period to prevent any femoral fracture, which appears to be the major RIA-related complication. The elective indications for RIA bone grafting are filling of bone defects in the epiphyseal and metaphyseal regions. Diaphyseal defects may also be managed using the RIA system provided the graft is placed in a constrained system (induced membrane) to prevent dispersal of the graft into the surrounding soft tissues and is aerated with a porous material to promote its revascularization. Other RIA indications include debridring intramedullary infections and reaming for intramedullary nailing of long bone fractures to reduce the risk of fat embolization. © 2012 Elsevier Masson SAS. All rights reserved.

Introduction

In the chapter of fracture healing and repair of diaphyseal segmental bone defects, the anterior and posterior iliac crests, the femoral condyles and the anterior tibial tubercle are the most conventional harvest sites for bone autografts. The use of reaming material from long bones, particularly the femur, significantly increases the amount...
of bone graft available in the treatment of non-unions and segmental bone defects but also preserves the conventional harvest sites. This specific harvest device wears the Anglo-Saxon acronym of Reamer-Irrigator-Aspirator (RIA). During the SoFCOT Symposium, the experiences of the first users were confronted. This article exclusively focuses on the design characteristics and harvest technique of the RIA system.

Principles of the system

The RIA device was originally designed as a simultaneous reaming, irrigation and aspiration system to reduce the intramedullary pressure, cortical heat generation and systemic effects of reaming during intramedullary nailing [1–4]. The RIA aspirate was analyzed and appeared to contain cancellous bone and osteoconductive cortical spicules loaded with biologically active substrate of osteogenic stem cells and osteoinductive growth factors [5–9]. This system has been widely used across the Atlantic as an autogenous bone graft harvester in the management of non-unions or bone defects [10–12].

Description of the device

The device incorporates a rigid reamer shaft surrounded by a flexible plastic tube that allows a dual irrigating and aspirating flow (Fig. 1). The reamer heads which diameter ranges from 12 to 16.5 mm in 0.5 mm increments, are attached to the reamer shaft. The reaming heads and irrigation-aspiration flexible tube are single-use. The whole assembly is placed over a guide rod previously inserted into the intramedullary femoral cavity; the locking mechanism and rubber joint allow connection to a low-torque high-speed driver. Gravity-flow irrigation of the canal is performed using a bag of normal saline during the reaming process; the reaming aspirate composed of bony particles and liquid material is trapped by a coarse filter located between the reamer and the vacuum source.

Harvest technique [13–16]

A meticulous preoperative planning is critical to determine the side to be harvested, the canal diameter at the isthmus of the femur and the intraoperative patient positioning. For a lower extremity graft, the homolateral femur is usually harvested except in case of severe osteoporosis induced by a prolonged lack of weight-bearing. The patient is positioned supine on a conventional radiolucent table (Fig. 2a). The canal diameter at the isthmus of the femur (the narrowest section of the intramedullary canal) should be meticulously determined. In the adult, a 15 mm reamer head does not significantly affect the femoral torsional strength [13]. The reaming head should not be oversized by more than 2 mm regarding the canal diameter at the isthmus of the femur as measured on a radiograph with no magnification.

![Figure 1](image-url)  
**Figure 1** The Device: a: the reamer head; b: the reamer head is locked to the reamer shaft; c: the Reamer-Irrigator-Aspirator (RIA) system components: two reamers of different lengths and the graft collection filter to capture the reaming material. In the background, the plastic tube, which ensures proper sealing of the device for both irrigation and aspiration; d: intraoperative assembly of the whole device. The motor has to be connected.
The general technique is similar to that of intramedullary nailing preparation. The leg is adducted with the pelvis slightly elevated by a firm cushion. The tip of the greater trochanter is identified in the coronal plane under fluoroscopic control and a short incision is made just proximally. The tip of the greater trochanter is perforated manually then the guide rod is advanced down the intramedullary canal up to the condylar region (Fig. 2b). The guide rod should be positioned concentrically in the canal to avoid cortex overthinning with the reamer shaft. The guide tip is slightly curved so as to be directed toward one of the two femoral condyles for epiphyseal cancellous bone collection. The epiphyseal region may thus be harvested by modifying the orientation of the guide tip [14]. Confirm guide rod positioning under fluoroscopy throughout the procedure. Antero-posterior views must be obtained to prevent any anterior mispositioning. Two or even three different reamer head sizes should be used. A 12 mm reamer head might be necessary to adapt the trochanteric region and "test" the intramedullary canal in thinner femurs. Then, a larger reamer head is progressively advanced down the intramedullary canal in an alternating advance and withdraw motion with short breaks to achieve optimal irrigation-aspiration [15]. Indeed, the reamer advancement appears to reduce irrigation and increase aspiration. Breaks during the reaming process increase irrigation, which dilutes the bony particles and facilitates aspiration. Rapid and large conventional reaming movements should be avoided since it may reduce the irrigation flow and prevent proper aspiration due to graft density. A good expertise of the technique is required to minimize heat generation and the likelihood of incarcerating the reamer head. The filtrate is collected several times by stopping the reaming process to prevent the flexible tube surrounding the reamer shaft from blocking and avoid excessive graft irrigation [16]. Moreover, aspiration should be interrupted when reaming is stopped to prevent blood loss.

Bone graft may be harvested from the trochanteric metaphyseal region, the diaphysis and the distal metaphyseal and epiphyseal regions. Reaming the medullary canal at the isthmus of the femur will allow to collect 20 to 30 cc volume of bone debris. Therefore, increasing the reamer size by 1 mm will double the collected bone volume. Overreaming the canal by 2 mm will generally produce between 80 and 90 cc of cortical-cancellous bone graft. In practice, in an adult of average height, a 15 mm reamer will collect a cylinder of compact bone of 6–7 cm long featuring a 4 cm diameter circular basis, which represents a volume comprised between 60 and 90 cc of extremely dense graft of moist sand consistency (Fig. 2c). As a comparison, the volume of cancellous bone obtained from the anterior iliac crest is between 20 cc and 60 cc for the posterior crest [11]. The iliac cancellous bone has a more structured and aerated consistency. At the host site, the bone graft obtained using the RIA system.
Figure 3  Case report: a: segmental defect of the distal third of the tibial diaphysis; b: first phase of the induced membrane technique with placement of a cement spacer; c: radiographic control after the second operative phase of membrane filling using a Reamer-Irrigator-Aspirator (RIA) graft; the immediate aspect of bone density demonstrates the graft compactness; d and e: bone healing 6 months after grafting.
must not be tightly packed; it should be combined with a reconstruction material such as autograft, cancellous allo-
graft or bone substitute, to aerate it and promote efficient revascularization.

When graft harvesting is performed in a healthy lower extremity, the patient is allowed to progressively increase weight-bearing. During the first 48 postoperative hours, pain is relieved using conventional analgesic treatment.

List of recommendations

The list of recommendations is as follows:

- the diameter of the isthmus of the medullary cavity should be determined on antero-posterior and lateral radiographs;
- the patient is positioned supine on a conventional radio-
lucent table with the homolateral pelvis elevated by a firm cushion;
- the starting point is placed at the tip of the greater trochanter;
- the guide rod should be centered on the AP and lateral planes;
- the reamer head size must not exceed 2 mm larger than the determined femoral isthmus diameter;
- the reaming process will have to be continuously moni-
tored under fluoroscopy in various planes;
- the reamer should be inserted in an alternating advance and withdraw motion interrupted by short breaks to achieve optimal irrigation/aspiration;
- the graft material should be regularly collected from the filter to prevent excessive graft irrigation;
- aspiration should be turned off when reaming is stopped to reduce bleeding;
- full AP and lateral radiographs of the femur should be made on leaving the operating room.

Complications

Various complications may occur. Some complications are not related to the harvest technique such as a too medial entry point of the reamer, which may lead to femoral neck weakening. Other complication are specific and should be avoided by using a rigorous technique:

- the reamer head may be stuck when advanced too rapidly down the medullary canal.
- eccentric insertion of the guide rod may induce a false trajectory of the reamer and lead to intraoperative frac-
ture.
- postoperative fracture may occur and results from over-
thinning the femoral cortices. In case of weight-bearing pain persisting beyond three postoperative weeks, a cor-
tical breach at risk of extending may be suspected. In such a case, weight-bearing should be postponed.

Indications and contraindications

RIA specific contraindications include metabolic bone dis-
ease, active metastatic disease and previous history of

osteitis. Osteoporosis, particularly when resulting from a lack of weight-bearing, and the old age of the patient are relative contraindications for RIA harvesting.

The elective indication for RIA bone graft is filling of epi-
physeal and metaphyso-diaphyseal bone defects (Fig. 3), the large surface area of the bone graft thus promoting meta-
physeal healing. On the other side, a graft of compact bone will show some central lucency suggesting partial resorption of the graft material due to a lack of revascularization. For that reason, the current trend in the reconstruction of dia-
physeal defects is to combine another material to provide a graft of lesser density for improved revascularization.

Other indications for
Reamer-Irrigator-Aspirator (RIA)

RIA may also be used for femoral reaming in a retrograde fashion, which has the disadvantage of requiring an arthro-
tomy of the knee joint. This variant has an interest in indications for knee reconstruction-arthrodesis.

RIA used in the medullary cavity of the tibia may provide a great amount of harvested bone but only represents one third of the volume obtained in the femur. The RIA system may also be used in the treatment of residual intramedullary osteitis [17] and intramedullary nailing of femoral frac-
tures in multiple wounded patients at risk for systemic complications.

Conclusion

The RIA method of bone harvesting is a valuable option since it provides larger volumes of bone graft. However, concerns still persist regarding the potential complications, the bio-
logical properties of the graft and its modalities for use. Irrigation and filtration appear to decrease the biological activity. Recycling of RIA liquid aspirate and filtrate content and combination with an allograft placed inside the filter and impregnated with an osteoinductive liquid material are the main objectives of the current research.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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