
CLINICAL ARTICLE

Autologous intramedullary bone graft harvesting as an alternative to conventional harvesting methods

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Abstract

Conventional bone graft harvesting using the iliac crest is often cited as having significant donor site morbidity and complications. A technique has become available in the form of intramedullary harvesting, using a reamer-irrigation-aspiration (RIA) system. It is hailed as a safe alternative, with minimal donor site morbidity and pain.

This study presents a retrospective case series of 16 patients where the RIA system was used as a harvesting technique from June 2008 to January 2010. This technique involves harvesting autograft from the femoral canal (anterograde or retrograde) by reaming the intramedullary cavity only once. A single surgeon performed the operations over a 24-month period. Fluoroscopy was used to size and measure the width of the canal and to confirm guide wire placement. Outcomes evaluated were post-operative pain perception and patient satisfaction. Bone harvest volumes, intra- and post-operative complications and bony union were noted. Telephonic interviews were conducted in all 16 cases.

The average age of the patients was 31 years (15–55 years). The femoral canal was used as the donor site in all the patients. The mean post-operative follow-up period was 18.8 months (8–27 months). The average amount of bone harvested was 39.6 cc (20–70 cc). Two technical complications were encountered intra-operatively and there were no systemic complications due to reaming. Although immediate post-operative pain was significant, all patients interviewed reported no or minimal pain at the harvest site with long-term follow-up.

The RIA system was found to be a safe technique, with reliable volumes of autograft obtained. Patients recovered quickly without wound complications and minimal donor-site morbidity. This technique seems to be a viable option as an alternative to conventional bone graft harvesting.

Ethical clearance was obtained from The Research Ethics Committee, Faculty of Health Sciences, University of Pretoria.

Key words: Reamer-irrigation-aspiration, bone graft harvesting, intramedullary harvesting, RIA, donor site morbidity, donor site complications

Introduction

Open bone graft harvesting continues to be recognised as the gold standard to obtain an autograft in patients needing additional bone for various reasons.^{1,2} Patients suffer from significant donor site morbidity following open graft techniques.³⁻¹²

Bone grafting is a standard orthopaedic procedure. Donor bone is usually harvested from the iliac crest. The intramedullary femoral canal can also be used as a donor site. It provides good quantity and quality autograft. To harvest bone from the intramedullary canal a reamer-irrigation-aspiration (RIA) system (*Figure 1*) is utilised. The same approach to the intramedullary canal is used as is used in the nailing of femoral fractures. This technique does have its disadvantages in that reaming the intramedullary canal can cause complications such as cortical penetration, iatrogenic fractures and excessive blood loss. The use of fluoroscopy also adds to radiation exposure, not only to the patient, but also to theatre personnel, but this can largely be eliminated.

We propose that bone grafting from this donor area has less donor site morbidity than conventional open bone graft harvesting from the iliac crest and should be made use of much more often.

Although the intra-medullary autograft harvesting technique provides one with the same osteo-inductive and osteo-conductive advantages, no single study could be found reporting primarily on donor site morbidity.

This retrospective review focuses on the post-operative pain and discomfort experienced by the patient at the donor site. Graft volumes obtained during this reaming technique were documented. Progressions to union at the graft site were noted using clinical and radiological assessments although this was not the aim of the study. Not all patients could be followed until bony union occurred.

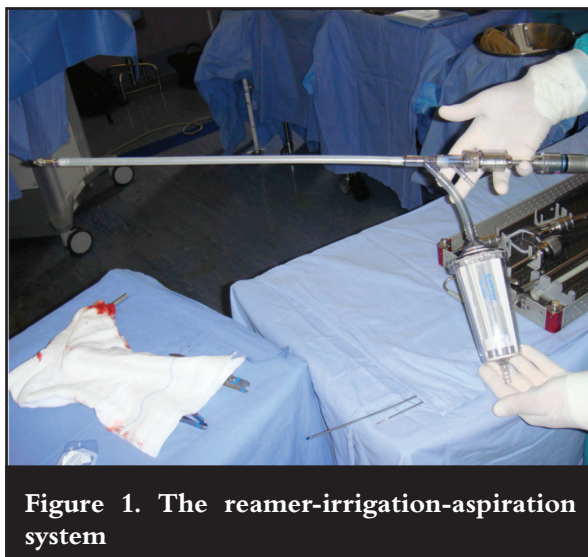


Figure 1. The reamer-irrigation-aspiration system

With permission from both the surgeon and the patient, surgical notes and patient files were examined for data. Graft volume obtained intra-operatively and any intra-operative complications were noted. These volumes could be measured accurately using the calibrated suction canister provided with this system.

Materials and methods

This is a retrospective study from June 2008 to September 2010. All patients who had undergone intramedullary harvesting during this period were reviewed. Twenty patients were treated over this time period by a single surgeon. All non-unions were included. Some of these fractures had multiple previous attempts at union, while other fractures were simply complicated by extensive comminution or severe soft tissue damage. This must be kept in mind when union rates are assessed.

Twenty cases underwent intramedullary bone harvesting using the RIA (Synthes®) system (*Figure 1*). Four cases were excluded from this study as the indication was to address underlying osteomyelitis. The medullary canal was sized intra-operatively using fluoroscopy (*Figure 2*). Bone harvesting using a single pass reaming technique was employed in all cases. The bone graft was collected and measured intra-operatively (*Figure 3*).

The 16 patients included in this study were contacted telephonically following surgery. The final interview was conducted during September 2010. During each interview a questionnaire was completed. Questions regarding pain focused on post-operative pain experienced and pain at the time of the interview. A pain analogue scale ranging from 1–10 (no pain to severe pain) was used to determine a pain score. All complications regarding the donor site were documented and included questions on the following:

- wound breakdown
- any visit to a general practitioner
- any oral antibiotics taken
- aesthetic appearance of the wound

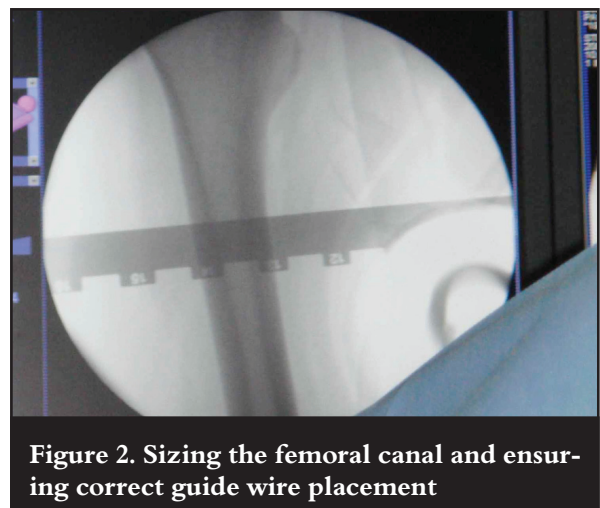


Figure 2. Sizing the femoral canal and ensuring correct guide wire placement

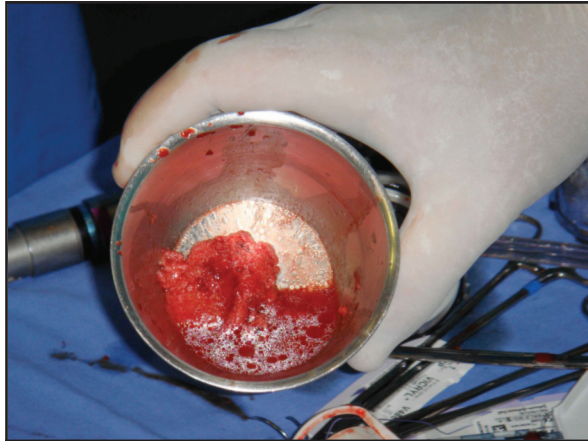


Figure 3. Intramedullary autograft from collection canister

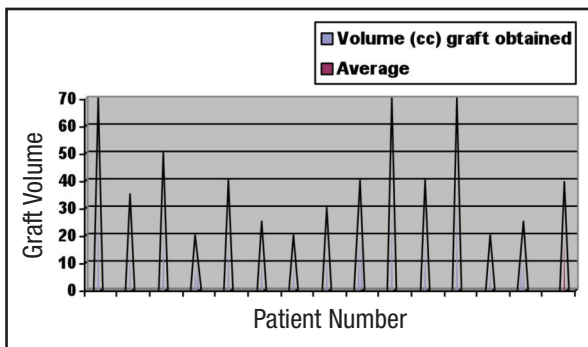


Figure 4. Graft volumes obtained (average 39.6 cc)

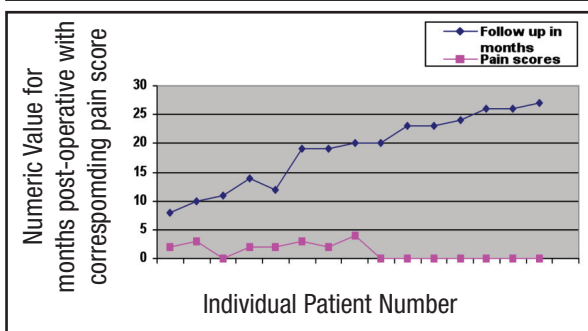


Figure 5. Rapid decline in pain score (VAS 1-10) with follow-up (months)

With permission from both the surgeon and the patient, surgical notes and patient files were examined for data. Graft volume obtained intra-operatively and any intra-operative complications were noted. These volumes could be measured accurately using the calibrated suction canister provided with this system.

Results

The 16 patients included four females and 12 males with an average age of 31 years (15–55 years). In all these patients the femur was used as the intramedullary harvest site (retrograde or antegrade). In 13 cases (81%) the tibia served as the graft site. The other three cases included a clavicle non-union and two non-unions of the femur.

In two cases no documentation of graft volume was available. The average volume of bone harvested was 39.6 cc (20–70 cc) (Figure 4). Two complications occurred during reaming of the canal. In one patient the reamer tip broke off (recovered by guide wire) and in the other case cortical penetration occurred. This patient was treated with protected weight bearing for 6 weeks and recovered uneventfully.

Final follow-up interviews were conducted during September 2010 establishing an average follow-up duration of 18.8 months (8–27 months). All patients reported mild to severe pain immediately post-op with an average pain score of 6.5 (1–10). Seven patients reported minor pain at the donor site during the last interview. Nine patients had no pain. All patients followed up after 21 months were pain free (Figure 5). No patient reported any complication with regards to the questionnaire on post-operative wound complications.

The incidence of non-union during the study period in the remaining cases can be explained by the complex nature of these injuries. Most of these patients had multiple previous surgical attempts to obtain union. This article focuses on donor site morbidity and not on the time to union. Taking these factors into consideration bony union was still achieved in 56.2% of patients. One patient was lost to long-term follow-up after an above-knee amputation at his request.

Discussion

Bone graft donor site morbidity

The osteo-inductive and osteo-conductive advantages of autogenous bone graft over allograft to ensure bony union of spinal fusions is well known and documented.³⁻⁵ The risks of using allograft include histocompatibility differences, impaired healing, increased risk of infection and transmission of infectious diseases and structural weakness.⁶ Complications such as haematoma, pain, numbness, limping, scarring, bone contour deficit and irritability of local tissue might necessitate the need for another means of obtaining autogenous bone graft other than from the iliac crest.^{6,7,12} Less frequent but severe complications of the ilium as donor site include infection, pseudo-aneurysm of the pelvic vasculature, urethral injury, nerve injuries (lateral femoral cutaneous or ilioinguinal nerve), peritonitis, herniation and iliac crest fractures.^{6,8,9} Our aim was to make use of an alternative autograft site that would have the same osteogenic potential as cancellous autograft from the ilium, but without the detrimental side effects of current donor sites.¹³

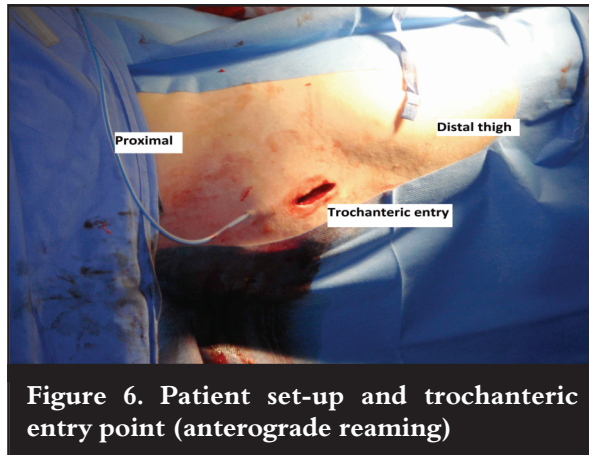


Figure 6. Patient set-up and trochanteric entry point (anterograde reaming)

A large number of published studies on conventional bone graft harvesting raise concerns about the detrimental sequelae of the procedure.^{3-12,14-19} The volume of graft taken, the donor site for bone grafting and the method of taking the graft all influence the donor site morbidity.⁸ Due to its accessibility the iliac crest is the most commonly used graft site.

In a comparative study done by Ahlmann *et al* the complication rate of posterior iliac crest graft harvesting was found to be less than anterior iliac crest graft harvesting.¹² Complication rates following iliac crest bone graft harvesting have been reported to range between 2.8% and 39%.^{4,10} This wide discrepancy in published figures might be attributed to the difference in analytical methods used.¹¹ Another reason for this large discrepancy may be the fact that the perception of pain is multifactorial, combining mechanical injury with emotional elements.¹¹ Sasso *et al* confirmed long-term donor site pain at 2 years post-operatively.¹⁰ Although harvesting from the proximal tibia was associated with a lower morbidity rate, the amount of graft obtainable is questionable.¹³

A further study by Sasso *et al* published data on 202 patients reviewed after undergoing anterior lumbar interbody fusion with bone graft taken from the iliac crest. Only two patients had no donor site pain on discharge from the hospital. After six months 41% of these patients still had donor site pain and this number decreased to an alarming 33% of patients only after 1 year. At the 2-year follow-up review 31% of patients still had pain at their donor site.¹⁰

In a retrospective study by Goulet *et al* reviewing 170 patients who underwent iliac crest grafting, 37.9% of patients still had pain 6 months after surgery at the donor site. This figure declined to 18.3% after two years, indicating a very slow decrease in pain over time.⁹

Of concern is not only the functional outcome of the patient, but also the aesthetic appearance of the wound.

Silber *et al* compiled data from 134 patients retrospectively who underwent anterior iliac crest bone graft harvesting. Difficult ambulation of patients in the acute period (less than 3 months) occurred in 50.7% of patients. The incidence of chronic pain (>3months) at the donor site was 26.1%.⁴ This study demonstrated significant donor site morbidity even when small amounts of graft were harvested.

Heary *et al* performed an independent outcome assessment on 105 patients who had iliac crest donor grafts. Sixty-six of these grafts were from the anterior iliac crest, 18 were from posterior and 21 were anteroposterior combined grafts. Independent interviewers determined the incidence in donor site pain to be as high as 34% compared to 8% when the assessment was done by the operating surgeon. This study infers that the incidence of graft harvest site pain may be considerably higher than indicated by the operating surgeon's clinical assessments.¹¹ The same study showed no difference in donor site pain with regards to sex, obesity, site (anterior versus posterior iliac crest) and the volume of graft harvested.¹¹

Of concern is not only the functional outcome of the patient, but also the aesthetic appearance of the wound. In a study published by Sasso *et al* 16% of patients who had open iliac crest bone harvesting rated their donor site wounds as fair or poor after 2 years.¹⁰

With review of the literature it is clear that donor site morbidity is complex in nature and common in prevalence. The discomfort during the post-operative period is substantial and the improvement of symptoms occurs slowly. The surgeon's method of dissection, different approaches to the donor site, the graft volume and even complex emotional patient factors must be considered.¹¹

Effects of intramedullary reaming

Reaming the intramedullary canal is not without complications. First, intramedullary blood supply to the femur is largely destroyed.^{20,21}

Court-Brown refers in his article to the work of Schemitsch *et al* who showed that cortical revascularisation does occur and takes about 12 weeks.²¹ In the same article, he mentions that Reichert *et al* suggest that reaming may actually be beneficial to fracture union by inducing an increase in periosteal blood supply.²¹ They do not actually show an increase in overall blood supply but postulate that the increase in periosteal supply compensates for the decreased intramedullary circulation.²¹

Secondly, thermal energy is produced and the risk of thermal necrosis exists. The critical temperature for thermal injury to bone is 56 °C, but extensive cortical necrosis occurs only at around 70 °C.²⁰ Although cortical necrosis is often quoted, clinical evidence is rare with only ten cases reported in the literature.²⁰

Thirdly, and probably the most concerning, is fat embolism resulting in fat embolism syndrome and respiratory compromise. The main reason for marrow extravasation is related to the peak pressure generated by the reaming process^{20,23} and should not exceed 40 mmHg.²⁴

The risk of resultant lung compromise, though, seems to be related to pre-existing lung contusion in addition to reaming.^{20,23-25} In a recent review article by Court-Brown²¹ the conclusion from a number of experimental studies is that reamed intramedullary femoral nailing under most circumstances does not cause significant respiratory compromise. The risk of fat embolisation is further reduced by simultaneous reaming and aspiration, which reduces intramedullary pressure^{2,25} with resultant decrease in the systemic effects, i.e. lung compromise. Newer reamer designs have also been shown to decrease peak pressures while reaming.^{23,24}

Sarasin referred in his article to the work of Muller *et al* who showed that a reamer shaft that is narrow and flexible and a head that is hollow with enlarged flutes will also result in lower peak pressures.²³ Lastly, reaming should be done with a sharp reamer and a controlled slower rate of reamer advancement down the canal, which will also result in lower pressures.²⁴

When looking at RIA specifically, Belthur *et al* reported only two reamer-specific complications in their group of 41 RIA harvested patients, namely one with anterior femoral shaft penetration which was managed non-operatively and one patient who had excessive reaming of the base of the femoral neck as a result of a piriformis entry point. This patient underwent prophylactic femoral neck fixation.²

In a case series reported by Lowe *et al*, four patients encountered fractures through the donor bone and two patients experienced acute RIA-associated events.²⁶ He concluded that pre-operative bone quality evaluation, patient selection and careful fluoroscopic-guided reaming may prevent these complications.²⁶

In a cohort study published by Quintero *et al*, 19 of their 20 patients reported no pain at the entry portal and there were no cases of infection, heterotopic ossification or post-operative antalgic gait due to donor site complications.²⁷ He did, however, warn surgeons to be aware of blood loss from the medullary canal, to prevent unnecessary aspiration while not reaming and to use fluoroscopy to guide and control the reaming process.²⁷ These findings correlate well with a small pilot study done by Newman *et al*, where they analysed retrospective data of ten patients who underwent RIA bone harvesting. No donor site pain was reported within six weeks of the procedure and the union rate in this series was 90%.²⁸

Finnan *et al* studied the mechanical effect of reaming the intramedullary canal in 42 cadaveric femurs, using the RIA system to obtain adequate volumes of bone graft. These femurs were subjected to axial and torsional forces after reaming while the contralateral side served as a control. He concluded that intramedullary reaming did not degrade the mechanical behaviour of these femurs, regardless of the reamer entry site.²⁹

The effect of reaming does have benefits. It is a way of auto-grafting aseptic non-unions of tibias and femurs.^{20,22} Reaming debris is also an excellent source of growth factors and multipotent stem cells, including osteoblasts.^{1,2,20,30}

In a study by Schmidmaier *et al* on reaming, it was shown to contain higher concentrations of certain growth factors, including BMP-2, than pelvic bone grafts.³⁰ Besides the debris as a source of stem cells and growth factors, the reaming process itself has been shown to liberate growth factors within the body, possibly leading to its secondary osteogenic effect.²⁰ The volume of bone graft acquired when using the intramedullary canal as a source is substantial, with the literature reporting 30–90 ml.^{1,26,27} This was validated in a recent study by Belthur *et al* who reported between 25 ml and 75 ml of bone graft with the use of RIA.²

The effect of intra-operative fluoroscopy

The effect of fluoroscopy intra-operatively on the patient and the surgical team must be taken into consideration when introducing a new method of bone graft harvesting requiring such exposure to radiation. The RIA system will inevitably make use of fluoroscopic control, thereby exposing everybody in theatre to the harmful effects of radiation. These effects have gained increased attention during the past few years. The amount of exposure is determined by a number of factors including the type and difficulty of the procedure, the experience of the surgeon and the radiographer, as well as the protective measures taken.³¹

Perisinakis *et al* compared the risk of developing fatal cancer or genetic defects on patients treated for a femoral fracture to that of the normal American population not exposed to irradiation.³² Elderly patients had a risk lower than 1.3 per million for developing fatal cancer and a risk close to zero for genetic birth defects.

By exposing younger patients with fluoroscopic control, this risk increased to 0.4 cases per million with regards to genetic defects and 1.3 cases per million may develop fatal cancer.³² Perisinakis *et al* also found the age and gender average risk for developing fatal neoplastic disease and for severe hereditary disorders to be 110 per million and 4 per million of patients treated for pedicle screw internal fixation.³³ Given the fact that the average risk for spontaneous onset of cancer in the US is 20% (200 000 per million) and the incidence of serious birth defects is 6% (60 000 per million), these figures may be considered acceptable.^{32,33}

Reducing the time of fluoroscopic beam radiation still remains the most effective way to decrease patient exposure.³² The use of pulse fluoroscopy, last image hold and the avoidance of continuous screening together with surgeon and radiographer experience will decrease fluoroscopy time.³¹ The use of a protective apron and a thyroid shield decreases the effective dose received by theatre staff by a factor of 16.^{34,35} By ensuring a distance of more than 70 cm from the X-ray beam, a significant decrease in radiation exposure was detected.³⁴

Conclusion

Reaming the intramedullary canal to obtain autograft produces good volumes of bone that are rich in bone morphogenetic proteins. Although this procedure is not without complications, adverse events can be prevented by careful patient selection and fluoroscopic-guided reaming.

The use of fluoroscopy in theatre is well accepted and commonly practised. Taking the above into account the risks of radiation exposure can never be underestimated. However, current literature supports the fact that with adequate protection, knowledge and understanding of the commonly used C-arm, these risks may be very low and do not put the patient at risk of developing fatal cancer or hereditary defects.

No studies specifically focusing on donor site morbidity with regards to the RIA system could be found in our search of the literature.

The results of this study suggest a significant decrease in donor site morbidity. Pain at the donor site area declines rapidly, with most patients not experiencing any pain at the entry site after 21 months.

From the literature it is noted that patients ambulate quickly after surgery, experience less pain at the entry site and are generally more satisfied with the aesthetic appearance of the donor area (Figure 6).

There are some limitations to the study. These include a small sample size, telephonic interviews and subjective quantification of pain. Using this system also adds additional costs, prolonged set-up and anaesthetic time to the procedure.

This study shows a significant decrease in donor site morbidity that benefits patients in need of autograft harvesting.

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