A radiographic and clinical comparison of reamer–irrigator–aspirator versus iliac crest bone graft in ankle arthrodesis

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Abstract

Purpose We evaluated radiographic fusion at follow-up and complication rates in patients who had either iliac crest (ICBG) or femoral reamer–irrigator–aspirator (RIA) bone graft for tibiotalar fusion.

Methods We retrospectively reviewed charts and radiographs of all patients who had a tibiotalar fusion from August 2007 to February 2011. Records were analysed for patient demographics, complications, and clinical symptoms. Radiographs were reviewed in sequential order by two fellowship-trained foot and ankle surgeons and one orthopaedic surgeon who specialises in foot and ankle surgery to determine radiographic fusion at routine follow-up. Patients were contacted to determine current visual analog scores (VAS) at their graft site.

Results Mean patient age was 49.4 ± 12.1 years in the RIA group and 49.3 ± 15.4 years in the ICBG group ($p=.97$). Pre-operative characteristics showed no significant differences between groups. The ICBG group had significantly more nonunions than the RIA group (six vs. one, $p=0.04$). Two patients in the ICBG had chronic pain at their graft site based on their VAS score; there were none in the RIA group. Radiographic fusion at follow-up was similar between groups, with no significant difference (12.48 ± 3.85 weeks vs. 12.21 ± 3.19 weeks, $p=.80$).

Conclusions There was a significantly higher nonunion rate in the ICBG group, but both groups had a solid radiographic bony fusion at similar follow-up time points. Our results suggest RIA bone graft is a viable alternative to ICBG for tibiotalar fusion.

Keywords Ankle fusion · Reamer–irrigator–aspirator · Iliac crest bone graft · Autologous bone graft

Introduction

The use of synthetic or autologous bone graft to assist with arthrodesis procedures is a mainstay of modern orthopaedics. Many different autologous and synthetic graft products are now available [1–4], with each graft choice having its own unique advantages and disadvantages [1]. Autologous bone grafting remains the preferred option, which provides an abundance of osteogenic, osteoinductive and osteoconductive growth factors to assist with the fusion process [5]. Autologous iliac crest bone graft (ICBG) is the gold standard for many arthrodesis procedures, but femoral intramedullary reamer–irrigator–aspiration (RIA) bone grafting has become increasingly popular secondary to the potential morbidity associated with the ICBG harvest site [5–11].

The RIA system was originally developed to decrease systemic complications from pressurisation during long-bone reaming but is now more commonly used to acquire intramedullary bone graft [12]. Reamings obtained from the intramedullary canal using the RIA procedure have been extensively studied and found to have a molecular and histologic profile comparable with ICBG, suggesting it to be a viable autologous bone graft source [13, 14]. The successful use of RIA has been well described during various foot and ankle procedures, but little is documented regarding its efficacy during tibiotalar arthrodesis [15].

In this study, we sought to evaluate whether or not the type of bone graft used during tibiotalar arthrodesis had an influence on clinical or radiographic outcomes. We specifically evaluated the time to fusion at follow-up and complication rates in a consecutive cohort of patients who had either an anterior ICBG or femoral RIA bone graft for tibiotalar

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arthrodesis. We hypothesised the time to obtain radiographic fusion based on routine follow-up radiographs would be similar between groups and that RIA could serve as a reliable alternative to ICBG for tibiotalar arthrodesis.

Methods

Prior to beginning the study, approval was obtained from our Institutional Review Board. We retrospectively reviewed the charts and radiographs of all patients who had a tibiotalar fusion, with or without a syndesmotic fusion, from January 2006 to February of 2011. Charts were reviewed for patient demographics, comorbidities, surgical complications, length of hospital stay and any noted clinical symptoms pertaining to fusion or graft-harvest site. Patients were only excluded if they had a bony procedure other than syndesmotic fusion, were lost to follow-up or fusion was done as a revision procedure.

One fellowship-trained foot and ankle surgeon performed all fusion procedures. The RIA system became readily available to our institution in 2007, and prior to this, ICBG was the autologous graft of choice. After 2007, the decision to use RIA or ICBG was determined pre-operatively based on the amount of bone graft determined to be necessary. The RIA system was used if a large amount of graft was required due to significant pre-operative deformity or bone loss. Patients with femoral instrumentation on the ipsilateral side of the fusion or with a femoral deformity routinely received ICBG. Cancellous bone from either the ICBG or the RIA graft was placed between the prepared tibia and talus just prior to joint compression with the fusion construct. No structural graft component was used from the iliac crest. The fusion construct was composed of all partially threaded screws directed from the tibia to talus alone or with an anterior fusion plate (Tornier, Saint Ismier, France). In cases with syndesmotic fusion, two partially threaded screws were used, directed from the fibula to the tibia. Each patient received an anterior ICBG or femoral intramedullary bone graft from the RIA system (Synthes, West Chester, PA, USA) using the manufacturer's standard protocol for antegrade reaming. Reamer head size was determined using a radiopaque sizing ruler with metal rings in 1-mm increments that accompany the RIA set. The ruler was placed on the skin and a fluoroscopic image taken over the narrowest portion of the femoral canal. The smallest reamer was chosen that would contact the inner cortical margins at the narrowest portion of the femur to ensure the cortical bone was not overreamed and weakened. One pass of the reamer routinely obtained approximately 20–30 cc of graft material; if necessary, a second pass of the same reamer head usually produced another 10 cc. In the event that additional graft material was required, a larger head size was used, but our practice is to initially err on the side of a smaller head. No patient had a combination of bone grafts. The tibiotalar joint

was fused in neutral position in the sagittal plane and 0–3° of valgus in the coronal plane.

Postoperatively, patients were placed in a well-padded splint and not permitted weight bearing. After two weeks, the splint was removed and replaced with a short, non-weight-bearing cast for an additional four weeks. Six weeks postoperatively, they were transitioned to a controlled ankle motion (CAM) boot and allowed to bear approximately 50 lb for two weeks and then as tolerated in the CAM boot for an additional four weeks. At 12 weeks, if clinical and radiographic fusion were obtained, each patient would initiate a formal physical therapy programme.

Time to bony union across the tibiotalar joint was determined by two fellowship-trained foot and ankle surgeons and one orthopaedic surgeon who specializes in foot and ankle surgery with >20 years of experience. Reviewers were blinded to the type of bone graft used. Radiographs were routinely obtained at two, four, eight, 12 and 16 weeks and then as necessary as dictated by symptoms or lack of bony fusion. All three reviewers determined time to bony union by evaluating sequential radiographs, and the most conservative (or longest) time to fusion was used. Fusion was defined as obliteration of the tibiotalar joint with bridging bony trabeculae and non-union as the failure of bridging trabeculae across the joint that required a revision procedure. Patients were invited to return for clinical examination; when they were unable to do so, telephone interviews were conducted to determine current visual analogue scale (VAS) scores of 0 to 10 (0 no pain, 10 worst pain). Data were analysed using chi-square or Fisher's exact test, as appropriate, for categorical data. Independent *t* tests were used for continuous data. A *p* value < .05 was determined to be statistically significant.

Results

We reviewed charts and radiographs of 67 patients who had undergone tibiotalar fusion: 29 patients in the RIA group and 27 in the ICBG group met the inclusion criterion of an isolated tibiotalar fusion with or without syndesmotic fusion, resulting in 56 patients for evaluation. Of the nine excluded patients, five did not have appropriate radiographic follow-up because they had left the region and four were having the procedure done as a revision. There were 35 men and 21 women in our study population, and their mean age was 49.4 ± 12.1 years in the RIA group and 49.3 ± 15.4 years in the ICBG group ($p=.97$). Mean body mass index (BMI) in the RIA and ICBG groups was 30.3 ± 5.6 and 31.5 ± 6.8 , respectively ($p=.49$). One deep infection in the ICBG group and two superficial infections in the RIA group were treated without further complication. There were no statistically significant differences between groups according to the American Society of Anesthesiologists (ASA) score, tobacco use and

presence of diabetes mellitus (DM). The preoperative diagnosis was posttraumatic osteoarthritis (OA) in the majority of cases: 24 in the RIA group and 17 in the ICBG group. Of note, no patient had rheumatoid arthritis. There were significantly more nonunions in the ICBG than in the RIA group ($p=.04$). Group demographics and comorbidities were otherwise not statistically different (Table 1).

All 56 patients had appropriate radiographic follow-up for review. When both groups were combined, our overall fusion rate was 89 %. Sixteen patients in the RIA group and 22 in the ICBG had an associated syndesmotic fusion. The ICBG group had significantly more tibiotalar nonunions than the RIA group (six vs. one, respectively, $p=0.04$). The average time to revision for nonunion was eight months (range six to 14 months). Each patient with a nonunion had a revision fusion procedure with repeat autologous bone grafting and subsequent successful bony union. The identification of bony fusion based on routine postoperative radiographs was similar between groups and not statistically different (12.48 ± 3.85 weeks vs. 12.21 ± 3.19 weeks, respectively, $p=.80$). Three years following surgery, two patients in the ICBG group had chronic pain at their harvest site based on VAS score (8 and 5, respectively). This complication was not observed in the RIA group. Figure 1 shows that length of hospital stay was similar between groups, with 14/27 leaving ≤ 1 day in the ICBG group and 18/29 in the RIA group ($p=0.47$).

Discussion

Autologous bone graft is still preferred over synthetic graft materials for major orthopaedic procedures due to the abundance of osteogenic, osteoinductive and osteoconductive growth factors [16]. ICBG has well-described complications in the literature, making the use of the RIA system an attractive alternative for autologous bone graft [10, 17]. The RIA bone grafting technique is gaining popularity, and research focuses on validating it as an effective alternative to ICBG [13, 14, 18]. In this study, we sought to compare techniques by evaluating clinical and radiographic outcomes of patients who underwent a tibiotalar fusion with one of the two grafts.

Overall fusion rate was 89 %, which is similar to that reported in the literature [19, 20]. We had a significantly higher nonunion rate in the ICBG group. This finding was somewhat surprising but may be partially explained by Sagi et al., who compared histologic and biologic profiles of iliac crest and RIA bone graft in the same patient [13]. They prospectively evaluated graft materials in consecutive patients presenting with tibial or femoral nonunions and found higher levels of transcription factors associated with vascular, skeletal and haematopoietic tissues in the recovered RIA samples. They also found substantially higher levels of genes that encode for bone morphogenic protein-2 (BMP-2) and matrix

Table 1 Patient demographics and associated p values

Characteristic	RIA	ICBG	P value
Sex			0.08
M	15	20	
F	14	7	
Mean age	49.4 (SD=12.1)	49.3 (SD=15.4)	0.97
BMI	30.3 (SD=5.6)	31.5 (SD=6.8)	0.49
ASA			0.93
1	2	2	
2	17	17	
3	10	8	
Diabetic	6	5	0.84
Tobacco use	11	11	0.83
Time to fusion (weeks)	12.21 (SD=3.19)	12.48 (SD=3.85)	0.80
Diagnosis			
Osteoarthritis (OA)	4	8	
Posttraumatic OA	24	17	
Talar avascular necrosis	1	0	
Other	0	2	
Nonunion	1	6	0.04
Superficial infection	2	0	0.16
Deep infection	0	1	0.48

BMI body mass index, *ASA* American Society of Anesthesiologists, *OA* osteoarthritis, *RIA* reamer–irrigator–aspirator, *ICBG* iliac crest, *SD* standard deviation

metalloproteinase-14 (MMP-14) in the RIA bone graft material when compared with the ICBG. BMP-2 is highly active in the critical early phases of fracture healing and stimulates pluripotent mesenchymal stem cells and osteoprogenitor cells, making it an essential molecule during the bone-healing process [21]. Members of the MMP family, notably MMP-14, are critical in the repair and remodeling phase of bone healing

Fig. 1 Length of stay. The zero-day group represent patients who left the day of surgery. More patients from the reamer–irrigator–aspirator (RIA) group left the day of surgery ($n=8$ vs. $n=3$), which did not reach statistical significance

[22]. Based on these findings, upregulation of these and other molecules in the RIA bone graft may theoretically provide an additional or enhanced biologic environment for bone healing when compared with ICBG.

Patients undergoing tibiotalar fusion tend to be older or have comorbidities, which could adversely affect bony fusion. In our patient population, 22 of the 56 admitted to chronic tobacco use, 11 of the 56 had DM, and 18 of the 56 had an ASA score of three, indicating these patients had significant systemic disease prior to surgery [23]. All of these factors can contribute to a decrease in the overall blood supply and natural growth factors available for healing at the fusion site and increase the risk of delayed or nonunion [24–27]. One could speculate that the RIA bone graft may give these high-risk patients more of the essential biologic molecules and growth factors necessary, allowing for an increased probability of fusion across the joint. Further work directed at these assumptions is warranted.

We had two patients in the ICBG group with chronic pain at their graft site, and although not statistically significant with the numbers evaluated, this complication was not observed in the RIA group. Dimitriou et al. performed a systematic review evaluating complications associated with iliac crest and RIA bone grafting [18]. They found 14 complications associated with RIA, most of which were associated with poor reaming techniques, such as perforation of the anterior cortex of the femur; chronic pain at the graft site was not commonly cited as a major complication. Nearly 8 % of patients evaluated in the ICBG group complained of chronic pain at their graft site. These data suggest that RIA bone grafting may be less susceptible to this concerning complaint. Even with the small numbers evaluated in their study, our findings are consistent with their prior published results with regard to harvest-site morbidity. Of note, we observed no anterior femoral cortex fracture/perforation or any other major complications associated with the RIA system. Our institution has been using the RIA system since 2007, and the low complication rate in this study may be due to the overall experience with its use and our vigilant use of fluoroscopy during the reaming procedure.

We observed no difference in the length of hospital stay between groups; and eight patients in the RIA group were able to leave the hospital the day of surgery, compared with three in the ICBG group. Decreased pain in the acute postoperative setting at the graft site may be a purported advantage of the RIA system, but this has yet to be fully evaluated in the literature. Our results suggest RIA bone graft would allow for shorter hospital stay. Future work specifically evaluating length of stay between these two graft types is necessary, and we are unable to make any substantial conclusions in response to this finding.

The total cost of the RIA system is listed at US \$998, and we realise this is an added cost. We believe the potential benefit of an increased fusion rate, decreased chronic pain at

the graft site and lower overall patient morbidity associated with graft harvest may offset this additional cost [18, 28]. As our study was not designed to specifically evaluate overall cost effectiveness of RIA bone grafting, future work specifically evaluating this component is necessary.

A major strength of this study was that a single surgeon performed all fusion procedures, thereby limiting technique and procedural biases. We also limited our study to patients who had a tibiotalar fusion only with or without a syndesmotic fusion, which decreases confounding variables from alternate bony procedures that may influence fusion rates. Our exclusion criteria were also limited in order to include all available patients from the diverse patient population at our referral centre. The retrospective nature of this study is an inherent weakness, and prospective evaluation of this topic would be beneficial. The lack of computed tomography (CT) imaging of tibiotalar fusions was another limitation. The use of CT would have been a more accurate indicator of fusion across the joint, but we do not routinely obtain CT scans in asymptomatic patients. We used the most conservative (or longest) estimate to fusion at the joint as determined by three very experienced foot and ankle surgeons, which we believe gave us an accurate time of fusion at follow-up. Finally, we cannot comment on the timing in which each graft option obtained bony fusion, as we did not review imaging studies any more frequently than is customary for routine follow-up.

Summary and conclusion

In summary, our results suggest RIA bone graft is a reliable autologous graft option for tibiotalar fusions, with a statistically significant lower nonunion rate and a decreased incidence of chronic pain at the graft site compared with ICBG. Our results correlate well with the current literature, which suggests RIA may be a viable alternative to ICBG for fusion procedures. Future work evaluating the RIA system will be warranted as indications for this autogenous graft option expand.

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Conflict of interest None.

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