Autogenous Bone Grafts in Foot and Ankle Surgery

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INTRODUCTION

Despite the increasing availability of allograft bone and bone graft substitutes, autogenous bone graft is used frequently for surgery of the foot and ankle[1-7]. Fresh autogenous bone has osteoconductive and osteogenic properties[5, 8-11]. Further, autogenous grafts circumvent infectious and immunologic complications, and there is evidence that it they are incorporated more consistently than allograft[1, 5, 7, 10]. In foot and ankle surgery, the most frequent indications for the use of bone graft include arthrodeses and repair of non-union or fracture[1-4, 6-8, 12].

Iliac crest has been the most commonly used donor site for orthopedic procedures[1, 7]. In recent years however, the proximal tibia, distal tibia, and calcaneal tuberosity have gained in popularity as alternative donor sites. The main advantage of those sites is their anatomic proximity to the foot and ankle. Theoretical disadvantages include the limited volume of available graft, unknown quality of harvested bone, and iatrogenic fracture. Several studies showed successful clinical results and similar efficacy of iliac crest or tibial bone grafts in promoting fusion in foot and ankle procedures with low rates of non-unions[13-15]. No prospective study was found specifically designed to compare the fusion rates related to the use of different bone grafts. This should be investigated by future studies.

The purpose of this paper is to review the orthopedic literature and the results of previous studies that evaluate complication rates and morbidity associated with these different donor sites. In addition, an ongoing study indicates different features of iliac and tibial graft.

ANTERIOR ILIAC CREST

The iliac crest is a frequently used source of autogenous bone graft, largely because of easy access and the availability of large quantities of both cortical (for structural need) and cancellous (for scaffold and cellular contributions to neo-osteogenesis) bone. Several studies, however, have raised concern about the complications and morbidity associated with the use of iliac crest bone graft [1, 3, 4, 7, 16-19].

The most frequent donor site complications associated with iliac crest bone graft are nerve injury and hematoma [1, 3]. Other complications include hemorrhage, seroma, infection, chronic pain, cosmetic deformity, fracture, and peritoneal/abdominal injury.

Several studies have attempted to document the incidence of donor site complications when iliac crest graft was harvested for general orthopedic use. Ahlmann *et al.*[1] reviewed the records of 108 cases in 88 patients after undergoing iliac crest bone graft harvest, with 66 cases from the anterior aspect. In all cases, the bone graft was used for the treatment of chronic osteomyelitis and all grafts were procured by a single surgeon. The average volume of graft harvested from the anterior crest was 55 cc. The evaluation included peri-operative pain, residual chronic pain, sensory disturbance, functional limitations, cosmetic appearance, the volume of bone harvested, and overall patient satisfaction. Five patients (8%) had major complications: 3 injuries to the lateral femoral cutaneous nerve, 1 abdominal hernia, and 1 instance of chronic donor site pain. Ten patients (15%) sustained minor complications, including superficial hematoma, temporary sensory disturbance, and mild temporary wound pain. Notwithstanding these complications, a 98% patient satisfaction rate was noted with regard to cosmesis and the overall outcome of the procedure.

Westrich *et al.*[7] performed a retrospective chart review of 390 patients undergoing anterior iliac crest bone graft harvesting for orthopedic procedures of the upper or lower extremity. The study compared graft harvest using "traditional techniques" or harvest with an acetabular reamer. Erythema, ecchymoses, minor drainage during the first 4 days after surgery, and pain that occurred within 2 weeks of surgery were considered normal and did not qualify as complications. Overall, 51 patients (13.1%) developed complications, with comparable complication rates noted between the techniques. Although there was a slightly lower rate of major complications noted in the reamer group, this was statistically insignificant; the authors concluded that the complication rate for both groups was comparable. Logistical regression analysis revealed a correlation between obesity or smoking with the development of a complication.

Banwart *et al.*[16] studied 180 patients who underwent 195 iliac crest bone graft harvest procedures. In addition to chart review, further data was obtained by mailed questionnaires. The questionnaire presented open-ended questions to elicit all complaints, no matter how minimal. The operative diagnoses in this series included scoliosis, spondylolisthesis, degenerative disc disease, fractures, and others. In 14 cases, the bone graft was harvested from the anterior iliac crest. In those 14 patients, the reported complication rate was 43% (6 patients), compared with 47% of patients undergoing posterior iliac crest harvest. The specific details regarding the nature of the complications associated with harvest from the anterior crest was not provided.

Brawley *et al.*[4] reviewed the charts of a small series of 34

patients who underwent reconstructive procedures requiring bone graft supplementation. The average follow-up was 10 months. In 27 cases, the bone graft was taken from the anterior iliac crest. Similar to the technique reported by Westrich *et al.*[7], an acetabular reamer was to harvest corticocancellous bone, and in some cases the volume of harvested graft was more than 90 cc. In Brawley's series, there were no instances of donor site morbidity, including pain, paresthesias, numbness, hematoma, or infection.

Less information is available about complications with grafts used in foot and ankle surgery. Two studies documented complications and morbidity associated with anterior iliac crest bone graft used for foot and ankle surgery. In a study by Schulhofer *et al.*[19], the charts of 40 patients with 42 donor sites were retrospectively reviewed. All grafts were harvested from the ipsilateral anterior iliac crest. In addition, the patients were interviewed by telephone about satisfaction with the donor site and whether they would undergo the procedure again. The mean follow-up was 22 months. In that series, there was only a single complication (2.4%), consisting of an infected hematoma. No patients reported chronic pain associated with the donor site, and all patients reported that they would repeat the procedure.

Most recently, a study by DeOrio *et al.*[17] examined the charts of 180 patients who underwent anterior iliac crest bone graft harvest during a foot and ankle procedure. The authors reported no major complications. There were 17 (9.5%) minor peri-operative complications, including hematoma, seroma, and cutaneous nerve irritation. A survey of the patients by either telephone or a mailed questionnaire at an average follow-up of 6.5 years revealed that 10% of patients had persistent donor site pain. Further, 90% of the patients reported that they were satisfied with the bone graft harvest, but only 71% reported that they would undergo the procedure again. It should be noted that in this series persistent pain was evaluated separately and was not a part of the complication rate.

In summary, reported incidence of donor site complication rates for anterior iliac bone grafts ranges from 0% to 43%. Specifically for foot and ankle procedures, the range of complications is lower, from 2.4% to 9.5% [17, 19]. The lower rate and range may be due to the smaller amounts of bone graft used during foot and ankle procedures.

PROXIMAL TIBIA

The tibia has become an appealing source of autogenous bone graft for foot and ankle procedures. The major reason for this is anatomic proximity. In addition, in obese patients, the harvest is easier to perform because of the avoidance of abdominal pannus. Several studies have evaluated the morbidity associated with this donor site.

O'Keeffe *et al.*[20] reviewed the hospital and office charts of 206 patients who underwent 230 proximal tibial bone graft harvests for lower extremity procedures (i.e. not limited to the foot and ankle). Patients were kept non-weight-bearing for 6 weeks post-operatively. Minimum follow-up was 4 months or until clinical resolution of donor site symptoms. In this series, the overall rate of complications was 1.3% (3 cases). These included one undisplaced fracture of the tibial eminence that healed by using a knee immobilizer, one haematoma, and one superficial infection. There were no cases of iatrogenic fracture.

Alt *et al.*[21] reviewed hospital and office charts of 54 patients who underwent tibial bone graft harvest for the treatment of non-unions or acute fractures. All patients were allowed to bear weight on the operative extremity. The mean follow-up was 26 weeks. Of 54 patients with tibial grafts, there was just one minor complication (1.9%) consisting of a local hematoma. There were no major complications (defined as fracture or infection).

Proximal tibial bone graft morbidity in foot and ankle surgery was also studied by Geideman *et al.*[22] This investigation was a review of the charts of 155 patients who underwent harvest of proximal tibial bone graft. Follow-up was between 3 and 6 months, at which time there was clinical resolution of all donor site symptoms.. In this series, there were no major complications (defined as fracture, infection, or wound breakdown) and there were 4 (2.6%) minor complications. These included 3 cases of transient nerve injury and 1 hematoma. Although the volume of graft was not consistently recorded, in some cases as much as 30 cc were harvested. Those investigators noted that in the first 5 patients in this series the graft was harvested through a medial approach. After two of those developed transient dysesthesia, which was classified as a minor complication, the approach was changed to the lateral tibia. Thereafter, only one patient of 150 (0.7%) developed dysesthesia[22].

In summary, the proximal tibia presents an exceptionally safe alternative to the anterior iliac crest for harvesting enough autogenous bone graft for foot and ankle procedures. In the investigations reviewed, there were no major complications. With the use of proximal tibial bone graft, the nature of the index procedure (i.e. foot and ankle versus non-foot and ankle) did not seem to affect complication rate, as may have been the case with the iliac crest.

DISTAL TIBIA

Some information is available about the use of distal tibia bone grafts for foot and ankle procedures. Raikin *et al.*[6] reviewed the results of 70 patients who underwent distal tibial bone graft for arthrodesis of the hindfoot or midfoot. The complications directly related to the bone graft were evaluated by clinical evaluation, chart review, and questionnaires. Patients were also questioned about their satisfaction and their willingness to undergo bone grafting again. In this series, there were no major complications and 5 (7%) minor complications. The 5 patients had numbness in the saphenous nerve distribution. In addition, 3 patients had transient incisional sensitivity that was not considered to be a complication. All patients were satisfied with the bone graft procedure and all reported that they would undergo surgery again.

Danziger *et al.* studied 40 patients who underwent 41 distal tibia bone graft harvests for foot and ankle procedures[17]. At an average follow-up of 23.3 months, patients were examined and questioned about pain, incisional tenderness, cosmetic

satisfaction, and the ability to wear shoes. In this series, no donor site complications were noted. There were no fractures, no complaints regarding cosmetic appearance, and no chronic donor site pain.

Recently, Chou *et al*. described 4 patients (of a series of 100) who developed stress fracture following distal tibia bone graft.[8] The average time to diagnosis was 1.8 months, and all fractures healed with cast immobilization.

These investigations show that the distal tibial is safe site for harvesting autogenous bone graft for foot and ankle procedures. In the studies reviewed, proximal and distal tibial harvest resulted in similar low complication rates.

POSTERIOR CALCANEAL TUBEROSITY

Two studies examined the use of bone graft harvested from the posterior calcaneal tuberosity for foot and ankle surgery. As with the tibia, the main advantage of this donor site is anatomic proximity. Theoretical disadvantages include fracture risk, insufficient quantity of bone, and incisional irritation from footwear.

Biddinger *et al.*[12] evaluated 17 patients who underwent calcaneus bone graft harvest for foot and ankle procedures. In this series, the average follow-up was 7 months. Three (17%) patients reported mild chronic incisional pain while 5 (29%) noted persistent medial heel pain. The authors attributed the medial pain to primary conditions and not to the bone graft harvest. No fractures were noted.

Raikin *et al*.[6] evaluated complications by direct clinical evaluation, chart review, or questionnaire in 44 patients who underwent bone graft harvest from the posterolateral calcaneus. The primary procedures included various foot and ankle surgeries, including arthrodeses and non-union repair. There were no major complications (defined as fractures or deep infections). Two patients (4%) had persistent numbness in the sural nerve distribution. Five patients (11%) had transient incisional sensitivity with footwear that was not considered to be a complication.

HISTOLOGICAL DIFFERENCE BETWEEN ILIAC AND TIBIAL BONE GRAFTS

Little is known about the cellular contributions of grafts from different anatomical sites. Classical teachings of Parfitt characterized the iliac crest as the site with highest average osteogenic surface, at 12%, compared with other cancellous bone (6%) or with cortical bone (3%). Some osteoblasts on trabecular surfaces may survive transplantation, and viable active marrow contains osteogenic precursor cells that can establish centers of bone formation in supportive recipient sites. We have begun an evaluation of the quality of bone graft harvested from the anterior iliac crest or proximal tibia that was in excess of that needed clinically. Histological evaluation showed the all specimens contained fragments of trabecular bone with abundant osteocytes and no osteoclasts. Composition of the medullary compartment, however, differed dramatically. Iliac bone grafts show active hematopoietic marrow, an observation that indicates robust stroma. In contrast, medullary spaces of the tibial grafts were filled with quiescent fat. The striking histological differences noted in graft composition raise questions about cellular contributions of different graft types to bone healing.

CONCLUSION

Bone grafts from different donor sites are believed to function equivalently in supported new bone formation. The literature on complications related to different donor sites is difficult to use for direct comparisons because the studies used different surgical approaches and instrumentation, patient populations with different primary diagnosis, and different methods of assessing morbidity. Other limitations are that volumes of graft were rarely presented and exact definitions of complications or morbidity were not always given. For example, donor site pain was addressed either as part of the complication rate, was measured separately, or was not mentioned. These discrepancies may account for the different published rates of complications, with anterior iliac grafts reported at 0 to 43% for all types of orthopedic procedures. It is likely that multiple factors contribute to complications, such as volume, experience level of the operating surgeon, surgical approach and instrumentation used, and an array of patient variables, such as age, comorbidities, smoking history, and adiposity. Because of lack of standardization of methods used in the existing literature, it is not possible to say which of the possible factors correlate with the risk of complications.

Autogenous bone graft is commonly used in foot and ankle surgery; however surgeons are no longer restricted to the anterior iliac crest as a donor site. The reported overall complication rates for the proximal tibia were between 1.3% and 2.6%, for the distal tibia between 0% and 7%. These compare favorably with reports of complication rates with iliac crest for foot and ankle procedures, from 2.4% to 9.5%. Given the limitations in comparing different studies, it is reasonable to conclude that donor site complications are similar for foot and ankle procedures that require small to moderate graft volume. Thus, evidence shows that the proximal tibia, distal tibia, and calcaneal tuberosity offer safe and effective alternatives to the iliac crest for foot and ankle procedures.

References

1. **Ahlmann E, Patzakis M, Roidis N, Shepherd L, Holtom P.** Comparison of anterior and posterior iliac crest bone grafts in terms of harvest-site morbidity and functional outcomes. *J Bone Joint Surg Am.* 2002;84-A:716-720.
2. **Alt V, Meeder PJ, Seligson D, Schad A, Atienza C, Jr.** The proximal tibia metaphysis: a reliable donor site for bone grafting? *Clin Orthop Relat Res.* Sep 2003;414:315-321.
3. **Arrington ED, Smith WJ, Chambers HG, Bucknell AL, Davino NA.** Complications of iliac crest bone graft harvesting. *Clin Orthop Relat Res.* Aug 1996;329:300-309.
4. **Brawley SC, Simpson RB.** Results of an alternative autogenous iliac crest bone graft harvest method. *Orthopedics.* 2006;29:342-346.
5. **McGarvey WC, Braly WG.** Bone graft in hindfoot arthrodesis: allograft vs autograft. *Orthopedics.* 1996;19:389-394.
6. **Raikin SM, Brislin K.** Local bone graft harvested from the distal tibia or calcaneus for surgery of the foot and ankle. *Foot Ankle Int.* 2005;26:449-453.
7. **Westrich GH, Geller DS, O'Malley MJ, Deland JT, Helfet DL.** Anterior iliac crest bone graft harvesting using the corticocancellous reamer system. *J Orthop Trauma.* 2001;15:500-506.
8. **Chou LB, Mann RA, Coughlin MJ, McPeake WT, 3rd, Mizel MS.** Stress fracture as a complication of autogenous bone graft harvest from the distal tibia. *Foot Ankle Int.*2007;28:199-201.
9. **Friedlaender GE.** Bone grafts. The basic science rationale for clinical applications. *J Bone Joint Surg Am.*1987;69:786-790.
10. **Gross TP, Jinnah RH, Clarke HJ, Cox QG.** The biology of bone grafting. *Orthopedics.*1991;14:563-568.
11. **Mulliken JB, Kaban LB, Glowacki J.** Induced osteogenesis-the biological principle and clinical applications. *J Surg Res.*1984;37:487-496.
12. **Biddinger KR, Komenda GA, Schon LC, Myerson MS.** A new modified technique for harvest of calcaneal bone grafts in surgery on the foot and ankle. *Foot Ankle Int.*1998;19:322-326.
13. **O'Malley DF, Jr., Conti SF.** Results of distal tibial bone grafting in hindfoot arthrodeses. *Foot Ankle Int.*1996;17:374-377.
14. **Danziger MB, Abdo RV, Decker JE.** Distal tibia bone graft for arthrodesis of the foot and ankle. *Foot Ankle Int.*1995;16:187-190.
15. **Kitaoka HB, Patzer GL.** Arthrodesis for the treatment of arthrosis of the ankle and osteonecrosis of the talus. *J Bone Joint Surg Am.*1998;80:370-379.
16. **Banwart JC, Asher MA, Hassanein RS.** Iliac crest bone graft harvest donor site morbidity. A statistical evaluation. *Spine.* 1995;20:1055-1060.
17. **DeOrio JK, Farber DC.** Morbidity associated with anterior iliac crest bone grafting in foot and ankle surgery. *Foot Ankle Int.*2005;26:147-151.
18. **Heary RF, Schlenk RP, Sacchieri TA, Barone D, Brotea C.** Persistent iliac crest donor site pain: independent outcome assessment. *Neurosurgery.* 2002;50:510-516; discussion 516-517.
19. **Schulhofer SD, Oloff LM.** Iliac crest donor site morbidity in foot and ankle surgery. *J Foot Ankle Surg.*1997;36:155-158; discussion 161.
20. **O'Keeffe RM, Jr., Riemer BL, Butterfield SL.** Harvesting of autogenous cancellous bone graft from the proximal tibial metaphysis. A review of 230 cases. *J Orthop Trauma.* 1991;5:469-474.
21. **Alt V, Nawab A, Seligson D.** Bone grafting from the proximal tibia. *J Trauma.* 1999;47:555-557.
22. **Geideman W, Early JS, Brodsky J.** Clinical results of harvesting autogenous cancellous graft from the ipsilateral proximal tibia for use in foot and ankle surgery. *Foot Ankle Int.*2004;25:451-455.