FEMORAL HEAD BONE VIABILITY AFTER FREE VASCULARIZED FIBULAR GRAFTING FOR OSTEONECROSIS: SPECT/CT STUDY

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Purpose: To evaluate femoral head bone viability following free vascularized fibular grafting (FVFG) for osteonecrosis using SPECT/CT imaging. Methods: Ten hips (9 patients) with osteonecrosis of the femoral head (ONFH) undergoing FVFG were prospectively enrolled. Four cases showed ARCO stage II, while six showed ARCO stage III. The mean age at surgery was 15.7 years (range, 13–22 years). Hip Harris Score (HHS) was measured pre- and post-operative. Bone scintigraphy with SPECT/CT was performed at 2 weeks and 6 months following surgery. Results: Mean follow-up was 4.0 years (range, 2–5.9 years). Mean HHS increased from 37.2 to 92.3. SPECT/CT findings revealed a progressive increase of femoral head uptake in all cases, suggesting subchondral graft bone viability. No progressive deformation of the femoral head was evidenced in radiographic evaluation at final follow-up. Conclusions: This study demonstrates FVFG’s capacity for revitalizing femoral head subchondral bone grafting in patients with ONFH, surgically treated following Urbaniak’s technique. © 2015 Wiley Periodicals, Inc. Microsurgery 00:000–000, 2015.

Osteonecrosis of the femoral head (ONFH) is a disabling condition, with an unclear pathophysiology and challenging treatment.1–3 Among young patients, free vascularized fibular grafting (FVFG) stands as an effective treatment, delaying the need for hip replacement.4–9 Vascularized bone grafts have also been obtained from other sites.10 As described by Urbaniak et al.7 FVFG surgical technique entails removal of the subchondral necrotic bone of the femoral head, filling the gap with iliac crest bone, and transplantation of the vascularized fibular graft. The rationale behind this microsurgical technique is to provide adequate revascularization to the new subchondral bone while maintaining appropriate mechanical support of the femoral head.6,7,11 To our knowledge, however, there are no imaging studies analyzing the viability of the grafted bone and its healing potential.

Bone single-photon emission computed tomography (SPECT/CT) has recently been described as a valuable imaging modality in the diagnosis of ONFH,12 and could also perhaps determine femoral head viability following surgery. We therefore sought to assess post-FVFG femoral head bone viability through use of bone SPECT/CT in 10 adolescent patients with ONFH.

PATIENTS AND METHODS

In 2006, after implementation of FVFG for the treatment of ONFH in our institution, a prospective data register was designed for its evaluation. Our Institutional Review Board approved the study.

A total of nine patients with ONFH (10 hips) were included. Each was treated with FVFG, as described by Urbaniak et al.,7 and followed for a minimum of 2 years. The indications for surgery were 1) osteonecrosis ARCO (Association Research Circulation Osseous) stages II or III, and 2) disabling hip pain severely affecting quality of life. Five males and four females were studied, with a mean age of 15.7 years (range, 13–22 years). All patients were entered into the study prospectively. Follow-up visits took place at 1 week, 3 weeks, 3 months, 6 months, 9 months, and 12 months post surgery. After the first year, patients were followed up on a yearly basis. Preoperative and postoperative clinical assessment included the Hip Harris Score (HHS).13 Graft failure was defined as conversion to, or on the waiting list for, total hip replacement.12

Seven patients (77%) had steroid-induced ONFH, six of these as a consequence of immunosuppressive treatment for hematologic cancer, and one due to lung transplant immunosuppression secondary to cystic fibrosis. One patient had ONFH as a consequence of radiotherapy treatment for rhabdomyosarcoma. The last patient...
sustained a traumatic hip fracture-dislocation that eventually led to ONFH.

Preoperative bone SPECT/CT imaging was acquired 2 hours after intravenous administration of technecium99m-methylene diphosphonate (Tc99m-MDP) (Hawkeye SPECT/CT, GE Healthcare, Boston, MA). Phase III of the bone scan was used, since it represents bone metabolic activity and patency of bone vasculature. Additional preoperative bilateral hip imaging included standard plain radiographs (posteroanterior and axial projections) and magnetic resonance imaging (MRI), with multiplanar T1- and T2-weighted images and evaluation of bone enhancement after Gadolinium administration.

Postoperative bone SPECT/CT was performed at 2 weeks and 6 months following surgery. A scoring system was developed to evaluate bone graft viability. The fibular grafts were divided into three regions for the scoring system: greater trochanter, femoral neck, and femoral head. We compared the fibular graft SPECT/CT signal intensity with the intensity at the ipsilateral proximal femoral diaphysis. A graft intensity lower than that of the proximal femoral diaphyseal cortex was given a score of 1; equal intensity in both was given a score of 2, and a higher intensity in the bone graft was given a score of 3.

Statistics were limited to a descriptive analysis. Differences between patients related to etiology or predictive values were not considered, due to the limited sample size.

RESULTS

Mean follow-up was 4.0 years (range, 2–5.9 years). No patient was lost to follow-up.

According to ARCO’s classification for osteonecrosis, radiographic imaging revealed four cases of ARCO stage II (normal shape of femoral head) and six cases of ARCO stage III (alteration of femoral head), all with [mt]50% involvement. None showed hip joint degenerative changes. Bone scintigraphy and MRI findings were consistent with ONFH in all cases.

The average preoperative HHS was 37.2 (range, 28–42), and the average at final follow-up was 92.3 (range, 78–100), with excellent outcomes (scores > 90) in all hips. All hips showed a noticeable decrease in pain intensity and a decreased need for pain medication. No progressive deformation of the femoral head was evidenced in radiographic evaluation at final follow-up (Fig. 1).

Early postoperative SPECT/CT at 2-week follow-up showed an increased radiotracer uptake in the femoral diaphysis (score = 3) along the femoral neck, and a decreased uptake in the cancellous subchondral bone graft (score = 1) (Fig. 2).

Late postoperative SPECT/CT at 6-month follow-up revealed that the fibular diaphysis had a comparable uptake to the adjacent femoral bone (score = 2), while the femoral head had an increased uptake (score = 3) (Fig. 3).

DISCUSSION

Bone SPECT/CT has been shown to be a valid imaging test for diagnosing ONFH, yet its utility in detecting femoral head bone viability and monitoring the healing process after FVFG remains unknown. In this study, bone SPECT/CT showed increasing femoral head uptake in all 10 cases of adolescent ONFH treated with FVFG, suggesting subchondral bone viability.

The satisfactory long-term clinical and radiographic outcomes associated with FVFG treatment of ONFH stem largely from its potential for bone revitalization while still maintaining proper mechanical support of the femoral head. The importance of the revitalizing effect has been elucidated by studies comparing nonvascularized and vascularized fibular grafts. Plaksyuch et al. and Kim et al. have reported that vascularized fibular grafting is associated with decreased incidence of radiographic progression and collapse of the femoral head, when compared with the results of nonvascularized fibular grafting.

Bone scanning has been used to assess and predict bone viability in frostbite injuries, burns, and meningococcal septicemic injuries. Although the use of bone scans for diagnosis of ONFH remains controversial, it has been successfully utilized in assessing bone viability after FVFG. The femoral head is anatomically difficult to evaluate in detail by planar studies. The addition of CT to the SPECT refines this exploration, providing improved anatomical detail. In our study, bone SPECT/CT allowed us to determine 1) the viability of the FVFG...
(microanastomosis patency), and 2) the viability of the subchondral femoral head bone graft.

Scintigraphy directly determines osteocyte viability, and indirectly determines vascular supply. For Tc99m-MDP uptake to occur, the presence of both adequate perfusion and metabolically active osteocytes is required. Scintigraphy has been used previously in assessing FVFG bone viability in mandibular reconstruction, and is considered a valid tool for assessing patency of microanastomoses. Similarly, in our study, scintigraphy combined with SPECT/CT showed all FVFGs to be viable.

To our knowledge, no studies to date have evaluated subchondral bone graft activity using scintigraphy. Our results showed that the subchondral bone graft had a lower activity early post-surgery than in later SPECT/CT scans, suggesting bone graft viability induced by the vascularized fibular graft. The present study's results support Urbaniak's hypothesis concerning the relevance of vascular supply for subchondral bone graft viability. Digital subtraction angiography has been used for preoperative assessment of femoral head vascularity in ONFH. This technique might also be used to assess postoperative bone viability, and, combined with SPECT/CT, might allow better-substantiated conclusions to be drawn.

Our results regarding clinical improvement of the treated patients are similar to those in multiple previous reports.
This study’s limitations include the small number of cases treated, and the heterogeneity of their ONFH etiologies; a larger-cohort study is required. Another limitation is the study’s relatively brief follow-up period. Urbaniak et al.\textsuperscript{7} showed 11% conversion to total hip arthroplasty within 5 years after FVFG in an adult sample, while Dean et al.\textsuperscript{4} reported a 16% conversion rate in adolescents. In our study, no hip progressed to collapse or required further surgical treatment. Long-term outcome analysis is necessary to adequately study post-FVFG changes of the femoral head, and their clinical and imaging outcomes.

CONCLUSIONS

This study demonstrates the efficacy of FVFG for revitalization of femoral head subchondral bone grafting in patients with ONFH, surgically treated following Urbaniak’s technique.

REFERENCES


Figure 3. SPECT/CT of the right hip shown in Figure 1, performed 6 months post surgical treatment. Maximum radiotracer uptake is localized in cancellous subchondral bone graft (score = 3) within the femoral head.