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Review Article

Bone Scintigraphy for the Evaluation of Bone Grafts

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ABSTRACT

Bone defects may occur after trauma, surgery, infection, congenital deformities, malignancy and miscellaneous bone grafts are used for the repair of these defects. Bone grafts can be evaluated for graft viability, complications, vascular patency after graft surgery with histopathology, radiological methods such radiography and computed tomography, bone scintigraphy, bone mineral densitometry, Doppler blood flow study and partial oxygen pressure measurement. Bone scintigraphy is a noninvasive and effective imaging modality that shows the osteoblastic activity beside the blood flow and graft failure is detected 3-6 weeks before the radiography. Bone scintigraphy gives correlative data with clinical results. It has crucial role for the evaluation of viability of the bone grafts, but the main limitation is low specificity. In this review, we overviewed the effectiveness of bone scintigraphy in the evaluation of bone grafts.

Key words: Bone scintigraphy, graft, nuclear medicine, SPECT.

INTRODUCTION

Bone and joint defects may occur secondary to trauma, surgery, infection, congenital deformities, malignancy and miscellaneous bone grafts are used for the repair of these defects. [1] Incorporation of the bone grafts depends on the adequate blood flow and vital osteoblasts. Grafts are classified as autogenic, isogenic, allogenic and xenogenic immunologically. Ideal bone grafts have four main properties as osteointegration, osteoconduction, osteoinduction and osteogenesis. [2]

Histopathological evaluation, radiological methods such radiography and computed tomography (CT), bone scintigraphy, bone mineral densitometry, Doppler blood flow study and partial oxygen pressure measurement are used for the evaluation of graft viability, complications, vascular patency after graft surgery. [3] Bone scintigraphy is a noninvasive and effective imaging modality that shows the osteoblastic activity beside the blood flow and graft failure is detected 3-6 weeks before the radiography. [4] It gives correlative data with clinical results.

EVALUATION OF THE BONE GRAFTS WITH NUCLEAR MEDICINE IMAGING MODALITIES:

a) Tc-99m Diphosphonates

They attach to hydroxyapatite crystal in the bone by ion exchange. Radiopharmaceutical accumulation in the bone graft is accepted as the evidence of bone viability and patency of microvascular anastomosis. Bone scintigraphy was shown useful for the evaluation of graft vascularity and viability both in cortical [5,6] and cancellous [7-9] bone graft. In vital bone grafts blood flow in intact and increased activity accumulation in the late images. [6] In graft viability studies, planar imaging is

enough especially in extremities whereas because of superposition of other structures SPECT imaging is useful especially in mandibular grafts. [10] Diffuse activity accumulation in the graft as the normal bone tissue shows the graft incorporation. [11] the most used radiopharmaceuticals for the bone scintigraphy are Tc-99m MDP, Tc-99m HDP and Tc-99m HEDP. Blood supply of the lesion can be detected with three phase bone scintigraphy. Anterior and posterior whole body images are taken 2-6 hours after the radiopharmaceutical injection and additional static or SPECT images are taken from the suspected regions.

b) F-18 Florid

It is used for the discrimination of the fracture healing/nonhealing, and evaluation of osteonecrosis and graft incorporation. [12] It shows the osteoblastic activity accumulation in the bone grafts. Graft healing, graft failure in the early stage and nonunion is detected by the quantitative analysis. [13,14]

c) F-18 FDG PET, Tc-99m Nanocolloid and Leukocyte labeled scan

These modalities are used for the evaluation of graft viability and osteomyelitis. Glucose analogue F-18 FDG, enter the cell vis glucose transportation mechanism and phosphorylated with hexokinase and being trapped inside the cell. Tc-99m nanocolloid is used for the visualization of bone marrow especially for osteomyelitis. Tc-99m HMPAO labels leukocytes and a leukocyte goes to the infection site.

d) Tc-99m MIBI/Tetrofosmin or Tl-201 Scintigraphy

These agents are used for the viability evaluation beside the myocardial perfusion scintigraphy and tumor detection. Bone grafts with muscle pedicle can be evaluated.

Review of the Literature

Normal or increased uptake is seen in metabolically active and revascularized bone grafts (positive scan) with bone scintigraphy. Decreased uptake (negative scan) is associated with possible complications. [15-19] Positive scans after postoperative one week do not show intact blood flow, because it may be associated with creeping of new bone tissue onto the graft that is mostly unvital. [4,20,21] Also postoperative changes and osteonecrosis due to radiotherapy may cause false positive results. [4,15,22] Because of this in the evaluation of bone graft viability after radiotherapy of mandibular reconstruction, invasive methods may be used like graft biopsy. [17] Bone marrow scintigraphy can be used for the evaluation of bone graft because postoperative hyperemia and periosteal creeping do not affect the bone marrow. But this has two potential problems; firstly bone graft must have active bone marrow. Secondly, preoperative bone marrow scan should be acquired because bone marrow distribution varies much individually. [23]

Weiland mentioned that new bone formation on the surface of graft may cause false positive results [24] but there are many other studies that deny this. [15, 19, 21-27] Negative scans in the revascularized grafts after the postoperative one week are always related with complications. [25,27] Schuepbach et al mentioned that there is correlation between the postoperative early and following bone scintigraphies and early scan can exclude revision surgery. Scan should be done in the early period after surgery and again in case of suspicion. [28] Absence of activity accumulation in the first two weeks and not increase in the following 1-3 months shows complication of graft. [29] Hyperemia and bone remodeling that is seen in the early period return to the basal levels in one year when the graft incorporation completes. [30] In another study, returning to basal level lasts 2-3 years and even remodeling continues slowly longer. [31] Returning of the activity increase to basal level varies according to the graft material.

SPECT images also can be taken beside the planar images with bone scintigraphy. Fig et al evaluated 15 mandibular reconstruction patients with

planar and SPECT imaging. Planar and SPECT were compatible in 13 of 15 patients. In two patients planar images showed vascular failure whereas uniform activity accumulation was seen with SPECT and both patients had vital grafts. [32] Berding et al studied the same kind of patients and mentioned that SPECT precludes superposition of other tissues and gives more accurate results. [29] Ramsey et al used autologous cancellous bone grafts in 20 rhinoplasty surgery. Three phase bone scintigraphy was taken in second and fifteenth weeks. Two patients had same or lesser activity accumulation than adjacent soft tissue. These two patients had graft failure in follow up period. [8]

Gordon et al studied on acetabular bone graft with bone scintigraphy. Increased activity accumulation was present in the postoperative first year; normal activity uptake was seen in 4-7 years. [33]

Malizos et al evaluated the vascular fibular graft that is used for the aseptic necrosis of femur head. Bone scintigraphy was taken in postoperative seven day and digital angiography for lateral femoral circumflex artery and branches in 18 patients on the second week. All the patients except three had blood perfusion in three phase bone scintigraphy. Three patients had negative arteriogram with angiography. Two of three patients that had negative arteriogram had negative bone scintigraphy. They mentioned that perfusion phase of bone scintigraphy is very sensitive for the evaluation of graft viability, whereas digital angiography is more specific, but less sensitive. [34] Schimming et al took planar and SPECT bone scintigraphy in 48-72 hour and 12-14 days after the maxilla and mandibular reconstruction. Bone scintigraphy had prognostic value for the early detection of complications. Negative scans in the early oerişod were associated with late prior complications like partial or total graft failure. But partial failure of bone graft cannot be clearly detected in 12-14 day with bone scintigraphy. Because. if there is more than 90 % viability, nearby vital tissue can cover the unvital segments. [16] Takato et al followed the patients of mandibula reconstruction with serial bone scintigraphies until the six weeks and there were no false positive results. In the absence of Tc-99m MDP accumulation, all cases had fracture or sequestrum. They found the maximum activity accumulation in the 2-4 weeks. The intensity of Tc-99m MDP accumulation was related with osteoblastic activity in the vascularized bone. [25]

Lauer et al used microvascular bone transplantation for mandibular reconstruction and evaluated the graft viability with bone scintigraphy in 6-11 days as early and 11 months as late scan. They draw ROIs to the graft and cranium as background activity and calculated graft/background (G/B) ratio. G/B ratio was >1 in uncomplicated graft in early and late scan and G/B ratio was <1 in necrotic cases in early images. Increased activity accumulation in 6-11 days scan showed successful surgery and normal healing period. There were not false positive or false negative results in early scans and G/B ratio discriminates the vital and unvital grafts. [35] Roebuck et al studied complications after massive allograft usage for malign bone tumors. Bone scintigraphy was nonspecific, because increased activity accumulation was seen in many conditions like infection, tumor recurrence, fracture, nonunion and most of the complications that detected with bone scintigraphy were also detected with clinically and radiographic. Scintigraphy has additional value in rare conditions. [36]

Itoman et al showed increased activity accumulation starts from the bone and graft junction with bone scintigraphy and same pattern was present histopathologically. [37] Bar-Sever et al used allograft after osteosarcoma resection of the lower limb. In 99% of the cases there was decreased activity in the allograft, mildly peripheral annular increased activity accumulation in 95% and increased activity accumulation at the junction of allograft and recipient bone tissue in 78%. [38] Fox et al studied complications after frozen allograft

usage for proximal femoral bone lesion resection on 137 patients. The mean follow up was 7.9±5.6 years. Fracture was present in 29 (19%) patients, infection in 15 (11%) and nonunion in 20 (15%) patients. Allograft reconstruction successful ratio was 80%. [39] Voggenreiter et al used frozen allograft for extremity reconstruction and complication ratio was 43%. There was still increased activity accumulation in the postoperative nine years and mentioned that remodelling lasts for many years. [40] Hervas et al determined that bone scintigraphy is useful for the evaluation of viability and microvascular fibular graft complications after mandibular reconstruction with fibular graft. Bone scintigraphy had diagnostic role for the recurrent surgeries. [17] Atilgan et al rabbits' evaluated the efficacy of bone scintigraphy for parietal bone defects with combined bone grafts. In the early period false positive activity accumulation may be present secondary to severe inflammation in some kind of bone graft combination. [3]

CONCLUSION

Bone scintigraphy has crucial role for the evaluation of viability of the bone grafts, but the main limitation is low specificity. Although increased activity accumulation is compatible with graft viability, increased activity accumulation may be due to periosteal creeping, postoperative changes, osteonecrosis or severe inflammation. So, increased activity accumulation in the graft should not always be understood as graft viability and in suspicious cases biopsy should be in mind as future evaluation.

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