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Overview of Imaging Modalities in Evaluation of Bone Allograft Viability

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Abstract

The goal of this review is to assess the importance of various imaging modalities which can be used in assessing the viability and integrity of the bone allograft. As it is widely in use in majority of major and minor reconstructive procedures.

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Introduction

Reconstructive orthopedic procedures widely use bone graft materials to promote new bone formation and bone healing . Bone graft provides a substrate and scaffolding for development of bone structure.[1] Bone graft materials include autografts, allografts, and synthetic substitutes. An allograft in the form of bone chips or morsels, which is more prone to post operative complications as it is taken from the cadaveric donor. Both osteogenic cells and bone volume are supplied by an autograft, which will ultimately help in bone formation

Postoperative imaging features is essential for differentiation between grafts and recurrent disease or viability/non viability. [2]

Bone grafts promote new bone formation and bone healing, provide scaffolding for these processes and are rapidly gaining wide acceptance due to their utility in a wide spectrum of reconstructive procedures for osseous defects

The primary function of bone graft is through new bone formation and structural support . It provides healing of the defects. Osteogenesis, osteoinduction, and osteoconduction are three major processes undergone by bone graft materials which is responsible for new bone growth and formation .[3][4]

Graft osteogenesis is due to transplantation of osteogenic precursor cells that causes new bone formation from the graft or the host bed.

Osteoinduction is the process in which mesenchymal cells are from the surrounding tissue differentiates into osteoblasts. (due to growth factors)

Osteoconduction occurs when an implant acts as a scaffold to facilitate the ingrowth of vessels and the migration of host cells. As new bone is formed, the graft may be partially or completely resorbed through a process described as creeping substitution.

Mechanical stress leads to successful incorporation of bone graft, thus helps in new bone formation. Myriad of clinical procedures uses bone graft materials in fracture stabilization, osseous defects, osseous fusion. Sequential process is followed by the graft incorporation just like healing process. [5]

Allografts

Allografts can be used as a substitute for autografts as the latter is associated with morbidity and limited donor site availability. Allograft lacks osteoinductive properties. The graft undergoes vascular and osteogenic precursor cell invasion and surrounded by granulation matrix . [3] The interface between allograft and host tissue is the site of osteoclastic activity and bone resorption. Balance is necessary between Osteolysis and osteogenesis . Allografts also has some limitations , such as, host immune response , graft rejection, and inconsistent incorporation. [6] Tissue sterilization lowers the risk for disease transmission . Allograft functions as a composite graft, bone void filler and an in vivo antibiotic delivery system a composite graft , and an onlay graft . Onlay or strut allografts function as long-bone scaffolds. Strut graft complications may include fracture nonunion or graft fracture[7][8]. Both osteoconductive and osteoinductive properties can be attained by combining the graft materials. Autologous platelet-rich plasma can be used along with allografts , which is responsible for osteoinduction by providing growth proteins that are secreted by the platelets . Thus both structural integrity and growth factors can be attained with. Only the allograft material is detectable on radiographs. [9]

Radiographs or CT Scan

Allografts have opacity or attenuation similar to that of cortical bone. Grafts in the form of chips or morsels do not retain the defined cortical and medullary margins these characteristics at imaging. They appear as high-attenuating conglomerates within the bone defects. CT or conventional tomography can be used in suspected graft failure .The junction between the graft-host is obliterated when the union progresses due to trabecular ingrowth, and the medullary canal is replaced by fibrous tissue.[10][2]. Grafts which are placed in the form of chips or morsels appear as high-attenuating conglomerates within the bone defects and do not retain the defined cortex and medullary canal.

Initially, bone resorption occurs at the margins of the allograft and is most prominent between 7 and 10 weeks postoperatively . Radiodensity will then increase due to osteopenia of the surrounding bone and necrosis

of the allograft. Radiodensity of the graft starts to decrease approximately 6 months after transplantation and will continue this pattern for 18 months

Xray is unreliable for determining bone graft viability during the first months because changes in the mineral content can only be detected if the alteration amounts to at least 30-40%. Also , it provides no functional information regarding graft viability and integrity. [11][12][13]

MRI

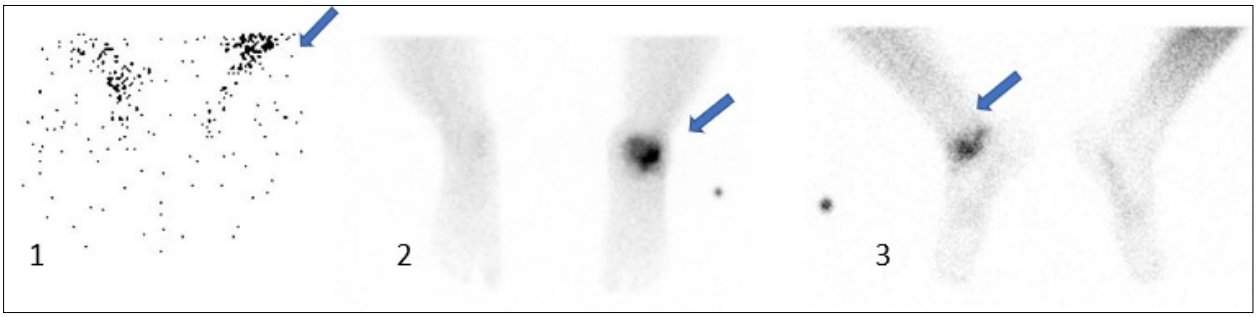
MR imaging can be useful to evaluate the presence or absence of marrow signal intensity, which indicates graft incorporation or failure, respectively . Signal hypointensity on both T1- and T2-weighted MR images is seen in immediate post operative period. The presence of a red-marrow signal can be seen when marrow is replaced by the hematopoietic tissue , in later images . A consistent finding with lack of complete graft incorporation is associated with a persistent signal intensity lower than that of marrow on T1- and T2-weighted images. [3] Autografts have variable appearances , as may appear hyperintense on T1-weighted images and hypointense on T2-weighted images, or hypointense on T1- weighted images and isointense to hyperintense on T2-weighted images. In the immediate postoperative period, allografts have signal hypointensity on both T1- and T2-weighted MR images. [14]The change or lack of change in the allograft marrow signal intensity can help in ascertaining the graft failure or unable to incorporate.

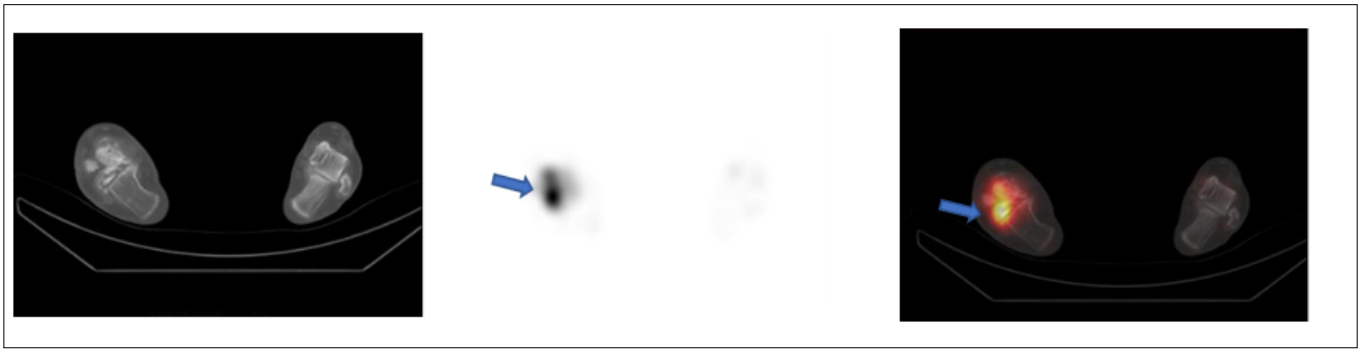
Bone Scintigraphy

Single photon emission computed tomography with CT (SPECT-CT) is an emerging diagnostic modality that combines the sensitivity of bone scintigraphy with the high specificity of CT . It has an advantage of showing the bones's metabolic activity that surrounds the prosthesis and is less prone to be affected by metal artifact compared to MRI[15] . It reflects the physiological activity of the bone and combines the anatomical and functional data and increases the diagnostic yield of the scan to evaluate the viability and integrity of the allograft during follow up. Three phase component of the bone scan reflects the integrity of the graft as it indicates the blood flow . [16]An uptake is elevated by the repair and remodeling of the bone , inflammation , and increase in blood flow. Thus , measured uptake over time by bone scintigraphy can be used to study the bone remodeling. [17]Radiopharmaceutical accumulation in the bone graft is accepted as the evidence of bone viability and patency of microvascular anastomosis. Negative scans after postoperative one week are always related with complications and not increase in the uptake in the following 1-3 months shows complications of graft. Sequential bone scans are thus required to monitor the viability of the graft based on the uptake in the graft region. [18][19][20]

Three phase Bone scan : Increased flow (1) indicates preserved blood supply to graft region along with increased blood pooling in the (2) image with spot (3) at delayed 3hr reveals increased tracer uptake ascertaining the integrity and viability of the bone allograft

SPECT/CT depicting increased tracer uptake after one month at the site of allogenic bone grafting (same above patient) done for avascular necrosis right talus.





Conclusion

Bone autografts and allografts have high opacity and attenuation on initial postoperative radiographs and CT scans, which gradually decreases over time, as graft incorporation progresses.

SPECT/CT is an emerging diagnostic modality which has the advantage of showing the bones metabolic activity, that surrounds the prosthesis and is less prone to be affected by metal artifact compared to MRI[14] It combines anatomical and functional data and increases the diagnostic yield of the scan to evaluate the viability and integrity of the allograft during follow up . Thus, an overall one stop investigation which can be done sequentially to assess the ongoing healing of the bone and incorporation of the bone graft. [21]

Other imaging modalities , such as , Xray is beneficial only when there is 30-40 % alteration in the mineral content of the bone, whereas MRI , although widely available investigation , but has a high burden of the cost.

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