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Hans C. Pape and Timothy G. Weber

Bone Defects Caused by High-energy Injuries, Bone Loss, Infected Nonunions, and Nonunions **1**

Andrea Wiese and Hans C. Pape

Bone defects represent a difficult problem for the clinician. They entail a sustained increase in hospitalization, risk of complications, and associated increase in expenses. This article discusses bone defects caused by high-energy injuries, bone loss, infected nonunions, and nonunions.

Viable Bone and Circulatory Factors Required for Survival of Bone Grafts **5**

Lisa K. Cannada

The healing of fractures and nonunions has significant science background to it; however, the application of the products in the surgeon's hands should be considered an art in the science of bone healing. The surgeon must choose adequate fixation for stability and to promote healing by not making the construct too stiff. If a bone graft substitute is necessary, the surgeon must choose the type of bone graft substitute depending on patient factors and surgeon factors involving the treatment of the fracture.

Use of Solid and Cancellous Autologous Bone Graft for Fractures and Nonunions **15**

James T. Marino and Bruce H. Ziran

Bone is the second most commonly implanted material in the human body, after blood transfusion, with an estimated 600,000 grafts performed annually. Although the market for bone graft substitutes is more than $1 billion, that of bone graft itself is still more than half that amount. Reports of autologous bone grafting date back to the ancient Egyptians, yet the modern scientific study of grafting began in the early 19th century. Since then, the indications, methodology, and science of bone grafts in nonunion and bone loss have been established and refined, and new methods of harvesting and treatment are being developed and implemented. This article describes the use of solid and cancellous bone graft in the treatment of acute bone loss and nonunion.

The Concept of Induced Membrane for Reconstruction of Long Bone Defects **27**

Alain C. Masquelet and Thierry Begue

Clinical, experimental, and fundamental studies have shown the interest of a foreign body-induced membrane to promote the consolidation of a conventional cancellous bone autograft for reconstruction of long bone defects. The main properties of the membrane are to prevent the resorption of the graft and to secrete growth factors. The induced membrane appears as a biological chamber, which allows the conception of numerous experimental models of bone reconstruction. This concept could probably be extended to other tissue repair.

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Richard P. Meinig

The reconstruction of large bone defects remains a clinically challenging condition. Although many treatment approaches exist, they all have limitations. Recently, bioresorbable polylactide membranes have become commercially available. These membranes, when applied to bone defects, enhance bone healing by direct osteoconduction, exclusion of nonosseous tissues, and enhancing the osteogenic environment for autologous grafts. When combined with appropriate internal fixation and autologous bone graft, bioresorbable polylactide membranes allow for single-step reconstruction of large bone defects.

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Véronique Viateau, Morad Bensidhoum, Genevi7ve Guillemin, Hervé Petite, Didier Hannouche, Fani Anagnostou, and Philippe Pélissier

Animal experiments using the induced membrane procedure for bone tissue engineering purposes have provided evidence that the membrane has structural characteristics and biologic properties that may be used for bone tissue engineering purposes. Clinically relevant animal models have demonstrated that standardized particulate bone constructs can be used to repair large bone defects using the procedure and that the osteogenic ability of these constructs partially approaches that of bone autografts.

Biological Rationale for the Intramedullary Canal as a Source of Autograft Material 57

David J. Hak and Jason L. Pittman

Bone harvested by intramedullary reaming offers a minimally invasive alternative to harvesting bone from the iliac crest, which has long been considered the gold standard for autogenous bone grafting. The biologic potential of intramedullary reaming material has been studied both in vitro and in vivo. The material provides osteogenic, osteoinductive, and osteoconductive properties that are comparable to the material harvested from the iliac crest. In addition to the ability to obtain a large volume of bone, the graft harvested by the Reamer-Irrigator-Aspirator has been shown to be rich in growth factors, including BMP-2, TGF-β1, IGF-I, FGFa, and PDGFbb.

Treatment of Large Segmental Bone Defects with Reamer-Irrigator-Aspirator Bone Graft: Technique and Case Series 63

Todd A. McCall, David S. Brokaw, Bradley A. Jelen, D. Kevin Scheid, Angela V. Scharfenberger, Dean C. Maar, James M. Green, Melanie R. Shipps, Marcus B. Stone, Dana Musapatika, and Timothy G. Weber

Treatment of large segmental defects using conventional autogenous iliac crest bone graft can be limited by volume of cancellous bone and donor site morbidity. The reamer-irrigator-aspirator (RIA) technique allows access to a large volume of cancellous bone graft containing growth factors with potency equal to or greater than autograft material from the iliac crest. The purpose of this study was to evaluate the effectiveness of RIA-harvested autogenous bone graft for treating large segmental defects of long bones.

Autograft and Nonunions: Morbidity with Intramedullary Bone Graft versus Iliac Crest Bone Graft 75

Janet D. Conway

This article focuses on comparing patient morbidity with harvesting bone graft for the treatment of nonunions from three different sites. Anterior iliac crest graft is the most commonly used site; however, the posterior iliac crest and intramedullary canal provide greater quantities of bone. The anterior and posterior iliac crests also have some donor site complications such as nerve injury and persistent pain. The intramedullary canal, when compared with anterior and posterior iliac crest, offers the largest quantity of bone graft with the least amount of patient donor site morbidity. The intramedullary canal also appears to be a bone graft source that can be reharvested, unlike the anterior and posterior iliac crest donor sites.

Autologous Bone Graft: When Shall We Add Growth Factors? 85

Peter V. Giannoudis and Haralampos T. Dinopoulos

Although the unquestionable value of autologous bone grafting and the analogous value of the reaming by-products in nonunion treatment have been mentioned extensively in the literature, there is ongoing vivid discussion for the treatment of those case scenarios where the fracture nonunion is complicated by other local environment adverse circumstances. The graft expansion with growth factors as the bone morphogenetic proteins (BMPs) offers the possibility to reduce the number of operative procedures, complications, length of hospital stay, and time to union. In this article, we consider the potential clinical scenarios for graft expansion with BMPs.

Quantitative Analysis of Growth Factors from a Second Filter Using the Reamer-Irrigator-Aspirator System: Description of a Novel Technique 95

James P. Stannard, Ashoke K. Sathy, Fariba Moeinpour, Rena L. Stewart, and David A. Volgas

Use of the Reamer-Irrigator-Aspirator (RIA) as a source of autogenous bone graft in the treatment of nonunions is increasing. We report on our novel technique of using a second filter containing beta-tricalcium phosphate (TCP) as a graft extender while using the RIA system. We also quantify growth factor concentrations in the collections from the TCP filter. A second filter attached in series with the standard RIA filtration system yields TCP with substantial concentrations of bioactive proteins that are equal to those seen in the bone graft that is harvested in the first filter.

RIA: One Community's Experience 99

Christopher G. Finkemeier, Rafael Neiman, and Domingo Hallare

The Reamer Irrigator Aspirator (RIA) has three main indications in our community trauma practice. The most common indication for RIA is harvesting of autololgous bone graft from the femur for nonstructural bone graft. The second most common indication is for irrigation and debridement of intramedullary osteomyelitis. The final indication for RIA is for acute nailing of femoral shaft fractures in patients with multiple long bone fractures with or without pulmonary injury. If one pays careful attention to the details of the technique, RIA is a safe and effective method of harvesting autologous bone graft with minimal morbidity. Autologous bone graft harvested with RIA is our graft of choice for nearly all of our bone grafting cases.

Managing Bone Deficiency and Nonunions of the Proximal Femur **105**

John J. Perry, Brent Winter, and Jeffrey W. Mast

Revision surgery of the proximal femur with bone loss secondary to failed cephalomedullary nails is problematic and becoming more prevalent as their use grows. This article presents a technique of deformity correction, bone graft techniques that reconstitute residual defects, and definitive fixation using load-sharing devices that provide immediate stability for bone healing and early rehabilitation. Preoperative planning and the potential advantages and disadvantages of newer fixed-angled plates versus established implants are discussed. With proper planning, surgical execution with proved techniques, augmented by the addition of newer graft harvesting techniques, anatomic restoration, and bone reconstitution with healing, has invariably been the result.

Soft Tissue and Biomechanical Challenges Encountered with the Management of Distal Tibia Nonunions **119**

Ivan S. Tarkin, Peter A. Siska, and Boris A. Zelle

A thoughtful treatment algorithm is required to optimally treat distal tibia nonunion. A healthy respect for the tenuous soft tissue envelope, compromised vascularity, and challenging mechanical environment is advisable. Achieving osseous union and improved functionality requires an individualized plan of care based on the personality of the nonunion and host. Attention must be focused on providing mechanical stability at the site of nonunion and providing biologic supplementation.

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