CHAPTER 22

BONE MARROW ASPIRATE: Science and Application in Foot and Ankle Surgery

Michael C. McGlamry, DPM

Bone marrow aspirate (BMA) has been used as an adjunct in bone and soft tissue healing throughout the body. Specifically there have been numerous publications in recent history analyzing its application in foot and ankle surgery. In a recent article published by Hatzokos and colleagues, their analysis illustrated just how significant the healing potential of BMA may be. In the study, the group looked retrospectively at the historically problematic docking site with bone transport. They compared compression to debridement and autogenous iliac crest bone grafting, to debridement and grafting with BMA concentrate mixed with fiber-based demineralized bone matrix (DBM) putty and found the greatest success with the BMA DBM group.

In its simplest iteration BMA is harvested percutaneously from a cancellous-rich site such as the iliac crest, proximal tibia, or calcaneus utilizing a bone marrow needle and large-gauge syringe. Typically the BMA is mixed with an anticoagulant to prevent clotting and allow for further enhancement by concentration of active desired components such as mesenchymal stem cells (MSCs), hematopoetic stem cells (HSCs) and endothelial progenitor cells (EPCs) using one of the available systems for BMA concentration. The surgeon should have a clear understanding of the yield from different devices as well as recognize which systems ultimately give the greatest number of viable cells. The systems available will concentrate anywhere from 3-8 times baseline and may actually separate via different methods with varying results

It has been shown that the relative number of available stem cells is highest centrally in locations such as the iliac crest. Jia, Peters, and Schon found that the concentration at the proximal tibia level has been shown to be approximately 40% of the level found in the iliac crest however the growth factor concentration was similar. However, a high quality concentrate may still be obtained with numerous small aspirations and multiple repositionings of the aspiration needle in the proximal tibial metaphysis.

The number of stem cells has been noted to decrease with patient age, but without statistically significant deviation between men and women. Hernigou et al established the importance of achieving a concentration of >1,500 progenitor cells/ml in achieving successful consolidation of established nonunions and noted that without concentration this level was rarely seen in the baseline aspirate.

Concentration of the desired stem cells is accomplished most commonly by processing with a 2 stage centrifugation system. This process yields a low volume high concentration product that can be directly administered by injection to a defect or nonunion site, or mixed with other products such as DBM, bone chips, or other carriers to generate a relative autograft equivalent.

TECHNIQUE

To obtain the greatest available concentration of MSC's within the author's scope, without the necessity of going to the iliac crest, the proximal tibia has been most frequently utilized (Figure 1). In most patients this has been able to yield 30-40 cc of BMA with little difficulty.

Several tips for a good aspiration should be observed. First the BMA should be obtained at the beginning of the case, prior to inflation of the tourniquet and prior to incision or other insult that would initiate the inflammatory cascade, which might attract desired cells away from the aspiration site. This allows the BMA concentrate (BMAC) to be processed and ready to use when that point of the procedure is reached. Some surgeons have expressed concern over the delay between aspiration/processing and

Figure 1. Bone marrow aspirate needle being driven through the cortex to start the aspiration procedure. This is performed prior to the start of the reconstructive procedure.

use. Although the concern is logical, the BMAC has been shown to be viable and stable for longer than 4 hours

Once the cortex of the harvest site has been penetrated, the harvesting procedure is begun. For the aspiration itself, it is best to use a negative plunging method of 3-4 plunges per location prior to repositioning the tip of the needle so as to limit the amount of venous blood pulled into the sample (Figure 2). Volume at each level should ideally limited to no greater than 2 mls. This ultimately prevents dilution of the MSCs with peripheral venous blood. Muschler et al demonstrated that increasing the local aspirate volume from 1 to 4 mls ultimately resulted in a 50% decrease in the overall number of alkaline phosphatase positive colonies, which was correlated with a decrease in the number of osteoblast progenitor cells present.

Various techniques have been described of either driving the trochar/needle into deep position and then withdrawing with serial aspirations or the opposite with initial aspiration after penetrating the cortex followed by tapping the needle progressively deeper for follow-up aspirations. The technique utilized as well as the degree of repositioning necessary will be affected by the aspiration needle selection, i.e., a needle with a single opening at the tip may require less angular reorientation while a needle with an open tip and side fenestrations will more easily draw the desired volume at each repositioning but will require greater angular reorientation to reach fresh or untapped marrow (Figure 3). Ultimately the needle utilized is based on surgeon preference and availability.

After the aspirate has been obtained, the syringe is passed off to the technician for processing. The concentration process typically takes about 30 minutes and generally yields about 10% of the original volume as BMAC (Figure 4). For the typical draw of 35 ccs (40 ccs total less the 5 ccs ACDA) the process typically yields about 4 ccs.

APPLICATIONS

The use of BMAC has been widely published in recent literature with applications ranging from percutaneous treatment of nonunions and unicameral bone cysts to open surgical applications where BMA is used independently at closure or combined with other carriers such as DBM's, allograft blocks, autograft, or synthetic bone graft substitutes, in efforts to manipulate the biology of the local healing environment (Figures 5, 6, 7).

In summary BMAC is a simple, technologically-sound method of enhancing the healing in procedures where biology is compromised such as Charcot reconstruction or even in isolated ankle fusion procedures in compromised hosts such as diabetic patients or smokers.

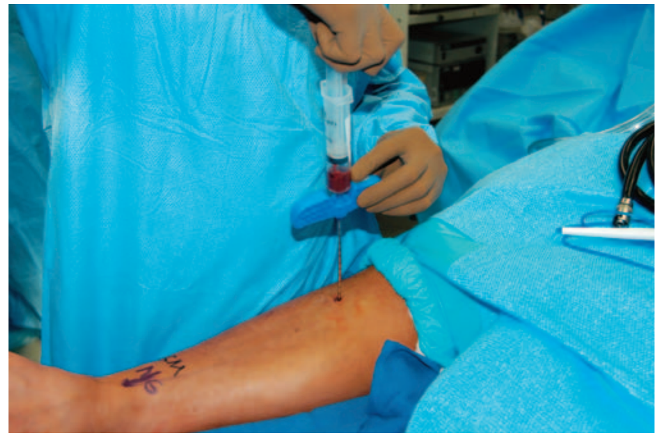

Figure 2. Aspiration of the proximal tibial bone marrow. Negative plunging is evidenced by the vacuum space above the BMA in the syringe.

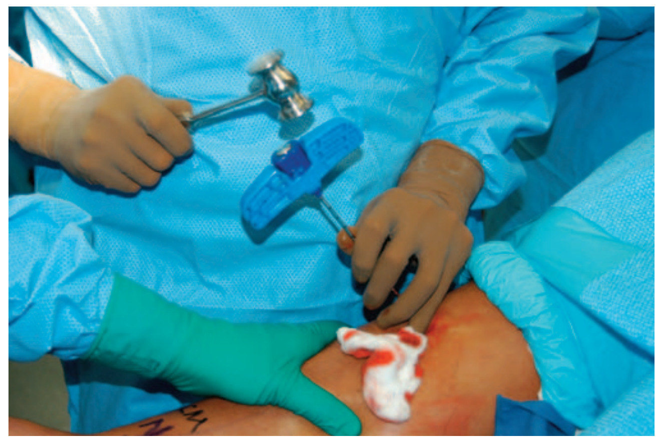

Figure 3. After the first series of aspirations, the needle is withdrawn and is now being reinserted about 30 degrees off of the initial aspiration track. Care should be taken when reorienting proximally as seen here, to be keenly aware of the proximity to the knee joint so as to avoid inadvertent violation of the knee.

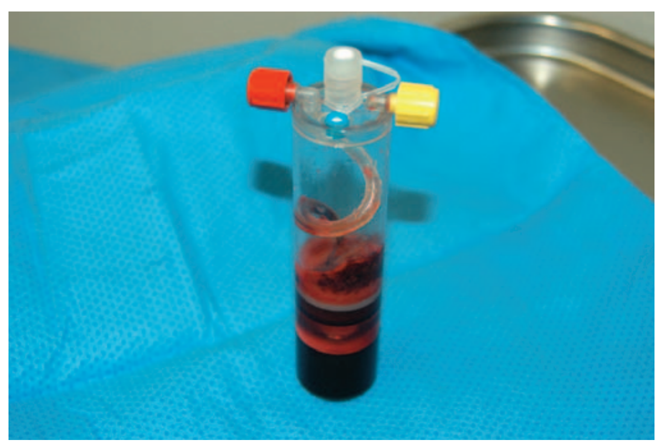

Figure 4. BMAC after the platelet poor fraction has been aspirated.

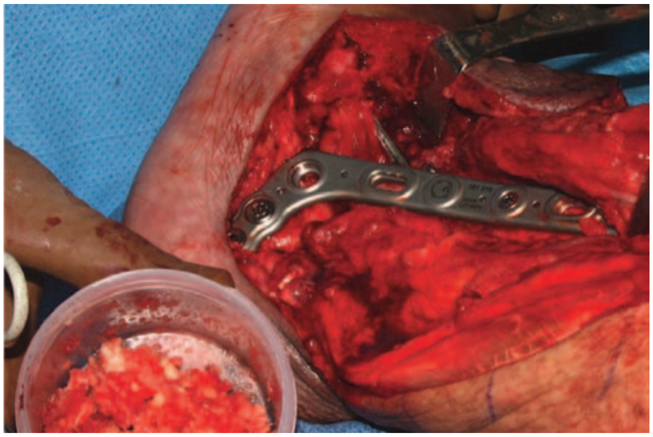

Figure 5. BMAC is combined with autologous milled cortical bone and fiber DBM with corticocancellous chips thus delivering all desirable graft properties in a high risk revision Charcot ankle/hindfoot fusion.

Figure 6. Postoperative radiograph with BMA and DBM in place around final hardware construct.

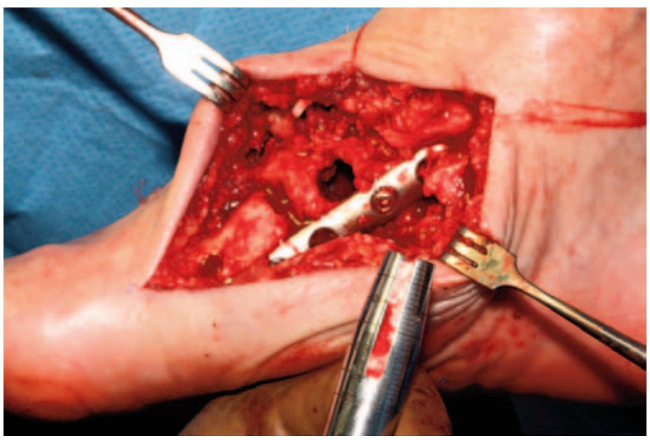

Figure 7. Midfoot Charcot reconstruction with all fixation in place and BMAC soaked synthetic allograft composite dowel about to be delivered to enhance midfoot arthrodesis biology.

BIBLIOGRAPHY

Cuomo A, Virk M, Petrigliano F, Morgan E, Lieberman J. Mesenchymal stem cell concentration and bone repair: potential pitfalls from bench to bedside. J Bone Joint Surg Am 2009;91:1073-83.

Hatzokos I, Stavridis S, Iosifidou E, Karataglis D, Christodoulou A. Autologous bone marrow grafting combined with demineralized bone matrix improves consolidation of docking site after distraction osteogenesis. J Bone Joint Surg 2011;93:671-8.

Hernigou P, Poignard A, Beaujean F, Rouard H. Percutaneous autologous bone marrow grafting for nonunions. J Bone Joint Surg 2005;87:1430-7

Muschler G, Boehm C, Easley K. Aspiration to obtain osteoblast progenitor cells from human bone marrow: the influence of aspirate volume. J Bone Joint Surg Am 1997;79:1699-709.

Pinzur M. Use of platelet rich concentrate and bone marrow aspirate in high risk patients with charcot arthropathy of the foot. Foot Ankle Int 2009:30:124-7

Rao RD, Gourab K, Bagaria V, Shidham V, Metkar U, Cooley BC. The effect of platelet rich plasma and bone marrow on murine posterolateral lumbar spine arthrodesis with bone morphogeneic protein. J Bone Joint Surg Am 2009;91:1199-206.

Roukis T, Hyer C, Philbin T, Berlet G, Lee T. Complications associated with autogenous bone marrow aspirate harvest from the lower extremity: and observational cohort study. J Foot Ankle Surg 2009;48:668-71.

Schweinberger M, Roukis T. Percutaneous autologous bone marrow harvest from calcaneus and proximal tibia: surgical technique. J Foot Ankle Surg 200746;5:411-4.