Core Decompression Augmented With Autologous Bone Marrow Aspiration Concentrate for Early Avascular Necrosis of the Femoral Head

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Abstract: Lack of necessary perfusion to the femoral head can lead to necrosis of the underlying bone (avascular necrosis) and result in femoral and acetabular surface changes in advanced stages. Numerous treatments have been reported in the literature, including nonoperative and surgical procedures. In addition to the standard core decompression, we describe the use of bone marrow aspirate to stimulate a healing response and bone grafting, allowing for immediate weight bearing postoperatively. The purpose of this article was to describe our method of core decompression augmented with bone marrow aspirate concentrate and bone grafting for the treatment of early avascular necrosis of the femoral head.

A vascular necrosis (AVN) of the femoral head is the result of decreased blood flow to the femoral head, often due to intravascular coagulation of the intraosseous microcirculation. This lack of adequate perfusion can result in necrosis of the bone, micro-fracture, and articular surface collapse in the later stages.¹ The main risk factors include alcohol and corticosteroids, which are involved in more than 50% of the cases. Other risk factors include irradiation, trauma, and sickle cell disease. However, up to 40% of cases are idiopathic.² Ten percent of total hip replacements (THRs) are the result of AVN.³

In the early stages, AVN of the femoral head is frequently asymptomatic, but it can present as limited range of motion and groin pain exacerbated by forced internal rotation.⁴ Anteroposterior (AP) and frog-leg

© 2016 by the Arthroscopy Association of North America 2212-6287/151187/\$36.00 http://dx.doi.org/10.1016/j.eats.2016.02.009 lateral radiographs are routinely obtained but usually appear unremarkable. Magnetic resonance imaging (MRI) is the diagnostic gold standard⁵ and should be performed in every case of classic AVN presenting with unremarkable radiographs. In 70% of cases, presentation is bilateral.⁴ The size and location of the lesion are prognostic factors for disease progression and are best assessed by MRI.⁶ Early diagnosis is crucial for optimal treatment of AVN.⁴ If left untreated, about 70% to 80% of patients progress to collapse and secondary osteoarthritis of the hip.⁷

Many treatments have been proposed for AVN of the femoral head. Nonsurgical treatments include pharmacologic therapies, such as lipid-lowering agents, anticoagulants, vasoactive substances, and bisphosphonates, and nonpharmacologic therapies, including extracorporeal shockwave therapy, pulse electromagnetic therapy, and hyperbaric oxygen therapy.⁴ Surgical treatments range from core decompression to total hip arthroplasty.⁵

Core decompression is a widespread and accepted technique for the treatment of early AVN of the femoral head. Good results have been reported when performed in the initial or pre-collapse phases (Ficat stages 0 through II)⁵; however, less-than-desirable results have been reported when performed in advanced stages (Ficat stage III or IV).⁸ It has been suggested that one reason for poor healing in some patients is that there might be insufficient osteoprogenitor cells in the femoral head to support the repair of the necrotic

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Table 1. Ficat Classification

Stage	Pain	Radiographic Findings
0 (preclinical)	None	Normal
I (pre-radiographic)	+	Normal
II A (pre-collapse)	+	Changes in bone trabeculae with
		sclerosis or cystic changes
II B (pre-collapse)	+	Presence of crescent sign
III (early collapse)	++	Normal joint space, presence of crescent
		sign, osteochondral fracture with
		sequestrum
IV (osteoarthritis)	+++	Collapse of head, decreased joint space,
		flattened contour

bone.⁹ Therefore, bone marrow aspiration concentrate (BMAC) therapy has been proposed as an adjuvant therapy to core decompression. Several studies have reported better results when core decompression is combined with BMAC, as compared with results with core decompression alone.¹⁰⁻¹⁵

Traditionally, core decompression has been performed with multiple drill holes in the femoral head. This required patients to be non—weight bearing for 6 weeks postoperatively. The proposed surgical technique uses a single drill hole and a 6-mm cannulated trocar rod that perforates the exact area of necrosis and is augmented with BMAC and bone allograft. This procedure allows patients to bear weight as tolerated immediately after surgery. The purpose of this technical note was to describe the method of core decompression augmented with BMAC and bone grafting for the treatment of early AVN of the femoral head.

Surgical Technique

Diagnosis

Diagnosis is based on the patient's history and clinical presentation. A history of corticosteroid use and alcohol abuse can help guide the clinician toward a diagnosis. Patients often complain of pain, limping, or limited mobility, especially in internal rotation. However, it is



Fig 2. Iliac bone marrow is obtained percutaneously through the use of bone marrow aspiration needles bilaterally. (ASIS, anterosuperior iliac spine.)

not uncommon for this disease to present only as occasional isolated discomfort. In the early stages, AP and frog-leg lateral radiographs are usually unremarkable or they may show cysts and sclerosis that can be observed in the anterior and superior part of the femoral head. The Ficat classification is the most commonly used system to stage AVN of the hip (Table 1).^{16,17} Moreover, MRI should be performed in all cases of suspected AVN because it can show findings not evident on plain radiographs.

Indications and Contraindications

Core decompression is indicated in the pre-collapse stages of AVN (Ficat stages 0 through II).¹⁸ It should not be performed in patients with collapse of the femoral head (Ficat stage III or IV).

Patient Positioning

The patient is positioned supine on a fracture table (Hana Table; Mizuho OSI, Union City, CA) with both feet secured in traction boots (Fig 1). A second option is to place the patient supine on a radiolucent table. General anesthesia is used for induction. Internal



Fig 1. The patient is positioned supine on a fracture table with both feet secured in traction boots and internally rotated. A right hip setup is shown.



Fig 3. The PerFuse rod is placed over the skin to determine the anteroposterior skin markings on a right hip. (ASIS, anterosuperior iliac spine.)

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Fig 4. Fluoroscopy of a right hip: anteroposterior (A) and lateral (B) views. The trocar is advanced, making sure the location matches the area of avascular necrosis.

rotation of both feet is performed by positioning the patella facing straight up. It is necessary to ensure that AP and lateral views can be taken with a fluoroscope before preparing the patient. Draping should be performed in a sterile manner that provides exposure of the anterosuperior iliac spine proximally and continues below the knee distally (Video 1).

Bone Marrow Aspiration

Bone marrow aspiration is performed proximal to the anterosuperior iliac spine. Iliac bone marrow is obtained percutaneously through the use of a bone marrow aspiration needle (MarrowStim; Biomet Biologics, Warsaw, IN) introduced manually or with light mallet blows. The bone marrow aspiration needle runs parallel between both cortices of the iliac crest. A total of 100 mL of bone marrow is aspirated using a 60-mL or 10-mL syringe, with the 10 mL syringe being preferable. Each syringe will be preloaded with 10 mL of heparin (1,000 U/mL) to avoid coagulation and clot formation (Fig 2). It is also important to prime the bone marrow aspiration needles with anticoagulant to avoid clot formation.

Blood Sample Centrifugation

The bone marrow aspirate samples are placed in a centrifuge (Drucker Diagnostics, Port Matilda, PA) and spun for 15 minutes at a speed of 3,200 rpm.

Core Decompression

Core decompression is initiated while the blood sample is processing. The C-arm is used to locate the starting point. The PerFuse rod (Biomet Biologics) is placed over the skin to determine the AP and superoinferior skin markings. A lateral image is also obtained by referencing the PerFuse rod radiographically, which will provide landmarks for the lateral skin marking. The intersection of these skin markings is the incision location. This should be at the lateral cortex at the location of the lesser tuberosity or proximal to it (Fig 3).

A 1-cm incision is then performed at the corresponding entry point over the lateral aspect of the femur, just below the vastus ridge of the trochanter. The starting point is maintained proximal to the level of the lesser trochanter and distal to the vastus ridge. When the ideal starting point has been obtained, the trocar is advanced from lateral to medial under fluoroscopy.



Fig 5. Delivery of bone marrow aspiration concentrate (BMAC) through a disposable cannula in a right hip. Injection is performed directly into the necrotic zone.



Fig 6. Bone graft is introduced using a syringe through the cannula. The bone graft is pushed into the canal with the use of a trocar rod in a right hip.

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Fig 7. (A, B) Fluoroscopic images showing sequential filling of the tunnel with bone graft in a right hip.

This must be performed under the AP and lateral views, with the surgeon making sure the trocar location matches the area of AVN (Fig 4).

The instrument is advanced into the necrotic lesion by striking the PerFuse trocar with a mallet. Typically, a change in the mallet ping pitch is noted when the trocar reaches the necrotic bone. The area of necrosis can be entered with the trocar, but the trocar should not be advanced to within 5 mm of subchondral bone to prevent joint violation. Once the trocar is located in the area of AVN, the inner guide is removed and the BMAC is inoculated.

Removal of Instrument Handle and Preparation for BMAC Inoculation

The handle and trocar are separated from the cannula by engaging the quick release while maintaining the 6-mm cannula in the necrotic portion of the femoral head. Approximately 6 mL of BMAC is obtained after

Table 2. Pearls and Pitfalls

Pearls

- The surgeon should use fluoroscopy throughout the case for guidance.
- A change in the mallet ping pitch is noted when the trocar reaches the necrotic bone.
- The BMAC should be inoculated in the area of necrosis through the syringe placed into the cannula.
- Postoperatively, WBAT with crutches is immediately initiated. Pitfalls
 - Failure to use frequent fluoroscopic imaging can result in joint violation from advancing the trocar too far.
 - Failure to add heparin to the syringes and prime the needles with anticoagulant can result in clot formation when extracting the bone marrow.
 - If resistance is present, the surgeon should withdraw the cannula by a couple of millimeters and reattempt inoculation of the BMAC.

BMAC, bone marrow aspiration concentrate; WBAT, weight bearing as tolerated.

centrifugation. A 60-mL syringe containing the BMAC is attached to the PerFuse disposable cannula (Biomet Biologics). The BMAC is injected directly into the necrotic zone (Fig 5). Sometimes, significant resistance is encountered because of the sclerotic bone. Should this occur, the surgeon should remove the cannula by 2 to 3 mm and reattempt injection.

Bone Grafting

Bone matrix allograft (Bonus CC Matrix; Zimmer Biomet, Warsaw, IN) is added to fill in the hole that was left from the drilling (Fig 6). Before inoculation, the bone graft is crushed to obtain small chips. The chips are introduced through the cannula and impacted along the tunnel with a rod. It is useful to use a syringe to help introduce the bone chips into the cannula.

The cannula is removed progressively, and the procedure is repeated: The surgeon introduces the bone graft chips, impacts the bone, and withdraws the cannula, allowing the drilled hole to be filled by bone graft (Fig 7). Sometimes, the PerFuse Slide Hammer (Biomet Biologics) can be used to aid removal. Surgical pearls and pitfalls of this procedure are listed in Table 2.

Postoperative Guidelines

This surgical procedure is typically performed on an outpatient basis. If a bilateral procedure is performed, the patient is admitted overnight. Weight bearing as tolerated (WBAT) is permitted with the use of crutches for the first 2 weeks. Most patients have rapid pain relief that is noticeable within a few days after the procedure. Some patients require oral analgesics for the first 2 or 3 weeks after the procedure. All patients are prescribed aspirin (325 mg twice a day) for 3 weeks to prevent deep venous thrombosis. Advantages and disadvantages of this technique are listed in Table 3.

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Table 3. Advantages and Limitations

Advantages

The procedure is minimally invasive.

The patient's own bone marrow is used to stimulate biological healing.

The patient can bear weight as tolerated immediately after surgery. BMAC is inoculated in the area of necrosis.

The procedure is an outpatient procedure.

Limitations

The procedure is not indicated in later stages of avascular necrosis. It is not safe to perform without the aid of intraoperative imaging. General anesthesia is needed.

BMAC, bone marrow aspirate concentrate.

Discussion

We have described a percutaneous technique of core decompression augmented with BMAC and bone allograft for the treatment of early AVN of the hip. This technique is innovative because it uses a 6-mm cannulated trocar, allowing inoculation of BMAC in the precise AVN location followed by bone allograft of the drilling area. The patient is allowed to be WBAT immediately after surgery.

Core decompression augmented with BMAC was first described by Hernigou and Beaujean in 2002.¹⁹ He presented 189 hips treated with core decompression with a 3-mm trocar and bone marrow grafting. Better results were observed in early stages of AVN. All the groups reported improved Harris Hip Scores after treatment, but 18% of hips required THR at an average of 26 months. The stage of AVN at the time of the procedure proved highly significant. Only 2% and 8% of patients required THR in stages I and II, respectively, whereas 41% and 63% required THR in stages III and IV, respectively.

Several studies have compared isolated core decompression with core decompression augmented with bone marrow graft. Gangji and Hauzeur¹² reported that bone marrow implantation delayed the progression of AVN from stages I and II to stage III at 60 months of follow-up and provided a significant decrease in pain, as compared with isolated core decompression. On the other hand, they did not report any significant difference in the time to arthroplasty between the 2 groups. Sen et al.¹⁰ reported on 51 stage I and II AVN hips. Their study showed that bone marrow implantation increased hip survival but without any noticeable differences on imaging between the 2 groups. They reported that patients with post-traumatic AVN had better outcomes than those with nontraumatic AVN. Tabatabaee et al.¹⁴ performed a prospective randomized clinical trial on 28 hips, comparing isolated core decompression with bone marrow augmentation in addition to core decompression. Pain ratings at 24 months were significantly lower in the group

augmented with bone marrow. Western Ontario and McMaster Universities Osteoarthritis Index scores improved in both groups but were significantly higher in the group treated with bone marrow. Zhao et al.²⁰ compared the results of 51 hips that underwent core decompression and 53 hips that underwent core decompression augmented with bone marrow. Higher Harris Hip Scores were reported in the bone marrow group at the end of follow-up, and significantly fewer patients from the bone marrow group required an additional procedure such as THR or fibular vascularized graft. Zhao et al. concluded that the size and location of AVN of the femoral head was the most important outcome factor.

Lieberman et al.²¹ used autologous bone morphogenetic proteins to augment core decompression in 15 patients. Their results were good in 12 cases at final follow-up (mean, 53 months; range, 26 to 94 months). However, 3 patients required a total hip arthroplasty, all of whom had at least two-thirds of the femoral head affected before decompression. Lieberman et al. concluded that success was dependent on the necrotic femoral head weight-bearing area involved.

Percutaneous core decompression combined with augmented BMAC and bone allograft is a minimally invasive technique that is simple and allows the patient to be WBAT immediately after surgery. Although the use of BMAC in conjunction with core decompression had been previously described, the addition of bone grafting with the use of a 6-mm trocar with permitted immediate postoperative weight bearing has not been previously reported. We recommend this procedure for early stages of AVN (Ficat stages 0 through II) of the femoral head and encourage other groups to investigate this technique and report their findings.

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