Intraoperative Fat Embolism During Core Decompression and Bone Grafting for Osteonecrosis of the Hip: Report of 3 Cases and Literature Review

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Abstract

Osteonecrosis (ON) of the femoral head, without timely intervention, often progresses to debilitating hip arthritis.

Core decompression (CD) with bone grafting was used to treat patients with early-stage ON. In 3 cases, intraoperative oxygen saturation, end-tidal carbon dioxide fluctuations, and/or vital sign fluctuations were observed during insertion of the graft, a mixture of bone marrow and demineralized bone matrix. In 1 case, continued postoperative pulmonary symptoms required admission to intensive care.

In this article, we describe these cases and provide supporting evidence that they were caused by fat emboli secondary to forceful insertion of bone graft. We review the literature and present complications data.

Although no cases of fat emboli were reported as complications of any CD series with or without bone grafting, CD augmented with bone graft may carry risks not seen before in CD alone. Care should be taken to avoid these complications, possibly through technique modification.

Osteonecrosis (ON) of the femoral head, without timely intervention, often progresses to debilitating hip arthritis. Core decompression (CD) is a safe and successful procedure for the treatment of early-stage precollapsed femoral head ON.[1-4] It aims to halt or delay disease progression and joint destruction in order to decrease the pain and to delay or avoid total hip replacement. Its efficacy is believed to derive from reduction in intramedullary pressure along with increasing neovascularization and creeping substitution.[5] More recent developments in CD include augmentation with osteoinductive substances or structural augments.[2,6-16]

Intramedullary implantation or impaction of material during femoral nailing or insertion of prostheses is known to result in fat embolism, particularly during intramedullary nailing of the femur.[17,18] To the authors' knowledge, however, no fat emboli during CD procedures, with or without grafting augmentation, have been reported in the literature.

During surgery, fat embolism can be diagnosed based on hemodynamic, oxygenation, and end-tidal partial pressure of carbon dioxide ($P_{ET}CO_2$) changes and the temporal relationship with surgical events. Clinically, a rapid fall in $P_{ET}CO_2$ is usually the first indication of a significant pulmonary embolism (PE), including fat embolism.[19] Helical computed tomography (CT) is the preferred definitive diagnostic study, but transesophageal echocardiography may be valuable in making a presumptive diagnosis in the operating room.[20,21]

In this report, we describe 3 cases of intraoperative drop in $P_{ET}CO_2$ temporally related to bone-graft impaction during CD for femoral head ON. The patients provided written informed consent for print and electronic publication of these case reports.

Case Reports

Case 1

A 22-year-old woman with bilateral hip ON (Ficat stage II) underwent elective right hip CD and bone grafting. The patient had no history of deep vein thrombosis (DVT) or PE.

CD was performed with an 8-mm reamer. Representative intraoperative fluoroscopic images are shown in **Figures 1 to 3**. Bone marrow totaling 6 mL was aspirated from the greater trochanter and mixed with 10 mL of demineralized bone matrix. The mixture was shaped into a bullet and delivered into the CD tract using a specialized insertion tool (**Figure 3**) with inserter tip outer diameter of 8 mm and inserter shaft outer diameter of 10 mm.

During bone-graft insertion, oxygen desaturation and

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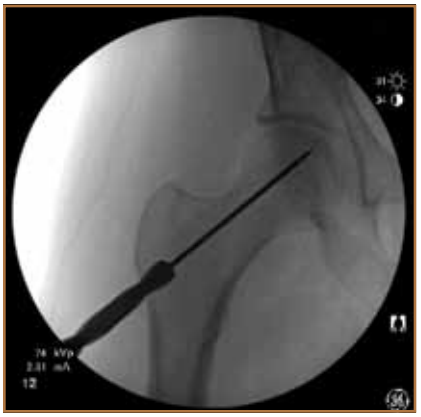

Figure 1. Intraoperative anteroposterior fluoroscopic image shows reaming over guide wire using 8-mm reamer.

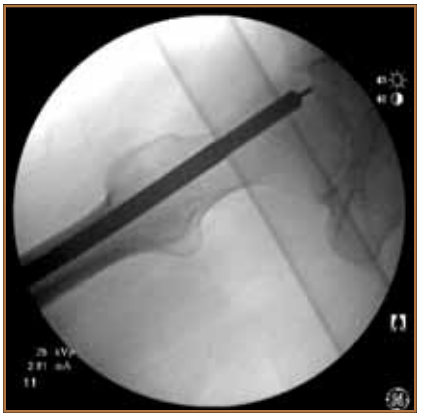

Figure 2. Intraoperative lateral fluoroscopic image shows reaming over guide wire using 8-mm reamer.

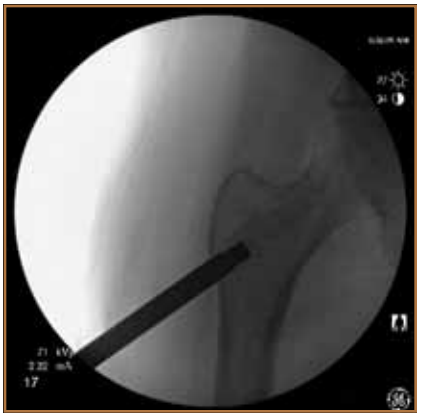

Figure 3. Intraoperative fluoroscopic image shows bone-graft insertion device. Outer diameter of inserter tip is 8 mm, and outer diameter of inserter shaft is 10 mm.

tachycardia occurred very briefly, and with an accompanying $P_{ET}CO_2$ decrease, possibly caused, it was thought, by fat emboli. Concern about this development prompted transfer to the surgical intensive care unit (SICU) for extubation and observation. There were no further issues during the patient's short ICU admission, and she was discharged the next day with no further complications.

Case 2

A 31-year-old man with bilateral hip ON (Ficat stage II) underwent elective left hip CD and bone grafting. The patient's medical history included systemic lupus erythematosus complicated by chronic kidney disease (stage III) and hypertension. There was no history of DVT or PE. Levels of hypercoagulation-causing anti-phospholipid antibodies (lupus antibody and anti-cardiolipin immunoglobulins M and G) were normal. The procedure was performed in the same manner as described in case 1.

At time of bone-graft insertion, the patient's $P_{ET}CO_2$ suddenly decreased, by about 65%. On examination, breath sounds were present bilaterally without wheezing. After 3 to 4 minutes, ST segment elevation up to 3.4 mm was noted in leads I, II, and V5. Oxygen saturation (SaO_2) remained at 100% throughout the event. The patient was hemodynamically and oximetrically stable throughout the procedure. He was treated with 100% fraction of inspired oxygen (FiO_2). $P_{ET}CO_2$ remained very low for 20 minutes or more and recovered to physiologic levels only when mechanical ventilation was reduced by two-thirds. The postoperative course was unremarkable.

Case 3

A 27-year-old woman with right hip ON (Ficat stage II) underwent elective CD and bone grafting. The patient's medical history included oligodendroglioma brain tumor. She was on a steroid taper at time of presentation for right-side hip pain. There was no history of DVT or PE. The procedure was performed in the same manner as described in case 1.

Immediately after insertion of the bone graft, there was a transient decrease in both $P_{ET}CO_2$ and SaO_2. On arrival at the postanesthesia care unit (PACU), the patient was tachycardic to 130 to 140 bpm and required oxygen. On examination, her breath sounds were clear. For about an hour in the PACU, she remained tachycardic, was hypotensive to 74/50 and tachypneic to 28, and could not be weaned off oxygen (she quickly desaturated to 82% when placed on room air). She was asymptomatic except for a new dry cough. She received stress–dose steroids at anesthesia induction and in the PACU. Because of this complication and because of concern for adrenal crisis, the decision was made to admit her to the ICU. Chest radiography showed increased lower lobe, predominantly peripheral, mixed interstitial and airspace opacification with focal patchy opacification in the mid-lungs bilaterally. Helical CT pulmonary angiogram was negative for PE to the subsegmental level but showed bilateral multifocal alveolar opacities in conjunction with small bilateral pleural effusions. Both imaging studies were noted to be possibly consistent with multifocal fat emboli. The patient took 2 days to recover in the ICU before being transferred to the medical floor. She was discharged home on postoperative day 3 without further incident.

Discussion

CD is the most commonly used treatment for symptomatic, precollapse ON (Steinberg stages IB, IIB) of the femoral head,[22] and its results in smaller necrotic lesions have been especially promising.[1,4,23,24] Soohoo and colleagues[25] found that CD can be highly cost-effective if it delays the need for total hip arthroplasty for 5 years or longer.

Our review of the CD literature found only 1 case of PE as a complication of CD. This case was reported by Steinberg and colleagues[23,26,27] and mentioned in a 1996 meta-analysis (1206 CD-treated hips, 24 studies) by Mont and colleagues.[28] The PE was massive but nonfatal, and there is no indication it was intraoperative or a fat embolism. In a more recent review, Marker and colleagues[1] examined outcomes of 26 studies for a total of 1268 hips since 1992, but did not report complications

Table. **Summary of Reported Perioperative Complications of CD Procedures in Recent Studies**

Study	Year	Procedure	No. of Cases	No. of Hips	Perioperative Complications
Steinberg et al[23,26,27]	1989 1995 2001	CD with bone grafting	285	406	1 massive nonfatal pulmonary embolism, 1 proximal femoral thrombophlebitis, 1 pneumonia, 2 fractures within 1 mo of surgery, 1 intertrochanteric, 1 subcapital
Mont et al[13]	2003	BMP-enriched bone allograft through femoral head–neck junction	19	21	No intraoperative complications; 2 deep vein thromboses, 1 femoral neck fracture 2 weeks after surgery
Gangji et al[9,29,30]	2004 2005 2011	CD with or without bone-marrow cell implantation	19	24	No major complications; 3 pain at aspiration site, 1 hematoma at decompression site, 1 bone-marrow culture positive for coagulase-negative staphylococci (treated, no sepsis)
Lieberman et al[8]	2004	CD and allogeneic, cortical bone perfused with human BMP and noncollagenous proteins	15	17	None
Bellot et al[3]	2005	CD	25	32	1 subtrochanteric fracture from fall 3 weeks after surgery
Tsao et al[31]	2005	CD and porous tantalum implant	98	113	4 intraoperative implant damage, 1 recurring issue with bone-coring localization
Veillette et al[16]	2006	CD and porous tantalum implant	54	60	1 superficial infection, 1 deep infection, 1 trochanteric bursitis
Shuler et al[15]	2007	CD and porous tantalum implant	24	—	No implant-associated complications reported
					1 intraoperative failure
		CD and vascularized fibular graft	21		1 pneumonia
					2 harvest-site complications
Seyler et al[10]	2008	Nonvascularized bone graft with OP-1	33	39	None reported
Wang et al[11]	2010	Bone-grafting femoral head–neck junction	110	138	1 ectopic ossification, 1 lateral femoral cutaneous nerve lesion, 1 joint infection
Wang et al[32]	2010	CD and autologous BMMC injection	45	59	None observed during or after operation
Floerkemeier et al[33]	2011	CD and tantalum rod	19	23	1 subtrochanteric fracture, 1 footdrop
Sen et al[34]	2012	CD with or without autologous BMMCs	40	51	None observed
Helbig et al[12]	2012	CD and DBM implant	14	18	None related to core decompression
Civinini et al[14]	2012	CD and injection of autologous bone-marrow concentrate and composite injectable bone substitute (Pro-Dense)	31	37	None associated with procedure
Wang et al[35]	2012	CD and autogenous cancellous bone and allogenous fibular graft	25	28	No major surgical complications
Chotivichit et al[36]	2012	CD and concentrated autologous bone-marrow injection	12	13	No adverse effects or immediate complications
Zhao et al[7]	2012	CD and BMMSCs	50	53	None observed
		CD	50	51	
Lim et al[37]	2013	CD alone	21	31	No complication data reported
		CD and stem-cell implantation	86	128	
Beckman et al[39]	2013	CD alone	12	—	CD: none noted
		CD and intravenous iloprost	12		Iloprost: 2 headaches, 1 flushing, 1 angina pectoris
Liu et al[40]	2013	CD with or without BMMCs and hydroxylapatite composite filler	36	45	2 guide-wire breakage, 1 perforation of subchondral bone
Al Omran[41]	2013	Conventional CD	61[a]	—	2 wound infections, 1 acute chest syndrome, 1 transfusion reaction, 3 heterotopic bone
		Multiple small drilling	33[a]		
Calori et al[38]	2014	CD and recombinant morphogenetic proteins, autologous MSCs, and xenograft bone substitute	38	40	4 calcification near surgery access point, 1 subtrochanteric fracture of femur

Abbreviations: BMMC, bone marrow mononuclear cell; BMMSC, bone marrow–derived mesenchymal stem cell; BMP, bone morphogenetic protein; CD, core decompression; DBM, demineralized bone matrix; MSC, mesenchymal stem cell; OP-1, osteogenic protein 1 (a.k.a. BMP-7).

[a]All with sickle-cell disease.

data. Complications data and other findings of our literature review are summarized in the **Table**.[3,7-16,23,26,27,29-41] No additional case of PE was noted.

Although it is well described in other orthopedic procedures, fat embolism has not been reported in the literature as a complication of CD with or without bone grafting. Embolism during orthopedic procedures has been related to impaction maneuvers and is thought to be caused by increased intramedullary pressure leading to intravasation of marrow contents or bone particles into the venous system. This material can then travel to the lungs and, in the cases with right-to-left shunt, cause cerebral infarction.[42,43]

In this report, we have described 3 cases of intraoperative abrupt drop in $P_{ET}CO_2$ temporally related to impaction maneuvers during CD and bone grafting. The most likely explanation for these events is intravasation of bone marrow resulting in fat embolism to the lungs. In case 3, this was confirmed by helical CT pulmonary angiogram. As fat embolism had not been anticipated in these cases, intraoperative echocardiography was not used. We think these embolisms occurred by the same mechanism (greatly increased intramedullary pressures secondary to impaction) found in impaction maneuvers in other orthopedic procedures.[17,18,42,43] The animal models that have been developed and tested based on this mechanism have shown that elevation of intramedullary pressure is a major factor in creating high levels of intravasation of marrow fat.[44-46]

Fat embolization is most often inconsequential but can sometimes result in progressive respiratory insufficiency and other end organ damage—a condition known as fat embolism syndrome (FES)[18,19,42,43,47]—or even intraoperative cardiovascular collapse and sudden death.[48] Signs and symptoms of FES include signs of pulmonary involvement (bilateral "snowstorm" appearance on chest radiograph, absence of heart failure), systemic inflammation (tachycardia, tachypnea, pyrexia), and systemic embolism (focal neurologic deficits, petechial rash on upper torso).[18] This condition is consistent with our 3 cases, particularly case 3, which was likely true FES. Cases 1 and 2 did not develop the full syndrome.

Akhtar[47] pointed out that, though the true incidence of FES is unknown, the number of orthopedic interventions known to provoke fat embolism is increasing. This is an indication that measures should be taken to decrease these risks. Parvizi and colleagues[48] found that, when modifications to hip arthroplasty operative techniques designed to minimize intramedullary hypertension were implemented, there was a 3-fold reduction in overall intraoperative mortality.

Conclusion

We have described 3 cases in which fat emboli resulted from impaction grafting during CD, demonstrating that CD augmented with bone graft may carry new risks not seen before in use of CD alone. Care should be taken to avoid these complications, possibly through technique modification, such as less forceful bone-graft impaction or device modification, to allow pressure equalization during impaction.

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