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Embolic Phenomena During Revision Total Hip Arthroplasty: Diagnosis with Transesophageal Echocardiography

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Abstract: Embolic material was seen in the right atrium during one or more phases of revision total hip arthroplasty (THA)in 17 of 21 ASA Class II or Class III patients (77%) who were monitored with transesophageal echocardiography (TEE). The largest volume of embolic material occurred during preparation and insertion of cemented femoral components. Multiple occurrences of embolization during the procedure appear to have an additive effect which precipitated an increased use of the intensive care unit and the need for greater pulmonary support postoperatively, $p < 0.05$. Although fat and marrow elements are suspect, the exact nature of the embolic material that has been observed is presently undefined.

Introduction

The occurrence of transient hypotension has been noted in a variable percentage of patients during total hip arthroplasty. Charnley noted this phenomenon in one-third of his patients [4]. Harris reported benign, transient hypotension in the majority of his patients [3]. Cardiac arrest has occurred in a minority of patients with introduction of the polymethylmethacrylate (PMMA) during total hip and knee arthroplasty [9]. The etiology of these adverse cardiac events have included air embolism, the depressive effect of the monomer of PMMA, and massive fat embolization [1,2,5,7,8,10,12]. Ereth and co-workers demonstrated fat embolization during primary cemented total hip arthroplasty with a new technique--transesophageal echocardiography (TEE)--to monitor intra-operative cardiac activity [5]. Patterson and co-workers [9] reported embolization of marrow contents into the venous system and the lung with the introduction of cemented, long stem femoral components into previously unoperated femoral canals [7]. These authors also reported that fat embolization was not observed with revision of the femoral component.

We have noted significant embolic material in the right atrium of patients during cement removal and the introduction of revision long-stem femoral components with PMMA. Those patients who experienced embolic phenomena required greater pulmonary support during their post-operative recovery. We wish to report our experience with TEE monitoring of cardiac activity during revision total hip arthroplasty.

Methods

Fourteen ASA Class II and seven ASA Class III patients who were having revision total hip arthroplasty were included. Seven of the 21 patients had revision of both the femoral and acetabular components. Acetabular component revision alone was performed in five of the 21 patients. Two additional patients had only the femoral component revised. The remaining seven patients had had a Girdlestone resection arthroplasty and both the acetabular and femoral components were implanted during the revision procedure. Pre-operatively, the eight patients with a Girdlestone resection arthroplasty had a normal erythrocyte sedimentation rate and a normal ^{111}In autologous white blood cell image. Eleven of the 14 patients with implants in place at the time of the revision total hip arthroplasty had roentgenographic evidence of aseptic loosening of cemented components. Two patients had roentgenographic evidence of aseptic loosening of cementless acetabular components. The final patient had a painful bipolar prosthesis with migration into the bony acetabulum. Intra-operative frozen section histological examination of surgical specimens revealed no evidence of an infectious process and subsequent microbiological assessment of multiple tissue specimens were sterile in all 21 patients (Table 1).

Table 1. Pulmonary embolization during revision total hip arthroplasty

Type of THA	Cement Removal Technique	Component Revised*	Type of Femoral Component Implanted	Femoral Perforations, Use of Allografts, and implants	Type of Acetabular Component Implanted	ASA Grade
Bipolar	Osteotomes	A	N/A		Cementless	2
PCA Acetab.	Osteotomes	A	N/A		Cementless	2
HD II	Osteotomes	A	N/A		Cementless	2
PFC Acetab.	Osteotomes	A	N/A			2
Cemented	Osteotomes	A	N/A		Cementless	2
Charnley-Muller	Osteotomes and Midas Rex	F	Biomet		N/A	3
HD II	Ultradrive	F	Precision	Femoral Perforation	N/A	3
Cemented	Osteotomes	B	Precision	Proximal Femoral Fx. Preop; Femoral Structural Allograft	Cementless	3
Cemented	Ultradrive and Midas Rex	B	Precision	Femoral Perforation; Femroral Structural Allograft	Cementless	2
Cemented '79	Ultradrive	B	Solution		Cementless	2
Townly	Osteotomes	B	Solution	Prophylactic Cables	Cemented	2
Cemented	Ultradrive	B	Biomet	Femoral Structural Allograft	Cemented	2
Cemented '78	Osteotomes	B	Cementless AML Calcar	Femoral Perforation by Old Stem	Cementless	3
Charnley-Muller	Osteotomes	B	Solution	Femoral Crack; Cables	Cementless	3
Charnley-Muller	N/A	G	Biomet		Cemented	3
Charnley-Muller	N/A	G	Solution Cemented	Femoral Crack; Cables	Cementless	2
Charnley-Muller	N/A	G	Solution		Cemented	3

Charnley-Muller	N/A	G	Precision	Femoral Crack; Cables	Cemented	2
Charnley-Muller	N/A	G	Precision	Femoral Structural Allograft	Cemented	2
Charnley-Muller	N/A	G	Biomet	Femoral Fx.; Acetabular Structural Allograft	Cemented	2
Charnley-Muller	N/A	G	Cementless AML		Cementless	2

[1]A = Acetabular component; F = Femoral component; B = Both femoral and acetabular components; G = Preoperative girdlestone.
[2]Total Embolic Score = Sum of the embolic grades.
N/A = Not applicable; SWM = Segmental wall motion abnormality.
[3] = Erth embolic grade (see text)

Table 1. Continued

Embolic Grades During Stages of Reconstruction[3]						Total Embolic Score[2]	ICU Postop	Oxygen Utilization (hours)
Removal of PMMA from Femur	**Preparation of Femur**	**Removal of PMMA from Acetabulum**	**Insertion of Acetabular Component**	**Insertion of Femoral Component**	**Relocation of Hip**			
N/A	N/A	0	0	N/A	0	0	No	17
N/A	N/A	0	0	N/A	0	0	No	14
N/A	N/A	0	0	N/A	0	0	No	15
N/A	N/A	0	II	N/A	0	2	No	10
N/A	N/A	0	I	N/A	I	2	No	17
II	II	N/A	N/A	0	0	4	Yes	40
0	I	N/A	N/A	0	0	1	Yes	1440
0	I	0	0	II	0	3	Yes	64
II	II	IV	0	0	III	11	Yes	50
0	0	0	0	0	0	0	No	18
0	II	0	0	0	0	2	No	15
0	II	0	0	0	0	2	Yes	20
0	0	0	0	0	0	0	Yes	16
0	0	0	0	0	0	0	No	15
N/A	IV-SWM	N/A	0	0	0	4	Yes	44
N/A	0	N/A	0	I	I	2	Yes	46
N/A	II	N/A	0	IV-SWM	II	8	Yes	70
N/A	I	N/A	I	IV/SWM	I	7	Yes	63
N/A	II	N/A	I	IV-SWM	III	10	Yes	24
N/A	II	N/A	0	II	I	5	Yes	47
N/A	I	N/A	0	0	0	1	No	17

All patients received their surgical treatment with general anesthesia and had standard monitoring including radial arterial catheterization and an oximeter pulmonary artery catheter to monitor central venous pressure, pulmonary artery pressure, cardiac output, and mixed venous oxygen saturation. A 5.0 MHz multiplane transesophageal echocardiograph (TEE, Omniplane, Hewlett Packard, Andover, MA) was used in the two-dimensional four-chamber horizontal view, for detection of emboli entering the heart. All patients were placed on 100% oxygen and given epinephrine 0.1 µg/kg/min 5 minutes before injection and pressurization of the femoral PMMA and insertion of the revision prosthesis.

Blood for cholesterol and fatty acid levels was obtained from the right atrium via the pulmonary artery catheter through the central line port. The blood samples were obtained when echogenic material obliterated the right atrium in six patients. The levels were compared with the serum cholesterol and fatty acid levels (Table 2).

Table 2. Serum triglyceride and cholesterol levels during embolization

Serum Levels		**Removal of PMMA from Femur**		**Preparation and Insertion of Femur**		**Removal of PMMA from Acetabulum**		**Insertion of Acetabular Comp**	
Triglyceride	Cholesterol	Triglyceride	Cholesterol	Triglyceride	Cholesterol	Triglyceride	Cholesterol	Triglyceride	Cholesterol
152	190			98	109				
89	185			69	117				
75	138			66	100				
138	189	141	190	157	121	153	151	151	124
107	78	114	63	130	78				
110	132			72	85			70	82

Results

The TEE proved to be an excellent monitor of the heart and the right atrium (Figure 1).

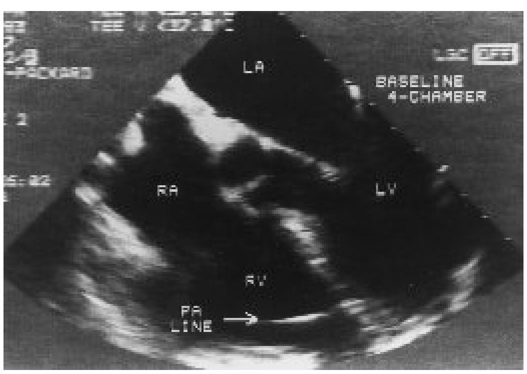

Fig. 1. Baseline 4-Chamber horizontal TEE view. RA = right atrium, RV = right ventricle, PA line = pulmonary artery catheter, LA = left atrium, LV = left ventricle.

Revision total hip arthroplasty was divided into six different segments: 1) removal of the femoral component and the PMMA, 2) preparation of the femoral canal for a new femoral component, 3) removal of the acetabular component and PMMA, 4) preparation and insertion of the new acetabular component, 5) insertion of the new femoral component, and 6) articulation of the two components. Because the clinical condition which necessitated revision total hip arthroplasty varied in this group of 21 patients, each patient did not have all six phases of the operation.

Sixteen of the 21 patients (76%) having revision arthroplasty were noted to have embolic material in the right atrium during one or more phases of the procedure. The TEE demonstration of embolic phenomena was divided into four categories as defined by Erth and co-workers [4]: Grade I consisted of transient emboli; Grade II consisted of obliteration of <50% of the right atrium by emboli; Grade III consisted of >50% but less than complete obliteration of the right atrium [5] (Table 1).

Femoral component and polymethylmethacrylate removal

Emboli were observed in two of the nine patients with aseptic loosening of a femoral component during the removal of the fixed PMMA from the distal femur following removal of the femoral component and the fragmented, proximal PMMA. Emboli were observed in the one patient in whom the Midas Rex was used to remove PMMA from the distal femur. Another patient in whom both the Midas Rex and the Ultradrive were used to remove distally fixed cement had echogenic embolization into the right atrium while both instruments were in operation. One-quarter to one-half of the right atrium was obliterated with embolic material while either the Ultradrive or the Midas Rex was in operation (Figure 2). There were no significant hemodynamic changes or alterations of oxygen saturation with application of either the Ultradrive or the Midas Rex.

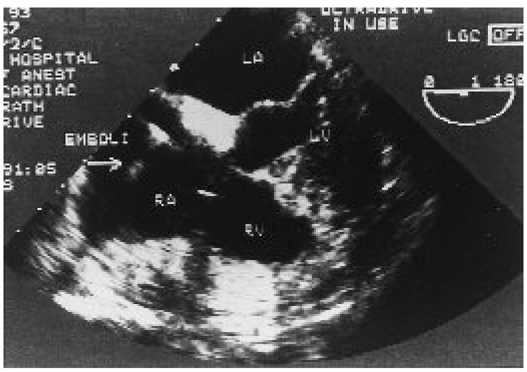

Fig. 2. Emboli can be seen in the RA during Ultradrive use.

Preparation of the femoral canal

Embolization was observed during preparation of the femoral canal for insertion of a trial femoral component in 10 of 16 patients. In one patient 50%--100% of the right atrium was obliterated by the embolic material. The embolization obliterated <50% of the right atrium in seven patients. In two patients the embolization was Grade I, i.e., transient emboli.

Removal of the acetabular component and implantation of a new component

One of 12 patients had obliteration of the right atrium (Grade IV) by echogenic material during removal of the acetabular component. In this patient the leg was repositioned from a flexed and externally rotated to an extended position with neutral rotation shortly before the development of the Grade IV embolization into the right atrium. Thus, it is impossible to be certain whether the removal of the PMMA from the bony acetabulum or the change in position of the lower extrimity or both contributed to the embolic episode. Grade I emboli (transient embolization) was observed in three patients and Grade II emboli (<50% obliteration of the right atrium) during preparation of the bony acetabulum and insertion of the new acetabular component with or without PMMA (eight and 12 patients, respectively).

Implantation of new femoral component

Six of the 17 patients had revision of the femoral component with a cemented femoral component. All of the cemented femoral stems implanted were long stems. During the injection and pressurization of the PMMA and insertion of a long-stem revision femoral component, complete filling of the right atrium (Grade IV) with emboli occurred in three patients and <50% of the right atrium (Grade II) was obliterated in one patient (Figure 3).

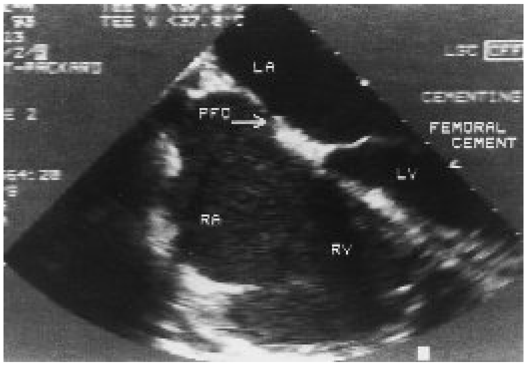

Fig. 3. Complete filling of RA with emboli during femoral cementing. PFO = patent foramen ovale. Small amount of emboli in LA just above the mitral valve leaflet secondary to the PFO.

In all three patients with Grade IV embolic phenomena mild to moderate right heart segmental wall motion (SWM) abnormalities were observed by the TEE four-Chamber horizontal view and treated by increasing the epinephrine infusion to 0.125--0.15 μg/kg/min. The duration of SWM abnormalities was 90--120 sec before returning to the baseline TEE examination. One patient had a patent foramen ovale (PFO) which resulted in paradoxical emboli (Figure 3). The two patients who did not have embolic abnormalities during the injection and pressurization of the PMMA and the insertion of a long-stem femoral component had a defect in the femoral cortex which occurred during removal of the residual PMMA. Thus, pressurization of the PMMA was not possible during the insertion of the revision femoral components in these two patients.

Two of the 11 patients treated with a cementless femoral component had embolic material observed in the right atrium while the component was implanted. The echogenic material was mild in both of these patients: Grade I and Grade II in one patient each. Neither experienced abnormal SWM.

Reduction of the components

Eight patients had a more dense echogenic embolization (5 Grade I, 1 Grade II, and 2 Grade III emboli) observed when the femoral component was articulated with the acetabular component, placing the involved lower extrimity through a range of motion to judge the stability of the implants (Figure 4).

Fig. 4. Three large emboli in RA following hip joint relocation. Emboli are in close proximity to PFO but none were seen to enter the LA.

These emboli were not associated with any SWM abnormalities. Although surgery was completed uneventfully, all patients remained intubated and were transferred to the recovery room for observation. Cardiac isoenzymes were negative in all patients, none developed clinical fat emboli syndrome, and there were no neurological deficits in the patient in whom paradoxical emboli occurred.

Twelve patients required treatment in the Intensive Care Unit after revision total hip arthroplasty. A higher total embolic score was associated with the need for treatment in the Intensive Care Unit after revision total hip arthroplasty, p = 0.005 (Exact Wilcoxon rank-sum test). Those patients requiring greater pulmonary support with oxygen after surgery had higher total embolic scores, p = 0.005 (Exact Wilcoxon rank-sum test). Similarly, those patients who had reconstruction of the femoral component with a cemented long-stem femoral component required more pulmonary support with oxygen, p = 0.001 (Exact Wilcoxon rank-sum test). Blood samples obtained from the right atrium for cholesterol and triglycerides were noted to be normal (Table 2).

Discussion

The surgical excision of fixed PMMA in the distal aspect of the femoral canal after removal the femoral component can be easy or very difficult. The adherent cement in the proximal femur is usually removed without difficulty with osteotomes. The adherent cement at the level of the isthmus and below the isthmus is poorly visualized through the proximal orifice of the femur, and several different techniques for its removal have been developed. These include the creation of multiple small holes, the creation of a large window, and the use of high-speed small drills with intra-operative roentgenographic visualization, using a portable image intensification system (C-arm). The use of ultrasonic vibrations to remove cement is a new technology in orthopedic surgery [1,2]. It has proven to be a time-saving technique to allow removal of cement without weakening the femoral cortex which occurs with the creatation of holes or windows. It is less destructive and safer than the use of either the Midas Rex high-speed drills or the Anspach drills as both techniques are associated with the creation of femoral cortical perforations in at least 15% of the femurs, even by surgeons experienced with their application. The Ultradrive can facilitate and save time during revision total hip arthroplasty. In this study the mild to moderate embolic phenomena in one of three patients evaluated during the application of the Ultradrive during removal of fixed femoral cement was not clinically significant. Embolic material was observed in the one patient in whom the Midas Rex instrumentation was utilized for excision of fixed femoral cement in the distal femur. Interestingly, no emboli were observed in the five patients in whom only osteotomes were utilized to removed cement from the femoral canal.

Echogenic embolic material occurred most commonly during the preparation of the femoral canal and insertion of a cemented long-stem femoral component. During preparation of the femur the endosteal surface of the femoral cortex was widened with intra-medullary reamers and a trial femoral component was passed through the isthmic area of the femur in a line-to-line or within a millimeter of line-to-line in those patients treated with a cementless femoral component. The resulting force on the endosteal surface of the femur appeared to be associated with the appearance of echogenic material in the right atrium. The force associated with the injection of four packages of PMMA and insertion of a long-stem femoral component was associated with the greatest amount of echogenic material in the right atrium. Pressurization of the femoral canal seemed to be instrumental in the development of the embolic material and the resultant abnormal SWM. The two patients who had a long-stem femoral component implanted and did not have echogenic material in the right atrium had perforation of the femoral cortex during removal of the retained PMMA or by the previously implanted prosthesis. Pressurization of the femur was not achieved in either of these patients. It has been demonstrated that reducing the femur intramedullary hypertension through the creation of a femoral defect (hole) is associated with significantly less embolic phenomena during primary total hip arthroplasty [6,8,12].

The emboli which were observed with relocation of the hip after insertion of the components to judge the stability of the arthroplasty in seven of the 21 patients were unanticipated. They were quite distinct in echogenic quality from those observed during removal and insertion of the components, and they had not been previously described. It is possible that these emboli were blood clots arising from the lower extremity following acute flexion and external rotation during the operative procedure.

Transesophageal echocardiography examination was essential in the diagnosis of embolism and extremely valuable in the early treatment of the SWM abnormalities associated with PMMA injection, PMMA pressurization, and insertion of the revision femoral component. One should consider TEE use in patients with significant cardiopulmonary disease during revision total hip arthroplasty, especially with the implantation of cemented femoral components. The TEE can monitor the quantity and the severity of embolism occurring, providing for early detection of wall motion abnormalities which will enable early pharmacologic intervention.

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