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Intraoperative Cerebral Arterial Embolization during Total Hip Arthroplasty

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Background: **Fat embolism to the pulmonary circulation is known to occur during total hip arthroplasty, especially during insertion of a cemented femoral component. Fat and air bubbles may enter the systemic circulation via a patent foramen ovale or through pulmonary circulation.**

Methods: **To determine whether microemboli to the brain were occurring during total hip arthroplasty, 23 patients underwent transcranial Doppler assessment of emboli to the middle cerebral artery during total hip arthroplasty. Surgery was performed with the patient in the lateral decubitus position so that the probe recorded from the nondependent side.**

Results: **Successful recordings were made in 20 patients, in 8 of 20 patients there were embolic signals, which ranging from 1 to 200. In all eight patients, signals were recorded during impaction of a cemented component or after relocation of the hip. Only one patient showed evidence of emboli with impaction of the acetabulum component. In two patients there were 150 and 200 embolic signals: in both mild respiratory symptoms developed. One patient became overtly agitated during a flurry of emboli.**

Conclusion: **Cerebral microemboli can occur during total hip arthroplasty. Whether this contributes to changes in postoperative cognitive function is unknown. (Key words: Cognitive function; fat embolism; pulmonary embolism.)**

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FAT embolism is known to occur after long-bone fracture and total hip arthroplasty (THA).[1,2] Showers of emboli (thought to be fat and thromboemboli both) can be seen by imaging of the right heart with use of transesophageal echocardiography during THA.[2–4] It is usually assumed that these emboli are trapped in the lung and do not reach the systemic circulation. On rare occasions, stroke may occur after THA, and this has been ascribed to paradoxical embolism *via* a patent foramen ovale (PFO).[3,5,6] Transpulmonary passage of small emboli, both fat and air, has recently been shown in experimental models.[7] This introduced the possibility that the microemboli entering the lung during THA could traverse the lung and undergo embolization into the systemic circulation. The following case describes this possible phenomenon.

A 43-yr-old woman was admitted for revision of a right THA. Medical history was remarkable for severe polyarticular rheumatoid arthritis, hypertension, gastroesophageal reflux, and peptic ulcer disease. Previous surgery included bilateral total knee arthroplasties, bilateral THAs, bilateral total shoulder arthroplasties, bilateral ankle fusions, cholecystectomy, and total abdominal hysterectomy. Medications at the time of surgery were methylprednisolone, azathioprine, furosemide, methotrexate, and diltiazem.

After routine monitoring devices were applied, a radial artery catheter was inserted for continuous blood pressure determination, and a pulmonary artery catheter was inserted for cardiovascular and volume monitoring. A 2-MHz transcranial Doppler (TCD) probe was applied over the right temporal window for continuous flow velocity and embolic signal determinations, as monitored by a dedicated technician.

During pressurization and cementation of the femoral canal with use of the femoral prosthesis, mean pulmonary artery pressure increased from 13 mmHg to

20 mmHg. Coincidentally, a shower of embolic signal was noted. Clinically, the patient became agitated and required additional sedation.

Postoperative course was remarkable for development of symptoms of chest heaviness and a decrease in partial pressure of oxygen (P_{O_2}) to 80 mmHg with administration of 4 l/min oxygen *via* nasal cannula. On the fifth postoperative day, a ventilation–perfusion scan was read as low probability. The patient was discharged on postoperative day 15 with routine follow-up.

Transcranial Doppler has been used extensively to assess microemboli to the brain during open heart surgery[8] and carotid angioplasty[9] and in medical patients at risk for embolic stroke.[10] In many patients, these microemboli produce no apparent clinical sequelae,[11] but, in cardiac surgery, patients with high numbers of emboli are more likely to experience stroke perioperatively.[8,12] In addition, it has been shown that emboli are most likely to occur during certain phases of the surgery, such as after removal of aortic clamps.[13]

In this preliminary study, we measured TCD signals from the middle cerebral artery in patients during THA and were able to detect the presence of cerebral emboli, primarily during insertion of cemented femoral components. This study introduces the possibility that systemic emboli are not uncommon during THA and may account for some of the cognitive impairment after total joint arthroplasty.[14,15]

Methods

After Institutional Review Board approval, 23 patients undergoing THA were prospectively studied. As is routine in this institution, after application of monitoring devices (*i.e.*, electrocardiography, oxygen saturation as measured by pulse oximetry [Sp_{O_2}], noninvasive blood pressure) and supplemental oxygen *via* nasal cannula, the patients received intravenous sedation with use of midazolam and fentanyl. Radial artery catheters were inserted in all patients. However, central venous pressure catheters and pulmonary artery catheters were inserted only if clinically indicated. The patients were placed in the lateral decubitus position, operative side up, and received a lumbar epidural (L2–L3, L3–L4) with use of either 0.75% bupivacaine or 2% lidocaine to obtain a sensory level of T2–T4. As described in previous studies,[16] mean arterial pressure was maintained at 50–60 mmHg, with use of infusions of 1–5 μg/min epinephrine. Intravenous lactated Ringer's solution was administered as needed. No patient received blood or colloid during the observation period. Antibiotics were administered before surgery, and intravenous injections were not performed during critical observation periods.

The middle cerebral artery "window" was identified preoperatively and, again, immediately before surgery. With the patient in the lateral decubitus position, the operative side uppermost, the middle cerebral artery was again determined and the probe secured with use of a headband. The epidural was then inserted and the patient remained in this position throughout surgery. A TCD model TC2-64A (Nicolet, Madison, WI) with a 2-MHz probe was used in 16 patients and a TCD (Medsonics, Mountain View, CA) in the other 4 patients. Recordings were made at a depth of 40–50 mm. A dedicated technician recorded the signal continuously during surgery. Embolic signals (ESs) were recorded manually by the technician and verified by inspection of recorded tracings. *ESs* were defined as high-amplitude, unidirectional, transient signals lasting less than 0.1 s and associated with a characteristic chirping sound.[17] ESs were copied to and stored on floppy disks and were subsequently reviewed and manually counted by a single examiner. The number of aggregate ESs was concurrently recorded by an automated counter. This number was only used where the series of embolization made manual counting impossible. The occurrence of signals was recorded in relation to surgical events: (1) reaming of the acetabulum, (2) impaction of a porous-coated acetabular component, (3) reaming the femoral canal, (4) impaction of a cemented femoral component, and (5) final relocation of the joint after implantation of the femoral component. Recordings were discontinued at the end of surgery.

Patients did not undergo echocardiography to detect the presence of a PFO, nor were cognitive function studies performed postoperatively.

Results

Three patients were excluded because a satisfactory assessment of the middle cerebral artery was not obtained; therefore, recordings were obtained for 20 patients. The mean age was 62 yr (range, 37–80 yr). Two patients were classified as American Society of Anesthesiologists physical status I, 15 as physical status II, and 3 as physical status III. There were 13 women and 7 men patients. ESs were detected in 8 of 20 patients. A recording of an isolated ES is shown in figure 1. The number of embolic events varied from 1 to 200 during surgery. Four of 11 patients undergoing unilateral primary THA, two of

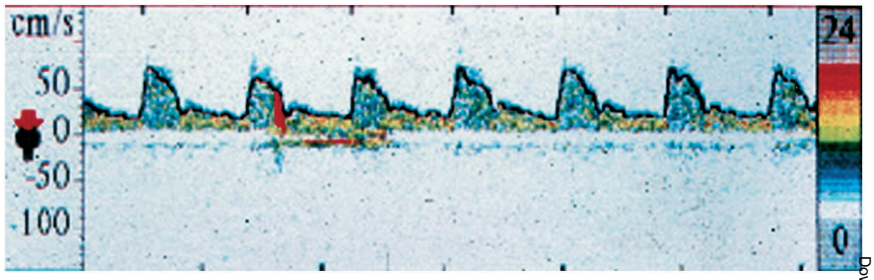

Fig. 1. A transcranial Doppler sonogram of the middle cerebral artery during total hip arthroplasty. Embolic signals are depicted in red.

five undergoing revision of a femoral component, and both patients undergoing one-stage bilateral THA experienced embolic events. ESs were not exhibited in either patient undergoing revision of an acetabular cup alone. The mean number of ESs varied according to the procedure, as shown in table 1. ESs were not noted during reaming of the acetabulum and were noted only in one patient during impaction of the cup. ESs were noted during impaction of the cemented component in five patients and during relocation of the hip joint in four patients.

More than 150 ESs were seen in two patients. In one patient in whom a cemented femoral component was reinserted, mean pulmonary artery pressure increased from 13 to 20 mmHg as the hip joint was reduced. Immediately thereafter, a shower of emboli was detected with use of TCD sonography. The patient became restless at this time and required additional sedation, but did not exhibit any change in oxygen saturation. After surgery, the patient became slightly hypoxemic, breathing nasal oxygen at 4 l/min (*p*H 7.46, partial pressure of arterial carbon dioxide [P_{aCO_2}] 34 mmHg, P_{O_2} 80 mmHg), had symptom of pleuritic chest pain, but the ventilation–perfusion scan showed negative findings. The other patient with more extensive embolic ESs underwent primary THA. Intraoperatively, an embolic shower of 200 ESs was noted. After surgery, mild chest pain and heaviness developed in the patient, but the ventilation–perfusion scan was normal. None of the 20 patients exhibited signs of confusion or stroke after surgery. Transpulmonary passage of these emboli may be consistent with the constellation of symptoms one can see with fat embolism syndrome.

Discussion

With use of TCD sonography, embolic signals in the middle cerebral artery were detected during THA in 8 of 20 patients studied. The majority of signals occurred either

Table 1. Patient Demography and Number of Embolic Signals

Patient No.	Age (yr)	Weight (kg)	Sex (M/F)	Total Hip Arthroplasty	Surgical Duration (h)	Comorbidities	Embolic Signals (No.)
1	37	84	F	Revision	3.5	Asthma	0
2	43	68	F	Revision	5	RA, HTN	158
3	40	68	M	Bilateral	3.5	Arthritis	4
4	41	75	M	Primary	1.5	Psoriasis, osteoporosis	10
5	67	72	F	Primary	1.5	HTN, glaucoma	0
6	75	75	F	Primary	2	HTN, NIDDM, hepatitis C	3
7	67	60	F	Primary	1.5	Asthma, hypothyroidism	0
8	78	96	M	Revision	2.5	CAD, HTN	0
9	78	73	F	Primary	1.5	Arthritis	0
10	56	73	F	Primary	1.5	MVP	200
11	55	59	F	Primary	2	Arthritis	0
12	46	71	F	Revision	4.5	Arthritis	3
13	55	55	F	Revision	3.5	RA, CAD	0
14	67	60	F	Revision	2.5	HTN, CAD	0
15	52	59	F	Revision	4.5	Thyroidectomy	0
16	82	73	M	Primary	3	CAD, HTN	0
17	69	103	M	Primary	2	HTN, hypothyroidism	1
18	72	73	F	Primary	2	HTN	0
19	61	75	M	Revision	2.5	HTN	0
20	70	75	M	Bilateral	4.5	CAD, HTN	92

CAD = coronary artery disease; HTN = hypertension; MVP = mitral valve prolapse; NIDDM = non-insulin dependent diabetes mellitus; RA = rheumatoid arthritis.

during insertion of the cemented femoral component or immediately after relocation of the hip joint. It is these particular surgical maneuvers that are also associated with intraoperative pulmonary emboli, as detected by echocardiography,[2,4] or with markers of thrombosis.[18] For this reason, we believe these signals represent fat or thrombi in the middle cerebral artery, which have bypassed the lung either through a PFO[3] or by transpulmonary passage.[7]

Intraoperative pulmonary embolization during total hip arthroplasty has been recognized for more than 20 yr but has recently been better characterized with use of intraoperative echocardiography. The emboli may be fine (particularly during reaming the femur) or large after implantation of cemented femoral components.[3] PFO may be present in up to 20% of patients and may allow emboli to pass into the left atrium when right-sided pressures exceed the left.[19] With pulmonary embolization, right-sided pressures increase,[18] and it is curious why stroke does not develop in more patients after total joint arthroplasty. Presumably, the passage of the emboli *via* a PFO is uncommon, or else these emboli are better tolerated by the cerebral circulation than one might imagine.

Recently, transpulmonary passage of fat emboli has been observed in dogs.[7] This raises the possibility that the emboli we noted could have traversed the lung. Factors facilitating transpulmonary passage are unknown, but acute pulmonary hypertension caused by the emboli may facilitate passage of tiny emboli through the lung into the systemic circulation.

The clinical significance of these findings is unclear because neurologic problems did not develop after surgery in any of the patients with evidence of emboli. This is not entirely surprising because patients undergoing cardiac surgery are unlikely to experience cognitive deterioration unless 100–200 ESs occur during surgery.[8,12] It is not clear whether these emboli noted in this study are well-tolerated by the brain (as may occur with air rather than plaque[11]) or whether the number of emboli is too small to result in cognitive deterioration. It is, however, possible that these emboli may lead to postoperative confusion in susceptible patients (*e.g.*, elderly patients) and may also account for a rather high rate of persistent cognitive deficit noted in patients after total knee arthroplasty.[15,20] Further studies are needed to clarify this.

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