

## FAT AND BONE MARROW EMBOLISM IN TOTAL HIP ARTHROPLASTY

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**A number of cardiovascular and pulmonary complications have been reported to occur occasionally after insertion of a total hip prosthesis. Of the proposed causes of these reactions, the possibility of fat embolism has received considerable support. The increase in intramedullary pressure, produced by the mechanical compression of the femoral canal during the insertion of the stem, seems to be the decisive pathogenic factor for the development of emboli.**

**Surgeons' proclivity to deny the clinical relevance of intraoperative emboli is directly related to their awareness of and their attempt to avoid this phenomenon. Depending on the preoperative clinical condition of the patient, the cardiorespiratory impairment may be subclinical for those with good reserve, or clinical for those with poor reserve. In cases with preexisting cardiorespiratory diseases, severe embolism can also lead to death. Moreover, tissue thromboplastin from bone marrow forced into the draining veins of the proximal femur during insertion of the stem leads to activation of the clotting cascade, lesions of the venous endothelium, and thrombogenesis.**

**A correlation was found between the embolic events observed using transesophageal echocardiography and the cardiopulmonary function of the patients during the perioperative period. A modified surgical technique was designed to reduce the intramedullary pressure during insertion of the stem to prevent intraoperative embolic events. Surgical prevention of fat and bone marrow embolism can also reduce the incidence of postoperative deep vein thrombosis.**

### INTRODUCTION

Fat and bone marrow embolism is one of the most potentially life threatening complications in orthopedic and trauma surgery involving the lower extremities (4, 9, 13, 14, 23, 32, 33, 61). Morbidity and mortality (32) depend on the amount of embolization affecting the pulmonary circulation or the systemic circulation through a patent foramen ovale of the heart (3, 7, 34). Surgeons' proclivity to deny the clinical relevance of intraoperative emboli is directly related to their awareness of and their attempt to avoid this phenomenon (4).

Fat and bone marrow embolism describes the presence of fat droplets from long bones in the blood vessels of the lung and peripheral circulation, and can be demonstrated histologically post-mortem. The so called "fat embolism syndrome" is the most serious clinical manifestation of fat

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emboli which can be generated in traumatic and nontraumatic conditions, including diabetes mellitus, burns, chronic pancreatitis, sickle-cell anemia, acute decompression sickness, and manipulations of the medullary canal of long bones like nailing and total hip or total knee arthroplasty (16, 23, 24). Gurd's criteria (11) for the diagnosis of the fat embolism syndrome are commonly used and divide into major and minor symptoms (table I). The definitive diagnosis requires at least one sign of major and four signs of minor criteria.

Since the fat embolism syndrome was first described by von Bergmann in 1873 (15), several hypotheses have been proposed to explain the pathophysiology of intraoperative complications (2, 8, 11, 13, 21, 30, 47, 48, 58).

### PATHOPHYSIOLOGY

The most decisive pathogenic factor for the development of a fat embolism syndrome is the increase in the intramedullary pressure (6, 7, 15, 16, 17, 19, 23, 24, 46, 47, 52, 59). Manipulation in the medullary canal during insertion of the femoral component or nailing generates an increase in the normal intramedullary pressure of 30-50 mm Hg (38) to peaks of 800 mm Hg. Cementing and insertion of the prosthesis can cause an additional peak up to 1400 mm Hg (15, 16, 17, 52). The medullary content migrates via the metaphyseal vessels along the natural venous drainage system, localized along the linea aspera (6, 36, 38, 39), into the right heart. This microembolization of fat and bone marrow can be visualized by transesophageal echocardiog-

raphy (8, 13, 18, 19, 20, 28, 53). Virchow's triad is a key factor for the formation of a macroembolus (endothelial lesion, venous stasis, and hypercoagulability) (1, 15, 16, 48, 49, 56). Owing to intravascular bone marrow content migration, the clotting system is activated not only in the operated leg, but also in contralateral veins or other locations in the body (49, 51, 60). Hypercoagulation (48, 49) in addition to stasis in the draining venous system (1), caused by the rotated position of the leg, generates mixed macroemboli up to 5 cm (18). Intima damage can occur as a result of torsion of the femoral vein (1) during the manipulation on the operated leg. This material is embolized into the pulmonary circulation and causes obstruction of the pulmonary arteries (15). The lung seems to be the main target organ of fat embolism (3). Massive obstruction of the pulmonary vessels may cause immediate right heart failure (33). A delayed reaction can be caused by inflammatory mediator release and can lead to local effects with endothelium damage of arteries in the pulmonary circulation (48). The consequence is interstitial edema or adult respiratory distress syndrome (ARDS) (15, 16, 19). The clinical symptom is respiratory insufficiency that aggravates hypoxemic lesions in other organs.

### MONITORING AND DIAGNOSIS

It remains fairly difficult to diagnose fat embolism during the surgical procedure. Clinical features are mostly related to disturbed pulmonary function, which is the primary indicator (29).

Table I. — Fat embolism syndrome according to Gurd

Major symptoms	Minor symptoms
<ul style="list-style-type: none"> <li>• petechial rash (axillary or subconjunctival)</li> <li>• respiratory symptoms plus bilateral signs with positive radiographic changes (<math>\text{PaO}_2 &lt; 60</math> mm Hg, <math>\text{FiO}_2 = 0.4</math>)</li> <li>• cerebral signs unrelated to head injury or any other condition</li> <li>• high erythrocyte sedimentation rate</li> </ul>	<ul style="list-style-type: none"> <li>• tachycardia (<math>&gt; 110</math>/min)</li> <li>• retinal changes (presence of emboli on retinal or fundoscopic examination)</li> <li>• sudden unexplainable drop in hemoglobin level</li> <li>• pyrexia (<math>&gt; 38.5^\circ</math>)</li> <li>• urinary changes (presence of fat)</li> <li>• sudden inexplicable thrombocytopenia</li> <li>• fat globules in the sputum</li> </ul>

Table II. — American Society of Anesthesiologists. New classification of physical status

ASA - class	
I	A normal, healthy patient
II	A patient with mild systemic disease
III	A patient with severe systemic disease that limits activity, but is not incapacitating
IV	A patient with incapacitating systemic disease that is a constant threat to life

Nevertheless development of ARDS in the postoperative period is a nonspecific pattern (19).

During anesthesia major pulmonary changes can be recognized by a drop in oxygen saturation (by pulse-oxymetry or gas analysis) (18, 36, 37, 46). A very sensitive marker for pulmonary emboli is a sudden drop of end-tidal carbon dioxide tension measured by capnometry.

General high-risk factors for fat embolism syndrome are reduced cardiorespiratory reserve (e.g. physical status classified ASA 3 or 4) (table II), age (27), hypovolemic state and pulmonary impairment after trauma (21, 24). Perioperative monitoring can be used to assess the efficacy of methods developed for the reduction of fat and bone marrow release in regard to quantity and time course (8, 18, 36, 20). After clinical manifestation of a fat embolism syndrome, diagnostic measures can identify the grade of embolization and its clinical relevance.

### 1. Transesophageal echocardiography

Transesophageal echocardiography is a method to assess embolic cascades continuously during the surgical period (5, 8, 13, 18, 20, 28, 32, 34, 36-41, 44, 53, 55). Embolic events have been scored to predict their clinical relevance in correlation with clinical parameters (fig. 1). In addition, echocardiography is a sensitive method during the perioperative period for detecting myocardial ischemia, intracardiac shunts and wall motion abnormalities (44,55). The four-chamber view allows detection of the intracardiac emboli and embolization through a possible patent foramen ovale (18, 34, 36). Measurement of the doppler-flow velocity on the right ventricular outflow tract can correlate with the increase in the pressure within the occluded pulmonary arteries (26).

### 2. Transthoracic echocardiography

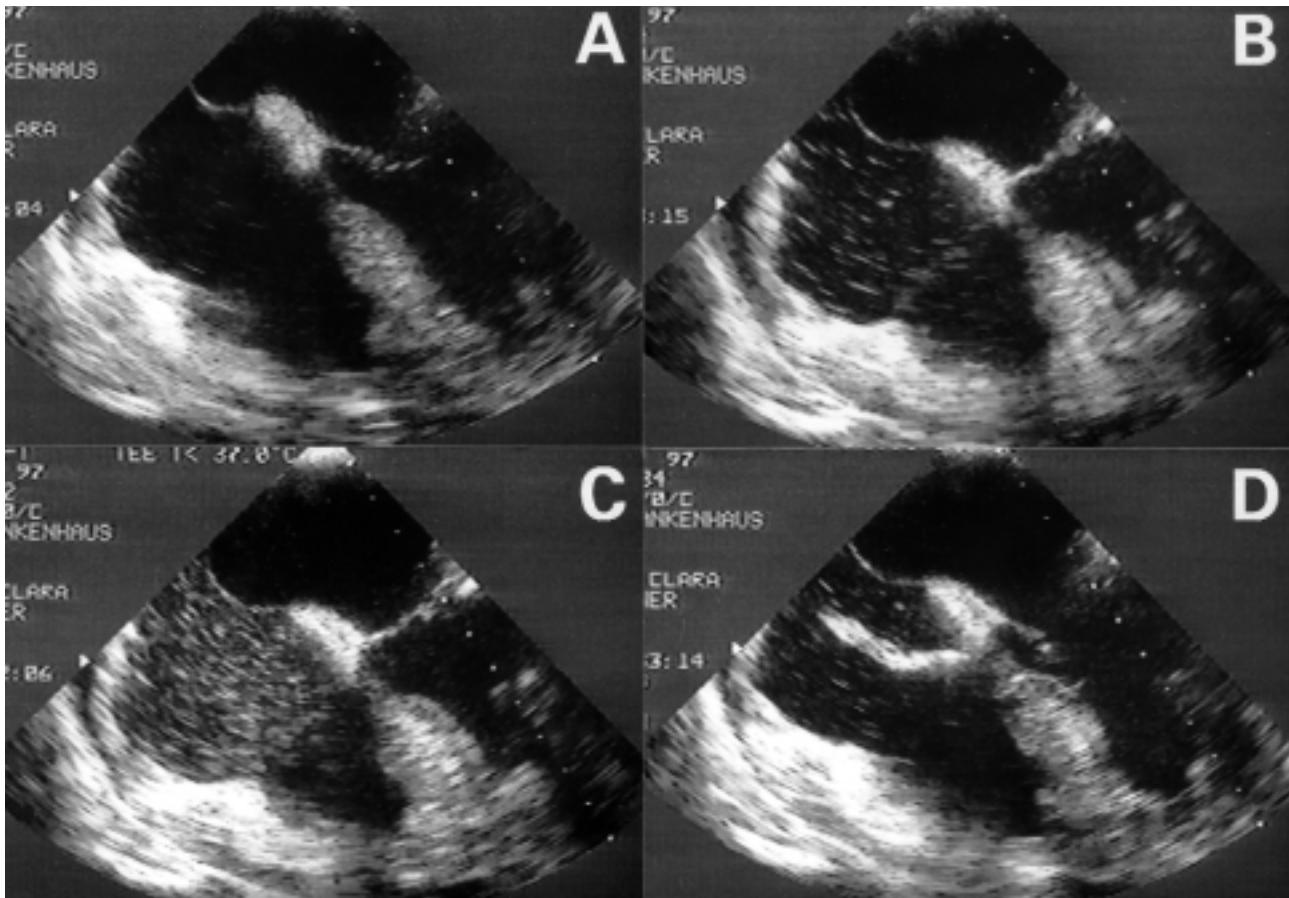
Transthoracic echocardiography of the lung may be a new technique for the detection of peripheral embolization of fat and bone marrow. Lung effusion can be detected in the alveolar space several minutes after pulmonary artery occlusion, following the decrease in production of surfactant. The method has a sensitivity varying from 77% to 98 %, and a specificity varying from 66% to 83 % (25, 26,45).

### 3. Laboratory analysis

Laboratory analysis can identify fat globules in blood, urine, and sputum. The Gurd-test is a fluorescence-microscopic method to detect fat globules from blood aspiration of the right atrium during echocardiographic opacification. The test has a 70-80 % sensitivity (11). Results from data of the clotting cascade confirm the diagnosis, but they are nonspecific (45, 48, 49).

### 4. Pulmonary artery catheter

A pulmonary artery catheter (PAC) is a method for diagnosis of mechanical obstruction of the right ventricular outflow tract. This invasive cardiac monitoring should not be used routinely. After fat embolism has occurred, PAC can show an increase in pulmonary artery pressure, right arterial pressure and central venous pressure (8, 12, 28, 55). Because of the reduced left ventricular preload, the pulmonary artery occlusion pressure, the cardiac output and left ventricular ejection fraction area may decrease (12, 28, 44). The mixed venous oxygen saturation measured from blood gas analysis allows calculation of the pulmonary shunt, accord-



**fig. 1.** — Transesophageal echocardiograms (four-chamber view) made during total hip arthroplasty, showing the main echogenic patterns. *With permission from Springer Verlag (see reference N° 40).*

A : Grade 0 : No emboli or small echogenic particles in the right atrium and right ventricle.

B : Grade 1 : A cascade of fine emboli ; the right atrium and ventricle are partially opacified with echogenic material.

C : Grade 2 : A cascade of fine emboli or embolic masses with a diameter of less than five mm. The right atrium and ventricle are completely opacified with echogenic material.

D : Grade 3 : Fine emboli mixed with large embolic masses that have a diameter of more than five mm or serpentine emboli.

ing to the Fick principle. Pulmonary shunted blood is the portion of blood that passes the lung without taking part in the gas exchange (18).

##### 5. Transcranial doppler

Transcranial doppler is used to detect microemboli during open heart surgery and carotid angioplasty. In these patients cerebral embolization can lead to transient neurologic insults or even stroke. In patients undergoing total hip arthroplasty it is assumed that emboli are trapped in the lung.

Doppler signals from the middle cerebral artery can represent fat embolization, when this material passes into systemic circulation through a patent foramen ovale or a transpulmonary passage (3, 7).

##### 6. Radiological and nuclear diagnostic techniques

Radiological and nuclear diagnostic techniques may show embolization in the postoperative period, but they are not specific for fat and bone marrow emboli (45). A thoracic xray has a low sensitivity for acute embolic events ; the first signs can

be seen only two days after the event, and these signs are similar to the signs of pulmonary edema or of adult respiratory distress syndrome. The thoracic xray presents multifocal alveolar opacities that look like "snow-flurries", especially in the upper lung zones. Fat embolism is not primarily an obstruction of large pulmonary arteries, but rather a diffuse occlusion of peripheral vessels (19). A ventilation-perfusion scan (12) can demonstrate that ventilated areas of the lung may not be perfused because of obstruction; it is used today as an exclusion criterion for marginal embolization. A conventional CT-scan or helical CT-scan is more sensitive, but peripheral embolization can also be overlooked (10, 50).

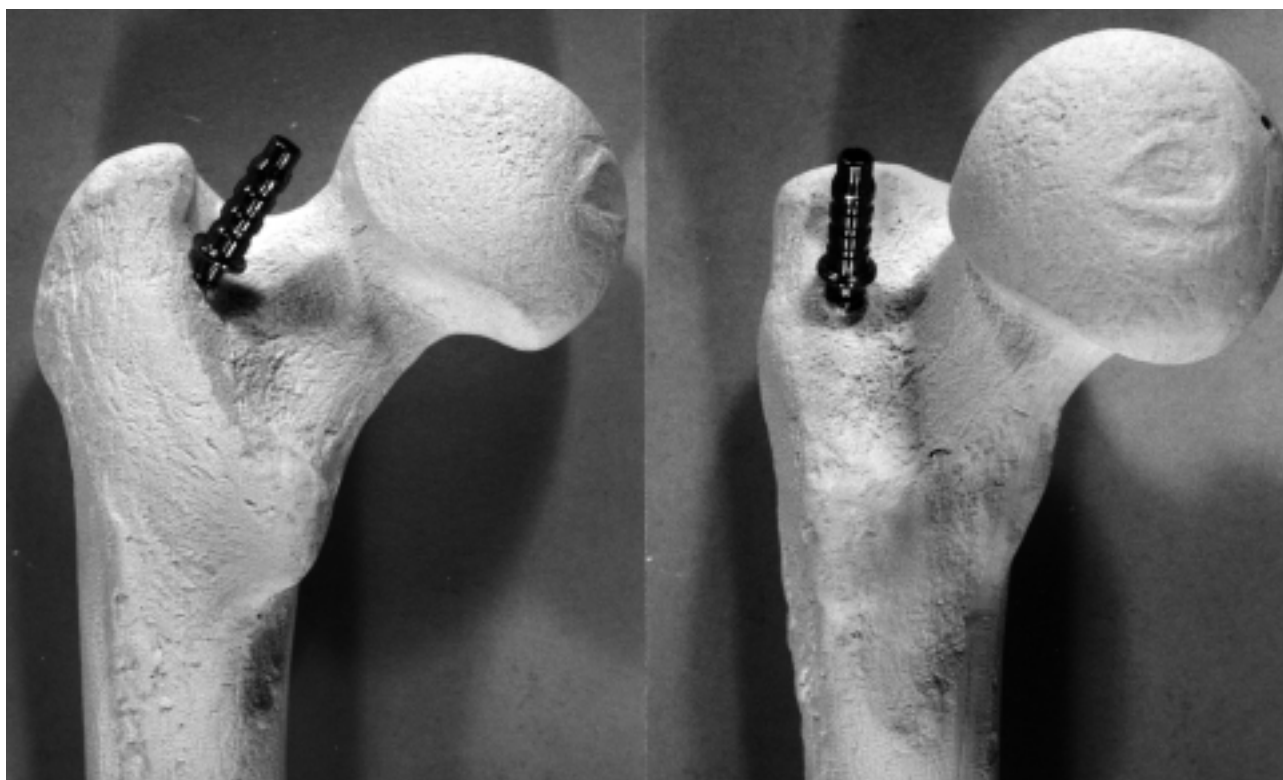
#### 7. Inert-gas technique

Ventilation-perfusion pattern assessment using the inert-gas technique was described in a clinical

study (12, 19). One disadvantage of this method is the long time it requires for calibration of the equipment. Acute embolization during surgery is not detectable with this method.

#### PREVENTION

Measures to prevent fat embolism should begin during surgery rather than during the postoperative period and should be applied during the preparation of the femur and the insertion of the femoral component (6, 38, 54, 57, 59). Thus, we designed two prospective, controlled studies in patients who underwent total hip arthroplasty. The first goal of the investigation was to define the clinical relevance of the embolic events observed during the operation using transesophageal echocardiography (TEE). The second goal was to determine the efficacy of a modified surgical technique designed to reduce the increase in intramedullary pressure dur-



**fig. 2.** — The position of the proximal drainage cannula used for the bone vacuum cementing technique. The cannula is placed between the greater and the lesser trochanters, in the trochanteric fossa, along the projection of the linea aspera. Care is taken to avoid intramedullary placement of the 20-mm long cannula. *Original.*

ing insertion of the stem (6, 36, 38). The third goal was to assess whether the reduction of intraoperative embolic events can also prevent thrombogenesis and reduce the incidence of postoperative deep vein thrombosis (1, 35, 41, 42, 43, 48, 49, 51).

### CLINICAL RELEVANCE OF FAT EMBOLISM (19)

One hundred twenty patients were randomized into two groups. Group 1 received a total hip arthroplasty cemented conventionally, while group 2 was cemented using a modified technique, the so-called bone-vacuum cementing technique (6, 38, 39, 54). The modification consists in vacuum drainage of the proximal femur, used to reduce the increase in intramedullary pressure during the insertion of the prosthesis. A cannula with a 4.5-mm diameter was positioned along the prolongation of the linea aspera into the cancellous bone of the intertrochanteric region (fig. 2). The cannula was connected to a vacuum pump with a suction tube. Continuous transesophageal echocardiography was recorded during the surgical period. A

four-chamber view of the heart was achieved in order to detect echogenic material in the right heart, as well as possible embolization through a patent foramen ovale. Rating was done after published criteria with a four-grade score (19, 36) (fig. 1). Echocardiographic findings were compared with clinical, laboratory data and calculated pulmonary shunt values.

A cascade of fine echogenic material smaller than 5 mm (grade 2) was imaged during the insertion of the femoral component in 56 patients (93.4 %) operated using the conventional cementing technique, and in eight patients using the modified technique (13.4%), which is a substantial reduction ( $p < 0.05$ ). Severe embolic events with a diameter of more than 5 mm (grade 3) were imaged after relocation of the hip joint ; the prevalence in the two groups of patients was also significantly different (51.7% versus 8.3%,  $p < 0.05$ ) (table III).

A nearly immediate cause-and-effect relationship was observed between grade 2 and 3 embolic events imaged during the operative procedure and changes of hemodynamic and cardiorespiratory function. Pulse oxymetric oxygen saturation and

Table III. — Transatrial embolic events observed during the operative procedure

Event	Group 1 Conventional cementing technique (n = 60 patients)			Group 2 Modified cementing technique (n = 60 patients)		
	Grade 1	Grade 2	Grade 3	Grade 1	Grade 2	Grade 3
Insertion of the cup	5 (8.3%) 5±1 sec.	...	...	3 (5.1%) 6±2 sec.	1 (1.7%) 2 sec.	...
Preparation of the femoral canal	4 (6.7%) 6±3 sec.	11 (18.7%) 4±4 sec.	...	4 (6.7%) 5±2 sec.	...	...
Insertion of the stem	4 (6.7%) 13±5 sec.	<b>56 (93.4%)</b> <b>10±5 sec.</b>	...	52 (86.7%) 8±4 sec.	<b>8 (13.4%)</b> <b>5±3 sec.</b>	...
Relocation of the hip joint	...	29 (48.3%) 8±4 sec.	<b>31 (51.7%)</b>	49 (81.6%) 13±4 sec.	6 (10%) 5±2 sec.	<b>5 (8.3%)</b>

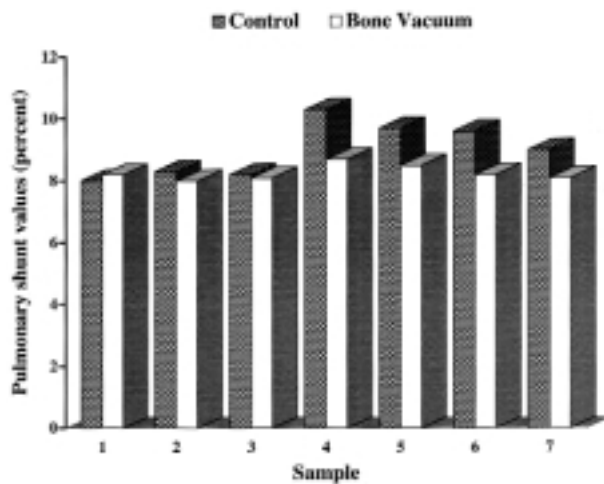
Number of patients (percent), mean duration of embolic event ± standard deviation.

Grade 1 : A few fine emboli ; Grade 2 : A cascade of fine emboli or embolic masses with a diameter of less than 5 mm. The right atrium is opacified with echogenic material ; Grade 3 : Fine emboli mixed and large embolic masses with a diameter of more than 5 mm or serpentine emboli.

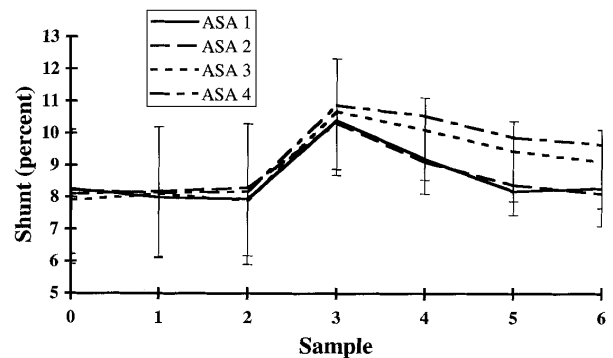
The bold numbers indicate that the intensity of the echogenic events (grade 2) during the insertion of the stem, and (grade 3) after the relocation of the hip joint was significantly different from that in the other group of patients ( $p < 0.05$ ) (two tailed, unpaired t-test).

end-tidal carbon dioxide tension changed significantly over time. A significant increase in pulmonary shunt values ranging from 8.2% to 10.3% ( $p < 0.05$ ) was observed after conventional insertion of the femoral component, indicating intraoperative ventilation/perfusion mismatching (fig. 3) (Sample 1 : operative incision, 2 : 5 minutes after insertion of the cup, 3 : after preparation of the femur, 4 : 5 minutes after insertion of the stem, 5 : 5 minutes after relocation of the hip joint, 6 : 15 minutes after relocation of the hip joint, 7 : 2 hours after the end of the operation). In patients who had a stem inserted with the modified cementing technique, the mean pulmonary shunt values showed a slight increase (8.1% to 8.7%) during the operation. Baseline pulmonary shunt values of healthy patients or patients with mild systemic disease (ASA class 1 or 2) who sustained embolic events graded 2 and 3 were reestablished uneventfully at the end of the operation. In contrast, pulmonary shunt values of patients with severe systemic disease (ASA class 3 or 4) remained abnormally high even in the postoperative period (fig. 4). Heart rhythm and heart rate remained stable in all patients during the operation. Twenty-two of 64 patients (34.4%) who had a cascade of fine emboli (grade 2) during the insertion of the stem reacted with a transient decrease of systolic blood pressure of more than 20 mm Hg. Hypotensive reactions were observed in the same set of patients after relocation of the hip joint. No patients experienced cardiac arrest or demonstrated evidence of postoperative fat embolism syndrome.

The results of the study show that transesophageal echocardiography is a reliable method to detect and quantify pulmonary embolus during cemented total hip arthroplasty. Embolic events observed using transesophageal echocardiography can cause cardiorespiratory impairment in patients with severe systemic disease. Transesophageal echocardiography gives information on the effect of therapeutic strategies to prevent this embolization. A vacuum drainage of the proximal femur



**fig. 3.** — Mean calculated pulmonary shunt values in group 1 (conventional cementing technique) and group 2 (bone-vacuum cementing technique) during surgery. The mean value 5 minutes after the insertion of the femoral component (sample 4) in the group of patients operated conventionally was markedly higher (10.3%) than the mean intraoperative baseline values (8.2%). On the other hand, the mean value 5 minutes after the insertion of the femoral component in the study group 2 of patients showed no significant changes (from 8.1% to 8.7%).



**fig. 4.** — Mean calculated pulmonary shunt values and physical status of the 64 patients who sustained embolic events graded 2 and 3 assessed according to the criteria of the American Society of Anesthesiologists (ASA). A more pronounced and prolonged increase of pulmonary shunt values was observed in patients with severe preexisting systemic disease (ASA 3) who presented massive embolism during surgery. The difference in observations after cementing of the femoral component (sample 4) between ASA 1 and 2 patients, and ASA 3 patients is statistically significant ( $p < 0.05$ ). ASA 1 (n=20 patients) ; ASA 2 (n=25 patients) ; ASA 3 (n=16 patients) ; ASA 4 (n=3 patients).

Table IV. — Detection of deep vein thrombosis after total hip arthroplasty at postoperative day 4 by duplex ultrasonography

	No DVT	Total DVT	Proximal DVT	Distal DVT
Group 1 Conventional Cementing Technique No. (percent) of hips	53 (81.5%)	12 (18.5%)*	7 (10.8%)	5 (7.7%)
Group 2 Bone-Vacuum Cementing Technique No. (percent) of hips	63 (96.9%)	2 (3.1%)	...	2 (3.1%)

DVT = deep vein thrombosis. The asterisk indicates that the relative frequency of thrombosis of the venous system in the control group of patients was significantly different from that in the bone-vacuum group of patients ( $p=0.009$ ).

along the linea aspera is a logical and effective method to reduce high intramedullary pressure and migration of fat and bone marrow into the venous system (6, 36, 54). Patients with pre-existing diseases can profit from a reduction in intraoperative large emboli which result in cardiorespiratory impairment (37).

#### FAT EMBOLISM AND DEEP VEIN THROMBOSIS (41)

Of 130 consecutive patients who were to have a primary total hip arthroplasty, 65 were randomized to receive a femoral component cemented using the conventional technique, and 65 to receive a femoral component cemented with the vacuum-suction technique (6, 36, 38). The primary outcome measure was again the incidence of intraoperative fat and bone marrow emboli, as determined by echocardiography using a transesophageal probe. A secondary outcome measure was the incidence of deep vein thrombosis, as determined by serial duplex ultrasonography on the preoperative day, and on postoperative days 4, 14 and 45.

The control group had more severe and prolonged embolic events than the bone-vacuum group. A cascade of fine echogenic particles or embolic masses with a diameter as large as 5 mm was observed during the insertion of the stem in 59 hips (90.8 %) operated using conventional cementing technique and in 10 hips (15.4 %) oper-

ated using the bone-vacuum cementing technique ( $p < 0.05$ ).

A higher prevalence of deep vein thrombosis was found in patients who presented embolism during the operation. Thrombosis of the venous system was detected using duplex ultrasonography on postoperative day 4 in 12 of 65 patients (18.5 %) of the control group and in two of 65 patients (3.1 %) of the bone-vacuum group (table IV) ( $p < 0.05$ ). Thrombosis of the distal venous system was found in five patients in the control group and in both patients of the bone-vacuum group. Distal thrombosis was asymptomatic in all seven patients. Thrombosis of the proximal venous system was observed in seven patients operated using conventional cementing technique, but was not observed in the patients operated using the bone-vacuum cementing technique. Proximal DVT was symptomatic in one patient. Of 14 DVT's, 13 were detected in the operated extremity, and one in the nonoperated extremity of a patient in the control group. Two patients (3.1 %) in the control group, who had a negative postoperative day 4 duplex ultrasonography, showed an asymptomatic distal DVT on postoperative day 14. No thrombosis of the venous system occurred in the two groups of patients after discharge (table V). Resolution of the DVT was observed at postoperative day 45 in 15 of 16 patients with positive ultrasonography after the index operation.

The results of this randomized study show that surgical prophylaxis of fat and bone marrow



Table V. — Detection of deep vein thrombosis after total hip arthroplasty at postoperative days 4, 14 and 45 by duplex ultrasonography

	PO Day 4	PO Day 14	PO Day 45
Patients			
1-14 (n=14)	Proximal DVT (n=7) Distal DVT (n=7)	—	—
15-16 (n=2)	Negative	Distal DVT (n=2)	—
17-130 (n=114)	Negative	—	—

PO = postoperative ; DVT = deep vein thrombosis

embolization during cemented total hip arthroplasty can reduce the incidence of postoperative deep vein thrombosis. Hence, the surgeon has a further opportunity to prevent thrombogenesis in the operating room.

### CONCLUSION

These two studies confirm that transesophageal echocardiography is a reliable method to detect and quantify a pulmonary embolus during cemented total hip arthroplasty. Furthermore, it gives information on the effect of therapeutic strategies to prevent this embolization. The release of intravenous fat and bone marrow content is dependent on the technique used during operation for the fixation of the femoral component. The results of the studies show the efficacy of a bone vacuum technique for reduction of severe embolization. Vacuum drainage of the proximal femur along the linea aspera is a logical and effective method to reduce high intramedullary pressure and migration of fat and bone marrow into the venous system. Patients with pre-existing diseases can profit from a reduction of large intraoperative emboli and resulting cardiorespiratory impairment. In addition the surgeon has a further opportunity to reduce the risk of thrombogenesis in the operating room. Owing to the results of these two investigations, we now use the bone vacuum technique routinely in all cemented total hip arthroplasties.

### WORK IN PROGRESS

It is usually assumed that fat and bone marrow emboli are trapped by the pulmonary filtering mechanism, and cannot reach the systemic circulation. Nevertheless, the pathophysiology of some clinical signs of fat embolism syndrome (11, 19, 24), e.g. cerebral symptoms (22, 27, 31), fat globules in the sputum and urine as well as retinal changes (presence of emboli in retinal or fundoscopic examination), remains controversial, because systemic spread of embolic material is required. The following two theories could explain these phenomena (24) :

1. It is assumed that these symptoms can be caused by the passage of fat and bone marrow across the pulmonary vessels (3) or across a patent foramen ovale (34). Recent studies (3,7) supported this hypothesis. Fat globules were demonstrated in animals after bilateral cemented hip arthroplasty, using electron microscopy of brain tissues, kidney and heart capillaries. But after injection of radiolabeled microspheres of a similar size to fat globules into the right atrium, they were not detected in systemic organs. These facts suggest an influence of the embolic material on the capacity of pulmonary filtering or a different reaction on solid or fat particles. It may be that in the presence of pulmonary arterial hypertension caused by the embolization itself, a transpulmonary passage of eventually deformable globules can occur. Evidence of fat in

systemic organs has been documented histologically in humans (7). This may be concordant to clinical and neurological impairment observed in the postoperative period (22, 30, 39). Transcranial doppler assessment showed evidence of microemboli during open heart surgery and during total hip arthroplasty in the middle cerebral artery (7).

2. Another explanation for the systemic symptoms could be an intravascular biochemical reaction due to the presence of floating fat particles. This hypothesis is based on a release of free fatty acid followed by a reaction with a tissue lipase (19). The response explains a delayed inflammatory reaction to these free fatty acids, leading to endothelial damage and increased capillary permeability. Fat globules on the other hand are also thought to stimulate a local release of serotonin, histamine and activators of the clotting cascade (1,48). This can result in platelet aggregation and thrombus formation in the systemic circulation (49). The clinical features can be pulmonary or cerebral edema and ARDS, developing with a 12- to 72-hour latency. Fat emboli may also be derived from chylomicrons agglutinated in the blood (21). This theory may also be supported by some magnetic resonance (MRI) findings that show high-intensity signals located in areas of the brain perfused by perforating arteries, which are thought to be characteristic of focal perivascular edema (31).

In conclusion, it can be stated that during total hip arthroplasty cerebral lesions can occur. MRI scans are able to detect them in the postsurgery period as abnormal signals. They can represent irreversible brain damage associated with structural cerebral changes and neuron loss or a transient brain insult, particularly in the elderly patient. The encephalopathic changes result in nonspecific neurologic complications and cognitive dysfunction. The prevention of fat embolism during the operation can probably be an effective prophylactic means to reduce the risk of neurological sequelae.

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## SAMENVATTING.

*M. J. KOESSLER, R. P. PITTO. Vet- en beenmergembolie bij totale heuparthroplastie*

Een aantal cardiovasculaire en pulmonaire verwikkelingen zijn mogelijk na het plaatsen van een totale heupprothese. De verklaring voor deze verwikkelingen, die het meest wordt aangenomen is het vetembool syndroom. De stijging van intramedullaire druk door de mechanische compressie van het femoraal kanaal, tijdens het inkloppen van de stem van de prothese, schijnt de overwegende factor te zijn in de pathogenese van vetembolie. Een chirurg is meer geneigd de klinische betekenis van intraoperatieve embolisatie te relativeren naarmate hij meer oplettend is voor dit fenomeen en het vermijden ervan. De preoperatieve klinische toestand van de patient bepaalt zijn ontvankelijkheid: de cardiorespiratoire weerslag kan beperkt blijven bij iemand met grote reserve en kan klinisch tot uiting komen bij iemand met beperkte reserve. Een ernstig vetembool kan dodelijk zijn bij patienten met een cardiovasculaire aandoening. Tijdens de inbreng van de stem kan weefselthromboplastine van het beenmerg in de afvoervenen van het proximale femur terecht komen, de stollingscascade activeren, met aantasting van de veneuze vaatwanden en thrombogenesis.

In onze prospectieve studie is een verband aangetoond tussen embolische activiteit op transoesophagale echocardiographie en de cardiopulmonaire functie van de patient in de perioperatieve periode. De chirurgische techniek tijdens de inbreng van de prothese stem werd aangepast om de stijging van de intramedullaire druk te ondervangen en embolische accidenten te voorkomen. Vastgesteld werd dat het voorkomen van vet- en mergembolen ook de incidentie van postoperatieve diepe veneuze thrombose duidelijk vermindert.

## RESUME

*M. J. KOESSLER, R. P. PITTO. Embolisation de graisse et de moelle osseuses au cours de l'arthroplastie totale de hanche.*

Des complications cardio-vasculaires et pulmonaires ont été rapportées occasionnellement après arthroplastie totale de hanche. Parmi leurs causes possibles, l'hypothèse d'une embolie graisseuse apparaît sérieusement fondée. L'élévation de la pression intra-médullaire engendrée mécaniquement par l'introduction de la tige prothétique semble être le facteur pathogénique princi-

pal de cette embolisation. Certains chirurgiens ont tendance à nier l'importance clinique de cette embolisation peropératoire, probablement dans la mesure où, conscients du risque, ils ont déjà pris des mesures pour le réduire. En fonction de l'état clinique du patient avant l'intervention, l'interférence avec les fonctions cardio-respiratoires peut rester subclinique chez les patients qui ont une bonne réserve ou avoir une expression clinique chez les patients à réserve faible. Une embolie massive peut même conduire à la mort chez les patients qui présentaient déjà une pathologie cardio-respiratoire avant l'intervention. De plus, la thromboplastine tissulaire de la moelle osseuse, chassée en force dans les veines de drainage du fémur proximal lors de l'insertion

de la tige prothétique, conduit à l'activation du cycle de la coagulation, à une lésion de l'endothélium veineux et à une thrombogénèse.

Les auteurs ont mis en évidence une corrélation entre les phénomènes emboliques, détectés par échocardiographie transoesophagienne, et la fonction cardio-pulmonaire des patients pendant la période péri-opératoire. Ils ont mis au point une technique particulière pour réduire la pression intra-médullaire pendant l'insertion de la tige fémorale, de façon à prévenir les phénomènes emboliques. En prévenant l'embolisation de graisse et de moelle osseuse par cette technique, ils ont également réduit l'incidence des thromboses veineuses profondes post-opératoires.