Reports of Investigation

Clinical features and echocardiography of embolism during cemented hip arthroplasty

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Purpose: In previous studies the degree of embolization detected by transoesophageal echocardiography (TEE) during cemented total hip arthroplasty (THA) did not correlate with changes in haemodynamic variables nor did it result in persistent ventilation-perfusion mismatching. The aim of this study was to record evidence of embolism and to relate the findings to demographic data and the subsequent clinical course of the patients during THA.

Method: Forty-eight patients scheduled to undergo elective cemented THA during general anaesthesia were monitored. A TEE probe was inserted with special attention to the right atrium (RA), the right ventricle (RV). Haemodynamic (heart rate, arterial blood pressure, central venous pressure) and blood-gas variables were measured repeatedly during the operative procedure (after induction, placement of the acetabular component, placement of the femoral component, relocation of the hip joint). Grading of venous embolism at these times was based on the size of particles detected by TEE (three-minutes video segments of each periods) and correlated with demographic, haemodynamic and blood-gas data.

Results: The TEE monitoring revealed showers of echogenic material traversing the RA and RV in all but one patients during reaming and cementing of the acetabular and femoral components, and during relocation of the hip joint. No correlation was observed between frequency or size of embolic particles and demographic or blood-gas and haemodynamic variables studied at the same times.

Conclusion: This study failed to show any clinical impact of TEE detected emboli during cemented THA.

Objectif : Des études anténeures ont montré que le degré de l'embolisation décelé par échographie transoesophagienne (ETO) pendant l'arthroplastie totale de la hanche (ATH) cimentée ne corrélait pas avec les changements des paramètres hémodynamiques et ne provoquait pas d'inégalités persistantes du rapport ventilation-perfusion. Cette étude visait à enregistrer, au cours de l'ATH, l'apparition des embolies et de corréler ces données avec les données démographiques et l'évolution clinique subséquente des opérés.

Méthodes : Quarante-huit patients programmés pour subir une ATH cimentée non urgente étaient monitorés sous anesthésie générale. La sonde ETO était insérée en ciblant spécialement l'oreillette droite (OD) et le ventricule droit (VD). Les paramètres hémodynamiques (fréquence cardiaque, pression artérielle, tension veineuse centrale) et la gazométrie étaient mesurés à intervalles fixes pendant l'intervention chirurgicale (après l'induction, pendant l'installation du segment acétabulaire, à l'installation du segment fémoral, et lors de la réduction de la dislocation de la hanche). Le degré d'embolisation veineuse était alors établi selon la grosseur des particules détectées par ETO (enregistrements vidéo de trois minutes pour chacune des périodes) et corrélé avec les données démographiques, hémodynamiques et gazométriques.

Résultats : Le monitorage ETO a révélé que, chez tous les patients, une pluie de matériel échogène traversait l'OD et le VD pendant l'alésage et la cimentation des segments acétabulaire et fémoral et pendant la réduction de la dislocation de la hanche. Il n'y avait pas de corrélation entre la fréquence et la grosseur des particules emboliques et les paramètres démographiques, gazométriques et hémodynamiques enregistrés simultanément.

Conclusion : Cette étude n'a pas montré que les embolies détectées par ETO pendant l'ATH cimentée avaient un impact clinique.

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BONE cement implantation syndrome during total hip arthroplasty (THA) is associated with venous emboli that may be detected with transoesophageal echocardiography (TEE).[1-3] The use of TEE to detect embolic material as it passes through the heart was suggested in a case report by Wenda *et al.*[4] Ereth *et al.* have shown that the degree of embolization during THA did not correlate with changes in haemodynamic variables nor did it result in persistent ventilation-perfusion mismatching. Ereth's data suggested that non-cemented THA is associated with fewer emboli.[1] In a case report, Lafont *et al.* failed to demonstrate haemodynamic consequences of a large amount of echogenic material that was embolized into the right heart and partially entrapped in the pulmonary bed, confirming the preceding results.[3]

The aim of this study using TEE was to record evidence of embolism and to relate the findings to demographic data and the subsequent clinical course during THA.

Materials

After local ethical committee approval, 48 patients scheduled to undergo elective cemented THA during general anaesthesia were monitored. Most of the patients were premedicated with 3 mg midazolam and 0.25 mg atropine sulfate *im* one hour before induction of anaesthesia. In the operating room, a cannula was inserted into a forearm vein and lactated Ringer's solution was given. Monitoring included a 3-lead ECG, finger-pulse oximetry (SpO_2) and measurement of end-tidal carbon dioxide ($P_{ET}CO_2$).

General anaesthesia was induced with 0.3 mg·kg^{-1} etomidate combined with 100 μg fentanyl® (Janssens Pharmaceutica, Belgium). Muscle relaxation was induced with 0.1 mg·kg^{-1} pancuronium. Anaesthesia was maintained with halothane in a mixture of 50% O_2:50% N_2O and intermittent doses of fentanyl (50 to 100 μg) and pancuronium (2 mg). Ventilation was controlled with a tidal volume of 10 ml·kg^{-1} to maintain $PaCO_2$ of 34–38 mmHg.

A 20 gauge radial artery catheter and a central venous catheter were inserted percutaneously. The haemodynamic variables (heart rate, arterial blood pressure, central venous pressure) and SpO_2 were continuously monitored. Before the patient was placed in the lateral decubitus position, a 5-MHz multiplanar transoesophageal echocardiographic probe (Vingmed Sonotron 750®) was introduced into the oesophagus via the oropharynx to obtain a four-chamber view of the heart, with special attention to the right atrium (RA) and the right ventricle (RV). The gain setting was optimized to avoid any artefact. Echocardiography was performed continuously throughout the surgery. The probe was removed before termination of anaesthesia.

The following variables were measured repeatedly during the operative procedure: heart rate (HR), blood pressure (BP), central venous pressure (CVP), SpO_2, $P_{ET}CO_2$, arterial blood-gas analyses. Measurements were performed at 13 intervals (1: after induction, 2: before incision, 3: after incision, 4: preparation of the acetabulum, 5: placement of the acetabular component, 6: five minutes later, 7: 10 min later, 8: reaming and preparation of the femur, 9: placement of the femoral component, 10: five minutes later, 11: 10 min later, 12: relocation of the hip joint, 13: skin closure).

The TEE data were stored, and representative three-minutes video segments from each of the 13 periods were analysed by two independant observers who were blinded to the patient identity and period. Grading of venous embolism was a simplification of Ereth *et al.*[1]: 0: none, 1: "snow flurry picture," 2: embol(i) from 0 to 10 mm, 3: embol(i) >10 mm. Emboli were considered significant if present for more than five seconds.

After completion of the operation, the patients were transferred to the surgical intensive care unit and the lungs were ventilated until complete recovery from anaesthesia. The endotracheal tube was removed when the patients were fully awake. The monitored variables were continuously recorded.

Statistical analysis

All data are reported as mean ± SD. Statistical analysis comprised ANOVA for repeated measures or chi-square tests when necessary. Bonferroni's method was used for *post hoc* multiple comparison when analysis of variance was significant. $P < 0.05$ was considered significant.

Results

Complete data were recorded for all 48 patients. Mean age, height, weight, sex, and ASA physical status of patients are presented in Table I and risk factors in Table II. No patient had metastatic disease of femur. The mean duration of the surgical procedures was 167 ± 60 min. No adverse event was observed at the time of introduction or removal of the TEE probe.

TABLE I Demographic variables

Age	67.7 ± 9.9
Weight (kg)	76.1 ± 15.2
Height (cm)	167.2 ± 7.7
Sex (M/F)	16/32
ASA (1/2/3)	5/31/11

TABLE II Patient risk factor

	n
Age > 65 yr	26
Coronary artery disease	11
Cardiac failure	2
Hypertension	21
Pulmonary disease	9
Diabetes	2
Vascular disease	3
Smokers	6
ECG abnormalities	10

n = Number of patients with the specific characteristic (total population n = 48)

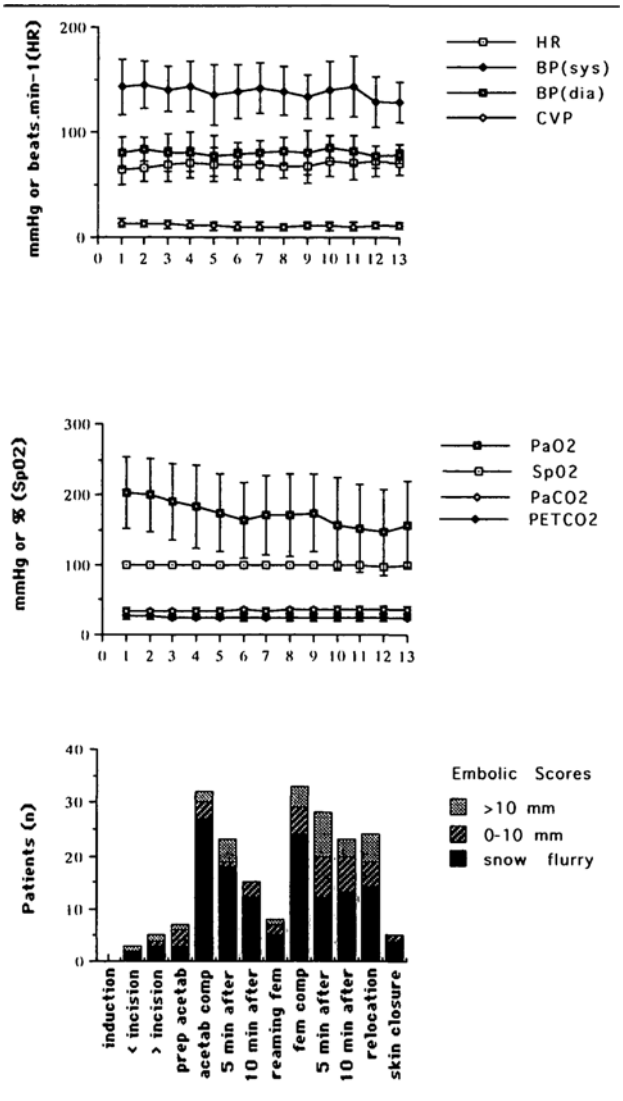

FIGURE 2 Intraoperative heart rate (HR), systolic (sys) and diastolic (dia) arterial blood pressures (BP), central venous pressure (CVP), PaO_2, $PaCO_2$, SpO_2, $P_{ET}CO_2$ and frequency of emboli at the different times of the surgical procedure.

Transoesophageal echocardiography monitoring revealed showers of echogenic material traversing the RA and RV in 47 patients during reaming and cementing of the acetabular and femoral components (Figure 1). Both observers independently agreed on patient classification to groups in all 47 events. Fifteen patients exhibited an embolism score of 1, 18 a score of 2 and 14 a score of 3. The mean sizes of the greatest echogenic particles observed were 1.74 ± 2.68 mm for the grade 2 and 17.3 ± 11.80 mm for the grade 3 often vermiform.

No correlation was observed between demographic data and frequency or size of embolic particles.

The frequency of embolism during the different times of the surgical procedure is shown in Figure 2. Emboli were seen during acetabular and femoral reaming and cementing of the components. The greatest scores were registered during placement of the femoral component. No change was observed in any of the mean haemodynamic variables (Figure 2) or right ventricle size. Only one patient exhibited an episode of hypotension (decrease in systolic blood pressure >30%) at the time of acetabular placement. Embolic score was 0 and oxygen saturation 95% during this event. The patient did not suffer postoperative complication.

Also no deterioration of mean SpO_2, $P_{ET}CO_2$, PaO_2, $PaCO_2$ (Figure 2) was observed and no correlation could be established between these variables and the concurrent embolic scores. Sudden desaturation (defined as a decrease in oxygen saturation ≥5%) appeared in eight patients during insertion of the femoral component. The minimum SpO_2 was 91%. The concurrent embolic scores were 0 in three cases and 1 in the other five (NS).

One patient with patent foramen ovale had an episode of paradoxical embolism during insertion of the femoral component and, in the postoperative period, experienced a transient neurological complication (right hemiparesia) that resolved without sequelae in the next 48 hr.

More discrete emboli were observed during reduction of the relocation of the hip joint.

The TEE four-chamber view was clear at the conclusion of surgery.

Discussion

This study agrees with others that failed to show any haemodynamic impact of TEE detected emboli during THA.[1-3] At the time of placement of the acetabular and, especially, the femoral components, several emboli of various sizes were detected in the right atrium and ventricle. The emboli were well tolerated by the patients: no haemodynamic or blood gas modifications

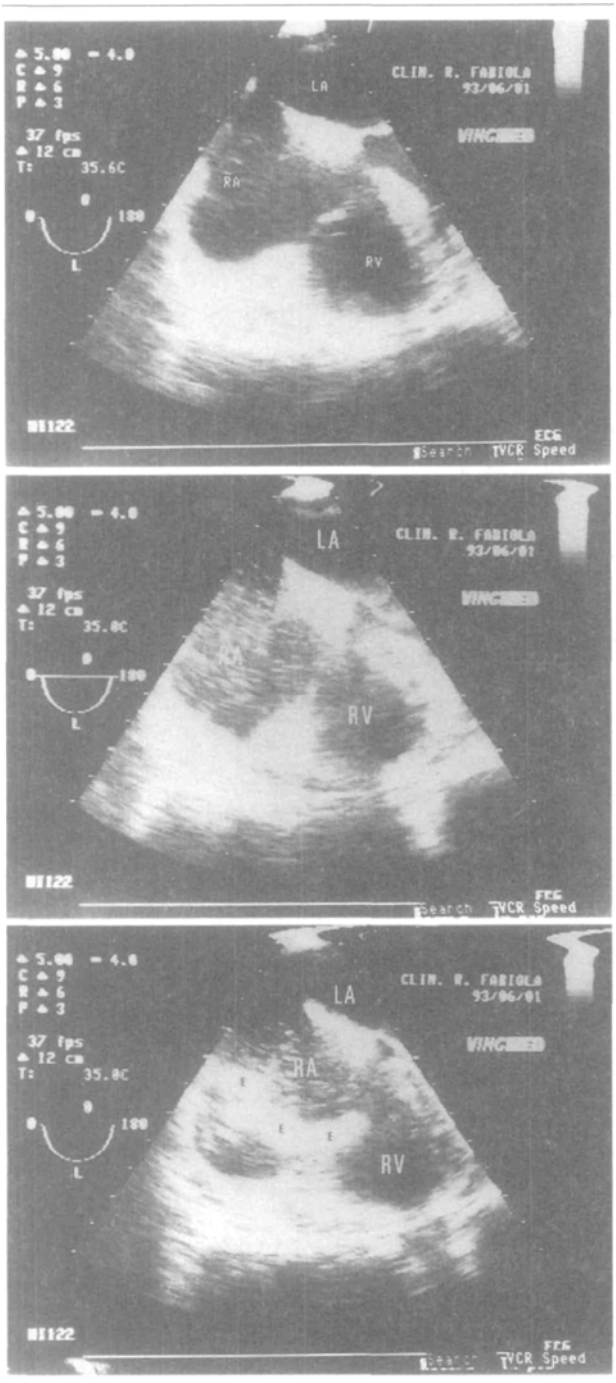

FIGURE 1 Four-chamber transoesophageal echocardiographic views showing embolism during total hip arthroplasty: (A) control view, (B) "snow flurry" in the right atrium, (C) small and large emboli in the right atrium. RA = right atrium; RV = right ventricle; LA = left atrium; SF = snow flurry; E = embolus.

were observed. No relationship was found between patients' characteristics i.e. age, height, weight, sex and frequency or size of emboli. A finding of particular interest was the demonstration of paradoxical embolism in one case.

During insertion of the prosthesis in THA, embolization of intramedullary fat, bone marrow, methylmethacrylate, bone cement, or air can cause bone cement implantation syndrome.[5,6] The syndrome is characterized by hypotension, hypoxaemia, cardiac arrythmias, cardiac arrest or a combination of these features. It might cause sudden death.[7–11] These complications frequently occur within minutes after implantation of the methylmethacrylate bone cement and the prosthetic component and are also observed with non-cemented THA.[12]

The syndrome is due to embolism during THA resulting from high intramedullary pressure (575 mmHg).[6,13–15] Air, fat, bone marrow, haematopoietic stem cells, endothelial cells and other intramedullary debris are embolized into the femoral venous channels by the expanding and pressurized bone prothesis interface and eventually embolize to the heart and lungs or, in the case of paradoxical embolism, to the brain.[16,17] However, so far, the haemodynamic impact of TEE detected emboli during THA has been imprecise.

Transoesophageal echocardiography is a new imaging technique that is gaining popularity as an intraoperative monitor of cardiac function in high risk patients, for detection of ischaemia, for assessing left ventricular preload, afterload, cardiac output and ejection fraction.[18] Because of high resolution and excellent image quality, TEE currently represents the method of choice for patent foramen ovale detection. In our study, one patient suffered a neurological complication following paradoxical embolism that had been observed with TEE. However, the equipment is expensive and requires specific technical and interpretative expertise.[19] At present, routine echocardiographic monitoring cannot be recommended for THA but future research may provide guidelines for using TEE in such situations. It will be interesting to investigate how intraoperative TEE data could guide real-time decision making.

One hypothesis concerning the aetiology of the bone cement implantation syndrome could be the nature of the embolic material. Current echocardiographic techniques do not permit tissue characterization of embolic material. Echogenic emboli could consist of marrow content (fat), bone cement, air or fresh thrombus. Since similar echogenic particles have been demonstrated with uncemented hip arthroplasty, the echogenic material most likely is not bone cement. Spiess *et al.* aspirated air from a central venous catheter in 10% of patients undergoing THA.[20] Investigators have observed similar echogenic emboli during orthopaedic procedures involving manipulation of the marrow cavity. In a patient undergoing

fixation of a femoral neck fracture, Pell *et al.* sampled venous blood during embolic showers and demonstrated the presence of microscopic fat globules.[21] Polymethylmethacrylate activates the coagulation cascade and stimulates platelet aggregation thus providing the conditions necessary to stimulate thrombus formation.[16,22]

Further studies are warranted to delineate the specific mechanical, biochemical, and physiological responses to emboli in patients having cemented THA. Methods of intervention such as a technique for filtering emboli from the venous blood, biochemical dissolving of emboli, or aspiration of emboli seen on TEE need to be explored.

There are some limitations to this study. First, the scoring of intracardiac emboli was performed postoperatively by two observers blinded to the clinical events but intra- and inter-observer variability was not determined. However, this methodology has been used recently by Urban *et al.*[23] Second, the total duration of echogenesis was not measured as in the preceding study. Third, right heart catheterism was not realised to evaluate the pulmonary blood pressure repercussions of emboli. Our patients may have compensated for pulmonary hypertension which could be life-threatening to other patients: therefore, the study results may not be directly generalizable to patients with more severely compromised cardiopulmonary reserve which could not compensate for the embolic load. Lastly, other diagnostic uses of TEE such as the detection of ventricular dysfonction like regional wall-motion abnormalities were not examined.[24] Thus, the overall clinical utility of TEE could increase.

In conclusion, this study showed that the impact of emboli detected by TEE during cemented THA is not clear. No relationship was found between embolic frequency or size and demographic or clinical data.

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