Title

Pathological evaluation of venous emboli during total hip arthroplasty

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Subsidiary title

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Summary

One of the possible mechanisms of bone cement implantation syndrome during total hip arthroplasty is the pulmonary embolism that has been detected by transesophageal echocardiography. However, tissue characteristics of them are not well clarified. We studied 4 patients using cement for the insertion of femoral component and 3 patients without using cement. We pathologically evaluated the blood obtained from the right atrium when "Snow Flurry," one of the most typical embolic images was detected by TEE. "Snow Flurry" images were detected in all patients. Amorphous eosinophilic fine granular materials were observed in all specimens. The materials did not originate from the cement components. Fat and bone marrow were not detected. In conclusion, unknown fine granular materials were observed in the blood, when "Snow Flurry" was detected by transesophageal echocardiography during total hip arthroplasty. The materials may be "bone dust" originated from the reamed bone.

Keywords *intraoperative complications:* pulmonary embolism. *orthopedic surgery*: total hip arthroplasty. *monitoring*: transesophageal echocardiography.

There are many reports about the occurrence of respiratory and circulatory complications including acute hypotension, hypoxemia and cardiac arrest during cemented arthroplasty [1-3]. These complications have been called “cement implantation syndrome” [4]. The mechanism of cement implantation syndrome remains incompletely understood. Ereth, et al [5] first reported that one of the possible mechanisms was the pulmonary embolism that has been detected by transesophageal echocardiography (TEE). They and subsequent several investigators showed that many fine emboli were detected during hip arthroplasty by TEE [3,5,6,7]. Lafont, et al named this image “Snow flurry” [8,9]. Many previous reports have demonstrated that the possible materials of the emboli were fat, air or bone marrow [6,7,10-12]. However, the main tissue characteristics of the emboli remain controversial. In this study, we evaluated the pathological characteristics of the emboli obtained from the right atrium (RA) when “Snow Flurry” was observed by TEE during total hip arthroplasty (THA).

Methods

We obtained institutional approval and written informed consent from all the patients. We studied 4 patients (4 females, aged 65 to 75 years, mean 67.5) undergoing elective THA using cement for the insertion of the femoral component (cement-THA). Combination of cementless acetabular component and femoral component with using cement (so called, the hybrid method) was utilized for this. Harris precoat stem (Bristol-Myers Squibb K.K. Zimmer Division, Warsow, IN, USA) was employed for the femoral component. We also studied 3 patients (3 females, aged 43 to 57 years, mean 51.3) treated with THA without using cement (cementless-THA). S-ROM (J & J Professional Inc. Raynham, MA, USA) was used for this. An epidural catheter was placed at the L3-L4 interspace preoperatively. Anesthesia was induced with 2 $mg.kg^{-1}$ propofol and 0.1 mg fentanyl and tracheal intubation was facilitated with 0.1 $mg.kg^{-1}$ vecuronium. Anesthesia was maintained with inhalation anesthesia (1-2 % sevoflurane in 40 % oxygen and a balance of nitrous oxide) and with epidural anesthesia

(intermittent doses of 5 - 10 ml of 1.5% lidocaine with epinephrine).

Before the start of surgery, a 6.2 MHz biplane TEE probe (OMNI PLANE II, Hewlett Packard, Andover, MA, USA) was introduced to obtain a view of the RA and the right ventricle (RV). A 7 Fr., central venous catheter (CS-17702-E, Arrow, Reeding PA, USA) was inserted from the right internal jugular vein and we confirmed that the tip was placed in the RA by TEE. Heart rate, arterial pressure, central venous pressure, oxygen saturation by pulse oximetry (SpO_2) and end-tidal CO_2 ($ETCO_2$) were monitored.

When the "Snow Flurry" was detected before and after the placement of the femoral component, we withdrew 10 ml of blood from the RA via the central venous catheter. Blood was obtained twice before the placement of the femoral component and also obtained twice after the event. The blood was centrifuged (15 min., 3000 r.p.m.), serum was discarded, and the clot was fixed by the same amount of 10% neutral formalin. Some blocks of blood clot for paraffin sections were prepared. The sections were stained with hematoxylin and eosin (HE).

And they were also stained with phosphotungstic acid hematoxylin (PTAH) solution.

Results

The “Snow flurry” was detected by TEE in all cement- and cementless-THA cases (Fig. 1). It was observed intermittently from the start of reaming to the end of operation in both cases. Before the insertion of component, it was detected concomitantly with reaming the femur and the acetabulum. “Snow Flurry” was especially strong at insertion of femoral component and relocation of hip joint after insertion in cement-THA. This strong “Snow Flurry” was observed for a few seconds. On the contrary, increase in “Snow Flurry” was not observed at any particular period in cementless-THA cases. Blood pressure, heart rate, SpO_2 and $ETCO_2$ showed almost no change while “Snow Flurry” was observed.

Histological evaluation of blood showed amorphous eosinophilic fine granular materials in the paraffin sections of all the patients undergoing both cement- and

cementless-THA (Fig. 2a). In cement-THA cases, the same finding was observed before and after the insertion of bone cement. Although the margin of the materials was positive for PTAH staining, the materials themselves were negative for it (Fig. 2b). These findings indicated that fibrin was attached to the surface of the materials. Fat, bone marrow and bony tissue (bone trabeculae consisting of collagen fibers and extracellular matrix, which include osteocystes) were not detected in any specimens. Air could not remain in the specimens by our histological procedure. However, air was not aspirated from RA at anytime.

Discussion

There have been only a few reports about the pathological findings of blood such as by HE staining in hip surgery [10,11]. Moreover, there have been no reports, like this study, which examined the pathological findings of blood that was taken just when the “Snow Flurry” was detected by TEE.

In the 70’s, Herdon, et al. [11] reported the presence of fat globules in the

femoral venous blood of patients undergoing cement-THA by the cryostat and Gurd's test [13]. Modig, et al. [10] reported the presence of fat particles by Gurd's test in pulmonary arterial blood obtained from patients with THA. They also showed the presence of bone marrow and large aggregations of platelets and fibrin by May-Glünwald-Giemsa staining [10]. In the 80's, Andersen [14] and Spiess, et al. [12] reported that air was aspirated from the central venous catheter during THA. In the 90's, Pell, et al. reported the presence of fat in central venous blood samples by Gurd's test during reamed intramedullary nailing [7]. They also found a deposition of fat globules in the microvasculature of both pulmonary and systemic circulation in a patient who died after developing fat embolism syndrome [7]. Cristie, et al. reported the presence of fat and marrow in specimens of blood samples withdrawn from a central venous catheter during cemented and uncemented hemiarthroplasty [6]. Thus, many reports have demonstrated the presence of fat, bone marrow, thrombus, or air as embolic materials [6,7,10-12,14].

In our study, amorphous eosinophilic fine granular materials were observed in the blood obtained from RA when “Snow Flurry was detected in TEE. The materials were also seen before using cement as well as after using cement in cement-THA cases. They were also observed in the cementless-THA cases. Accordingly, the materials did not originate from the cement, but originated from intracorporeal tissue. However, these materials did not show histological images of fat or bone marrow. The fact that only the margin of the materials was positive for PTAH indicated that the material was not an aggregation of blood itself. Considering the findings that “Snow Flurry” was observed just after the start of reaming bone, we might speculate that the fine granular materials were “bone dust”, to the surface of which fibrin was attached.

The grade of “Snow Flurry” was especially strong at insertion of femoral component and relocation of hip joint after insertion of femoral component in cement-THA. A greater amount of bone dust may enter the vessels at insertion of femoral component because some reports indicated that intramedullary pressure

increased more by using bone cement [5,15,16]. At relocation of hip joint, some bone dust accumulated in the leg vein [6] may have been released and then flowed into RA.

Theoretically, echogenicity of an organic structure is known to depend on the difference of its acoustic impedance from that of the surrounding tissue [17]. In blood as a background substance, acoustic impedance of a bony structure is much greater than that of fat, therefore the former should show stronger echogenicity [17]. "Snow Flurry" showed hyperechoic image compared to blood in our and other studies [3,5-7,9]. Accordingly, the echo findings in these studies also supported that bone dust should be one of, and the main embolic materials of “Snow Flurry” image.

In our study, we made pathological sections from the sediment of the centrifuged blood. However, fat may almost exist in the supernatant of the centrifuged blood considering from the method of Gurd’s test [13]. For this reason, we might not have been able to detect fat in our specimens、although we also

cannot assert that fat was completely moved to serum section. Modig et al. could detect large aggregation of platelets and fibrin in blood centrifuged at 8000 r.p.m. for 20 min [10]. We centrifuged our blood sample at 3000 r.p.m. for 15 min. Accordingly, we assumed that thrombi did not disappear under our centrifugation conditions if they exist in blood. No air was aspirated from RA at any time. Accordingly, we speculate the possibility of air as embolic materials was low even though air could not remain in the specimens by our histological procedure.

In conclusion, when "Snow Flurry", one of the most typical embolic images was detected by TEE during THA, amorphous eosinophilic fine granular materials were observed in the blood obtained from RA. The materials may be "bone dust" originated from the reamed bone, although this study does not completely deny that other materials such as fat may also make up some part of the embolic images.

Acknowledgment

We would like to thank Drs. H. Itoh and M. Hirayama, orthopedic surgeons for their orhtopedic advises, and Mr. H Mikami, an ultrasonographer and Dr. T Nanbu, a radiologist for their echographic advises.

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Figure legends

Figure 1 Transesophageal echocardiogram.

a: control view

b: “Snow Flurry” image in the right atrium.

RA, right atrium; RV, right ventricle; LA, left atrium; A valve, aortic valve.

Figure 2 Fine granular material (FGM) in the blood clot. HE staining of paraffin section.

a: x 10 (original magnification)

b: x 50 (original magnification)

Figure 3 Fibrin (arrows) in the peripheral area of FGM. PTAH staining for fibrin of paraffin section.

x 50 (original magnification)