Fat Emboli in Total Knee Arthroplasty

A Prospective Randomized Study of Computer-Assisted Navigation vs Standard Surgical Technique

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Abstract: A prospective exploratory study of fat emboli in patients undergoing total knee arthroplasty was performed in patients randomly assigned to surgery with computer-assisted navigation or standard technique. Transesophageal echocardiography of the right atrium was recorded for 5 consecutive 1-minute intervals after tourniquet deflation. Emboli were graded on a scale of 0 to 3 based on embolism size, amount of atrium filled, and duration of embolic shower, creating an overall score of 0 to 9. The mean (SD, range) of the 5 overall scores for each total knee arthroplasty was 6.00 (0.76, 4.6-7.4) for computer-assisted navigation (22 patients) and 6.42 (0.97, 4.6-7.9) for standard technique (22 patients) (P = .14), with a 95% confidence interval for the difference of −0.11 to 0.95. We conclude that any difference in extent of emboli between the 2 surgical techniques is unlikely to be of clinical significance. **Keywords:** computer-assisted navigation, embolism, fat emboli, total knee arthroplasty.

Echogenic material may enter the heart through the venous system during total knee arthroplasty (TKA). This material is often referred to as "fat emboli," although it may be composed of bone marrow elements, air, and blood clot in addition to fat. Such embolic material may negatively impact the patient's cardiac, pulmonary, and cognitive status, and even result in death [1-5].

An increase in intramedullary pressure has been shown to be a critical factor in the pathogenesis of fat emboli [6]. This pressure increase occurs in TKAs performed with the standard technique of placing an intramedullary femoral guide to align the distal femoral cutting block. Total knee arthroplasties performed with computer-assisted navigation can avoid using an intramedullary femoral guide. This raises the question of whether less embolic material is generated during TKA performed with computer-assisted navigation. The safety of TKA would be improved with a procedure that resulted in fewer fat emboli.

The purpose of this exploratory study was to compare the extent of fat emboli, as detected by transesophageal echocardiography (TEE), between patients randomly assigned prospectively to TKA performed with use of either computer-assisted navigation or intramedullary femoral and extramedullary tibial alignment guides (standard surgical technique). The hypothesis was that computer-assisted navigation for performance of TKA would decrease the extent of fat emboli as detected via TEE as the femoral intramedullary canal would not be violated. Prior studies [2,7] have demonstrated that the peak of embolic activity occurs within 1 minute of tourniquet deflation in TKA. In this study, the extent of embolic activity was measured by TEE recordings for the first 5 minutes after tourniquet deflation. Recordings were analyzed for the amount of atrium filled by echogenic particles, the duration of echogenesis, and the size of the embolic material.

Materials and Methods

Study Design

This study was designed as a substudy of a larger trial already under way at this institution in which a total of 200 patients were randomly assigned to undergo TKA

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with either computer-assisted navigation or standard surgical techniques to measure any potential difference in mechanical axis alignment between the 2 groups. Randomization assignments were computer-generated using the method of randomly permuted blocks and sealed opaque envelopes containing assignments were opened the day before surgery. Computer-assisted navigation was performed with an optical image-free navigation system (BrianLab, Munich, Germany). Institutional review board approval was obtained for this study, and all patients provided informed consent.

Inclusion criteria for this study (and the parent study) required the subject to be an adult patient with sufficient symptoms from articular knee pathology to be an appropriate candidate for TKA. Exclusion criteria included prior TKA, ipsilateral upper tibial osteotomy, ipsilateral total hip arthroplasty, and morbid obesity. Additional exclusion criteria for patients enrolled in this study of fat emboli included esophageal disease and recent anticoagulation therapy.

The same surgeon completed all but 3 of the TKAs included in this study. As many surgical variables as possible were standardized, including the surgical approach (subvastus), implant type (PFC Sigma posterior cruciate-substituting femoral, cobalt chrome tibial tray, and all-polyethylene patellar components; DePuy Orthopaedics, Warsaw, Ind), fixation (all components were cemented with the same type of bone cement), and tourniquet pressure (300 mm Hg). Venting of the femoral canal was not performed in any patient. In all patients, the limb was elevated, the knee flexed, and the tourniquet inflated just before the skin incision. After the femoral, tibial, and patellar components had been cemented, the knee was held in extension with a trial polyethylene insert in place. After the cement had hardened, the tourniquet was deflated. The surgeon then removed the trial polyethylene insert and placed the real polyethylene tibial insert. Thereafter, the limb rested in a semiflexed position, and wound closure commenced without further manipulation of the extremity.

In the standard technique patients, an entry hole was drilled into the distal femur to gain entrance to the intramedullary canal. The entry hole was enlarged with the drill so the diameter of the entry hole was clearly larger than the diameter of the intramedullary femoral guide rod. A large bulb syringe was then used to irrigate the femoral intramedullary canal, and a suction catheter was placed into the canal to remove marrow contents before insertion of the fluted intramedullary femoral alignment rod. In the computer-assisted navigation group, 2 fixation pins were placed in the distal femur for fixation of the distal femoral navigation array, and 2 fixation pins were placed in the proximal tibia for fixation of the proximal tibial navigation array. The femoral canal was not opened with a drill and was not irrigated and suctioned.

The diameter of the femoral canal was measured on a computed tomographic scan performed on each patient in the 3 to 4 months after surgery. This computed tomographic scan was part of the protocol of the parent study. The measurement recorded was the narrowest portion of the femoral diaphysis. The intramedullary guide was a fixed diameter of 7.9 mm.

Anesthetic techniques were also standardized. All patients underwent general anesthesia consisting of propofol induction, rocuronium to facilitate intubation and insertion of the TEE probe, and oxygen/nitrous oxide/isoflurane for maintenance of anesthesia. After intubation, the anesthesiologist placed the TEE probe. The echocardiographic view was standardized to a 4-chamber view with visualization of the right atrium. Anesthetic providers ventilated the patients to an end-tidal carbon dioxide level of 35 to 50 mm Hg.

Data Collection and Analysis

The extent of fat emboli was classified on the basis of the system used by Ereth et al [8] (Table 1). This system uses 3 parameters (the amount of echogenic filling of the right atrium, the duration of embolic shower during a 1-minute video segment, and the size of the embolic particles), with a value of 0 to 3 assigned for each parameter. The maximum total score is 9. Ereth et al [8] used "representative one-minute video segments" from each of 9 periods during total hip arthroplasty, analyzed by 2 blinded observers. In this study of TKA, TEE was recorded on a videotape for 5 consecutive 1-minute segments, starting at tourniquet deflation. During the time of TEE recording, the intravenous infusions were minimized to prevent microbubbles from passing through the heart and being mistaken for emboli. A fully computerized pulse oximeter monitored the oxygen saturation at 1-minute intervals.

Patients were not evaluated for the presence of a patent foramen ovale (PFO). There were several reasons for this decision. First, the study focused on embolic material entering the right atrium; therefore, the presence or absence of a PFO would not influence the results. Second, different TEE views would have been required for evaluation of a PFO, and our focus was on excellent visualization of the right atrium. Finally, in patients

Table 1. Grading of Venous Embolism Based on TEE Analysis

Score*	Amount†	Duration, s‡	Size, mm§
0	None	None	None
1	<1/2	<5	<5
2	>1/2	5-30	5-10
3	Complete	>30	>10

Adapted with permission from Mayo Clin Proc. 67:1992;1066.
*The total score ranges from 0 to 9.
†Amount of right atrium filled by echogenic particles.
‡Duration of echogenesis during 1-minute video segment.
§Diameter of largest echogenic particle.