Incidence of embolic events during acetabular prosthesis insertion in total hip arthroplasty, and effect of intramedullary decompression in preventing embolism: higher risk of embolism with one-piece type prosthesis

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Abstract
Purpose. In total hip arthroplasty (THA), there is a high risk of bone marrow embolism during femoral prosthesis insertion. However, the incidence during acetabular prosthesis insertion has received less attention. The first goal of this study was to determine the incidence of bone marrow embolism associated with acetabular prosthesis insertion. The second goal was to evaluate the effects of intramedullary decompression of the acetabulum in suppressing bone marrow embolism.

Methods. To achieve the first goal, we evaluated the effects of prosthesis insertion on the incidence of bone marrow embolism, and on respiratory and cardiovascular dynamics. For the evaluation of bone marrow embolism, images obtained by transesophageal echocardiography were rated using Pitto’s classification. To achieve the second goal, patients undergoing THA with a one-piece type acetabular prosthesis were divided into a control group and an acetabulum-decompression group, and the effects of insertion were analyzed in the same fashion.

Results. In the 150 patients in the study, bone marrow embolism was rated as grade 0 in 9, grade 1 in 46, grade 2 in 61, and grade 3 in 34 patients. Patients rated as grade 2 and 3 exhibited significant reductions in blood pressure and \( P_{aO_2} \), 5 min after acetabular prosthesis insertion. The results of multivariate analysis suggested that the incidence of bone marrow embolism was higher for the one-piece type prosthesis than for the two-piece type. Among the 60 patients who underwent THA with a one-piece type prosthesis, the incidence of bone marrow embolism was significantly lower in the decompression group.

Conclusion. As there are increasing indications for one-piece type acetabular prostheses in Japan, we must pay attention to the possibility of bone marrow embolism, not only during femoral prosthesis insertion but also during acetabular prosthesis insertion.

Key words Bone marrow embolism · Total hip arthroplasty (THA) · Acetabular prosthesis · Intramedullary decompression

Introduction

Total hip arthroplasty (THA) involves the risk of bone marrow embolism, which occasionally leads to cardiac arrest or death as a result of hypotension, hypoxemia, pulmonary hypertension, and other effects [1–6]. Regarding the mechanism of bone marrow embolism during THA, it is thought that the insertion of a prosthesis elevates the pressure in the bone marrow and pushes fat, bone marrow, thrombi, air, and other materials into the veins, causing obstruction of the right heart or the pulmonary artery. The insertion of a prosthesis on the femoral side using bone cement is thought to involve a particularly high risk of severe embolism [7–11].

However, the incidence of bone marrow embolism associated with the insertion of a prosthesis on the acetabular side has received less attention. We recently encountered several patients in whom reduction in blood pressure and \( S_{PO_2} \) was observed following the insertion of certain types of prostheses on the acetabular side during THA. The first goal of the present study was to determine the incidence of bone marrow embolism associated with acetabular prosthesis insertion during THA and to examine factors affecting the onset of this complication, using transesophageal echocardiography. The second goal was to evaluate the effects of intramedullary decompression of the acetabulum in suppressing bone marrow embolism. To our knowledge, no previous study has examined the onset of bone marrow embolism associated with acetabular prosthesis insertion during THA and the effects of prosthesis
structure and type on the incidence of bone marrow embolism. This is the first report dealing with factor analysis of the influence of acetabular prosthesis insertion on the occurrence of bone marrow embolism and exploring a valid means of preventing its occurrence.

Patients, materials, and methods

This study was conducted under the authorization of the Ethics Committee of our facility. Informed consent was obtained in writing from each patient prior to the start of the study.

To achieve goal 1 (analysis of the incidence of bone marrow embolism and factors affecting its occurrence), 150 patients (28 men and 122 women) with American Society of Anesthesiologists (ASA) status I or II undergoing scheduled primary THA were enrolled in the study. For these patients, surgery was conducted under general anesthesia combined with lumbar epidural anesthesia. Anesthesia was initiated with thiamylal (3–4 mg·kg$^{-1}$) or propofol (1–2 mg·kg$^{-1}$) and maintained with nitrous oxide (67%), sevoflurane (1.0%), and fentanyl (3–5 µg·kg$^{-1}$). The use of epidural anesthesia was permitted after prosthesis insertion was finished, in order to eliminate circulatory changes induced by the epidural anesthesia. During surgery, the patient lay on his/her side with the affected leg above the intact leg, and 5 cmH$_2$O positive end-expiratory pressure (PEEP) was used. After tracheal intubation with 0.1–0.15 mg·kg$^{-1}$ vecuronium, a 5.0/3.7-MHz probe (21364A; Philips Medical Systems, Andover, MA, USA) for transesophageal echocardiography (SONOS 1500 or SONOS 5500; Philips Medical Systems) was inserted. The right atrium and ventricle were observed in a four-chamber view [12–15]. The ultrasound images taken during prosthesis insertion were serially saved on a VCR, and examiners, without knowledge of patient characteristics or surgical procedure, assessed the grade of emboli on the basis of these images. Grading of emboli was performed in accordance with the classification of Pitto et al. [16,17]: grade 0 (no embolus), grade 1 (small numbers of fine emboli, below 5 mm in diameter), grade 2 (large numbers of emboli, below 5 mm in diameter), and grade 3 (emboli over 5 mm in diameter). To avoid artifacts, intravenous fluid administration was suspended during ultrasonography.

To evaluate the effects of bone marrow embolism on respiratory and cardiovascular dynamics, the radial artery was cannulated for invasive blood pressure measurement of systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean blood pressure (MBP); and arterial blood gas analysis of $P_{aO_2}$, $S_{aO_2}$, and $P_{aCO_2}$. In addition, peripheral oxygen saturation ($S_{pO_2}$), and end-tidal carbon dioxide pressure ($P_{ETCO_2}$) were monitored. Each parameter was measured immediately before and 5 and 10 min after the insertion of a prosthesis on the acetabular side. In all patients, ethylphenylephrine was administered when SBP fell below 80 mmHg, and the frequency of its use was recorded. If the anesthesiologists in charge judged it necessary to administer catecholamine (e.g., dopamine and epinephrine) for circulatory support, the use of such drugs was permitted and the frequency of their use was recorded.

Surgery on all patients was performed by the same team of orthopedic surgeons. The type and size of prosthesis to be used in each patient were determined at a preoperative conference of orthopedic surgeons. A two-piece type prosthesis with holes was used in 64 patients, a two-piece type prosthesis with one hole was used in 50 patients, and a one-piece type prosthesis without holes was employed in 36 patients. Bone cement was not used for fixation of the prosthesis in any of the patients. When a prosthesis with holes was used, additional fixation with screws was performed as needed, as judged intraoperatively by the orthopedic surgeons. The acetabular prosthesis used for THA is conventionally composed of two pieces (an outer metallic shell and an inner portion made of high-density polyethylene). The one-piece type prosthesis without holes is primarily used for surface-replacement type THA, of which the advantages are keeping the bone-head diameter physiological, making postoperative dislocation unlikely, remaining more bone, and making revision easier. After McMinn et al. [18] developed the Birmingham Hip Resurfacing System (Smith & Nephew, London, UK), which has a highly anti-abrasive metal-on-metal sliding surface, in 1996, the surface-replacement type of THA with this system yielded reliable results at several facilities [19,20]. At our facility, this system began to be used clinically in 1998. In young or middle-aged patients with diseases of the hip joint caused by dysplasia or congenital dislocation (which are frequently seen among Japanese) these conditions are a good indication for the surface-replacement type of THA, because the shape of femoral head can be better maintained and severe osteoporosis is not associated. Necrosis of the femoral head with moderate deformation and favorable ossein content is also an indication for the surface-replacement type of THA.

To achieve goal 2 (evaluation of the effects of acetabular decompression in preventing bone marrow embolism), the 60 patients rated ASA I or II who underwent scheduled primary THA using a one-piece type acetabular prosthesis without holes were divided into a non-decompression group (control group; $n = 30$) and a decompression group ($n = 30$). These patients were prepared and assessed in the same fashion as for goal 1. In the control group, prosthesis insertion was carried out using the routine press-fit method. In the decompres-