The trapdoor procedure using autogenous cortical and cancellous bone grafts for osteonecrosis of the femoral head

Michael A. Mont, Thomas A. Einhorn, Paul D. Sponseller, David S. Hungerford

From the Good Samaritan Hospital, Baltimore and Boston University Medical Center, USA

We have reviewed the results of 30 operations performed on 23 patients with Ficat stage-III or stage-IV osteonecrosis of the femoral head in which autogenous cortical and cancellous bone grafting had been performed through a so-called trapdoor made in the femoral head.

At a mean of 56 months (30 to 60) after operation 20 of 24 stage-III hips (83%) had a good or excellent result as determined by the Harris hip-scoring system. Two of six stage-IV hips (33%) had good or excellent results. Eighteen of 21 hips (86%) with a combined necrotic angle of 200° had good or excellent clinical results compared with only four of nine hips (44%) with a combined necrotic angle of more than 200°. Six of the eight hips which had fair or poor results were in patients who had received corticosteroids; five of these six hips had lesions with a combined necrotic angle of greater than 200° or were in a late stage (stage IV). There were no perioperative complications.

Our results suggest that the trapdoor procedure with autogenous cancellous and cortical bone grafting can be successful in Ficat and Arlet stage-III osteonecrosis of the hip in patients with small- to medium-sized lesions.

Received 21 May 1997; Accepted 26 August 1997

The treatment of osteonecrosis of the femoral head remains a challenge. Of the 209 000 total hip arthroplasties (THA) performed in the USA in 1991, 21 000 (10%) were for osteonecrosis. This condition generally occurs in young patients, typically in the second to fifth decades, and loss of income and productivity can create additional problems. Many authors have reported high rates of failure of THA in these patients, citing various causes including their relative youth (average age of 38 years), their long life expectancy, the poor quality of the femoral bone and persistent defects in bone mineral metabolism. Examples of studies with high rates of failure include that of Dorr et al who found that ten of 22 hips (45%) failed and of Cornell et al who reported 11 failures (39%) in 28 arthroplasties. In a recent ten-year follow-up by Fyda et al eight of 48 hips (17%) had been revised and an equal number showed radiological evidence of impending failure. Improved results have been claimed using modern cementing techniques or cementless stems, but these are short-term studies and their outcomes are still inferior to those for THA performed for other conditions.

There are a number of possible options for treatment other than THA in stage-III and stage-IV osteonecrosis of the femoral head as classified by Ficat and Arlet, including core decompression, rotational osteotomy, vascularised or non-vascularised bone grafting, and limited resurfacing of the femoral head. The number and variety of procedures indicate the lack of a successful treatment and the wish to avoid THA.

Bone grafting of the femoral head through a so-called trapdoor in the articular cartilage and subchondral bone has been used to treat late-stage osteonecrosis of the hip. Dead bone is removed and replaced by cancellous and cortical autografts which stimulate bone formation (osteoinduction) and support the subchondral bone and articular cartilage of the femoral head (osteoconduction). We now describe our experience with this procedure for stage-III and early stage-IV osteonecrosis of the femoral head.

Patients and Methods

Between March 1992 and January 1994, we treated 30 painful hips with Ficat and Arlet stage-III or early stage-IV osteonecrosis in 23 patients using the trapdoor procedure. The patients have been followed up for a minimum of two
years; none has been lost to follow-up, although one (two hips) was included who died 48 months after operation from causes unrelated to the surgery. Patients were seen yearly and assessed clinically and radiologically; the mean duration of follow-up was 56 months (30 to 60). The 16 men (19 hips) and seven women (11 hips) had a mean age of 26 years (14 to 46) at the time of surgery. The operation was not carried out in patients older than 50 years of age. Seven patients (nine hips) were less than 20 years of age at the time of operation. One female patient had an open growth plate but had reached the height of 168 cm at the age of 14 years and had little remaining growth potential in her femoral capital epiphysis.

Before operation all patients had severe pain in the groin on weight-bearing, with a variable degree of pain at rest. The radiographs showed stage-III or early stage-IV osteonecrosis (Table I). Early stage-IV disease was defined as a minimum of 2 mm of circumferentially intact joint space on the anteroposterior and lateral radiographs and thus determines preservation of the joint space and does not refer to the size or location of the lesion. Before operation 24 hips were graded as stage III and six as stage IV; 18 had recently been offered THA elsewhere.

Eleven patients (16 hips) had been given corticosteroids: in six (nine hips) for systemic lupus erythematosus, in three (three hips) for inflammatory bowel disease, in one (two hips) for idiopathic thrombocytopenic purpura and in one (two hips) for Hodgkin’s disease. All had received more than 20 mg of prednisone daily for a minimum of three months before and after the operation. A further six patients (eight hips) had a history of alcohol intake of greater than 400 ml a week. Two patients (two hips) had sickle-cell anaemia and another (one hip) severe third-degree burns. No associated risk factors were found in the remaining three patients (three hips).

A diagnosis of osteonecrosis was made on the basis of the clinical history and the appearance on anteroposterior, frog-leg lateral, and lateral radiographs. A biopsy of a specimen obtained from a previous core decompression had shown osteonecrosis in two hips with stage-III disease. The remaining hips had not undergone operation, but had radiological changes consistent with osteonecrosis, including an anterolateral sequestrum and a crescent sign, with a variable degree of collapse of the femoral head. The 30 hips in this study correspond to stages III, IV and V of the Steinberg rating scale and stages IIIC, IVC and VC of the classification proposed by the Association of Research on Circulation Osseous.

Operative technique. A diagram of the trapdoor procedure is shown in Figure 1. The patient lay in the lateral decubitus position. An anterolateral approach was used to preserve the blood supply to the femoral head. The anterior two-thirds of gluteus medius and all of gluteus minimus were elevated from the bone to expose the capsule of the hip. The hip was dislocated and the area of the segmental collapse exposed (Fig. 2a). Using

### Table I. Ficat and Arlet staging system for osteonecrosis of the femoral head

<table>
<thead>
<tr>
<th>Stage</th>
<th>Radiological appearance of femoral head</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Normal</td>
</tr>
<tr>
<td>II</td>
<td>Cystic or osteosclerotic lesions, or both, normal contour of femoral head, no subchondral fracture</td>
</tr>
<tr>
<td>III</td>
<td>Crescent sign or subchondral collapse</td>
</tr>
<tr>
<td>IV</td>
<td>Joint-space narrowing, secondary acetabular changes (cysts, marginal osteophytes and destruction of the cartilage)</td>
</tr>
</tbody>
</table>

Fig. 1

Diagram of the trapdoor procedure.
a scalpel and an osteotome the edges of the segment were defined, elevated and hinged back on its base (Fig. 2b). The size of the trapdoor was not specifically measured but was always greater than 10% and less than 30% of the surface of the femoral head. Necrotic bone was then removed using osteotomes, curettage and power burrs until a bleeding surface was encountered at the base of the cavity; all visible dead bone was removed.

Bone graft, consisting of corticocancellous struts and cancellous bone, was taken from the iliac crest (Fig. 1). Depending on the size of the lesion, two to three cortical struts were placed in troughs made in the remaining femoral head, perpendicular to the articular surface, to support the segment of articular cartilage which had been elevated (Fig. 2c). The remaining space was packed with cancellous autogenous bone (Fig. 2d). The trapdoor was replaced (Fig. 1) and fixed with two or three Orthosorb absorbable pins (Johnson & Johnson, New Brunswick, New Jersey). The hip was reduced and the capsule loosely sutured. Gluteus medius and gluteus minimus were sutured to their sites of insertion through the bone as described by Krackow et al. After operation the patients began exercising the hip on the first or second day and were mobilised on crutches, with a maximum of 10 kg of weight through the toes, for six weeks. They then used one crutch for another six weeks with up to 50% of weight-bearing. Full weight-bearing without support was allowed at 12 to 26 weeks depending on progress and comfort.

Clinical evaluation. The most recent follow-up was carried out by three of the researchers (MAM, TAE, PDS) either clinically (21 patients) or by telephone with both the patient and their current orthopaedic surgeon (two patients). All hips were assessed before operation and at the latest follow-up by the Harris hip-scoring system with 90 to 100 points indicating an excellent result, 80 to 89 good, 70 to 79 fair, and less than 70 a poor result. Treatment was classified as failed in patients who had a Harris hip score of less than 80 points or who subsequently had a THA. Clinical success was defined as a Harris hip score of 80 points or more.

Radiological evaluation. The preoperative radiographs were assessed by two of the authors (MAM and PDS) to
determine the staging according to the system of Ficat and Arlet\textsuperscript{16} and the combined necrotic angle.\textsuperscript{23} This angle is the sum of the angles obtained by using a goniometer to measure the surface of the femoral head involved by the necrosis on the anteroposterior and lateral radiographs (Fig. 3).

The radiographs were also assessed for evidence of collapse of the head or narrowing of the joint space. To eliminate variation in magnification, when possible, the films were taken at a standard tube-to-plate distance in the same radiology suite. The amount of joint-space narrowing was assessed using the technique of Dalldorf et al\textsuperscript{61} in which the width of the most superior aspect of the joint space is measured in millimetres with a microcalliper. The width of the joint space at the final follow-up was compared with that shown on earlier radiographs taken within six weeks of operation.

Results

**Clinical.** Twenty-two of the 30 hips (73\%) had a good (6 hips) or excellent (16 hips) result, with improvement in the Harris hip score from a mean of 41 points (31 to 64) before operation to a mean of 92 points (80 to 100) at the latest follow-up. Of the 16 hips in the 11 patients who had received corticosteroids, ten (63\%) had a hip score of 80 points or more. In the 14 hips in patients who had not received corticosteroids, 12 (86\%) had a good or excellent result (Fig. 4). Corticosteroids appeared to affect the size and stage of the lesion since five of the six hips which failed had stage-IV necrosis and/or large lesions with a combined necrotic angle greater than 200°.

Eight hips (27\%) had fair or poor results; subsequently five had a limited hemiarthroplasty, two a THA and one an intertrochanteric osteotomy. The average time to failure was 24 months (18 to 40) (Fig. 5). None of these operations was complicated by problems associated with having a previous procedure on the hip.

Of the seven patients under the age of 20 years, three were in stage III and four in stage IV at the time of the trapdoor procedure. All three stage-III hips were successful clinically and all four stage-IV hips needed revision to THA. The two patients with sickle-cell disease both required conversion to a THA.

Ten of the 14 hips (71\%) with bilateral procedures were successful clinically as were 12 of 16 unilateral hips (75\%). Four (67\%) of six patients with unilateral disease and 18 of 24 hips (75\%) with bilateral disease had clinical success.

Six of the hips were examined at the time of revision when only four (67\%) femoral heads had marked collapse; the other two had less than 2 mm of collapse. The cartilage-cartilage interface of the segment did not appear to be healed in any hips.

**Radiological.** Twenty of the 24 stage-III hips (83\%) had good or excellent results and four of the six hips (67\%)

---

**Fig. 3**

Diagram of combined necrotic angle.

---

**Fig. 4a**

**Fig. 4b**

**Fig. 4c**

Radiographs of a 26-year-old man with stage-III disease of the right hip before operation (a), six weeks after operation on the right hip (b) and four years after operation (c). There is minimal evidence of joint-space narrowing.
with stage-IV disease required a THA. Overall, 18 of 21 hips (86%) with combined necrotic angles of less than 200° had good or excellent results while only four of nine hips (44%) with lesions which had angles greater than 200° had good or excellent results. For the 24 stage-III hips, 16 (89%) of the 18 with combined necrotic angles of less than 200° had good or excellent results. Of the remaining six stage-III hips with angles greater than 200°, four (67%) had good or excellent results. The two hips with stage-IV disease which had been treated successfully had a combined necrotic angle of less than 200°. Three (75%) of the four failures with stage-IV disease had necrotic angles greater than 200°.

Of the hips which had good or excellent results when last seen, four had developed a slight loss of joint space with narrowing of 1 to 2 mm, but had no increase in symptoms; their Harris hip scores remained above 90 points. Of the 20 stage-III hips with good and excellent results, three (15%) had minimal loss of joint space. The four stage-III failures showed progressive narrowing of 2 to 3 mm. The four stage-IV hips which were all unsuccessful clinically, and one of the two which were satisfactory had progressive narrowing of the joint space; those which were clinically successful did not show evidence of this.

Complications. There were no intraoperative complications and no fractures. One patient sustained a deep-vein thrombosis which was treated with heparin followed by sodium warfarin for three months.

Discussion

The numerous methods of treatment which have been suggested for stage-III and early stage-IV osteonecrosis of the femoral head reflect the size of the problem and the uncertainty in its management. For small lesions in young patients with early stage-III disease without involvement of the acetabulum, corrective osteotomy and vascularised or non-vascularised bone grafting have been used. The results have been variable, but are better than THA in these patients. Of 27 reports describing the outcome of this last procedure in osteonecrosis compared with other conditions, only one described favourable results. Dorr et al found a failure rate of 91% in 57 hips when reviewed at 12 years. We do not yet know whether modern techniques of cementing and newer cementless prostheses will give better results.

Non-vascularised bone grafting may be achieved by a cortical graft through a core decompression tract, by way of a window made in the femoral neck or a trapdoor in the articular cartilage. Cortical struts may be harvested from the ilium, fibula oribia and placed in a core tract in the femoral head, but the long-term results have been unsatisfactory. Smith et al found that only 16 of 53 hips (30%) had a good clinical result after a mean of 14 years (4 to 27). Buckley et al combined core decompression with cortical autografts and achieved excellent results in 18 of 20 hips (90%) at an average follow-up of eight years, but their patients included some with Ficat and Arlet stage-I or stage-II disease.

Itoman and Yamamoto used a graft placed through a cortical window in the femoral neck and reported good and excellent results in 23 of 38 (61%) stage-II and stage-III hips at an average follow-up of nine years. Scher and Jakim combined this procedure with valgus osteotomy and had good or excellent clinical results in 36 of 45 hips (80%) at an average follow-up of five years. Rosenwasser et al used a similar procedure with cancellous iliac-crest bone and achieved excellent results in 13 of 15 hips (87%) with stage-II and stage-III disease at an average follow-up of 12 years.

Several authors have described similar results to ours using a trapdoor procedure. Meyers and Convery had a good and excellent outcome in eight out of nine stage-III hips at a mean follow-up of three years. Our study combines the features of the cancellous grafting procedure of Meyers and Convery with the cortical strut grafting of Itoman and Yamamoto and Yamamoto et al since we believe that the cortical struts provide excellent support to the subchondral bone and articular cartilage while healing occurs.
Variable results have been achieved using vascularised bone grafts in an effort to enhance revascularisation. Some have claimed success in 60% to 90% of patients with a follow-up of less than three years.\textsuperscript{28-39,63} These procedures, however, require considerable technical expertise and operating time. Even with the use of two operating teams, one to harvest the donor bone and the other to prepare the femur, the operating time averaged 210 minutes\textsuperscript{16} compared with 104 minutes for the trapdoor procedure in our study. Moreover, in a series of 247 legs in which the fibula had been used for the graft the morbidity included motor weakness, subjective discomfort in the ankle, and sensory abnormalities in the leg in 19%.\textsuperscript{64} The procedure may be reserved for large lesions only.

The worst results have been in patients with acetalubar involvement (stage-IV disease). If stage-IV hips had been excluded from our study, good or excellent results would have been achieved in 20 of 24 hips (83%). The use of the rating system of Steinberg et al\textsuperscript{21} to classify the hips would have given similar results, since all four Steinberg stage-III hips and 16 of 20 (80%) stage-IV hips were successful. A Steinberg stage-V hip corresponds to the early Ficat and Arlet stage IV. In our series only two of six (33%) such hips had good or excellent results.

Despite our early clinical success, we expect that some hips will deteriorate and may require reconstructive surgery later. Nevertheless, the arrest of the progression of symptoms for an average of more than 56 months suggests that the natural progression of the disease has been delayed. Many studies involving hips at similar stages of disease have shown that more than 80% required THA. In a recent meta-analysis,\textsuperscript{19} only 182 of 819 hips (22%) treated conservatively had good clinical results at a mean follow-up of 34 months (20 months to 10 years) and in stage-III hips only 13% were satisfactory. Eighteen of our 23 patients (78%) had already been offered a THA before we saw them.

In the seven patients in this series who required conversion to THA the procedures were performed without complications related to the previous trapdoor procedure.

On the basis of our results, the use of the trapdoor procedure with autogenous cortical and cancellous bone grafting appears to be a successful treatment for selected patients with stage-III osteonecrosis of the femoral head.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References


