Acetabular development after bipolar hemiarthroplasty for osteosarcoma in children

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A retrospective analysis was performed of eight patients with an open triradiate cartilage, who underwent resection for osteosarcoma and reconstruction of the proximal femur with a hemiarthroplasty, in order to identify changes of acetabular development. An analysis of the centre-edge angle, teardrop-to-medial prosthesis distance, superior joint space, teardrop-to-superior prosthesis distance, degree of lateral translation, and arthritic changes, was performed on serial radiographs. The median age at the time of the initial surgery was 11 years (5 to 14).

All patients developed progressive superior and lateral migration of the prosthetic femoral head. Following hemiarthroplasty in the immature acetabulum, the normal deepening and enlargement of the acetabulum is arrested. The degree of superior and lateral migration of the prosthetic head depends on the age at diagnosis and the length of follow-up.

With the development of expandable prostheses, hemiarthroplasty of the proximal femur is becoming more common in children.1-4 Acetabular development following femoral hemiarthroplasty in the skeletally immature patient has not been well described. Young adults with a bipolar hip hemiarthroplasty have developed progressive proximal migration and medial translation,5,6 whereas patients with juvenile rheumatoid arthritis treated with bipolar hemiarthroplasty develop progressive protrusio acetabuli.7 Adults with a standard bipolar and unipolar hemiarthroplasty develop acetabular erosions and proximal migration with long-term follow-up.8-13

The aim of the study was to evaluate the acetabular changes following hemiarthroplasty in the skeletally immature patient and the time course of the progressive changes in the centre of rotation of the hip.

Patients and Methods

From 1989 to 2003, 14 children with an open triradiate cartilage underwent a proximal or total femoral resection and hemiarthroplasty. Eight patients had sufficient radiographic and clinical documentation for analysis. Four patients were excluded because of loss of radiographic studies and two patients had less than two years of follow-up because of fatal progression of disease. There were four girls and four boys. The median age at the time of the initial surgery was 11 years (5 to 14). The median and mean follow-up periods were 53 and 60 months (24 to 105), respectively. The follow-up period for the study ended at conversion to total hip arthroplasty or until the time of death. Diagnoses were osteogenic sarcoma in four (all stage IIIB)14 and Ewing’s sarcoma in four (all stage IIIB).14 Reconstructions included a total femur in two, a proximal femoral replacement in three and an alloprosthetic reconstruction in three. All non-alloprosthetic prostheses were expandable (Table I). A bipolar femoral component was used in seven patients and a standard 32-mm femoral head in one. Femoral head size was matched by the replacement component, and all prostheses had a standard neck-shaft angle of 135°. Retrospective information was obtained from records, radiographic imaging, and pathological reports. Extended follow-up consisted of clinical visits, serial radiographs, and routine annual patient questionnaires. Internal Review Board approval was obtained for this study.

Radiographic assessment. We compared the first post-operative and the yearly follow-up radiographs with the hemiarthroplasty in place. On anteroposterior radiographs of the pelvis, an analysis of the centre-edge angle, medial joint space, superior joint space, teardrop-to-superior prosthesis distance, lateral displacement, and arthritic changes was performed. The classic centre-edge angle of Wiberg was formed by

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a line starting from the centre of the prosthetic head and parallel to the long axis of the body and the line connecting the centre of the prosthesis with the lateral point of the acetabular roof.\textsuperscript{15,16} Because of inconsistencies caused by rotation of the pelvis\textsuperscript{17-20} the medial gap was measured from the prosthesis to the lateral wall of the tear drop. In addition, superior migration was determined by drawing a coordinate parallel to the inferior aspect of the bilateral teardrops and measuring the perpendicular co-ordinate to the top of the femoral head component.\textsuperscript{18} The superior joint space was measured from the top of the femoral prosthesis to the acetabular roof. The lateral displacement was determined by the perpendicular distance from Perkin's line (the vertical line at the lateral margin of the acetabular roof) to the most lateral aspect of the femoral head component;\textsuperscript{20,21} the degree of lateral displacement (as a percentage) was the quotient of the lateral displacement and the size of the prosthetic head (Fig. 1). All radiographs were assessed at three different times by a resident (WT), a fellow (MWM), and an attending surgeon (CDM). Digital and hard copy radiographic measurements were standardised to the known size of the femoral head component to eliminate errors of measurement of magnification.

**Functional assessment.** The Musculoskeletal Tumor Society functional grading system\textsuperscript{22} for the lower extremity was used to assess the functional outcome of the reconstruction. All patients had functional scores prospectively collected.

**Results**

**Clinical assessment.** On final evaluation, four patients had no existing disease, one had died of disease, and three were alive with disease. Six of the eight reconstructions have remained in place, giving a five-year prosthetic survival of 80\% (SE 18). One prosthesis was removed because of deep infection, and a second prosthesis was converted to a total hip arthroplasty at 93 months. Four patients received expandable prostheses. Three underwent expansion of the prosthesis (cases 1, 3 and 4), and one developed distant recurrence and plans for expansion were halted (case 1). Four lengthening procedures were performed in three patients with a mean lengthening distance of 14.5 mm (SE 1.7). There were no local recurrences. One patient with an allograft prosthesis underwent a delayed contralateral distal femoral epiphysiodesis. The mean leg-length discrepancy at final follow-up was -9.8 mm (SE 3).

Complications requiring re-operation occurred in three of eight patients (38\%). One patient who had a proximal femoral replacement developed superficial breakdown of the wound during chemotherapy, and required revision surgery. One of the three patients with an allograft prosthesis developed a nonunion and required four bone grafting procedures to obtain union. A third child developed a deep infection and dislocated his prosthesis, requiring its removal.

**Radiographic assessment.** Following surgery, no patient had deepening or enlargement of the acetabulum as occurs with normal hip development. No patient had early closure of the triradiate cartilage. Closure had occurred in two boys at the age of 15 years, and in three girls at the age of 13. With follow-up, all patients demonstrated progressive lateral translation (Fig. 2) and a decrease in superior cover with a

### Table I. Patients' details

<table>
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<tr>
<th>Case</th>
<th>Diagnosis</th>
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<th>Procedure</th>
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</table>

**Fig. 1**

Radiograph showing how radiographic assessment was measured (a, lateral displacement; b, teardrop-to-superior prosthesis displacement; c, medial gap; d, superior joint space).
declining centre-edge angle (Fig. 3). Only one patient had frank dislocation and this followed a deep infection. One patient was prophylactically converted to a total hip replacement because of concern for dislocation with a centre-edge angle of 12° and a laterally uncovered prosthetic head of 43%. The acetabular roof migrated superiorly with increasing follow-up (Fig. 4) causing a progressive rise in the centre of rotation of the hip. At final follow-up, the mean lateral migration was 30.7% (SE 4). Patients who were younger than 11 years of age had a greater degree of lateral migration with a mean of 36.8% loss of cover (SE 3) versus patients aged 11 years and older who had a mean of 27% (SE 1). The mean change in the centre-edge angle was -13° (SE 5). Children who were younger than 11 years of age had the greatest change in the centre-edge angle of -18° (SE 7) as opposed to older patients with a mean change in the centre-edge angle of -10° (SE 0.5). In addition to age, the type of reconstruction appeared to influence the degree of reduction in the centre-edge angle. Children with proximal femoral reconstructions had a mean loss in the centre-edge angle of 15° (SE 4) as compared with total femoral reconstructions which had a mean loss of 9° (SE 1). Age also influenced the degree of superior migration, with patients younger than 11 years of age having a mean superior migration of 8.5 mm (SE 1.2) as opposed to older patients with a mean migration of 5.2 mm (SE 1.0) (Fig. 5). Because of the small sample size apparent differences between subgroups may not be real. Arthritic changes of osteophyte formation, superior joint space narrowing, and subchondral sclerosis were seen to some degree after 30 months. Only two patients (cases 3 and 8), with 93 and 105 months of follow-up, developed subchondral cyst formation.

**Discussion**

The normal acetabulum deepens and enlarges with maturity.23 Following hemiarthroplasty of the hip in the skeletally immature, the acetabulum has a tendency to become shallower, with a decreasing centre-edge angle and an increase in lateral translation. In addition, the hip centre rises with proximal migration of the prosthesis. Superior migration became most apparent in patients who were younger than 11 years of age. The phenomenon may be attributed to a combination of three factors. First, because of an increased potential for acetabular remodelling in the younger patient, as older patients have limited adaptive...
changes when nearing closure of the triradiate cartilage. Secondly, because of increased pressure and greater wear on the cartilage surface and subchondral bone of the acetabular dome from the smaller head component used in the younger patients; however, this variable could not be assessed independently due to its correlation with age. Thirdly, because of muscle balance. Proximal femoral replacements, as opposed to total femoral replacements, have intact adductor insertions and, at least, an intact adductor magnus generating a major adductor moment. The ensuing adductor-abductor imbalance may cause a greater degree of lateral translation in the proximal femoral reconstructions. A similar phenomenon occurs with cerebral palsy and following abductor resection in the skeletally immature patient with the subsequent development of a valgus neck deformity and subluxation of the hip. The development of acetabular dysplasia with progressive superior and lateral migration following bipolar hemiarthroplasty is a unique mechanism of failure in children. In the adult population, failure in hemiarthroplasty occurs on
the acetabular side with progressive superomedial migration because of cartilage wear after fracture treatment,\textsuperscript{9,13} and in the treatment of arthritis in dysplastic hips.\textsuperscript{11} One review investigating acetabular changes in young adults treated with bipolar hemiarthroplasty for proximal femoral osteosarcomas found the development of acetabular erosions and medial migration with time.\textsuperscript{5} The progressive dysplasia can lead to complications of inadequate bone-stock in the roof and posterior wall of the acetabulum at the time of conversion to a total hip arthroplasty. Understanding the pattern of acetabular deficiency becomes particularly important when the need for revision surgery arises.

Functional outcomes following femoral hemiarthroplasty in the skeletally immature were good. Five patients did not need walking aids and two used a single stick or crutch only for prolonged walking periods. The mean total score for the series of 77% is the same as that from a similar study of nine patients with expandable proximal femoral replacements in Birmingham, United Kingdom.\textsuperscript{1} However, assessments of acetabular changes were not reported in that series.

The prevention and treatment of acetabular dysplasia after hip reconstruction in patients with an open triradiate cartilage continues to be an unsolved problem for the orthopaedic oncologist. The problems of superior migration and lateral translation suggest that attention to soft-tissue reconstruction around the hip joint may retard the progression of the observed changes. As very young patients survive their disease, novel interventions to ensure satisfactory functional outcomes will be needed. Consideration should be given at the initial surgery to the implantation of prostheses with increased offset. A more varus prosthesis may help to maintain the femoral head in the acetabulum. Unanswered questions of future management issues after early reconstruction surgery were raised by this study. One might consider the need for an acetabular osteotomy early in the progression of lateral translation and superior migration, in order to improve cover of the prosthetic head. Soft-tissue adductor-abductor imbalance could also be improved at the time of initial surgery with a gluteus maximus or iliopsoas transfer.

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

**References**