Autologous capping during resection arthroplasty of the hip in patients with cerebral palsy

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In patients with severe quadriplegic cerebral palsy and painful hip dislocation proximal femoral resection arthroplasty can reduce pain, but the risk of heterotopic ossification is significant. We present a surgical technique of autologous capping of the femoral stump in order to reduce this risk, using the resected femoral head as the graft.

A retrospective study of 31 patients (43 hips) who had undergone proximal femoral resection arthroplasty with (29 hips) and without autologous capping (14 hips) was undertaken. Heterotopic ossification was less frequent in patients with autologous capping, and a more predictable pattern of bony overgrowth was found.

For a selected group of non-ambulatory patients with long-standing painful dislocation of the hip, we recommend femoral resection arthroplasty over more complicated reconstructive operations. The risk of heterotopic ossification, which is a major disadvantage of this operation, is reduced by autologous capping.

The surgical treatment of secondary dislocation of the hip is one of the most challenging problems in patients with cerebral palsy. Approximately 60% of children with cerebral palsy who are not walking by five years of age are likely to develop migration and deformity of the femoral head,\(^1,2\) which in 33% to 70% of cases is painful.\(^3,4\)

The deformity with dislocation often interferes with perineal hygiene, nursing care and positioning in bed and in a wheelchair. The goal of treatment is a painless mobile hip, which allows nursing care, sitting, standing for transfer and an upright posture, important for safe feeding and better pulmonary ventilation. The incidence of dislocation of the hip in cerebral palsy is related to function as assessed by the Gross Motor Function Classification System (GMFCS),\(^5\) in which in grade 1 patients the rate of dislocation of the hip is almost identical to that of healthy controls, increasing up to 64% in grade 5 patients.

Operative treatment to prevent dislocation of the hip includes soft tissue release to neutralise muscle imbalance. Progressive dislocation requires extended treatment. The combination of soft-tissue release, varus osteotomy and acetabular procedures enable adequate reduction and prevention of further dislocation.\(^4\) More recently, resurfacing or total hip replacement have been included in the treatment options.\(^6\)

Palliative operations, including soft-tissue release combined with osteotomy and resection of the head of the femur may be considered in patients with failed reconstruction or severe dislocations.

Excision of the head and neck gives unsatisfactory results in these children. Although pain is relieved, there is instability and proximal migration of the greater trochanter, leading to recurrent deformity, periarticular ossification and skin breakdown.\(^7,8\) In 1978, Castle and Schneider\(^9\) described a technique of proximal femoral resection and interposition arthroplasty, with good results.\(^10\) A long-term outcome study by Widmann et al\(^11\) confirmed the efficacy of resection arthroplasty for the treatment of painful dislocation of the hip in non-ambulatory patients with cerebral palsy. However, there was a high rate of heterotopic ossification leading to limitation of movement, and a further study reported such ossification in 57% of cases.\(^12\) In the study by Widmann et al\(^11\) many patients received radiation therapy which, although effective for the prevention of heterotopic ossification, can be associated with acute sequelae with an skin irritation and chronic sequelae with an increased risk of malignancies and fibrosis, including a reduced range of motion.\(^13\) It is therefore undesirable to use this treatment widely in children.

Overgrowth of bone has been observed in children with congenital or traumatic amputation and autologous capping of the stump is a procedure designed to prevent this.\(^14\) We have
developed a corresponding technique to prevent heterotopic ossification after resection arthroplasty for dislocation of the hip. The aim of this study was to compare the outcomes of resection arthroplasty with or without autologous capping in patients with severe cerebral palsy and painful dislocation of the hip.

**Patients and Methods**

Between 2002 and 2006, 31 non-ambulatory patients (43 hips) with cerebral palsy and severe spastic quadriplegia were treated for painful dislocation of the hip and sitting difficulties. All had long-standing dislocation with lateral femoral head defects and were GMFCS level 5. Patients with hips which could be reconstructed, those with obviously open growth plates and those below the age of 12 were excluded. All hips were treated with resection arthroplasty, and 29 hips (20 patients) received autologous capping of the proximal femur. Bilateral resection arthroplasty was indicated in 12 patients (24 hips) and performed during the same operation. Radiation therapy or non-steroidal anti-inflammatory drugs were given to prevent heterotopic ossification. Medication for pain relief included paracetamol, metamizole and tilidine.

Ethical approval was obtained to allow retrospective analysis, and parents or carers gave informed consent. The study design included a review of records, radiographs and questionnaires. No radiographs were performed for study purposes.
Operative technique. With the patient supine and the affected leg(s) draped to allow free movement, a straight lateral incision is made 6 cm to 10 cm proximal to the greater trochanter, extending distally along the outer aspect of the thigh. Alternatively, a curved incision and a Watson-Jones approach to the hip can be used. The fascia lata is split, vastus lateralis detached, and circumferential subperiosteal dissection of the subtrochanteric region of the femur is carried out (Fig. 1a). The proximal diaphysis is divided 2 cm to 3 cm below the lesser trochanter using an oscillating saw (Fig. 1b). Gluteus medius, minimus and psoas are detached from their insertions and resorbable sutures inserted for later positioning with the acetabulum. Gluteus maximus is detached from the greater trochanter using electrocautery. The short external rotators are divided and the capsule incised circumferentially at the base of the neck. The ligamentum teres is divided and the proximal femur removed (Fig. 1c), taking care to include the entire periosteum.

An osteotomy is performed between the neck and head of the removed femur to prepare it for autologous capping (Fig. 1d). A groove is created in the femoral head by removing 3.5 mm of spongious bone and the capping graft is then placed over the proximal femoral stump, which has to be narrower than the graft. It is sometimes necessary to shape the stump to obtain optimal fitting of the head (Fig. 2a). Fixation of the graft is by two intra-osseous cerclage wires arranged perpendicularly to each other (Figs 2b to 2d). They are tightened carefully to avoid cutting through the soft head. The twisted ends are bent proximally (Fig. 2e). The acetabulum is sealed off by oversewing the capsular edges (Fig. 2f). The gluteal muscles are interposed between the acetabulum and the proximal femur as a further soft-tissue cushion. The sutures at the muscle/ligament help to identify these structures and can be used directly for sewing. The proximal end of the femur is covered by the vastus lateralis and the wound closed in layers. The patient is placed in skeletal traction for two weeks and then on skin traction for an additional four weeks. Transfer to a wheelchair is started two weeks after operation.

A questionnaire designed for this study was sent to the families assessing pain, difficulties with seating and personal hygiene before and after the operation and was...
completed by 87% of the parents or primary carers. The level of pain was assessed additionally using a visual analogue scale (0 to 10). Changes in the ability to sit, transfer to a wheelchair and nursing care were documented using semi-quantitative systems.

Radiographs of the pelvis from pre-operative planning, immediately post-operatively and at the most recent clinic visit were available for all patients. Radiographs were reviewed by an independent examiner (SM) to determine the pre-operative appearance according to Tönnis, including deformity of the femoral head, the grade of heterotopic ossification as described by Brooker et al, and migration of the femur according to the position of the proximal femur relative to the acetabulum.

Statistical analysis. Statistical analyses were performed by SPSS software (SPSS Inc., Chicago, Illinois). The results are presented as mean values and SD if not otherwise stated. A normal distribution of data was determined for continuous numbers. The mean values of the groups were compared using Student’s t-test. Non-parametric testing was used when the data were not normally distributed. The non-directional Mann-Whitney U test was used to assess the differences for ordinal characters such as improvements in functional status or Brooker classification. A p-value < 0.05 was considered statistically significant.

Results
The 31 patients had a mean age of 21.8 years (13 to 42) and a mean follow-up of 2.7 years (0.6 to 5.7). Pre-operatively, they were complaining of pain and difficulties with sitting and personal hygiene (Table I). Resection arthroplasty with autologous capping was performed in 29 hips and resection arthroplasty alone in 14. Complications related to the operation requiring secondary intervention were seen in 11% (five hips) of the study group. There were two deep wound infections after autologous capping which required surgical revision, and one haematoma after resection arthroplasty alone. One patient required revision of the stump for proximal migration, and another underwent removal of heterotopic bone, both following resection arthroplasty alone.

Using the visual analogue scale the mean pain was reduced significantly from 9.1 (SD 0.9) pre-operatively to 2.8 (SD 2.0) at a mean follow-up of 2.7 years (0.6 to 5.7) (p < 0.001). A total of 28 patients had improvement in nursing care, sitting ability, transfer to a wheelchair and mobility of the hips. There were no significant differences between patients with or without autologous capping. The overall satisfaction with the operation was obtained from the carers, and for 26 (84%) of the patients they were content with the surgical treatment.

All pre-operative radiographs showed a severe dislocation of the hip (Tönnis stage 4), and deformation of the

| Table I. Demographic data, medical history and functional ability of the study cohort |
|-----------------------------------|-----------------|-----------------|-----------------|
|                                   | All             | Resection arthroplasty only | With autologous capping |
| Number of patients/hips           | 31/43           | 11/14            | 20/29           |
| Age in yrs (mean, SD)             | 21.8 (9.4)      | 23.6 (8.0)       | 19.3 (6.8)      |
| Follow-up in yrs (SD, range)      | 2.7 (1.7) (0.6 to 5.7) | 3.7 (1.8) (0.6 to 5.7) | 2.2 (1.4) (0.6 to 4.2) |
| Clinical features (%)             |                 |                 |                 |
| Pain                              | 100             | 100             | 100             |
| Sitting problems                   | 84              | 86              | 83              |
| Problems with perineal care        | 79              | 86              | 75              |

| Table II. The migration of the proximal femur was measured in relation to the centre of the acetabulum. Heterotopic ossification was classified according to Brooker et al in anteroposterior radiographs |
|-------------------------------------------------|-----------------|-----------------|-----------------|
| Migration of proximal femur (%)                 | All (n = 43)    | Resection arthroplasty only (n = 14) | With autologous capping (n = 29) |
| Below acetabulum                                | 11.6 (n = 5)   | 7.1 (n = 1)     | 13.8 (n = 4)    |
| Level of acetabulum                             | 65.1 (n = 28)  | 64.3 (n = 9)    | 65.5 (n = 19)   |
| Above acetabulum                                | 23.3 (n = 10)  | 28.8 (n = 4)    | 20.7 (n = 6)    |
| Heterotopic ossification (Brooker grade) (%)    |                 |                 |                 |
| 0                                               | 48.8 (n = 21)  | 35.7 (n = 5)    | 55.2 (n = 16)   |
| 1                                               | 30.2 (n = 13)  | 28.6 (n = 4)    | 31.0 (n = 9)    |
| 2                                               | 11.6 (n = 5)   | 14.3 (n = 2)    | 10.3 (n = 3)    |
| 3                                               | 9.3 (n = 4)    | 21.4 (n = 3)    | 3.4 (n = 1)     |
Femoral head was seen in 40 hips (93%). After operation, there was no significant difference in relation to the position of the proximal femur between the groups (p = 0.208). Heterotopic ossification around the proximal femur was seen in 22 hips (51%) (Table II). This was less prevalent in the autologous capping group (p = 0.107) and showed a more predictable pattern of bony overgrowth which did not extend towards the pelvis (Fig. 3). Osteopenia and a reduction in diameter of the bone graft were seen in two of 29 hips, indicating necrosis of the graft. However, none showed radiolucency around the cerclage wires, or other signs of nonunion.

Discussion
The preferred treatment for secondary dislocation of the hip in cerebral palsy includes open reduction with soft-tissue release, femoral osteotomy and pelvic reconstruction.17 Whereas these procedures may succeed in young patients where there is still potential for remodelling of the femoral head and acetabulum, dislocation in the older child or adult presents a greater problem. In patients able to perform transfer standing and with regular use of standing frames we initially evaluate the option of open reduction with femoral and pelvic osteotomies. In non-ambulatory patients with a painful dislocation, salvage procedures such as subtrochanteric valgus osteotomy and proximal femoral head resection are more likely options. Leet et al18 reported similar overall satisfaction after valgus osteotomy (McHale procedure) and resection arthroplasty, and we had similar results.19 Although excellent post-operative range of movement and pain relief is reported after resection arthroplasty, the high risk of heterotopic ossification, up to 60%, is a major disadvantage.11,12 Non-steroidal anti-inflammatory medication is mostly ineffective in the prevention of ectopic bone, and radiation therapy carries the risk of additional harm, particularly to the young patient.

All our patients had significant or complete resolution of pain, and 89% of the carers reported improvement in sitting and hygiene. Considering the high level of pre-operative impairment, the expectations of a gain in function after surgery are low. Relief from pain helped our patients to sit better and return to standing transfers, as also reported in previous reviews of this technique.10-12 The only report that disagrees with these findings is by Boldingh et al,2 who reported only a 33% satisfaction rate following femoral head resection in ten patients.

Using the same surgical technique as Castle and Schneider,3 heterotopic ossification was reported in 81% (44 of 54) of hips by McCarthy et al,20 and in 57% (12 of 21) by Abu-Rajab and Bennet.12 In our series the number of hips with heterotopic ossification was reduced from 64% in the resection arthroplasty group to 45% in the group with autologous capping. Furthermore, radiation therapy for the treatment of heterotopic ossification was avoided and analgesics were restricted to those that did not influence bone metabolism. The improvement involved only the rate of heterotopic ossification and no difference was found in functional outcome.

Although the bone graft might be at risk of osteonecrosis due to an interrupted blood supply, in 27 of 29 hips the femoral head was intact during follow-up without radiological signs of osteonecrosis or nonunion. Similarly, Bernd et al,14 in their series of juvenile amputations reported that none of their patients developed nonunion of the grafts taken from either the distal end of the amputated bone or the posterior part of the iliac crest. We had two cases of deep wound infection, one requiring removal of the bone graft and wires, and our overall rate of surgical related complications is similar to that of other reports.12,18 However, care should be taken to reduce the risk of infection by intravenous antibiotics and to secure suture of the capsular flaps and muscles between the acetabulum and proximal femur in order to reduce the risk of haemtoma.

There were no accurate data on the duration of operation and blood loss. However, as no longer than 15 minutes are needed for the autologous capping, this represents a minimal lengthening of the operation and no significant further blood loss.
Limitations of this study are the different sizes and follow-up of the two groups and the retrospective design of the investigation. Data collection after surgery may have caused a recall bias, particularly for the functional outcome, as assessed by the primary carers. However, non-significant differences in the anthropometric data demonstrate that the groups are comparable and the radiological analysis was not biased by retrospective data collection.

We suggest that hip subluxation and dislocation in cerebral palsy are best treated by early reconstruction. However, in non-ambulatory patients with long-standing painful dislocated hips, proximal femoral resection arthroplasty is a safe and effective method to relieve pain and improve sitting and perineal care. The risk of heterotopic ossification can be reduced by autologous capping of the femoral stump.

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References