ONCOLOGY

Ice-cream cone reconstruction of the pelvis: a new type of pelvic replacement

EARLY RESULTS

Primary bone tumours of the pelvis are rare, representing approximately 10% of all primary bone sarcomas.1 Of these tumours, chondrosarcomas are the most common in skeletally mature patients, whereas in children osteosarcomas and Ewing's sarcoma predominate.1 Other locally destructive tumours such as giant cell tumours can also involve the pelvis.

Although hindquarter amputation was the traditional treatment for these tumours, the procedure had a high morbidity and left patients with considerable cosmetic and functional disability.2

Limb salvage became increasingly popular in the 1980s and the different types of resection have been classified by Enneking and Dunham.3 Of all the types of pelvic resection, those involving the hip joint (P2)4 are the most technically challenging. Various operations have been used to preserve some function of the hip. The most simple method is to perform an excision arthroplasty, leaving a flail limb with an unstable pseudarthrosis, which can be painful and is associated with a much shorter leg. This hip transposition technique4 is nevertheless still associated with high morbidity, but early results are promising. Complications are diminishing with increasing experience.

Endoprosthetic replacement of the pelvis is one of the most challenging types of limb-salvage surgery, with a high rate of complications. In an attempt to reduce this and build greater versatility into the reconstruction process, a new type of pelvic endoprosthesis was developed in 2003, based on the old McKee-Farrar prosthesis. This study reviews the outcomes in 27 patients who had an ice-cream cone pelvic prosthesis inserted at two different specialist bone tumour centres in the United Kingdom over the past six years. The indications for treatment included primary bone tumours in 19 patients and metastatic disease in two, and six implants were inserted following failure of a previous pelvic reconstruction. Most of the patients had a P2+P3 resection as classified by Enneking, and most had resection of the ilium above the sciatic notch. The mean age of the patients at operation was 49 years (13 to 81). Complications occurred in ten patients (37.0%), of which dislocation was the most common, affecting four patients (14.8%). A total of three patients (11.1%) developed a deep infection around the prosthesis but all were successfully controlled by early intervention and two patients (7.4%) developed a local recurrence, at the same time as widespread metastases appeared. In one patient the prosthesis was removed for severe pain.

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and secondary bone tumours. Reconstruction of the pelvis using a custom-made endoprosthesis is technically challenging and expensive. The long-term results of this method are acceptable, but the risk of complications remains high, with rates of infection of 10% to 30% and dislocation of 15% to 25%.

In 2003 we developed a new type of pelvic replacement (Coned Hemi-Pelvis; Stanmore Implants, Elstree, United Kingdom) which would be simple to make, easy to use, and which would hopefully reduce the incidence of complications while being versatile to use even when there was little pelvis remaining. The concept is based on the old design of the McKee-Farrar stemmed hip replacement (Howmedica, Staines, United Kingdom), and has become known as the ‘ice-cream’ cone prosthesis, as it looks like an inverted ice-cream cone (Fig. 1). It is inserted into the remnant of the pelvis and surrounded by antibiotic-laden bone cement. We report the use of this prosthesis to reconstruct defects after resection of malignant periacetabular tumours or defects caused by the removal of a previous failed pelvic reconstruction. We discuss the short- to medium-term outcome, functional results and surgical complications of this procedure.

**Patients and Methods**

Between 2004 and 2009, 27 patients underwent pelvic resection and acetabular reconstruction using this prosthesis at two separate units in the United Kingdom. The indications for treatment included primary bone tumours in 19 patients (chondrosarcoma in 12, Ewing’s sarcoma in three, giant cell tumour in one, osteosarcoma in one, epithelioid haemangioendothelioma in one and myeloma in one). There were also two patients with metastatic disease and six with defects following previous failed reconstruction after resection of a primary bone tumour. The latter included three with large pelvic defects following removal of a failed endoprosthesis, one after a failed excision arthroplasty for chondrosarcoma, and one 11 years after irradiation and reimplantation of the hemipelvis for osteosarcoma. There was one unusual case of hydatid disease that had caused periacetabular destruction and loosening of a previously implanted hip replacement.

We reviewed the clinical data, case notes and imaging studies. All patients underwent pre-operative staging, including plain radiographs, MRI and CT scanning. Three patients had pulmonary metastases at the time of surgery. The surgical technique varied depending on the anatomical location of the tumour and the operating surgeon. In all cases the patient was positioned in the lateral position. The majority of procedures used an extended Ollier approach with trochanteric osteotomy, but others were carried out using an anterior ilioinguinal incision combined with a Kocher-Langenbeck approach. After excision of the tumour the stem of the ice-cream cone prosthesis was carefully positioned in the remaining ilium after reaming, and was targeted towards the posterior superior iliac spine. Fluoroscopic guidance was not routinely used to align the stem in the ilium, but it can be useful during the learning curve of the procedure. The stem of the prosthesis was designed to sit in the ilium alone and should not pass into the sacroiliac joint, as this can be a source of post-operative pain. Strategically placed screws or threaded rods were then placed into the remnant of the ilium to act as additional support, and both screws and prosthesis were then surrounded by antibiotic-laden bone cement, applied by a standard cement gun and then moulded by hand, in order to achieve a solid and stable construct (Figs 1 and 2). Palacos G cement (Biomet, Swindon, United Kingdom) was used with added vancomycin (1 g per mix), in an attempt to reduce rates of infection. The femur was then prepared in the standard fashion and a variety of femoral components...
were used. In one young active patient the femoral head was resurfaced rather than replaced, in order to obtain maximal stability (Fig. 3). Various methods were used to reduce the risk of dislocation: large-diameter bearing surfaces, or a captive acetabular component (Stryker, Newbury, United Kingdom), or ADM double mobility acetabular component (Stryker), or a Trevira tube (Implantcast, Buxtehude, Germany), which was sutured around the reconstruction and the neck to produce a ‘pseudocapsule’. The wound was closed around a suction drain for 48 to 72 hours. After operation, patients were given intravenous antibiotics for one to five days (cefuroxime 750 mg and metronidazole 500 mg for a minimum of 24 hours) and were allowed to bear weight as limited by pain. The one patient with myeloma and the two with metastatic disease received post-operative adjuvant radiotherapy.

Patients were reviewed six weeks after the operation, then every three months for the first two years and six-monthly thereafter. After 12 months, they completed the Toronto Extremity Salvage Score (TESS),\(^\text{24}\) a well-validated measure of functional outcome. No patients were lost to follow-up.

Results
The study group comprised 27 patients, 15 of whom were male and 12 female. Their mean age at operation was 49 years (13 to 81). At the time of review, 19 patients (70.4%) were alive with a mean follow-up of 39 months (18 to 80) and eight had died at a mean follow-up of 11.5 months (4 to 27). Of the eight patients who died, the cause was widespread metastases in six and cardiovascular disease in two.

At final review a TESS score was obtained for 15 of the surviving 19 patients. The mean TESS score was 69% (52% to 90%).

Complications. A total of ten patients (37.0%) had a significant complication, five of whom (18.5%) had a further procedure. Dislocation occurred in four patients (14.8%), of whom three had one isolated dislocation that was successfully reduced under general anaesthetic. All the dislocations occurred within six months of operation; one patient had three episodes of dislocation and underwent a stabilisation procedure. No dislocations occurred in patients fitted with a captive acetabular device.

One patient who had previously had an excision arthroplasty underwent removal of the implant after three years because of persistent pain. At the time of operation we found insufficient bone stock to secure the implant, which had therefore become loose.

Deep infection occurred in three patients (11.1%), all within the first two months after operation. It was controlled by aggressive wound debridement, washout and intravenous antibiotics.

Local recurrence occurred in two patients at the same time as the appearance of widespread metastases. Both had undergone marginal excision of a grade II chondrosarcoma.\(^\text{25}\) One patient underwent resection of a local recurrence from the ilium.

Discussion
Excision of pelvic tumours is one of the most technically demanding procedures in orthopaedic oncology, and reconstruction demands the all-embracing use of modern surgical techniques and orthopaedic implant technology. Although reconstruction of defects in the lower limb following the resection of primary bone tumours has proved successful,\(^\text{26,27}\) the search for the optimal implant to reconstruct pelvic defects continues. The overall complication rate in our series was 37%, with a re-operation rate of 18.5%, but so far only one patient has required removal of the implant. These figures are similar to those of other series when performing prosthetic reconstruction after resection of a pelvic tumour.\(^\text{12,14,19}\)

Infection is the most common complication following any type of pelvic reconstruction,\(^\text{2,5,12,15}\) confirmed in 11% of our series and successfully treated. This compares favourably with other implants, where infection rates as high as 30% have been reported, usually leading to removal of the prosthesis.\(^\text{19}\) One of the key design features of the ice-cream cone prosthesis is the large volume of antibiotic-laden cement used to support it. We believe that it is the resulting high concentration of antibiotics around the prosthesis that minimises deep infection and allows effective control if it occurs.

Dislocation occurred in four patients (15%), three in patients with a relatively small femoral head (28 mm diameter). In 2006 we began to use larger femoral heads to improve stability, often using a bipolar articulation, or a captive or semi-captive device. A large head diameter increases the head to neck ratio, which in turn allows for an increased arc of movement. It also increases the excursion distance, which in turn improves innate stability. We believe that these modifications have reduced the incidence of dislocation in line with that reported in total hip.

Fig. 3
Radiograph showing the ice-cream cone prosthesis with Birmingham Hip Resurfacing of the femoral head.
replacement.28 The main reason why dislocation happened in the patients is that in most cases they had undergone a P2/3 resection,3 meaning that virtually all the muscles that attached the leg to the pelvis had lost their origin. Indeed, following this sort of operation, sometimes the only remaining muscles holding the leg on to the rest of the body were the psoas and glutei. Dislocation can arise even if the patient just pulls themselves up the bed, leaving the leg behind. All patients are now taught to do ‘buttercup’ exercises, where they contract their buttock muscles before attempting to move their leg, to try and keep the hip in joint using the glutei. In recent cases this problem has been reduced by the use of a Trevira tube to form a pseudocapsule around the hip.19

A local recurrence rate of 7.4% is comparable to those of other reported series.17

The only long-term failure in this series was a patient who had a previous excision arthroplasty for a chondrosarcoma, as it was not thought that there was sufficient bone to carry out any form of pelvic reconstruction. She was dissatisfied with the result, and an attempt was subsequently made to insert a new hip joint using an ice-cream cone prosthesis fixed into the remnant of the ilium (about the top 3 cm). This failed and became painful, leading to its subsequent removal. In retrospect, there was not sufficient bone for fixation of the prosthesis. This is a major contraindication to this type of surgery.

A functional hip joint following acetabular reconstruction must be one of the key goals of prosthetic replacement. Approximately half of the patients in this study were high-demand patients, under the age of 50. Functional outcome was measured by the Toronto Extremity Salvage Score (TESS), which we chose because it is a patient-based, disease-specific measure of physical disability and has been shown to be the most responsive when compared to the Musculoskeletal Tumor Society (MSTS) and Short-Form 36 (SF-36) scoring systems.24 The mean TESS score for 15 of the 19 surviving patients was 69%, which compares well with other reports following pelvic reconstruction.19

With ever-increasing economic pressures on hospital budgets and healthcare systems, the cost of any endoprosthesis must be taken into consideration. Most pelvic endoprostheses19,29 are custom-made at great expense. In sharp contrast, the ice-cream cone prosthesis is not custom-made and is relatively inexpensive, with a current cost of £1775, compared to an average of £5285 for a custom-made implant.30

Simplicity and reproducibility of any surgical technique are essential for predictable long-term results. Custom-made pelvic endoprostheses need careful positioning at the time of surgery. Technically these are extremely demanding procedures with little room for error. Aggressive pelvic tumours can often progress rapidly after initial templating, and wide resection margins are essential to prevent local recurrence. The ice-cream cone prosthesis is an accommodating implant which can be used even when very little pelvis remains. Bony cuts around the ischium, pubis and acetabulum can be modified to accommodate the stem of the prosthesis, allowing a much more versatile reconstruction technique than when using a custom-made implant. For large defects following tumour resection, allografts can be used in conjunction with stemmed acetabular components to fill the defect and secure the stem into the remaining ischium. Although allograft is useful to fill massive defects, its use tends to increase the risk of infection.10

In summary, limb salvage with an ice-cream cone prosthesis for periacetabular tumours or a previous failed pelvic reconstruction is a major undertaking. It has a significant rate of complications and post-operative morbidity, particularly if infection or dislocation occurs. Patients need to be informed pre-operatively about the major complications, expected rates of local recurrence and long-term survival. Clearly there are some limitations to this series. The minimum follow-up in the survivors was only 18 months, with a mean of 39 months. These results must therefore be considered as an early indication of what will hopefully be longer-term success.

We feel that limb salvage using this prosthesis may well be the way forward for pelvic reconstruction because of its flexibility of use and lower complication rates compared to the more expensive pelvic endoprostheses. It may have particular benefit in patients with periacetabular destruction due to metastases, although our experience with this remains limited.

References


