Custom osteotomy guides for resection of a pelvic chondrosarcoma

William G Blakeney[1], Robert Day[2], Laurence Cusick[1,3], and Richard L Carey Smith[1,3,4]

[1]Department of Orthopaedic Surgery, Sir Charles Gairdner Hospital, Nedlands; [2]Medical Engineering and Physics, Royal Perth Hospital, Perth; [3]Plus Life (Perth Bone and Tissue Bank), Perth Orthopaedic Institute, Nedlands, [4]University of Western Australia, Australia.
Correspondence: Blakeney@gmail.com
Submitted 13-09-24. Accepted 13-10-22

Patients with malignant neoplasms of the pelvis often have poor outcomes (Marangolo et al. 1992). An important predictor of a poor surgical outcome is failure to achieve satisfactory resection margins (Ozaki et al. 2003, Fuchs et al. 2009). The complex bony anatomy of the pelvis and acetabulum makes surgery notoriously difficult.

Rapid prototyping is a manufacturing technology whereby computerized image data are used to create high-precision 3D structures (Rengier et al. 2010). This is a relatively new technology; applications of rapid prototyping in clinical medicine are being discovered every day. Very little has been published on its uses in orthopedic surgery (Frame et al. 2012).

We illustrate the use of rapid prototyping to create a 3D model of the pelvis in a patient with chondrosarcoma involving the left superior pubic ramus. From this model, custom-made osteotomy guides were created, aiding tumor resection with adequate margins.

Figure 1. 3D model of the pelvis with chondrosarcoma.

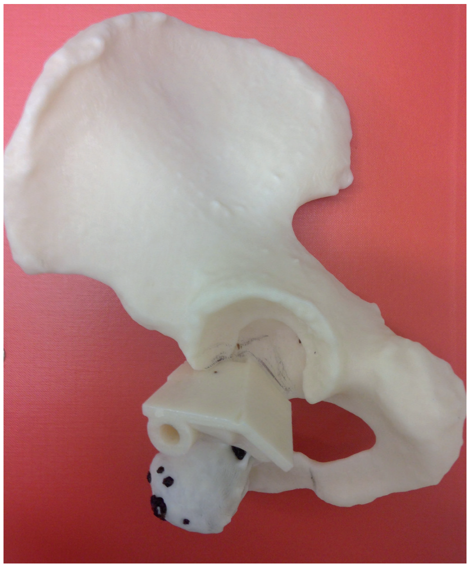

Figure 2. Custom osteotomy guide fitted to the model of the pelvis.

Surgical technique

A spiral CT series of the pelvis (500 slices at 0.5-mm spacing) was imported into Mimics 14.1 (Materialise, Leuven, Belgium) and the bony contours outlined. As the margins of the tumor were not well visualized on CT, an MRI scan was manually aligned with the CT series and the tumor borders checked against the CT outline.

A 3D model of the pelvis and tumor was then created and exported as an STL file to Freeform v12 (Geomagic Sensable, Wilmington, MA). Using a sensable haptic manipulator, the planned resection planes were placed on the 3D model and checked against the position of the tumor (Figure 1). A cutting block was then modeled using Freeform to cover a region of the anterior acetabular rim that would be exposed during the resection.

The pelvic model was extruded with 5° draft to a plane perpendicular to the resection plane and subtracted from the cutting block model. This extrusion filled in any re-entrant regions of the pelvis, which ensured that the cutting block could be placed onto the pelvis during surgery. The cutting block was then trimmed with the previously determined cutting planes to produce two planar surfaces to guide the saw (Figure 2). Finally, a hole for a handle was made in the model.

The finished cutting block model was processed with Catalyst 4.3 (Stratasys Inc., Eden Prairie, MN) and built in acrylonitrile butadiene styrene (ABS) plastic on a Stratasys Dimension SST 1200 3D printer. A handle was fitted and the whole device sterilized with ethylene oxide.

The patient was positioned supine for the surgery. An ilioinguinal approach with femoral

DOI 10.3109/17453674.2014.920988

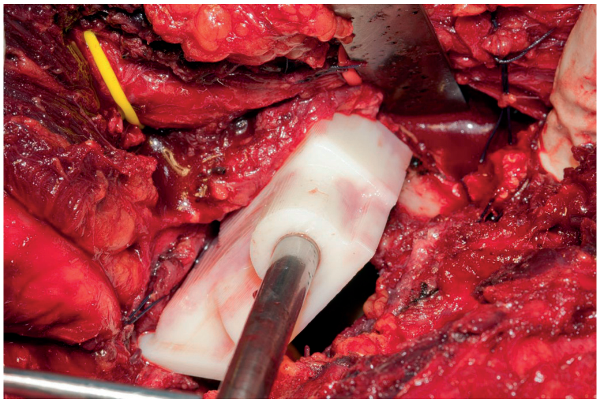

Figure 3. Intraoperative photograph showing the custom osteotomy guide on the patient's pelvis.

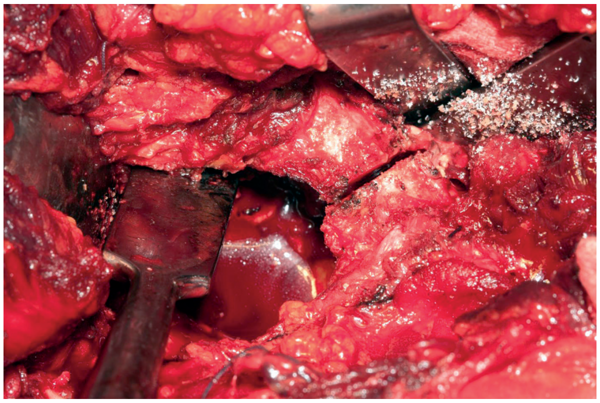

Figure 4. Osteotomies being completed with osteotome.

extension was used. The abdominal wall was reflected and the bladder dissected free and protected. A Gigli saw was used to cut through the center of the pubic symphisis. Further dissection laterally to identify and protect the obturator and femoral neurovascular bundles was then performed.

An anterior approach to the hip with femoral neck osteotomy was then required to visualize the acetabulum. Soft tissue was dissected away from the anteromedial aspect of the acetabulum to expose the underlying bone. The custom-made cutting guides were then used to perform osteotomies of the acetabulum, and superior and inferior pubic rami (Figures 3 and 4). The specimen was then dissected away from the soft tissues and sent for histopathology.

Part of the femoral head was then used to reconstruct the anterior column and wall of the acetabulum. A total hip replacement was then performed. A mesh repair of the abdominal wall was executed and the wound closed in layers over drains.

The patient

A morbidly obese 60-year-old woman was referred to the orthopedic oncology clinic by her general practitioner after noticing a painful mass in her left groin. Plain radiographs (Figure 5) and MRI (Figure 6) showed a 6-cm expansile lucent lesion involving the left superior pubic ramus. The lesion underwent core biopsy under CT guidance and the histopathology was consistent with grade-2 chondrosarcoma. Staging CT and positron emission tomography (PET) scan showed no evidence of systemic disease.

At the multidisciplinary musculoskeletal tumor meeting, we decided on a wide local excision of the tumor. The location of the tumor combined with the bodily habitus of the patient was likely to make surgery difficult. We made a model of the pelvis with custom-made osteotomy guides to aid with the surgery.

The histopathology report confirmed a grade-II intramedullary chondrosarcoma 5 cm in maximum dimension invading through the anterior cortex into surrounding soft tissue. All margins were well clear. The patient recovered well from surgery and was mobilizing with minimal pain within 2 weeks, and walking with one crutch at 6 weeks (Figure 7). 6 months postoperatively, the patient was pain-free and ambulating independently. There was no evidence of tumor recurrence on imaging.

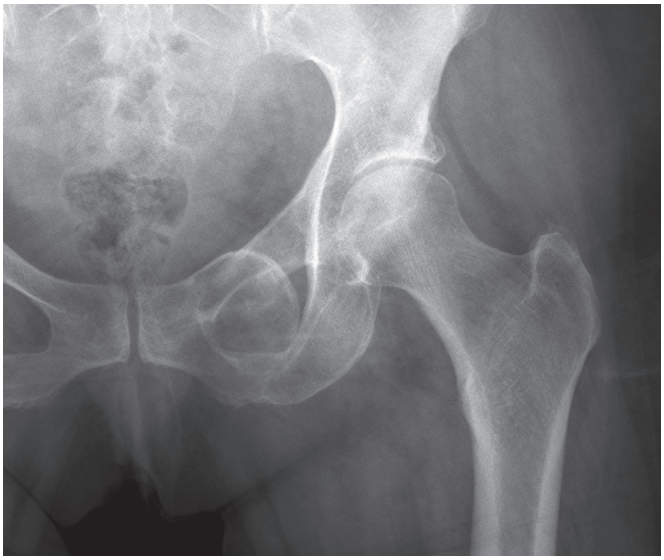

Figure 5.The pelvic chondrosarcoma.

Discussion

To our knowledge, this case report is the first description of the use of rapid prototyping technology to create custom osteotomy guides for resection of a pelvic neoplasm.

Rapid prototyping (also called 3D printing) is a manufacturing technology whereby computerized image data are used to create high-precision 3D physical structures by the sequential addition of material layers (Rengier et al. 2010). With additive fabrication, the machine reads in data from a computerized 3D

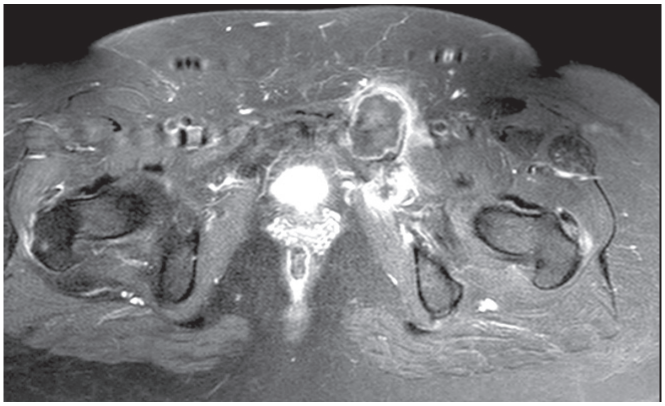

Figure 6. Axial MRI slice showing pelvic chondrosarcoma.

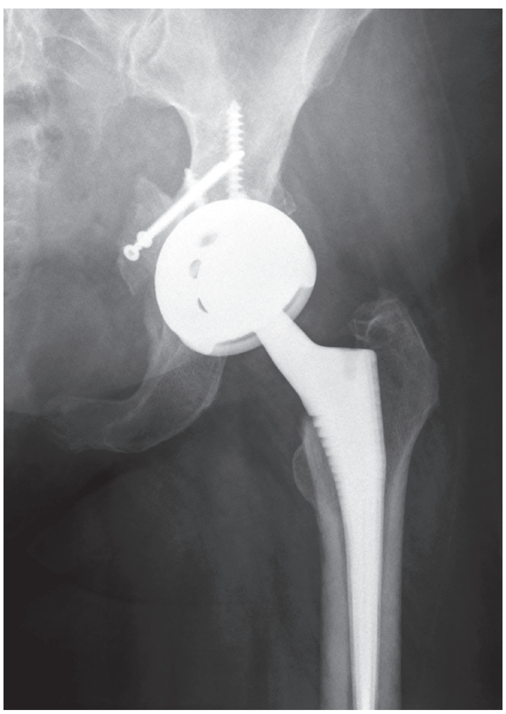

Figure 7. Postoperative radiograph showing pelvic resection, total hip arthroplasty, and bone block fixed to anterior column.

model and lays down successive layers of liquid, powder, or sheet material to build up a model. Each layer corresponds to a cross section from the computer model. The series of layers joined together form the final shape. This gives the user the ability to create almost any complex shape or geometric form.

Rapid prototyping technology has been used in maxillofacial surgery for several years (Lill et al. 1992). Hurson et al. (2007) looked at the difficulties in assessment, classification, and treatment of fractures of the pelvis and acetabulum due to the complex 3D anatomy of these structures. They produced full-sized models of acetabular fractures using rapid prototyping technology and found that they greatly assisted surgeons in understanding the character of these complex fractures prior to surgery.

Rapid prototyping models have been used successfully in preoperative planning and as an intraoperative reference for cases of multi-plane spinal or pelvic deformities (Guarino et al. 2007). A 3D rapid prototyping model has also been used as an aid to surgical planning in the resection of a large scapula osteochondroma (Tam et al. 2012).

Custom-made osteotomy templates, designed on the basis of a preoperative 3D computer simulation, have been produced through rapid prototyping technology (Murase et al. 2008). They were used successfully to correct long bone deformity of the upper limb in 22 patients. Another study found that correction of cubitus varus deformities in teenagers was successful using an osteotomy guide produced from 3D imaging and rapid prototyping (Zhang et al. 2011).

A study by Bellanova et al. (2013) investigated the use of custom-made surgical guides to reduce the width of the resection margin (while ensuring that the margin was adequate) for osteosarcomas of the tibia in 4 children. They used technology that was similar to that in the present study to manufacture a surgical guide by rapid prototyping, which was fitted to a unique position on the tibia. A second instrument was manufactured to cut the bone allograft so as to fit the resection gap perfectly. Histopathological evaluation of the resected specimens showed tumor-free resection margins in all cases. In 1 of the patients, the target margins were defined at 4 mm, which allowed for the preservation of the growth plate.

A growing number of applications is being found for rapid prototyping technology. Tumor surgery is one area in which precision of margins is imperative. Our case demonstrates the successful use of this technology for the resection of a pelvic chondrosarcoma. The use of this technology is likely to increase greatly as it becomes more readily available.

WB was involved with the protocol development, data collection, and drafting of the manuscript. RD is the bioengineer who developed the osteotomy guides and wrote the technical aspects of the surgical technique. LC assisted with the surgery and with critical appraisal of the manuscript. RCS is the head surgeon who came up with the concept and helped with critical appraisal of the manuscript.

No competing interests declared.

Bellanova L, Paul L, Docquier P L. Surgical guides (patient-specific instruments) for pediatric tibial bone sarcoma resection and allograft reconstruction. Sarcoma 2013; 2013:787653. Epub 2013 May 4.

Frame M, Huntley J S. Rapid prototyping in orthopaedic surgery: a user's guide. Sci World J 2012; 2012:838575. Epub 2012 May 1.

Fuchs B, Hoekzema N, Larson D R, Inwards C Y, Sim F H. Osteosarcoma of the pelvis: outcome analysis of surgical treatment. Clin Orthop 2009; (467) (2): 510-8.

Guarino J, Tennyson S, McCain G, Bond L, Shea K, King H. Rapid prototyping technology for surgeries of the pediatric spine and pelvis: benefits analysis. J Pediatr Orthop 2007; 27 (8): 955-60.

Hurson C, Tansey A, O'Donnchadha B, Nicholson P, Rice J, McElwain J. Rapid prototyping in the assessment, classification and preoperative planning of acetabular fractures. Injury 2007; 38 (10): 1158-62.

Lill W, Solar P, Ulm C, Watzek G, Blahout R, Matejka M. Reproducibility of three-dimensional CT-assisted model production in the maxillofacial area. Br J Oral Maxillofac Surg 1992; 30 (4): 233-6.

Marangolo M, Tienghi A, Fiorentini G, Dazzi C, Graziani G, Priori T, Emiliani E. Treatment of pelvic osteosarcoma. Ann Oncol (Suppl 2) 1992; 3: S19-21.

Murase T, Oka K, Moritomo H, Goto A, Yoshikawa H, Sugamoto K. Three-dimensional corrective osteotomy of malunited fractures of the upper extremity with use of a computer simulation system. J Bone Joint Surg (Am) 2008; 90 (11): 2375-89.

Ozaki T, Flege S, Kevric M, Lindner N, Maas R, Delling G, Schwarz R, von Hochstetter A R, Salzer-Kuntschik M, Berdel W E, Jurgens H, Exner G U, Reichardt P, Mayer-Steinacker R, Ewerbeck V, Kotz R, Winkelmann W, Bielack S S. Osteosarcoma of the pelvis: experience of the Cooperative Osteosarcoma Study Group. J Clin Oncol 2003; 21 (2): 334-41.

Rengier F, Mehndiratta A, von Tengg-Kobligk H, Zechmann C M, Unterhinninghofen R, Kauczor H U, Giesel F L. 3D printing based on imaging data: review of medical applications. Int J Comput Assist Radiol Surg 2010; 5 (4): 335-41.

Tam M D, Laycock S D, Bell D, Chojnowski A. 3-D printout of a DICOM file to aid surgical planning in a 6 year old patient with a large scapular osteochondroma complicating congenital diaphyseal aclasia. J Radiol Case Rep 2012; 6 (1): 31-7.

Zhang Y Z, Lu S, Chen B, Zhao J M, Liu R, Pei G X. Application of computer-aided design osteotomy template for treatment of cubitus varus deformity in teenagers: a pilot study. J Shoulder Elbow Surg 2011; 20 (1): 51-6.