Patient Specific Instruments for Complex Tumor Resection-Reconstruction Surgery within the Pelvis: A Series of 4 Cases

Eduard Cernat^{1,2}, Pierre-Louis Docquier^{1,3}, Laurent Paul^{1,3}, Xavier Banse¹, Ion-Bogdan Codorean²

¹Saint-Luc University Clinics, Department of Orthopaedic Surgery and Traumatology, Brussels, Belgium

²“Carol Davila” University Emergency Military Hospital, Clinical Orthopaedics and Traumatology, Bucharest, Romania

³Computed Assisted and Robotic Surgery (CARS), The Experimental and Clinical Research Institute, The Catholic University of Leuven, Brussels, Belgium

Rezumat

Instrumente specifice utilizate în chirurgia complexă a tumorilor (rezeecția – reconstrucția) situate în pelvis: o serie de 4 cazuri

Chirurgia de rezeecție-reconstrucție la nivelul pelvisului este una dintre cele mai dificile ramuri ale ortopediei. Aplicată pentru rezeecțiile tumorale, cât și pentru cazurile complexe de reconstrucție, acest tip de chirurgie necesită planificare atentă și este de lungă durată, totul pentru a obține acuratețe maximă. Când rezeecția nu este precisă consecințele pentru pacient sunt grave. Tehnologia PSI (patient specific instrument) s-a dovedit a fi precisă în timpul rezeecțiilor tumorale simulate, de la nivelul pelvisului. Acest articol prezintă o serie de 4 pacienți operați la Cliniques Universitaires St. Luc între Iunie 2014 și Martie 2015 pentru rezeecții-reconstrucții tumorale. Pacienții au fost investigați cu Ct și RMN, iar imaginile au fost reconstruite 3D. Din stocul băncii de os a fost aleasă cea mai apropiată allogrefă ca formă și dimensiune, iar imaginile CT stocate au fost reconstruite 3D. S-au conceput și imprimat ghiduri de tăiere specifice pacientului folosind tehnologia Rapid-Prototyping, pentru rezeecția țesutului nativ cât și pentru rezeecția allogrefei de

hemipelvis atent selectată. Implantarea alogrefelor s-a făcut cu potrivire exactă și a permis osteosinteza stabilă.

Cuvinte cheie: chirurgia de rezeecție-reconstrucție, pelvis

Abstract

The pelvis bone resection-reconstruction surgery is one of the most challenging fields in orthopedics. Being applied for tumors, as for other complex reconstruction cases, this type of surgery needs careful planning and is time consuming, in order to obtain proper accuracy. Unfortunately not all the time the expected accuracy is met, with consequences for the patients. PSI proved to provide good cutting accuracy during simulated tumor surgery within the pelvis. This article presents a series of 4 patients operated in our department between June 2014 and March 2015 for tumors resection-reconstructions. The patients were imaged using a CT and an MRI scan and the images were reconstructed in 3D. According to the bone bank stock, the most similar allograft was chosen and the stored CT scan was reconstructed in 3D. Patient specific instruments (PSI) were designed and manufactured using rapid-prototyping technology for the resection of the native tissues as for the resection of the carefully selected hemipelvic allografts. Allografts' fitting to the pelvis of the patients was excellent and allowed stable osteosynthesis.

Key words: resection-reconstruction surgery, pelvis

Corresponding author: E-mails: edy_cernat@yahoo.com
pierre-louis.docquier@uclouvain.be
laurent.paul@uclouvain.be
xavier.banse@uclouvain.be
dr.codorean@traumatologie-sportiva.ro

Introduction

The oncologic surgery in complex anatomy (pelvis, sacrum, spine) is challenging and sometimes the surgeon finds himself lost and lacks accuracy. Pelvis reconstruction with an allograft is further complicated by the difficulty of cutting the bone allograft to precisely fit the resection gap (1,2). This procedure also lacks in precision, leading to discrepancies at the host-allograft junctions and increased risks of osteosynthesis failure and nonunion.

PSI is commonly used by the knee surgeons and is proved to bring certain advantages. PSI improves alignment, surgical and OR time, reduces the number of instruments trays used compared to conventional instrumentation in patients undergoing TKA and results in fewer outliers in overall mechanical alignment in the coronal plane (3). On the other hand there are multicenter randomized controlled trials that sustain that the use of PSI in primary TKA did not reduce the proportion of outliers as measured by post-operative coronal alignment (4).

Unlike the knee surgery, in the complex pelvic surgery the mechanical alignment is not a concern, but the gap matching, the surgical time, the number of instruments trays used - these are advantages that we might improve significantly our patients' outcome. PSI proved to provide good cutting accuracy during simulated tumor surgery within the pelvis (5).

PSI-assisted bone tumor surgery has been tested in a recent series of 11 clinical cases with the specific goal of assessing how accurately a preoperative resection strategy can be replicated intraoperatively (6).

Patient and Method

Four patients operated in our department between June 2014 and mars 2015, referred for metastatic or primary tumors around the pelvis.

The first patient – A 15 years old teenager with Ewing sarcoma of the iliac wing (zone I) diagnosed by MRI, PetCT and biopsy in January 2014. Familiar hx of breast cancer, WPW syndrome treated up to the age of 10 (2012), C-section birth. Good response to chemotherapy following the Euro-Ewing protocol and multidisciplinary consensus towards surgical resection.

The second patient – A 53 years old man with isolated metastasis in the iliac wing of a renal cell carcinoma, responsive to the Anti-VGF treatment (slightly decreased in size in the last 12 months). No familiar hx, no fever, previous nephrectomy, obese, with systemic intolerance of the VEGFR inhibitor (Sunitinib) in the last month. Multidisciplinary consensus towards surgical resection.

The third patient – A 14 years old mad referred from abroad for the surgical resection of a Ewing sarcoma of the acetabular region with iliopubic and ischiopubic involvement (zone II+III). The diagnosis was made with CT, MRI and biopsy and the patient got chemotherapy following Ewing 99 protocol and 3 cycles of VIDE. Significant reduction of the tumor after the chemotherapy and consensus towards surgical resection.

The fourth patient - A 41 years old man with familiar history of neoplasm and genetic diagnose of Type I Neurofibromatosis in 2013. Referred by the oncologist for MPNST (malignant peripheral nerve sarcoma tumor) of the gluteal region (zone I+II+IV), diagnosed with PetCT, MRI and biopsy. Good response to the inductive chemotherapy (ifosfamide and adriamycine) and multidisciplinary consensus towards surgical resection.

The preop planning for resection has been done using CT and MRI scans.

The CT scan images for all patients were obtained with a Brilliance 40 CTscanner (Philips, the Netherlands; 0.5 mm spacing between slices, 1mm slice thickness, 120 kV peak volt-

Figure 1. Preop planing case 4 – superposition of the CT and MRI images, tumor delimitation

Figure 2. Preop planing case 4 – 3D model and cutting planes

age, and 99-mAtube current) and the MRI with a 1.5 TNTScan Intera (Philips, the Netherlands, 4 mm spacing between slices, 3mm slice thickness, 550 ms TR, and 14 ms TE). Each tumor was delineated on the CT-scan and MRI sequences who clearly showed the boundaries of the tumor using open-source software ITK-Snap 2.0 (<http://www.itksnap.org/>) (7).

We performed a multimodal registration with these sequences and built a 3D model of the pelvis and the tumors. This model was used to define the cutting plane in taking account the safe margin and the material lost due to the saw.

Cutting plans Tumor Sciatic notch

For the allograft choice we perform a CT-Scan of all pelvises available in the bone bank.

We use a Somatom Definition AS, Siemens, 0.35-mm slice thickness, 0.7mm spacing between slices, 120 kV peak voltage, and 99mA tube current. To choose the best allograft close to native pelvis we used a monomodal registration between the host pelvis and the allograft. A cutting plane was also planned exactly like those of patients.

The cutting guides were designed based of the tridimensional computer simulation and was produced as a thermoplastic (Polyamide) model using of rapid prototyping technology. We produced two PSIs for each patient, one for the tumor resection and the last one for the allograft cutting. The design of our surgical guide was perform by computer-aided design software package.

The surgery has been performed either in dorsal or lateral decubitus, using ilioinguinal, Kocher-Lamgenbeck or combined approaches. In each case the soft tissue dissection proved to be essential in order to obtain a good exposure of the tumor for making the cutting guides positioning possible. The perfect setting of the tumor cutting blocks is mandatory for obtaining the resection limit. The cutting guides fixation has been done with K-wires and the osteotomies with oscillating saws and osteotomes. At the end the tumor was released and detached and bone wax applied.

Before resecting the tumor the fresh frozen graft was warmed in normal saline. After the tumor resection, the graft was prepared using the graft cutting blocks. We find the positioning of

Figure 3. Cutting guides design

Figure 4. Cutting guides on the tumor

Figure 5. Cutting guide on the graft

Figure 6,7. Graft placement with very good apposition

the cutting blocks on the graft as important as the tumor resection, but much easier to achieve. The lack of the soft tissues makes the osteotomy easier and very precise.

Results

The mean skin to skin operation time was 7h25m, and the mean blood loss was 2230 ml. All the patients received

Table 1. Patient series, histological data, adjuvant therapy and outcomes

Patient	Histology	Enneking zones	Tumor volume	Operation time, blood loss	Reconstruction	Histological analysis	Adjuvant treatment	Complication	Follow up
BM (M, 15)	Ewing sarcoma	I		7h40m, 2330 ml	Allograft	R0	Chemotherapy Radiotherapy	Contralateral tibia and calcaneum stress fracture	12 M
FE (M, 53)	*RCC, Isolated metastasis	I		6h20m, 1350 ml	Allograft	R0	Chemotherapy Radiotherapy	Ileus postop	6 M
KZ (M, 14)	Ewing sarcoma	II + III		8h45m, 3600 ml	Allograft Prosthesis	R0	Chemotherapy	Deep infection Hip dislocation	2 M
AC (M, 41)	*MPNST, mixoid sarcoma	I + II + IV		7h, 1650 ml	Allograft	R0	Chemotherapy	-	2 M

*MPNST – malignant peripheral nerve sarcoma tumor *RCC – renal cell carcinoma

Figure 8-11. Postop results with very good bone to bone apposition

either platelets/red cells/both transfusions during the surgery, and after. The most important blood loss registered on the anaesthetic sheet was during the osteotomies.

We believe that the rigorous hemostasis is essential during the soft tissue dissection, in order to prevent a significant blood loss during this time of surgery. The blood loss during the osteotomy is almost impossible to control because of the fact that the cancellous bone becomes accessible to be filled with bone wax when all the planes are cut, but not before. So in order to accept the significant blood loss that occurs during the osteotomy, the surgeon needs to control the soft tissue bleedings as much as possible and to obtain a very good exposure that can facilitate a fast osteotomy.

Histopathological examination of the removed tumors classified each resection in R0. We found difficult to apply the cutting guides especially for the patient 4, where we used 2 complementary guides with individual apposition. For this patient we aimed a hip sparing surgery and resection limit was planned to be 3 mm. Even with this difficulty and with the 3 mm resection limit the histological examination of the resected tissue was satisfactory.

For accomplishing the safety resection limit we sacrificed each time the gluteus minimus, with or without the gluteus medius, but we never sacrificed the gluteus maximus that served as a good coverage flap. We also sacrificed at least partially the iliac muscle.

In the postoperative period we allowed for 2 patients (2 and 4) a weight bearing at tolerance (WBAT), but for the other 2 patients (1 and 3) we didn't allow the weight bearing (NWB) for 3 months.

One of the patients with NWB (15 yrs of age) developed a stress fracture of the tibia and calcaneus on the contra lateral side that healed with no persistent deformity. The postoperative X-rays were satisfactory each time.

The second patient, obese but with no other significant comorbidities, developed an ileus that was treated with NG tube for 5 days. We believe that the excessive use of morphine and the difficulties of mobilising the patient contributed more to this complication than the intra-abdominal surgical time of tumor resection, sacrificing the iliac muscle.

The third patient, the only one with prosthetic reconstruc-

tion, was operated by the senior pediatric orthopedic surgeon and a qualified hip reconstruction surgeon that imposed a good preservation of the inferior gluteal artery and nerve and a good gluteus maximus reinsertion in order to prevent a hip dislocation. Even so, the patient developed a deep infection and hip dislocation in 2 weeks time and he was reoperated for tissue sample, wash-out and hip relocation. He didn't require any additional wash-out after and the clinical and biological evolution were good with IV antibiotics.

The fourth patient had no complications and he was discharged from the hospital in one week time, being independent in crutches. For this patient, since we sacrificed the gluteus medius muscle, we used the same principles – good preservation of the inferior gluteal artery and nerve and iliac crest reinsertion of the gluteus maximus that served as a thick flap.

Conclusions

The tumor resection surgery within the pelvis remains difficult with or without PSI instrumentation, but this is a tool that can help the surgeon to obtain the aimed resection easier and probably with fewer risks for the patients. The mean operation time (7h25m) and the mean blood loss (2320 ml) prove that difficulty of the surgery imposes a well trained team and a great anaesthetic support.

For this type of surgery we find that it is difficult to design clinical trials with good level of evidence because each tool that can help the surgeon to obtain a better surgical result needs to be used in order to improve the outcome of our patients. The follow-up should continue to observe local recurrence rate and draw stronger conclusion about the use of PSI technology during bone tumor resection within the pelvis and its effect on clinical outcomes.

The multidisciplinary consensus is critical in order to planify the appropriate adjuvant therapy and to get the proper follow-up.

We consider that with this technique we might improve the outcome in terms of survival rate and functionality, but this needs to be proved.

References

- 1 Docquier P-L, Paul L, Cartiaux O, Delloye C, Banse X. Computer-assisted resection and reconstruction of pelvic tumor sarcoma. *Sarcoma*. 2010;2010:125162. doi: 10.1155/2010/125162. Epub 2010 Nov 28.
- 2 Cartiaux O, Docquier P-L, Paul L, Francq BG, Cornu OH, Delloye C, et al. Surgical inaccuracy of tumor resection and reconstruction within the pelvis: an experimental study. *Acta Orthop*. 2008;79(5):695-702. doi: 10.1080/17453670810016731.
- 3 Renson L, Poilvache P, Van den Wyngaert H. Improved alignment and operating room efficiency with patient-specific instrumentation for TKA. *Knee*. 2014;21(6):1216-20. doi: 10.1016/j.knee.2014.09.008. Epub 2014 Oct 30.
- 4 Abane L, Anract P, Boisgard S, Descamps S, Courpied JP, Hamadouche M. A comparison of patient-specific and conventional instrumentation for total knee arthroplasty: a multicentre randomised controlled trial. *Bone Joint J*. 2015;97-B(1):56-63. doi: 10.1302/0301-620X.97B1.34440.
- 5 Cartiaux O, Paul L, Francq BG, Banse X, Docquier P-L. Improved accuracy with 3D planning and patient-specific instruments during simulated pelvic bone tumor surgery. *Ann Biomed Eng*. 2014;42(1):205-13. doi: 10.1007/s10439-013-0890-7. Epub 2013 Aug 21.
- 6 Gouin F, Paul L, Odri GA, Cartiaux O. Computer-Assisted Planning and Patient-Specific Instruments for Bone Tumor Resection within the Pelvis: A Series of 11 Patients. *Sarcoma*. 2014;2014:842709. doi: 10.1155/2014/842709. Epub 2014 Jul 2.
- 7 Yushkevich PA, Piven J, Hazlett HC, Smith RG, Ho S, Gee JC, et al. User-guided 3D active contour segmentation of anatomical structures: significantly improved efficiency and reliability. *NeuroImage*. 2006;31(3):1116-28.