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Limb-salvage treatment of malignant pelvic bone tumor in China for past 20 years

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Resection of malignant pelvic bone tumors poses a major technique challenge for orthopedic oncologists due to the large tumor size which is undetectable at the early-onset and local complex anatomy with the severe extension to major neurovascular structures and intestinal and urinary tracts.[1] Traditionally, malignant pelvic bone tumors were resected by the hindquarter amputation and the procedure obviously influenced the detrimental cosmetic and physical outcomes. More attempts have been made to perform the limb-salvage and improve the reconstruction of the pelvis after tumor resection. However, the abundant clinical experience could not be accumulated at the single tumor center due to the low incidence of pelvic bone tumors. Furthermore, the poor prognosis previously occurred to patients with tumors due to the anatomic complexity and scanty clinical experience. With the development of surgical skills and related discipline, many hospitals, especially Musculoskeletal Tumor Center of Peking University People's Hospital (PKUPH), gathered a great deal of surgical experience of resecting the malignant pelvic tumors in the past two decades in China. The overall survival and limb-salvage rates and lower extremity function were significantly improved by more effects of many orthopedic oncologists in China in the past years. The present article was to review the limb-salvage surgery for the malignant pelvic tumors in the past two decades.

Hindquarter Amputation

Hindquarter amputation is the exclusive surgical treatment for the malignant bone tumor until 1970s. Based on the resection extension, the amputation is classified into four types, including classical hemipelvectomy, modified hemipelvectomy, extended hemipelvectomy, and compound hemipelvectomy. Meanwhile, it can be divided into anterior and posterior flaps hemipelvectomy according to the choice of flaps. With the development and application of the internal hemipelvectomy resection, most patients with pelvic tumors receive the limb-salvage surgery. But some patients with the huge ones cannot but undergo the hindquarter amputation.

Basis of Limb-salvage Surgery for Pelvic Tumors-partial Hemipelvectomy Resection

The partial hemipelvectomy resection includes iliac tumor resection (Type I), periacetabular tumor resection (Type II), pubis and ischium tumor resection (Type III), and resection of tumor involving the sacroiliac joint (Type IV). Most malignant tumors are involved in two or more zones of the pelvic bone. Since 1978, Steel, Enneking and Dunham reported several partial hemipelvectomy resection methods. Meanwhile, the surgical margins and their prognosis were roughly same to the hindquarter amputation.[1,2] Since 1980s, the orthopedic oncologists in China started to apply the partial hemipelvectomy resection surgery to solve the limb-salvage for patients with malignant pelvic tumors and these positive attempts acquired the satisfactory surgical margin. Taking a case series reported by PKUPH as an example, the rates of limb-salvage, en-block resection, and 5-year survival were respectively 90.5%, 61.9%, and 44%.[3] Furthermore, the rates above mentioned reported in China were superior to those in other countries.

Reconstruction After Type I or I + IV Resection

Previous resection of type I or I + IV without reconstruction which was complicated with acetabular adduction and shifting up caused pelvic tilt and scoliolosis. Since 2002, PKUPH reported that the durable stability was restored by utilizing pedicle/iliac screws and titanium rods and the defect was reconstructed with the fibular or residual iliac after resection of tumor involving the iliac or sacroiliac joint. With the development of 3 dimensional

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(3D)-printed, custom-made prosthesis, we designed the 3D-printed modular iliac prosthesis (global pelvic system [GPS] Type I) in 2015. The union of prosthesis interface with the residual iliac after tumor resection was easily achieved due to the design of metal trabecular struction and it was easy to implant the prosthesis because of the modulation designing. The reconstruction after the single Type III resection was not needed.

Reconstruction After Type II or II + III Resection

In 1979, the saddle prosthesis was designed for the reconstruction after Type II or II + III resection and it was gradually be utilized to the restoration for the periacetabular tumors until 1984. The saddle prosthesis was implanted based on the supporting with the sufficient iliac bone quantity. However, its surgical indication was limited and the complication rate was as high as 60%, including dislocation, prosthesis shifting up, iliac fracture, and heterotopic ossification.[4] Since 1996, Ozaki and Windhager *et al*[5,6] reported the clinical experience of custom-made hemipelvic endoprosthesis to reconstruct the bone defect after Type II or II + III resection. However, the rate of complication was unsatisfactory and as high as 20% to 40% (infection rate) In 2001, the Ice-Cream Cone Prosthesis (Stanmore Implants Worldwide Ltd, Elstree, UK) was designed to restore the pelvic continuity and the hip joint function. Furthermore, it was reported that the rates of infection and dislocation were as high as 20% to 47% and 20%, respectively in a European multi-center clinical trial.[7,8]

Since 2002, the modular hemipelvic endoprosthesis designed by PKUPH was applied in clinic. In 2007, the result was firstly reported that the rates of deep infection (14.3%) and mechanical failure (7.2%) were satisfactory in a 28 cases cohort study.[9] Ji *et al*[10] reported the experience of the modular hemipelvic endoprosthesis reconstruction in 100 patients with mid-term follow-up results and the rates of deep infection, mechanical failure, and dislocation were respectively 15%, 5%, and 9%. The mean Musculoskeletal Tumor Society (MSTS) 93 score was 57.2% and the average MSTS 93 score was 58.8% for Type II or II + III resection. The post-operative function of modular hemipelvic prostheses designed by PKUPH was excitedly superior to that of saddle prosthesis, Ice-Cream Cone Prosthesis, and custom-made hemipelvic endoprosthesis.

In recent years, the emergence of 3D-printed technology provided the possibility of accurate matching of pelvic prosthesis and fusion with the host bone, and several tumor centers in China started to apply it into clinic. In 2016, it was reported, in the literature, 35 patients with the pelvic tumor received the surgery of 3D-printed hemipelvic endoprosthesis designed by PKUPH and its safety and effectiveness were confirmed.[11] The new prosthesis designed by PKUTH exhibited its unique advantages in early stability, individualized accurate matching, long-term fusion with host bone (GPS Type II). Furthermore, the deep infection rate of 3D-printed hemipelvic endoprosthesis was also significantly lower than that of machine-made prosthesis in the past. Up to now, more than 200 cases of reconstruction with 3D-printed hemipelvic endoprosthesis have been completed and it is becoming the focus and trend for the development of the pelvic reconstruction technology after tumor resection. Meanwhile, 3D-printed hemipelvic endoprosthesis has been developed in the world and their long-term results are still under follow-up.

Reconstruction After Type I + II or I + II + IV or I + II + III Resection

How to reconstruct hip function is a very challenging problem for the reconstruction after Type I + II or I + II + IV or I + II + III resection. Due to the high complications of custom-made hemipelvic endoprosthesis and the difficulty of installation during operation, PKUPH adopted the method of translumbar fixation of the hemipelvic endoprosthesis in the world in 2007 and its therapy achieved satisfactory clinical results.[12] This type of hemipelvic endoprosthesis adopted a bi-axle gear-like structure and the acetabular angle could be adjusted arbitrarily during the operation. The designing concept of this prosthesis realized the destination of the mechanical fixation of prosthesis to the sacrum as minimizing the volume of prosthesis as possible. Meanwhile, it retained the characteristic that the prosthesis could be connected to the lumbar through the pedicle screw-rod system and improved the system stability by increasing the longitudinal load and mechanical strength. In 2015, the sacral contact surface of the hemipelvic endoprosthesis was changed to 3D-printed metal trabecular structure (GPS Type III). The new design could promote the growth of cancellous bone and induce the fuse with the sacral interface. Furthermore, the long-term service life of hemipelvic endoprosthesis was improved and complications such as mechanical failure were reduced.[13]

Classification of Pelvic Tumor Involving the Sacroiliac Joint and Resection/Reconstruction Methods

The surgical management of a pelvic sarcoma that invades the sacrum is challenging due to the large tumor size and the severe extension to major neurovascular structures and intestinal/urinary tracts. To achieve the clear surgical margin, better oncological prognosis, and functional recovery after operation, orthopedic oncologists need to face a series of problems, such as reducing intra-operative bleeding, avoiding pelvic organ damage, reducing loss of lumbosacral nerve function, and reconstruction of hip joint function. The conventional Enneking classification for pelvic tumors failed to establish standardized surgical treatment and reconstruction for tumors involving sacrum which was classified as Type IV. To date, there is no surgical classification for pelvic tumors involving sacrum in the world. In 2016, PKUPH formulated a systemic classification for the en bloc resection of pelvi-sacral tumors involving the different zones of the sacrum and designed the surgical approach, resection method and functional reconstruction route [Figure 1A].[14] This classification preferably evaluated the effect of the standardized surgical treatment on the acquisition of clear surgical margin, control of operative risk, and improvement of oncology and function.

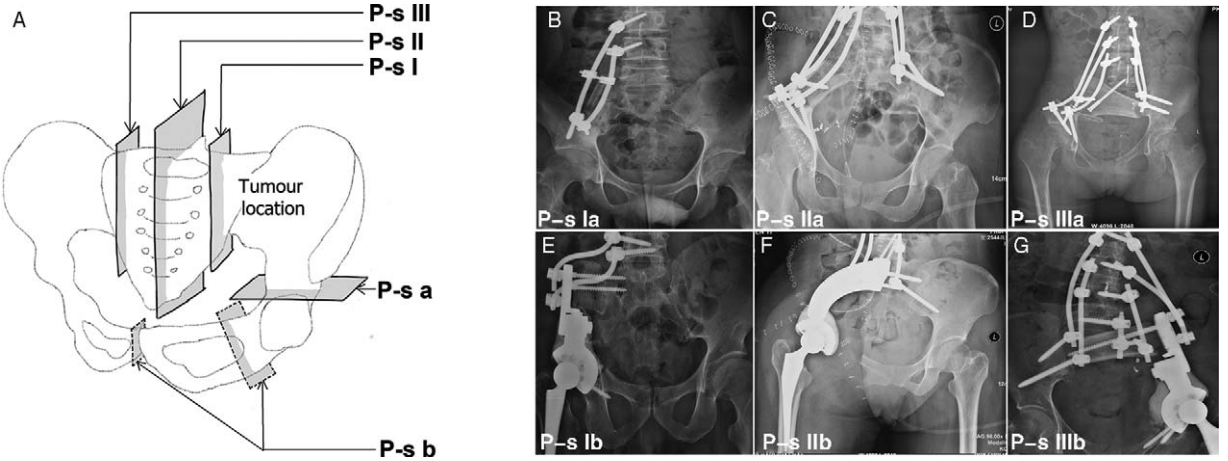

Figure 1: PKUPH classification for pelvi-sacral resections (A). Resection and reconstruction for pelvic tumor involving the sacrum based on PKUPH classification for pelvi-sacral resections (B–G). P-s I: Ipsilateral sacroiliac joint; P-s II: Ipsilateral sacral foramina; P-s III: Lateral to contralateral sacral foramina; P-s a: Absence of acetabular involvement; P-s b: Presence of acetabular involvement; PKUPH: Peking University People's Hospital.

The PKUPH classification for pelvi-sacral resections is defined as P-s I (ipsilateral sacroiliac joint), P-s II (ipsilateral sacral foramina), and P-s III (lateral to contralateral sacral foramina) based on the sagittal extent of sacral involvement and defined as P-s a (absence of acetabular involvement) and P-s b (presence of acetabular involvement) based on the acetabular involvement. Thus, the pelvic tumors involving sacrum are classified into six types, including P-s Ia, P-s IIa, P-s IIIa, P-s Ib, P-s IIb, and P-s IIIb. Furthermore, a set of functional reconstruction methods for six different kinds of bone defects were correspondingly established [Figure 1B–G].

Development of Adjuvant Therapy and Related Discipline

The intra-operative massive blood loss of resection for the pelvic and sacral tumors is a great challenge for the orthopedic oncologists. The effective control of the intra-operative blood loss provides a significant insurance for the thorough and safe en bloc resection. The Chinese orthopedic oncologists applied the technology of aortic balloon occlusion into the resection of pelvic and sacral tumors and acquired the satisfactory clinical effectiveness.[15] It made the resection of pelvic and sacral tumors to be more secure but not the surgery with the peri-operative highest mortality. Furthermore, the average intra-operative blood loss decreased from about 5000 to 2000 mL.

Pelvic osteosarcoma occurs mostly in young adults and its chemotherapy is far less effective than that of osteosarcoma in the limbs of adolescents. Thus, there is the controversy over whether chemotherapy is necessary for osteosarcoma of the central axis skeletal.[16] Meanwhile, radiotherapy technology has also made considerable progress. Furthermore, modern radiotherapy technology has been able to produce therapeutic effects on tumors which is relatively insensitive to radiotherapy. The local control and 5-year survival rates of combined radiotherapy and chemotherapy in the treatment of sacral Ewing sarcoma are not inferior to those of surgery or surgery combined with radiotherapy. Since 2010, with the development of targeted drug therapy for malignant tumor, the orthopedic oncologists have used denosumab to treat giant cell tumors of bone, which is a fully human monoclonal antibody that specifically inhibits receptor activator of nuclear factor-κB ligand (RANKL). Furthermore, it allows a large number of patients with giant cell tumors of the pelvic and sacrum to acquire the chance of surgery and decreases the intra-operative blood loss and recurrence rate.

Look back past 20 years, the surgical technology of treating the pelvic tumor has made great progress and achieved remarkable success through the unremitting effort of the orthopedic oncologists in China. The standardized and comprehensive treatment for the pelvic tumor has been widely applied and a great amount of patients benefited a lot who received the correct surgical therapy. However, we should recognize the fact that the local control and overall survival rates are still not wholly satisfactory and the reconstruction methods is precessing on the way.

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Conflicts of interest

None.

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