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Reconstructive techniques in musculoskeletal tumor surgery : management of pelvic and extremity bone tumors

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Chapter 10

General Summary

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Reconstructions for tumor resections in the pelvis and appendicular skeleton are among the most challenging procedures in modern orthopaedics. This thesis aimed to evaluate the outcomes of various reconstructive techniques, and to identify risk factors for complications or impaired outcome following reconstruction. Part I focused on the management of pelvic bone tumors; it discussed the management and outcome of conventional primary central chondrosarcoma of the pelvis, and two techniques for periacetabular reconstruction. Part II focused on different types of allograft reconstructions, as well as reconstructions with modular endoprostheses.

Part I – Management of Pelvic Bone Tumors

Chondrosarcoma is the most common pelvic bone tumor in adults, and poses specific challenges to orthopaedic surgeons because of the lack of effective adjuvant treatment modalities and the high rates of local relapse. **Chapter 2** contained a retrospective evaluation of 162 patients who were treated for a conventional primary central chondrosarcoma of the pelvis in five European centers of musculoskeletal oncology. Thirty-eight percent of our patients experienced a local recurrence, 30% had metastases. Tumor grade, resection margins and maximal tumor size were found to be independent factors of influence on disease-specific survival. Deep infection (19%) was the predominant complication, and the risk of infection was higher for patients with an endoprosthetic reconstruction. Our study included the largest series to date focusing on patients with a conventional primary central chondrosarcoma of pelvic bone. Because of the inability to reliably distinguish low- and high-grade tumors preoperatively, we concluded that any central pelvic chondrosarcoma should be treated with aggressive primary resection with the aim of obtaining wide resection margins.

Periacetabular tumor resections and their subsequent reconstruction are among the most challenging procedures in orthopaedic oncology. In **chapter 3**, we retrospectively evaluated the mid- to long-term clinical outcome of periacetabular reconstruction with the pedestal cup endoprosthesis. Between 2003 and 2009, a total of 19 patients underwent reconstruction with this implant in the two contributing centers. Complications occurred in 15 patients. Three (16%) had recurrent dislocations and three experienced aseptic loosening. There were

no mechanical failures of the implant itself. Infection occurred in nine patients (47%), six of whom required removal of the prosthesis. The implant survival rate at five years was 50% for all reasons, and 61% for non-oncological reasons. The mean MSTS score at final follow-up was 49% (13 to 87). We concluded that we no longer used this implant and advised caution if using it for reconstruction after periacetabular tumor resection.

Despite the poor results obtained with periacetabular reconstruction using the pedestal cup endoprosthesis, we considered the basic idea behind the implant suitable for pelvic reconstruction. Our experiences were incorporated in the design of the LUMiC. **Chapter 4** reflects on a retrospective European multicenter evaluation of clinical outcome in 47 patients who underwent reconstruction with the LUMiC after resection of a periacetabular tumor. The aim was to evaluate the short- to mid-term results of this novel implant. We demonstrated that the risk of dislocation was significantly lower in reconstructions with a dual-mobility cup than in those without (HR 0.11, i.e. an 89% reduction in dislocation risk in favor of the dual mobility cup). Loosening occurred in two uncemented reconstructions with poor initial fixation; both were revised. Infections occurred in 28%. We showed that the duration of surgery and amount of blood loss were associated with the risk of infection. The cumulative incidences of implant failure at 2 and 5 years were 2.1% and 17.3% for mechanical reasons and 6.4% and 9.2% for infection, respectively. Mean MSTS functional outcome score at follow-up was 70% (30 to 93). We concluded that, at short-term follow-up, the LUMiC prosthesis demonstrated a low frequency of mechanical complications and failure when used to reconstruct the acetabulum in patients who underwent major pelvic tumor resections. Moreover, we stated that dual-mobility articulation should be used after any internal hemipelvectomy to reduce the risk of dislocation.

Part II – Management of Extremity Bone Tumors

Intercalary allografts have long been the most important reconstructive option for the reconstruction of large segmental (diaphyseal) defects. **Chapter 5** described a retrospective evaluation of all intercalary allograft reconstructions in the treatment of primary bone tumors in all four centers of orthopaedic oncology in the Netherlands between 1989 and 2009. The incidence of and risk factors for failure and complications, time to full weight bearing, and optimal fixation methods were evaluated in a total of 87 reconstructions. Complications occurred

in 76% of patients. The major complications were nonunion (40%), fracture (29%), and infection (14%). The median time to full weight bearing was nine months. Fifteen grafts failed, twelve of which failed in the first four years. None of the tibial reconstructions failed. Reconstruction site, patient age, allograft length, nail-only fixation, and non-bridging osteosynthesis were the most important risk factors for complications. To reduce the number of failures, we recommended to reconsider the use of allografts for reconstructions of large defects, especially in older patients, and to apply bridging osteosynthesis with use of plate fixation.

It has been hypothesized that primary bone tumors can be adequately treated with hemicortical resection. Potential advantages of hemicortical resection include the preservation of joints, bone stock and cortical continuity. In **chapter 6**, we evaluated all hemicortical resections and subsequent inlay allograft reconstructions for primary bone tumors in a nationwide retrospective study. A total of 111 patients were evaluated for mechanical complications, infection, oncological outcome, and allograft survival. Thirty-three percent had non-oncological complications, with host bone fracture being the most common (18%). Other complications included nonunion (7%), infection (7%), and allograft fracture (3%). Of ninety-seven patients with a malignant tumor, 15% had a residual or recurrent tumor and 6% had metastasis. The risk of complications and fractures increased with the extent of cortical resection. We concluded that hemicortical resection is not recommended for high-grade lesions; however, it may be superior to segmental resection for treatment of carefully selected tumors, provided that it is possible to obtain adequate margins.

Osteoarticular allografts were commonly used to reconstruct articular defects following tumor resection in the Leiden University Medical Center after the Leiden Bone Bank was founded in December 1988. However, solid evidence on the long-term outcome of osteoarticular allograft reconstructions was lacking. In **chapter 7**, we presented a systematic review of the literature on osteoarticular allograft reconstructions in musculoskeletal tumor surgery, and evaluated our single-center experiences with this reconstructive technique. We included 31 studies in our systematic review. A total of 514 segmental reconstructions were analyzed. With distal femoral reconstructions as the reference, we demonstrated that reconstruction failure was less common in reconstructions of the distal radius (OR 0.3). Fractures were more common in the proximal humerus (OR 4.1) and

proximal tibia (OR 2.2). Infections occurred more often in the proximal tibia (OR 2.2) and less often in the distal radius (OR 0.1). In our retrospective study, we included 38 patients. With allograft-related failure as the end-point, graft survival rates at two, five and ten years were 91%, 54% and 42%. We concluded that osteoarticular allograft reconstruction of major joints is associated with an unacceptably high rate of complications, and cautioned others against the routine employment of segmental osteoarticular allografts for reconstructions around the knee or shoulder.

In the studies on allograft reconstructions, nonunion has been identified as one of the major complications and failure mechanisms. In **chapter 8**, we present an evaluation on risk factors for nonunion of allograft-host junctions in intercalary allograft reconstructions of the femur and tibia, and assessed the influence of cortical contact. To that end, we assessed the degree of contact in 96 transverse osteotomies that were fixed using plates, on two orthogonal views. We introduced a novel classification system, in which we classified the degree of cortical contact into grades 1 (full contact over the entire length of the osteotomy), 2A ($\geq 50\%$ contact), 2B ($< 50\%$ contact), and 3 (lack of cortical contact). We found that nonunion did not occur in grade 1 osteotomies. The risk of nonunion was 7% for grade 2A, 18% for grade 2B, and 50% for grade 3 junctions. Reconstruction site, patient age > 16 years, localization within the bone or chemotherapy use did not significantly influence nonunion risk. We concluded that, although future, larger studies will have to confirm our findings, care should be taken to obtain rigid fixation with firm contact at the junction site to minimize or even eliminate the risk of allograft-host nonunion.

Modular endoprostheses have largely replaced allografts as the method of choice for reconstruction of joints after tumor resection. In **chapter 9**, we reported the long-term results of knee replacement with MUTARS modular endoprostheses from two centers. A total of 110 consecutive reconstructions in 101 patients were evaluated with a minimum follow-up of five years. Eighty-nine reconstructions (81%) were distal femoral replacements (78 uncemented, 87%; 42 of which hydroxyapatite-coated, 54%), 21 (19%) were reconstructions of the proximal tibia. In 26 reconstructions (24%), surgery was preceded by a failed previous reconstruction. Complications of soft-tissue or instability occurred in 6%. Loosening occurred in 28% of the implants used for revision of a failed reconstruction and

in 12% of the primary reconstructions (HR 1.87). Uncemented HA-coated distal femoral replacements had a five-fold lower risk of loosening than uncemented uncoated distal femoral replacements (HR 0.21). Structural complications occurred in 15 reconstructions (14%), infections in 14 (13%). With failure for mechanical reasons as the endpoint, the cumulative incidences of implant failure at 5, 10, and 15 years were 16.9%, 20.7%, and 37.9%, respectively. We concluded that MUTARS modular endoprotheses represent a reliable long-term option for knee replacement after tumor resection, and recommended the use of uncemented hydroxyapatite-coated implants.

