The evolving role of computer navigation in musculoskeletal oncology

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Background: The surgical management of musculoskeletal tumours is a challenging problem, particularly in pelvic and diaphyseal tumour resection where accurate determination of bony transection points is extremely important to optimise oncologic, functional and reconstructive options. Precise wide local excision of the tumour with pre-planned resection margins is vital. As the surgeon must not compromise on oncological margins, the tendency is to overcompensate, however, greater than required margins can lead to difficult reconstruction and may compromise functional outcome. Advances in surgical technique and neo-adjuvant chemotherapy have lead towards a trend in limb-salvage surgery, aiming at improving function and quality of life post-operatively without compromising tumour margins. The use of computer navigation systems in spinal surgery, arthroplasty, deformity correction and trauma has improved surgical precision by providing more detailed information and guidance intraoperatively. In musculoskeletal oncology it has yet to find widespread use, though a number of authors report encouraging results. Computer assistance during musculoskeletal tumour surgery has the potential to allow for optimum bone resection without compromising the oncologic outcome. In addition, precise tumour resection in difficult anatomical locations would allow preservation of vital structures, bone stock and soft tissues, reducing the extent and difficulty of subsequent reconstruction. Furthermore, we propose that intra-operative computer assistance can be used to aide in accurate reconstruction particularly with regards to limb length and rotation.

Patients and Methods: We resected musculoskeletal tumours in fifteen patients using commercially available computer navigation software (Orthomap 3D). Of the eight pelvic tumours, three underwent biological reconstruction with extra corporeal irradiation; three endoprosthetic replacement (EPR) and two required no bony reconstruction. Four diaphyseal tumours had biological reconstruction. Two patients with proximal femoral sarcoma underwent extra-articular resection and EPR. One soft tissue sarcoma of the adductor compartment involving the femur was resected with EPR. Navigation was used to aide reconstruction in six cases.

Results: Pre-operative navigation planning took a mean of 45 minutes (range, 20 to 95 minutes). Time taken for preoperative planning significantly reduced after the initial cases. Mean preoperative planning time from 5th case onwards was 25 minutes. Intra-operative navigation time: Tracker insertion and registration took a mean of 30 minutes (range, 15 to 47). This also reduced with experience to a mean of 20 minutes from the fifth case onwards. Mean total operative time was seven hours (range, 2.5 to 9). Mean intra-operative registration error was 0.9 mm (range, 0.2 – 1.6mm) in 14 out of 15 patients. In one case we were unable to get registration error below two mm. This was due to a combination of high body mass index and limited exposure being required for resection of an iliac wing tumour. All resection levels and planes were classed as accurate on radiographic matching (within two mm of pre-planned planes) in the 14 patients where surgery was completed with intra-operative navigation assistance.

Histological examination revealed tumour free margins in all cases. Post-operative radiographs and CT show resection and reconstruction as planned in all cases. Several learning points were identified related to juvenile bony anatomy and intra-operative registration. Of the six patients where navigation was used to aide in reconstruction; Two of these patients had insertion of the stem of a coned pelvic implant in the posterior ilium under computer assistance to achieve the desired depth in the appropriate segment of bone.
One patient had the insertion of pins and placement of an acetabular socket under computer assistance to achieve the optimum level during Harrington type reconstruction of pelvic defect. Three patients had reconstruction of segmental/geometric diaphyseal defects in the femur, tibia (Fig.1) and humerus under computer assistance to restore optimum length, rotation and alignment. On radiographic assessment of these cases limb length and rotation is comparable to the contralateral side to within five mm and clinically limb lengths are equal with overall excellent alignment.

**Discussion:** The use of computer navigation in musculoskeletal oncology allows integration of local anatomy and tumour extent to identify resection margins accurately, and our experience thus far has been encouraging, reflecting that of other authors. We would suggest that the indications for computer navigation assistance include multiplanar and pelvic resections as previously described as well as diaphyseal and geometric resections. Furthermore, we would recommend using the information available during computer assisted tumour resection to be used to guide reconstruction if required in order to optimise limb length and alignment. We would, however, highlight several learning points with recommendations to avoid these early pitfalls. We have also described the use of computer assistance to aide reconstruction following resection, which may be of interest to surgeons currently using computer assistance. Furthermore this technique is an excellent teaching and training tool as preoperative planning is more detailed and provides better understanding to trainees with regards to principles of oncological surgery. In our experience computer navigation allows accurate tumour resection with adequate margins and aides in reconstruction, without significantly increasing operative time.