Technical Notes

Navigated multiplanar osteotomies for spinal primary bone tumors

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ABSTRACT

Background: Establishing the proper diagnosis and rendering appropriate treatment of spinal primary bone tumors (SPBT) can result in definitive cures. Notably, malignant, or benign SPBT (i.e., with aggressive local behavior) generally require en bloc resection. Osteotomies of the vertebral body in more than 1 plane may avoid critical structures, preserve nerve functions, and reduce the volume of healthy bone resected. Here, our objective was to report how we planned and performed navigated multiplanar osteotomies for en bloc resection of 14 SPBT.

Methods: We performed a retrospective analysis of 14 patients with malignant or locally aggressive benign SPBT operated on consecutively between 2014 and 2019 utilizing preoperative 3D planning/navigation. Tumors were resected in an en bloc fashion utilizing multiplanar osteotomies. Patients were followed for a minimum of 12 postoperative months.

Results: Diagnoses included three benign but locally aggressive bone tumors (i.e., all osteoblastomas) and 11 primary sarcomas (i.e., six chordomas and five chondrosarcomas). Eleven tumors involved the sacrum and the other three, the thoracic spine. In 12 patients, the en bloc margins were classified as marginal (<1 cm), and in two patients, as wide (>1 cm). Intraoperative navigation facilitated the performance of 40 osteotomies in 14 patients (median = 2.9, range = 2–6).

Conclusion: Navigated multiplanar osteotomies increased the precision and safety of en bloc resections for 14 primary spinal bone tumors SPBT that included 11 malignant and three benign/locally aggressive lesions.

Keywords: En bloc resection, Multiplanar osteotomies, Navigated osteotomies, Spinal primary bone tumors, Spine navigation

INTRODUCTION

Malignant or benign spinal primary bone tumors (SPBTs) with aggressive local behavior generally require en bloc resection. This entails removing the entire, intact tumor surrounded by a margin of healthy tissue. The challenge is to preserve as much surrounding normal tissue/structures as possible and avoid damaging contiguous spinal cord/nerves, and other vital
Osteotomies that pass through tumor-free tissue are now more readily/safely performed utilizing 3D preoperative planning and intraoperative navigation (i.e., to perform uniplanar cuts of the vertebral body [VB]). Here, we report our experience planning and performing navigated multiplanar osteotomies for 14 en bloc resections of SPBT.

**MATERIALS AND METHODS**

This was a retrospective analysis of 14 patients with SPBT; there were 11 malignant tumors (i.e., six chordomas and five chondrosarcomas) and three locally aggressive benign SPBT (i.e., osteoblastomas). These patients were operated on consecutively at a single center between 2014 and 2019. Eleven tumors (78.5%) were in the sacrum, while the three remaining were in the thoracic spine. The eight males and six females averaged 41.4 years of age [Table 1]. All patients underwent preoperative computed tomography (CT) and magnetic resonance (MR) examinations to determine tumor volume/location. Once images were merged, 3D preoperative planning was performed, and oncological margins were calculated utilizing two-dimensional images.

**Table 1: Patient data: 14 benign (locally aggressive) and malignant SPBT.**

| Author ref | Age | Gender | Diagnosis and location | Enneking stage and surgery | Number of osteotomies and margins | Mayor clinical advantage | Postoperative adjuvant therapy and incidence local recurrence (months) | Nononcological complications |
|------------|-----|--------|------------------------|----------------------------|-----------------------------------|-------------------------|---------------------------------------------------------------|-----------------------------|
| 1          | 19  | M      | Osteoblastoma T9       | Aggressive partial T9 en bloc hemivertebrectomy | 2 Marginal                        | Anterior stabilization avoidance | No                                             | None                        | -                           |
| 2          | 20  | F      | Osteoblastoma S3-4     | Aggressive partial S3-S4 en bloc hemisacrectomy  | 3 Marginal                        | Preservation of the right S3 and contralateral nerve roots | No                                             | None                        | -                           |
| 3          | 24  | M      | Chordoma S2 coccyx     | 2B S1 en bloc sacrectomy                     | 2 Wide                            | Bilateral S1 roots preservation | No                                             | None                        | Deep infection             |
| 4          | 24  | F      | Chordoma S3 coccyx     | 2A S3 en bloc sacrectomy                     | 3 Wide                            | Left S3 root preservation          | No                                             | None                        | Urinary incontinence        |
| 5          | 29  | M      | Osteoblastoma T2       | Aggressive left en bloc T2 pediculectomy     | 2 Marginal                        | Right T1-3 instrumentation avoidance | No                                             | None                        | -                           |
| 6          | 29  | M      | Chondrosarcoma (G2) S1 coccyx | 2B S1 en bloc sacrectomy                     | 3 Marginal                        | Left S1 root preservation          | No                                             | None                        | Deep infection             |
| 7          | 42  | M      | Chordoma S1 coccyx     | 2B S1 en bloc sacrectomy                     | 4 Marginal                        | Right S1-S2 roots preservation    | No                                             | None                        | -                           |
| 8          | 43  | M      | Chondrosarcoma (G1) T8-T9 | 1B Partial T8-9 hemivertebrectomy          | 2 Marginal                        | Anterior stabilization avoidance   | No                                             | None                        | -                           |
| 9          | 45  | M      | Chondrosarcoma (G2) S2 coccyx | 2B S2 en bloc sacrectomy                     | 3 Marginal                        | Left S2 root preservation          | No                                             | Yes (9)                     | -                           |
| 10         | 63  | F      | Chordoma S2 coccyx     | 2B S2 en bloc sacrectomy                     | 3 Marginal                        | Bilateral S1 roots preservation    | Yes (41)                                       | Radiotherapy                 | -                           |
| 11         | 64  | F      | Chordoma S2-4          | 2B S2/3 en bloc sacrectomy                   | 2 Marginal                        | Bilateral S2 and right S3 roots preservation | No                                             | None                        | Wound complication          |
| 12         | 68  | F      | Chordoma S1 coccyx     | 2B S1 en bloc sacrectomy                     | 3 Marginal                        | Bilateral S1 roots preservation    | Yes (24)                                       | Wound complication          | Deep infection             |
| 13         | 72  | F      | Chondrosarcoma (G2) S2 coccyx | 2B S2 en bloc right hemisacrectomy | 2 Marginal                        | Right S2 and sacral left roots preservation | Yes                                             | None                        | Deep infection             |
| 14         | 62  | M      | Chondrosarcoma (G2) L5-S4 | 2B L5-S4 en bloc posterior elements resection | 6 Marginal                        | L5 and sacral roots preservation   | No                                             | None                        | Pseudomeningocele          |

SPBT: Spinal primary bone tumor
Surgery

In all cases, a preoperative biopsy was performed under CT guidance, pathologists confirmed the histological diagnoses in all cases. All 14 tumor en bloc resections (i.e., employing 40 planned osteotomies) used the same navigation system. Registration used at least four reference points from the exposed bone surface and were then refined using at least 30 additional surface registration points. For at least 12 postoperative months, we evaluated; resection margins, the frequency of local tumor recurrence, and complications.

RESULTS

Forty en bloc resections in 14 patients were accompanied by osteotomies utilizing preoperative 3D planning and navigation [Figures 1 and 2]. Resection margins were classified by a musculoskeletal pathologist as tumor free; 12 were marginal (<1 cm) resections, while in two patients, margins were wide (>1 cm). Patients were followed for a mean average of 31 months (range 12–61) (i.e., quarterly for the first 2 years, semi-annually over the next 3 years, and annually after the 5th postoperative year). At last, follow-up, 3 patients (21.4%) had experienced local recurrences; all occurred in the sacrum (two chordomas and one chondrosarcoma) and were classified as Enneking Stage 2B [Table 1]. Seven (50%) of 14 patients developed nononcological complications; 3 (21.4%) involved postoperative deep infections treated with surgical debridement and intravenous antibiotics [Table 1].

DISCUSSION

Several authors have reported the advantages of using navigation during uniplanar osteotomies for en bloc resections of SPBT with different imaging and cutting technologies.[1,3–6] Preoperative reconstruction of the SPBT allows surgeons to plan, in detail, en bloc resection with multiplanar osteotomies, and preserve nerve structures, reduce the volume of healthy bone resected, and preserve stability. Total en bloc vertebrectomy is recommended when resecting lesions that have invaded more than half of the VB.[4] Although there is no consensus regarding instrumentation after a partial vertebrectomy, VB resections of <25% are generally not instrumented, those 25–50% are usually reinforced with posterior stabilization [Figure 1], while for resections of >50% circumferential stabilization are typically recommended.[7]

The availability of computer-assisted surgery since 2010 has facilitated 3D planning of en bloc resections of primary bone tumors, particularly in performing accurate osteotomies with safe margins preserving healthy tissues [Figure 3].[8,9] The main disadvantage of this technique, however, is the lack of worldwide availability of this technology. Although we believe that implementing
Figure 2: (a) T2-WI coronal magnetic resonance imaging showing right-sided osteoblastoma and relationship to 4th right sacral foramen. (b and c) Sagittal and coronal computed tomography (CT) images of spinal primary bone tumors. (d) Planned preoperative multiplanar osteotomies through the blue, yellow and red lines, the green area is the tumor reconstruction. (e) Intraoperative navigation/registration. (f) Intraoperative image of the medial osteotomy/correlation with the navigated tracker. (g) En bloc resection of tumor. (h) Postoperative CT total tumor excision with structural graft.

Figure 3: Navigated multiplanar osteotomies for en bloc resection of spinal primary bone tumors. (a) Preoperative planning of patient 6, an S1 coccyx chondrosarcoma (G2), 3 cuts (blue, yellow, and red lines) were made. (b) Patient 8, a T8-T9 chondrosarcoma (G1), 4 cuts (pink, blue, purple, and light-blue) were made the yellow part represents the partial osteotomy area. (c) Patient 7, S1 coccyx chordoma, 4 cuts were planned (cyan, light-blue, blue, and red lines). (d) Patient 12, an S1 coccyx chordoma, 3 line-cuts were done (green, red, and blue). (e) Correspond to patient 5, a T2 osteoblastoma, 2 osteotomies were done (light-blue and blue lines), the purple area represent the ipsilateral hemi-laminectomy. (f) Patient 10, an S2 coccyx chordoma were 3 osteotomies were planned.
navigated multiplanar osteotomies for en bloc resection of SPBT could shorten surgical times and improve clinical outcomes, further studies must be conducted to confirm these beliefs.

**CONCLUSION**

Navigated multiplanar osteotomies increased the precision and safety of en bloc resections for 14 primary spinal bone tumors SPBT that included 11 malignant and three benign/locally aggressive lesions.

**Declaration of patient consent**

Patient’s consent not required as patients identity is not disclosed or compromised.

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Nil.

**Conflicts of interest**

There are no conflicts of interest.

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