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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

structures.[10] 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]).[4,6] 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 year	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	Radiotherapy Yes (41)	-
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	Radiotherapy Yes (24)	Wound complication
13	72 F	Chondrosarcoma (G2) S2 coccyx	2B S2 *en bloc* right hemisacrectomy	2 Marginal	Right S2 and sacral left roots preservation	No 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 was 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].[2] 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

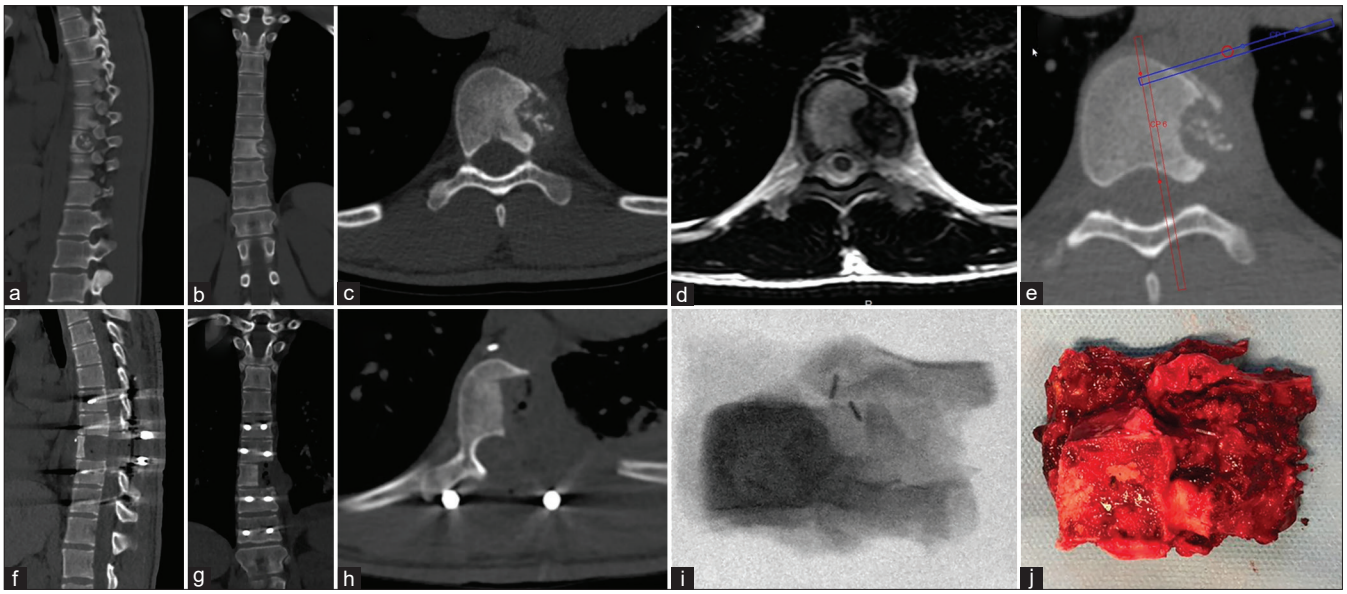

Figure 1: (a-c) Sagittal, coronal, and axial computed tomography (CT) of the left-sided T9 vertebral body osteoblastoma. (d) T2-WI magnetic resonance imaging of tumor's proximity to aorta, lung, and cord. (e) Preoperative multiplanar osteotomy planning. Red cut – first-step transthoracic approach; blue cut – second-step posterior approach to release the tumor *en bloc*. (f-h) Postoperative CT images demonstrate complete tumor resection. Images i and j show surgical sample of tumor in the left posterolateral T8 vertebral body surrounded by the T7 and T8 rib heads and soft tissue.

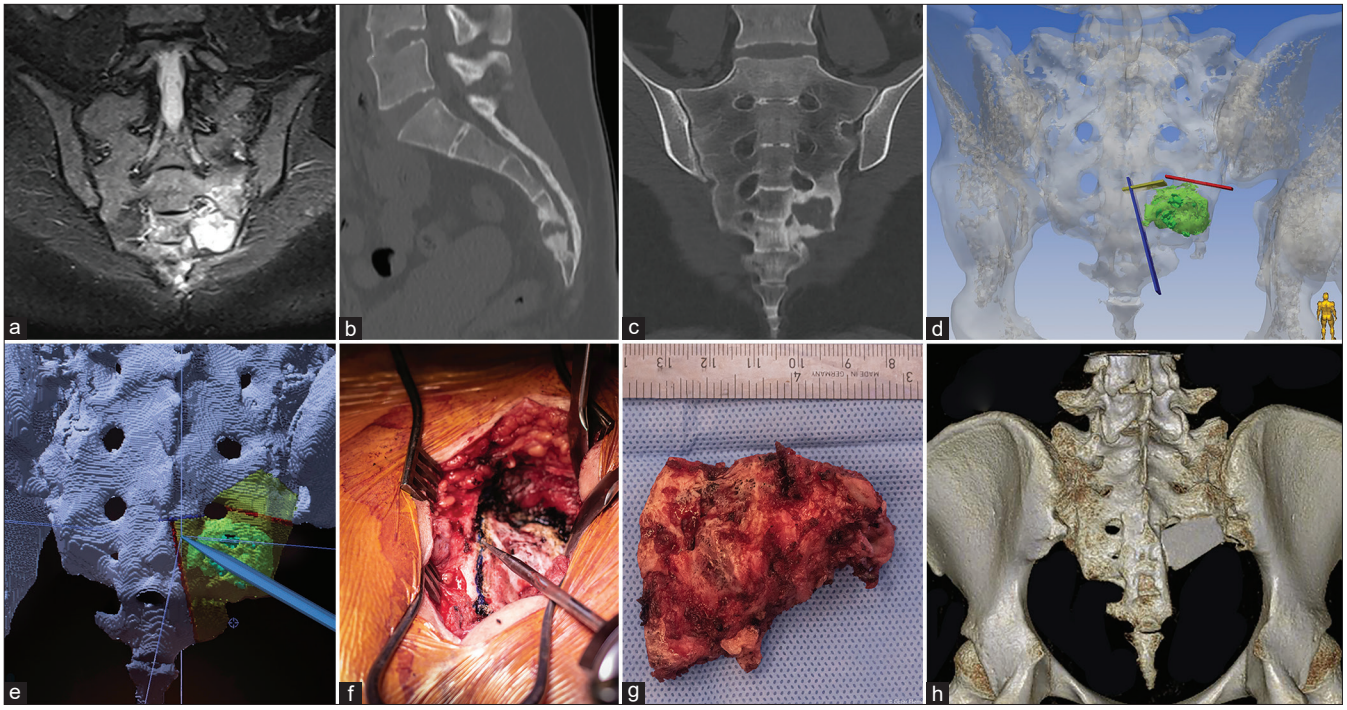

Figure 2: (a) T2-WI coronal magnetic resonance imaging showing right-sided osteoblastoma and relationship to 4th right sacral foramen. (b and c) Sagittal and coronal computed tomography (CT) images of spinal primary bone tumors. (d) Planned preoperative multiplanar osteotomies through the blue, yellow 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.

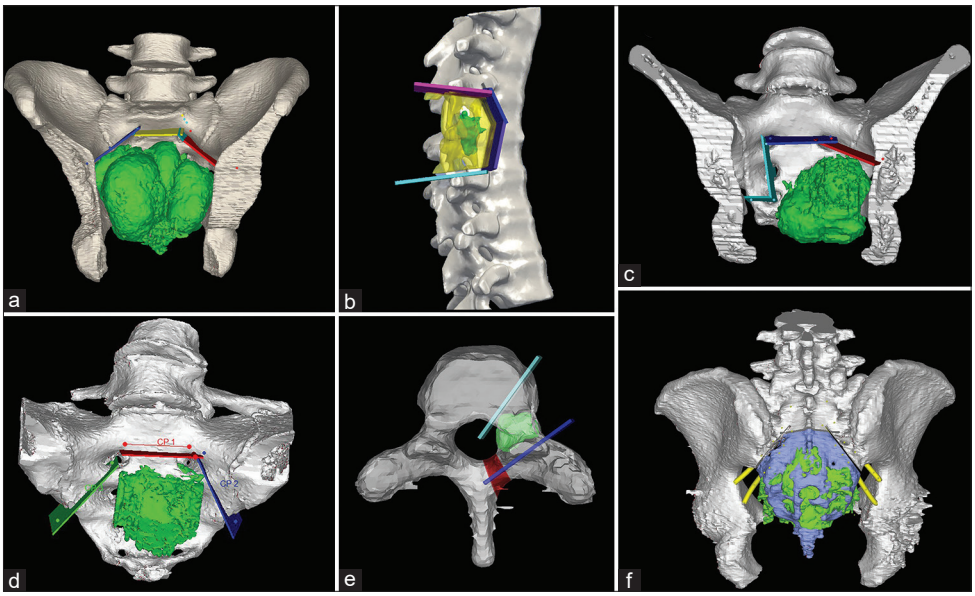

Figure 3: Navigated multiplanar osteotomies for *en bloc* resection of spinal primary bone tumors. (a) Preoperative planning of patient 6, an S1 coccyx chondrosarcoma (G2), 3 cuts (blue, yellow, and red lines) were made. (b) Patient 8, a T8-T9 chondrosarcoma (G1), 4 cuts (pink, blue, purple, and light-blue) 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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