ORIGINAL RESEARCH

What Does the Surgeon Want to Know About En Bloc Resection of Primary Spinal Tumors from a Radiologist's Perspective?

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Received: 20 February, 2023 Accepted: 25 March, 2023

ABSTRACT

En bloc resection in the spine is performed for both primary and metastatic bone lesions and has been proven to lengthen disease-free survival and decrease the likelihood of local recurrence. It is a complex procedure, which requires a thorough multi-disciplinary approach This article will discuss the role of the radiologist in characterizing the underlying tumor pathology, staging the tumor and helping to predict possible intraoperative challenges for en bloc resection of primary bone lesions. The postoperative appearances and complications following en bloc resection in the spine will be considered in subsequent articles.

INTRODUCTION

The complex operation of en bloc excision of the spine carries a high risk of morbidity and mortality.It is not a surgery that is frequently done, so a thorough multidisciplinary approach to each case is essential.[2]Imaging plays a crucial role in correctly staging the tumor and determining its suitability for resection in addition to assisting in characterizing the underlying tumor pathology.

The rationale for en bloc excision of the spine as well as the oncological staging of spinal tumors will be covered in this essay. It will also be discussed how the surgical approach is affected by the surgery staging of spinal tumors. The goal is to improve preoperative planning by giving the radiologist a better grasp of the surgeon's pre- and intraoperative considerations so they can produce reports that are pertinent.

ENBLOCK

En bloc resection (EBR) is the name given to the process that aims to eliminate a tumor in its entirety along with a margin of healthy tissue surrounding it.[1] En bloc tumor resection is based on oncological principles that were originally well established for bone tumors of the limbs. These principles later inspired a standard procedure for tumors of the spine.

Stener published the first account of full vertebral amputations for spinal tumors in 1989.[3] Roy Camille and Tomita outlined another widely used standard technique.[4] However, this method was only really effective for the thoracic spine and was only suitable if the tumor was located in the middle and completely confined within the vertebral body. It was clear that a staging system for spinal tumors was required, one that would characterize the extent and location of the tumor and enable a standard surgical procedure based on oncological principles. The Weinstein-Boriani-Biagini (WBB) staging method was created for this purpose.[1]

WHICH TUMORS CAN BE REMOVED IN ONE PIECE?

EBR's use is limited to specific tumor types due to the high morbidity and mortality rates linked with it. It is necessary to consider a tumor's behavior and characteristics before determining whether EBR is suitable for it. Applying the Enneking classification is how this is accomplished.[2] This form of oncological staging was initially created with regard to tumors of the long bones but has since been used with regard to spinal tumors.

BENIGN TUMORS

Mesenchymal tumors classified as normal and malignant are separated by the Enneking staging system. According to how their borders appear on radiographs, the benign tumors are divided into three groups. More latent lesions are represented by clearly defined boundaries than aggressive lesions are by clearly defined borders.[5] As the grade rises, the rate of repetition rises as well. Giant cell tumors (GCTs) and chondroblastoma are two examples of locally aggressive benign lesions that can metastasize; this is an uncommon occurrence.6 In instances of benign aggressive (Enneking stage 3) tumors like GCTs, chondroblastomas, and osteoblastomas, EBR is deemed appropriate.

In the IR and EBR categories, the local recurrence rates were 36.7 and 9.5%, respectively. Postoperative incident rates for IR were 36.4% and for EBR were 11.1 %.[12] As it is likely that surgeons would favor EBR in younger patients with fewer comorbidities and less tumor extension, it is obvious that these findings will be subject to a selection bias by the operating surgeon. It is significant to remember that while IR offers sufficient control of Enneking stage 2 tumors, EBR is linked with better local control of Enneking stage 3 GCTs.[8] This emphasizes how critical it is to consider the border and breadth of the lesion's radiological appearance when determining the Enneking stage.

OSTEOBLASTOMA

Osteoblastoma lesions (OBL) make up 40% of spine-related tumors, mostly in the cervical and lumbar areas.[14] OBL are usually found in the posterior elements of the vertebra, primarily the pedicle or lamina.[15] 80% of patients with OBL present before the age of 30, with OBL usually occurring in the second decade of life.[16.15] OBL can manifest at Enneking stages 2 or 3, just like GCT. Stage 3 Enneking OBL, also known as the "aggressive" variety, is linked to a 50% post-IR recurrence rate, whereas stage 2 OBL, or the "less aggressive" variant, is linked to a recurrence rate of between 10% and 15%.[17] Because of this, IR is advised for "active" OBL (Enneking stage 2), while EBR is advised for "aggressive" OBL (Enneking stage 3), when physically possible. This emphasizes the significance of examining the radiological appearance of the lesion's borders.

The staging of malignant tumors includes surgical grade, local extent, and presence of metastasis. Low nuclear to cytoplasmic ratio, low mitotic rates, and restricted pleomorphism in low surgical grade lesions all indicate a low chance of distant spread. High-grade lesions are characterized by mitotic figures, prominent nucleoli, and pleomorphism and have a greater incidence of metastasis.[5] However, some tumors, such as dedifferentiated chondrosarcoma, automatically fall into the high-grade group. Most lesions are graded based on their histology.[18]

Radiology is crucial in determining the existence of regional or distant metastases as well as the location of the tumor (intra- or extrac- ompartmental). In low-grade malignant tumors (Enneking stages 1A and 2B), like chordomas and chondrosarcomas, EBR is deemed suitable. Chemotherapy and radiotherapy should be taken into account for high-grade malignancies (Enneking stage 2). (RT). EBR has a very limited function in spine metastasis (Enneking stage 3), and it is only taken into consideration in a small number of cases where the multidisciplinary team believes it would enhance local control and lessen local recurrence. This won't be covered in this piece.

CHORDOMA

Rare bone tumors called "chordomas" that primarily affect the vertebrae, sacrum, and base of the skull are developed from embryonic notochord remnants.[19] They are aggressive tumors that can metastasize locally and frequently return locally.[20]

Male patients experience them twice as frequently as female patients do, and they most frequently manifest in the sixth decade.[19] Total EBR with a margin of unaffected tissue around its perimeter was originally thought to be the only course of treatment linked to a 5-year disease-free survival rate.[21] Due to its ability to further reduce local recurrence after maximum resection, proton beam radiation therapy has recently replaced other forms of radiation therapy as the first line of defense in the treatment of spinal chordomas.[22]

CHONDROSARCOMA

Less than 10% of all instances of chondrosarcoma, a low-grade malignant chondroid lesion, involve the spine.[23] Although they can happen anywhere along the mobile spine, they are most frequently found in the thoracic and lumbar areas.[24] Men are more frequently impacted than women, with an average age of 42 at diagnosis.[25] Radiation and chemotherapy are notoriously ineffective in treating the growth.[26]

With EBR being the gold standard of treatment, the degree of surgical resection is correlated with the total survival benefit.[27] En bloc has a lower relative risk (RR) for mortality and recurrence compared to other surgical methods of 78.8% (RR, 0.21; p 0.001) and 80.7% (RR, 0.19; p 0.001, respectively).[25,26,28]

OSTEOSARCOMA

Although osteosarcoma is one of the more frequent primary bone malignancies, only 0.85 to 3% of all osteosarcomas affect the spine. Instead, they typically affect the limbs.[29] It manifests around the fourth decade [30], later than extremity osteosarcoma, and is most frequently found in the thoraco-lumbar spine, particularly the posterior components.[31] Surgery is essential for the treatment of spinal osteosarcoma, even though adjuvant chemotherapy and radiation therapy are crucial.[27] Total en bloc resection with broad or marginal margins has been shown to have a better long-term prognosis and less local recurrence than intralesional or "piecemeal" resection throughout the spine.[27,32]

EWING`S SARCOMA

The second most frequent primary malignant bone cancer in children and teenagers, after osteosarcoma, is Ewing sarcoma (ES).[33] The spine is only impacted in 5% of instances; the pelvis, femur, and tibia are most frequently affected.[34] When the spine is affected, ES typically affects the thoracolumbar spine and typically begins in the posterior components before extending into the vertebral body.[35] In the spine, the outlook is worse, and there is discussion over the best strategy for local management. RT has typically been regarded as the main element of local therapy; however, this is constrained in lumbar spinal tumors due to the close proximity of the spinal cord and the kidneys.[36] The impact of total en bloc resection (TER) on local recurrence and disease-free survival has only been examined in a small number of trials. Combining these small studies, it has been established that, whenever feasible, TER combined with RT offers better local control compared to RT alone. Better local control is shown by [37] IR or EBR with IL borders than by RT and chemotherapy put together.[38]

STANDARDIZATION OF APPROACH (WBB STAGING) SURGICAL STAGING

To aid in and standardize the planning of EBR, the WBB surgical staging system was developed in 1997.[1] It has since been submitted to clinical evaluation and is the system used in most spinal oncology studies and has been implemented by most spinal oncology centers. The surgical strategy is then determined by this staging system, which classifies tumors according to their position in terms of zones and layers.[2] There are detailed a total of ten different surgical tactics.[2] The radiologist should be aware of the three primary approaches to help tailor their reports, but it would be outside the scope of this piece to provide an in-depth explanation of all 10. The following are the three primary strategies.

VERTEBRECTOMY (MARGINAL/WIDE EN BLOC EXCISION OF THE VERTEBRAL BODY)

This method works well for tumors that are centered in the vertebral body and have at least one preserved pedicle. (confined to zones 4–8 or 5–9). It begins with the healthy posterior components being removed using a posterior approach. This allows for the sectioning of the posterior longitudinal tendon and annulus fibrosis. The segmental arteries at the operative level above and below can then be ligatured using a subsequent anterior approach. Next, the vertebral column is extracted in one piece. A passage through the nearby vertebral bodies or proximal and distal discectomies are used to accomplish this. Therefore, it's crucial that the radiologist correctly describes the tumor's longitudinal extent and specifies whether the nearby intervertebral disc is involved. With this procedure, the complete vertebra—including the body and posterior components—is removed.

SAGITTAL RESECTION (MARGINAL/WIDE)

When a tumor is situated eccentrically in the vertebral body, pedicle, or transverse process, this is the best course of action. (confined to zones 3–5 or 8– 10). If required, more than one level and one or more ribs may be removed. The healthy posterior elements, including the unaffected pedicle, are removed in the first stage using a posterior approach. The nerve roots at the impacted layers are then strangled. The eccentric tumor in the vertebral body or transverse elements is then approached anteriorly while the patient is in a lateral decubitus posture. The vertebral body is sliced through through at least one zone that is remote from the tumor using a chisel or osteotome. The affected components are then entirely eliminated. A tiny portion of the healthy vertebral body will be preserved using this method.

RESECTION OF THE POSTERIOR ARCH (MARGINAL/ WIDE)

The tumor can be removed in one piece using only the posterior approach when it is restricted to the posterior components (zones 10-3). In order to reveal the dural sac, a wide laminectomy is initially done at the vertebral level above and below the tumor. The next step involves sectioning the pedicles with an osteotome or Gigli saw to remove the posterior components at the affected level all at once.

THE RADIOLOGICAL REPORT

The following is a recommended method for reporting preoperative planning aging for EBR after taking into account the surgical options.

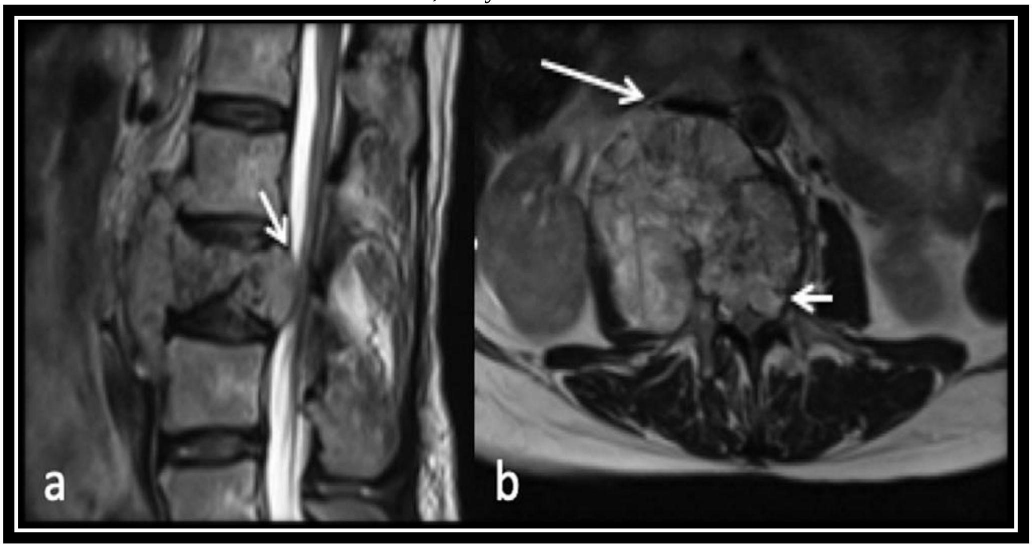
LONGITUDINAL EXTENT OF THE TUMOR

It should be stated at which vertebral level the tumor's location is located. To prevent wrong level surgery, transitional vertebrae should be given special consideration, and it should always be obvious in the report whether the radiologist is counting the vertebrae from the sacrum up or from C2 down. The longitudinal expansion of the tumor should also be covered in the report. The location of the longitudinal borders is a crucial surgical choice. The physician will perform a resection through the vertebral body above if the tumor is invading the disc above or below. Superior and inferior discectomies can be used to resect the damaged spinal body if the disc is unharmed.

TRANSVERSE EXTENT OF THE TUMOR

The radiologist will need to precisely describe the position and extent of the tumor in the transverse plane in order to enable application of the WBB staging system and to aid in the planning of approach.

To do this, describe the tumor's position in terms of the WBB zones and layers. The location and size of the tumor can be determined by dividing the vertebrae into five layers (A–E) and twelve radiating zones (1–12) in a clockwise direction. For instance, any retroperitoneal structures in the lumbar spine, or the mediastinum, pleura, or lung at the thoracic level, are examples of structures that should be mentioned when a tumor invades layer A (extra osseous soft tissue).



T2 sagittal (A) and axial (B) showing large chordoma with epidural component (small arrow). Tumor is compressing but not encasing the inferior vena cava (long arrow) (Weinstein-Boriani- Biagini4—10,a—d).

INVOLVEMENT OF NEURAL STRUCTURES

Knowing whether the tumor has spread into the vertebral canal is a crucial consideration for the spine surgeon. This can be characterized as extending into layer D (extra-osseous extra-dural) or layer E using the WBB staging system. (extraosseous intradural). An extraosseous intradural tumor will clearly have fewer options for removal than an extraosseous extradural tumor, even though the latter may be able to be peeled from the spinal cord and achieve adequate margins (Fig. 2).Any invasion of the tumor into the vertebral canal will result in contamination of that compartment when treating the resection of a spinal tumor using the same oncological rules as treating a mass in the long bones. Since it is obvious that the entire compartment cannot be removed, patients should be informed of any potential consequences for their prognosis and the requirement for adjuvant treatment. It might be necessary to sacrifice neurological structures in extreme circumstances where there has been a substantial invasion. Even the sacrifice of the cauda equina has been mentioned.[38] This is obviously not a decision that is taken lightly, and the patient, as well as the larger multidisciplinary team, needs to be informed about the advantages and disadvantages.

It's crucial to characterize any invasion or encasement of the segmental nerves by the tumor mass in addition to the cord itself. Once more, the physician will have to weigh the advantages of obtaining clear oncological margins against the functional loss brought on by sectioning these nerves.

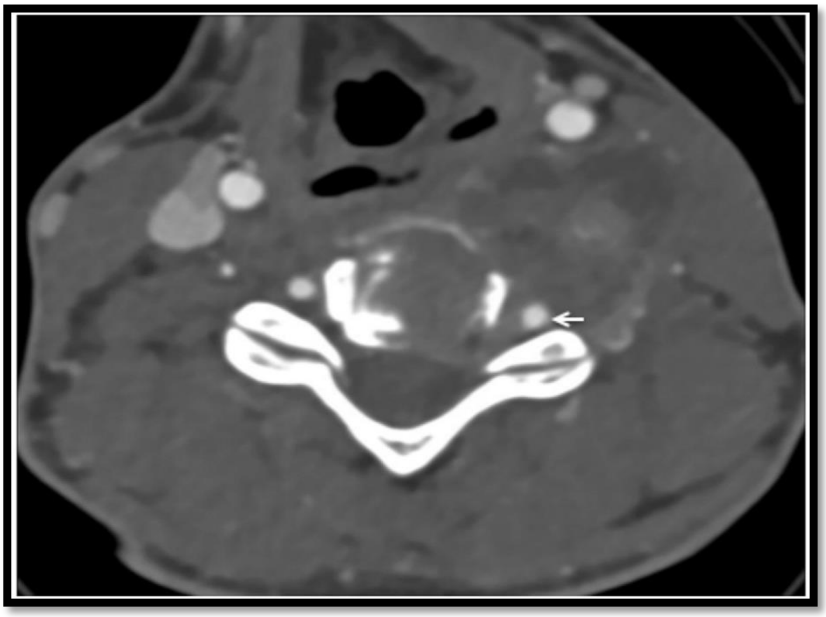


Fig. 3 Axial computed tomography angiogram image showing tumor displaced left carotid vessels anteriorly and encasing left vertebral artery (arrow).

INVOLVEMENT OF VASCULAR STRUCTURES

When feasible, it's important to describe how the tumor has invaded or engulfed any nearby vascular structures (Fig. 3). The aorta or vena cava involvement would be the most apparent, and in most cases, this would rule out EBR as a viable treatment option. Figures 2 and 4. A case report of a successful combined procedure that included the EBR of an osteosarcoma and the replacement of a damaged portion of the aorta is available.[39] Therefore, it is crucial to describe the size and length of the involved region when reporting vascular involvement. Due to their closeness to the aortic and venous (IVC) bifurcations, the lumbar vertebrae present unique difficulties. Because of this, specific surgical techniques are outlined for lumbar tumors and tumors at L5.[2.]

The vertebral artery's involvement in the cervical spine is of particular worry. Of course, it is crucial to characterize any tumor invasion and to note whether the vessel has been extensively encased, as this may make it challenging to resect a lesion in its entirety. Again, this might completely prevent EBR, but there might be methods to get around it. There have been instances of effective en bloc removal of a lesion without neurological damage being hampered by unilateral vertebral artery ligation. It would be prudent to perform a thorough computed tomography (CT) angiography in these circumstances to check for variations within the Willis circle and to conduct an occlusion test (Fig. 3).

Due to their small size and potential disruption by the surrounding lesion, assessment of the smaller segmental/radicular arteries on CT or magnetic resonance imaging (MRI) is unlikely to be feasible. In several of the methods mentioned above, it is essential to ligate the segmental artery at the affected level as well as at the levels above and below the lesion. When the tumor is anticipated to be highly vascular, it may also be essential to embolize these vessels prior to surgery in an effort to reduce intraoperative blood loss or the danger of massive hemorrhage.

Angiograms were initially used in these instances to establish the connection between the segmental vessels and the spinal arteries, particularly the artery of Adamkewitz. However, it has since been shown that neurological defects are extremely rare even when the main segmental artery feeding into the artery of Adamkewitz is severed. This is thought to be caused by the anterior spine artery's collateral supply. The number of segmental arteries that are severed is considered to be more important, with the risk of neurological issues greatly increasing when more than three pairs of segmental vessels are severed. An angiography could be helpful in these situations if the surgeon believes that it may be essential to do so prior to surgery. In a preliminary small study, the role of electrophysiological monitoring during major radicular artery embolization in guiding choices regarding the permanent occlusion of these vessels was evaluated. This information may be helpful in particularly difficult cases.[40]

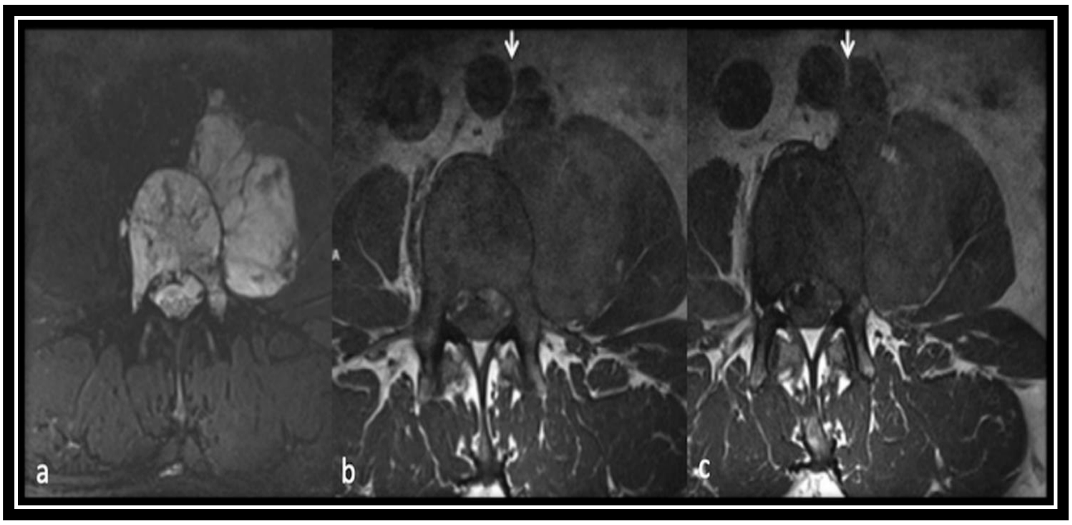


Fig. 4 Axial short tau inversion recovery (A), T1 (B and C) showing large chordoma that is closely related to the aorta with loss of fat plane between the tumor and aorta on image (C) (arrow). The tumor extends and involves the left psoas. (Weinstein-Boriani-Biagini 3–10, a–d).

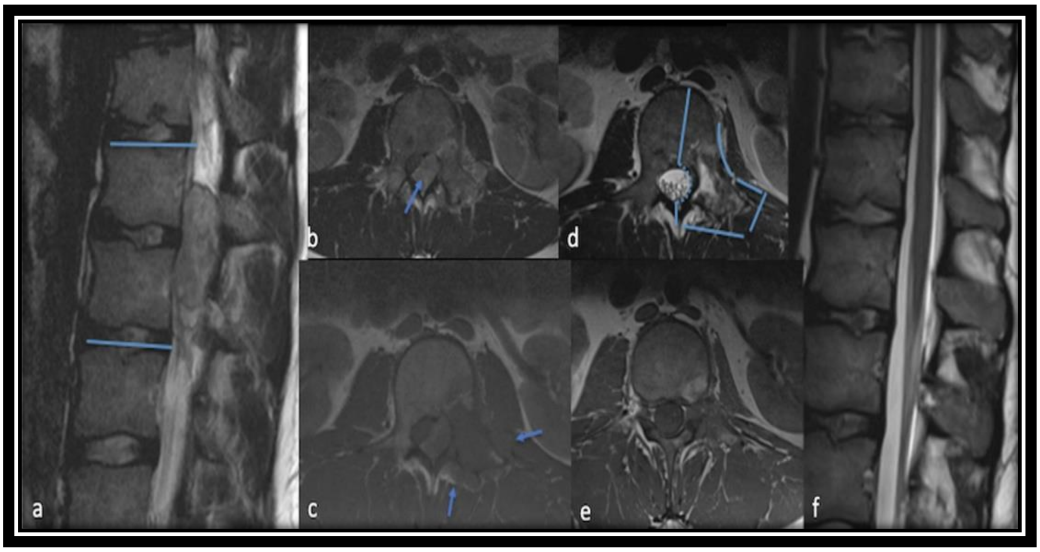


Fig. 5 Ewing's sarcoma. Sagittal T2 (A), axial T2 (B), T1 (C), post chemotherapy axial T2 (D), T1 (E), and sagittal T2 (F) showing tumors in the canal and extending into the left psoas (arrow). (Weinstein-Boriani-Biagini 2–5, A–E). The tumor has decreased significantly post chemotherapy and blue lines denote the resection margin.

STABILITY OF THE VERTEBRA

The best way to evaluate this is with prior CT imaging. The degree of bony encroachment should be discussed, particularly the destruction of cortical structures. The bony integrity of the involved spine as well as the vertebral levels above and below can be inferred from this. This is crucial in order to facilitate reconstruction after the EBR.

Cases: Figs. 5, 6, 7, and 8.

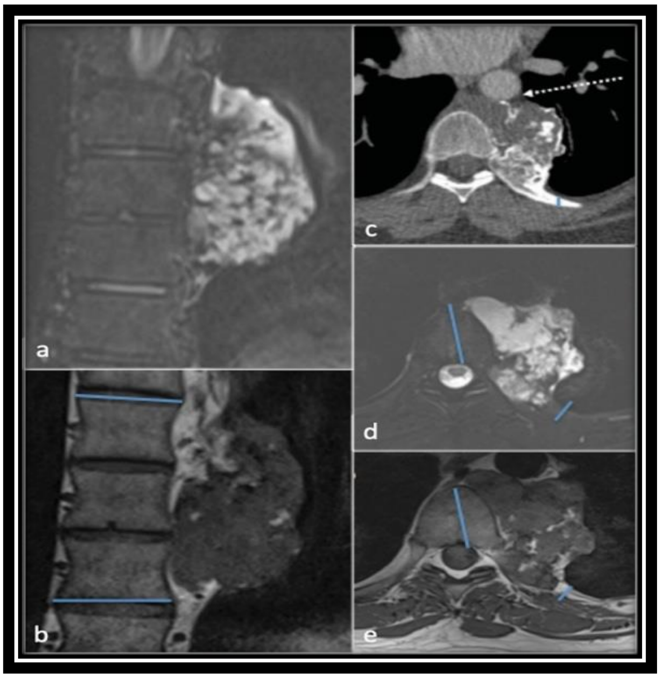


Fig. 6 Chondrosarcoma. Coronal short tau inversion recovery (STIR) (A) T1(B), axial computed tomography (C), axial STIR (D) and T1 (E) showing resection margins (blue lines). Arrow showing the tumor is close to the aorta. (Weinstein-Boriani-Biagini 2–6, A).

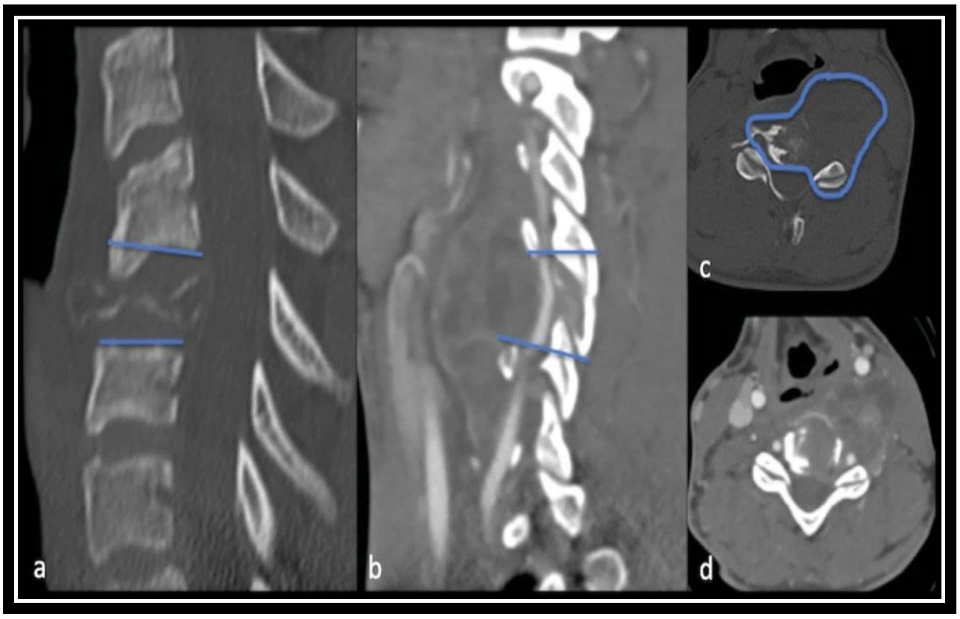


Fig. 7 Aneurysmal bone cyst. Sagittal computed tomography (CT) (bone windows) (A), sagittal CT angiogram (B), axial CT angiogram bone window (C),and soft tissue window (D) showing site of resection (bluelines).TheleftvertebralarteryandleftC6nerverootneedtobe resected. (Weinstein-Boriani-Biagini 2–9,a–c).

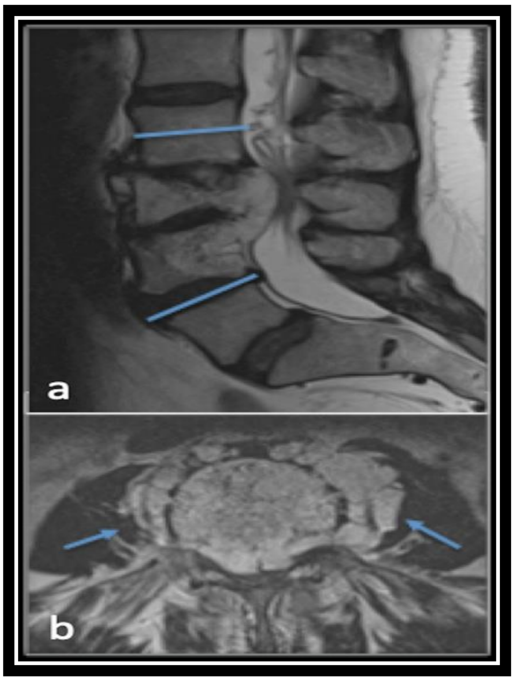


Fig. 8 Chordoma. Sagittal T2 (A) and axial T2 (B) showing resection marking(blue lines).The arrows demonstrate that the psoasmuscleis closely related to the tumor and might have to be resected. (Wein- stein-Boriani-Biagini 4–9,a–d).

Table 3: Reporting template

Template
1. Longitudinal extent of tumor
2. Transverse extent of tumor as per WBB
3. Stability—extent of bony destruction (best assessed on CT)
4. Neural structure involvement—cord and nerve roots
5.Vascularstructures,inparticularvertebralartery,seg- mental artery, aorta, inferior venacava

Abbreviations: CT, computed tomography; WBB, Weinstein-Boriani- Biagini.

CONCLUSION

The complex and difficult EBR procedure for vertebral tumors has the ability to significantly increase disease-free survival and reduce local recurrence. The Enneking staging system is used to forecast the behavior of the lesion in issue when evaluating the appropriateness of EBR. After that, the surgical approach is planned using the WBB staging scheme. The radiologist should concentrate on five key areas when describing preoperative planning for EBR, including the tumor's longitudinal extent, transverse extent, involvement of neurological structures, involvement of vascular structures, and vertebral stability (Table 3). The physician can use this to help plan the surgical strategy and anticipate any intraoperative complications. The creation of three-dimensional models for use in surgical planning and guidance can also be aided by preoperative MRI and CT.

FINANCIAL DISCLOSURES

No financial disclosures.

CONflICT OF INTEREST

No conflicts of interest.

REFERENCES

1. Boriani S, Weinstein JN, Biagini R. Primary bone tumors of the spine. Terminology and surgical staging. Spine 1997;22(09): 1036–1044
2. Boriani S. *En bloc* resection in the spine: a procedure of surgical oncology. J Spine Surg2018;4(03):668–676
3. Stener B. Complete removal of vertebrae for extirpation of tumors. A 20-year experience. Clin Orthop Relat Res1989;(245):72–82
4. Tomita K, Kawahara N, Murakami H, Demura S. Total en bloc spondylectomy for spinal tumors: improvement of the technique and its associated basic background. J Orthop Sci 2006;11(01): 3–12
5. Jawad MU, Scully SP. In brief: classifications in brief: Enneking classification: benign and malignant tumors of the musculoskel- etal system. Clin Orthop Relat Res 2010;468(07):2000–2002
6. Viswanathan S, Jambhekar NA. Metastatic giant cell tumor of bone: are there associated factors and best treatment modalities? Clin Orthop Relat Res

2010;468(03):827–833

7. Wilartratsami S, Muangsomboon S, Benjarassameroj S, Phimol- sarnti R, Chavasiri C, Luksanapruksa P. Prevalence of primary spinal tumors: 15-year data from Siriraj Hospital. J Med Assoc Thai 2014;97(Suppl 9):S83–S87
8. Boriani S, Bandiera S, Casadei R, et al. Giant cell tumor of the mobile spine: a review of 49 cases. Spine 2012;37(01):E37–E45
9. Si MJ, Wang CG, Wang CS, et al. Giant cell tumours of the mobile spine: characteristic imaging features and differential diagnosis. Radiol Med (Torino) 2014;119(09):681–693
10. Sanjay BK, Sim FH, Unni KK, McLeod RA, Klassen RA. Giant-cell tumours of the spine. J Bone Joint Surg Br 1993;75(01):148–154
11. Donthineni R, Boriani L, Ofluoglu O, Bandiera S. Metastatic behaviour of giant cell tumour of the spine. Int Orthop 2009;33(02):497–501
12. Luksanapruksa P, Buchowski JM, Singhatanadgige W, Bumpass DB. Systematic review and meta-analysis of en bloc vertebrec- tomycompared with intralesional resection for giant cell tumours of the mobile spine. Global Spine J 2016;6(08):798–803
13. Arkader A, Dormans JP. Osteoblastoma in the skeletally immature. J Pediatr Orthop 2008;28(05):555–560
14. Pieterse AS, Vernon-Roberts B, Paterson DC, Cornish BL, Lewis PR. Osteoid osteoma transforming to aggressive (low grade malig- nant) osteoblastoma: a case report and literature review. Histo- pathology 1983;7(05):789–800
15. Jacobs W, Fehlings M. Primary Vertebral Column Tumours. Spinal Cord and Spinal Column Tumours: Principles and Practice. New York: Thieme; 2006:369–386
16. Boriani S, Weinstein JN. Oncologic Classification of Vertebral Neoplasms. Spinal Cord and Spinal Column Tumours. New York: Thieme Medical Publishers, Inc.; 2006:37
17. Harrop JS, Schmidt MH, Boriani S, Shaffrey CI. Aggressive “benign” primary spine neoplasms: osteoblastoma, aneurysmal bone cyst, and giant cell tumor. Spine 2009;34(22, Suppl):S39–S47
18. Dickey ID, Rose PS, Fuchs B, et al. Dedifferentiated chondrosar- coma: the role of chemotherapy with updated outcomes. J Bone Joint Surg Am 2004;86(11):2412–2418
19. Lee IJ, Lee RJ, Fahim DK. Prognostic factors and survival outcome in patients with chordoma in the United States: a population- based analysis. World Neurosurg 2017;104:346–355
20. Bailey CS, Fisher CG, Boyd MC, Dvorak MF. En bloc marginal excision of a multilevel cervical chordoma. Case report. J Neuro- surg Spine 2006;4(05):409–414
21. Boriani S, Bandiera S, Biagini R, et al. Chordoma of the mobile spine: fifty years of experience. Spine 2006;31(04):493–503
22. Snider JW, Schneider RA, Poelma-Tap D, et al. Long-term out- comes and prognostic factors after pencil-beam scanning proton radiation therapy for spinal chordomas: a large, single-institution cohort. Int J Radiat Oncol Biol Phys 2018;101(01):226–233
23. Strike SA, McCarthy EF. Chondrosarcoma of the spine: a series of 16 cases and a review of the literature. Iowa Orthop J 2011; 31:154–159
24. Kelley SP, Ashford RU, Rao AS, Dickson RA. Primary bone tumours of the spine: a 42-year survey from the Leeds Regional Bone TumourRegistry.EurSpineJ2007;16(03):405–409
25. NissonPL,BergerGK,JamesWS,HurlbertRJ.Surgicaltechniques and associated outcomes of primary chondrosarcoma of the spine. World Neurosurg2018;119:e32–e45
26. BorianiS,DeIureF,BandieraS,etal.Chondrosarcomaof the mobile spine: report on 22 cases. Spine 2000;25(07): 804–812
27. Feng D, Yang X, Liu T, et al. Osteosarcoma of the spine: surgical treatmentandoutcomes.WorldJSurgOncol2013;11(01):89
28. ArshiA,SharimJ,ParkDY,etal.Chondrosarcomaoftheosseous spine: an analysis of epidemiology, patient outcomes, and prog- nostic factors using the SEER registry from 1973 to 2012. Spine 2017;42(09):644–652
29. SundaresanN,RosenG,HuvosAG,KrolG.Combinedtreatmentof osteosarcoma of the spine. Neurosurgery1988;23(06):714–719
30. Fielding JW, Fietti VG Jr, Hughes JE, Gabrielian JC. Primary osteogenic sarcoma of the cervical spine. A case report. J Bone Joint Surg Am1976;58(06):892–894
31. Ilaslan H, Sundaram M, Unni KK, Shives TC. Primary vertebral osteosarcoma: imaging findings. Radiology 2004;230(03): 697–702
32. Schwab J, Gasbarrini A, Bandiera S, et al. Osteosarcoma of the mobile spine. Spine2012;37(06):E381–E386
33. EwingJ.TheClassic:Diffuseendotheliomaofbone.Proceedingsof the New York Pathological Society. 1921;12:17. Clin Orthop Relat Res2006;450:25–27
34. BernsteinM,KovarH,PaulussenM,etal.Ewing’ssarcomafamily of tumors: current management. Oncologist 2006;11(05): 503–519
35. MechriM,RiahiH,SbouiI,BouazizM,Vanhoenacker F, LadebM. Imaging of malignant primitive tumours of the spine. J Belg Soc Radiol2018;102(01):56
36. SewellMD,TanKA,QuraishiNA,PredaC,VargaPP,WilliamsR. Systematic review of en bloc resection in the management of Ewing’ssarcomaofthemobilespinewithrespecttolocalcontrol and disease-free survival. Medicine (Baltimore) 2015;94(27): e1019
37. Boriani S, Amendola L, Corghi A, et al. Ewing’s sarcoma of the mobile spine. Eur Rev Med Pharmacol Sci 2011;15(07): 831–839
38. KeynanO,FisherCG,BoydMC,O’ConnellJX,DvorakMF.Ligation andpartialexcisionofthecaudaequinaaspartofawideresection of vertebral osteosarcoma: a case report and description of surgical technique. Spine2005;30(04):E97–E102
39. Pilger A, Tsilimparis N, Bockhorn M, Trepel M, Dreimann M. Combined modified en bloc corpectomy with replacement of the aorta in curative interdisciplinary treatment of a large osteo- sarcoma infiltrating the aorta. Eur Spine J 2016;25(1, Suppl 1):58–62
40. SalameK,MaimonS,RegevGJ,etal.Electrophysiologicalmoni- toring during preoperative angiography to guide decisions re- garding

permanent occlusion of major radicular arteries in patients undergoing total en bloc spondylectomy. Neurosurg Focus2016;41(02):E19