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En-bloc resection of a chordoma in L3 by a combined open posterior and less invasive retroperitoneal approach: technical description and case report

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Abstract

Introduction To fulfill oncological criteria, extensive open anterior and posterior approaches are usually performed in the lumbar spine to obtain an appropriate en-bloc spondylectomy. It is commonly accepted that the price of a tumor-free margin includes such extensive incisions and soft-tissue damage, with consequent relevant blood loss and possible postoperative complications as delayed wound healing. In this article, a case of chordoma in L3 is presented, submitted to an oncologically appropriate en-bloc resection performed by an open posterior approach combined with a mini-retroperitoneal approach. The successful oncologic procedure was combined with a short and uneventful postoperative course.

Materials and methods The authors present the surgical technique and the possible challenges of minimally invasive anterior oncologic surgery as a contribution to a limited literature.

Results Up to date, palliative care of single metastases has been the main setting in which anterior, minimally invasive surgery has been performed in the lumbar spine. The authors explained how, in selected cases, this approach can be performed in combination with an open posterior access for an oncologically appropriate treatment of a primary malignant tumor.

Conclusion Anterior, minimally invasive surgery can have a role in selected patients with primary malignant tumors of the lumbar spine. The surgical team should have extensive training both in oncologic and minimally invasive surgery.

Keywords Chordoma · Minimally invasive surgery · Trans-psoas approach · Lumbar spine tumor · Malignant spine tumor

Introduction

Chordoma is the most frequent primary malignant tumor of the mobile spine, with an incidence of 0.8 per 100,000 people and mainly occurring in the male population in the fifth-to-seventh decade [1]. In the mobile spine, the most frequently reported symptom is pain with gradual onset; cord compression and nerve root involvement are found only in a minority of the patients [2]. Due to the slow growth, chordoma can reach a considerable size, thus making en-bloc resection challenging and increasing the risk of tumor violation ("intralesional margin") [1]. For this reason, palliative decompression with or without radiation therapy was often the only possible treatment in the past [2], but the development of imaging techniques such as magnetic resonance imaging (MRI) allowed the detection of smaller lesions, which can more easily be resected en-bloc [2, 3]. The term "en-bloc resection" should not refer to the excision of the entire affected vertebra, but to the removal of the entire tumoral mass with appropriate oncologic margins [4]. Chordoma has a high local recurrence rate after an incomplete resection of the tumor, ranging from 100% of patients treated with intralesional, palliative surgery to 46–50% in patients who underwent en-bloc resection with inadequate margins [1, 2]. After en-bloc resection with adequate margins, the local recurrence rate drops to 16–20% [1, 2]: thus, complete resection with adequate margins should always be the aim in the treatment of chordoma.

As reported in larger retrospective series, the risk of local recurrence after en-bloc resection is higher for chordomas compared to other low-grade malignancies like chondrosarcoma, and this is probably due to the higher possibility to

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squeeze tumor cells by manipulating a jelly tumor like chordoma compared to a more solid and thick tumor like chondrosarcoma [1, 2, 5]. Despite favorable oncological outcomes, en-bloc resection still represents a challenging intervention [5]: because of the different relevant anatomical structures surrounding the spine, the achievement of adequate margins may involve the sacrifice of neural or vascular structures [6–9]. Surgical planning is generally based on the Weinstein–Boriani–Biagini (WBB) classification [10]. According to the localization of the tumoral mass in the vertebra and to the anatomical structures involved, Boriani proposed seven different surgical approaches for en-bloc resection of spinal tumors [4]. It is of note that the technique of en-bloc resection of lumbar tumors evolved over the years. In the early 90s, the original technique by RoyCamille for lumbar en-bloc vertebrectomies [11] was performed (so-called type 5 [4]) including a posterior approach and a second step with either a T-shaped incision or the combination of an anterior approach with the re-opening of the posterior approach. At a critical revision of the morbidity of this procedure, such an aggressive strategy was found significantly associated to a higher intra- and postoperative complication rate [12] and was replaced by a staged operation (first anterior, then posterior, type 3b; first posterior then anterior, type 7) [4]. In the continuing effort to achieve the best oncological result while reducing surgical aggressiveness and morbidity, the case here presented underwent en-bloc resection of a L3 chordoma planned as type 7 resection in the aforementioned classification [4, 13], where the usual open posterior approach was combined with mini-retroperitoneal approach. The key anatomical point to make possible an oncologically appropriate resection by type 7 is represented by the possibility to remove the full posterior arch without breaching the tumor by posterior approach, allowing to complete the removal by anterior approach with a continuous tumor-free margin. Usually, to achieve such result, an extensive anterior incision [11] is required for full release of the vertebra by the vascular structures. In this case, a minimally invasive approach was successfully performed: to minimize the complication rate and to ensure complete resection with adequate margins. While minimally invasive approaches have been reported in case of single vertebral metastases, mostly in palliative settings [14–16], en-bloc resection performed with a minimally invasive technique for a chordoma was reported only in the thoracic spine [17]. The peculiarity of the presented case is the combination of oncological principles with minimally invasive techniques in the treatment of a malignant tumor of the lumbar spine.

Case presentation

The patient, a 61 year-old male (68 kg, 174 cm), was referred to our institution for surgical therapy after diagnosis of a chordoma of L3 by CT-scan guided trocar biopsy. In the preoperative imaging, the tumor was located in the areas 4–9, layers B–D according to the WBB classification [10] (Fig. 1). A type 7 WBB-based en-bloc resection was planned [4], as the most difficult margins were posterior: canal invasion, nerve root involvement, and pedicles partially eroded. The planning considered a very careful release of the tumor from such elements trying to achieve the best oncological margin and sacrifice only minimal functions. Once concluded such demanding steps without breaching the tumor capsule and performed the diskectomies, a mesh was left to help finding the achieved margin by anterior approach. Thanks to such careful job by posterior approach, the anterior approach could be performed by minimally invasive procedure. The specimen resulted already mobilized and was safely removed by minimally invasive approach. Lastly, the vertebral body was replaced by a spacer filled with graft for fusion purpose. Due to the high risk of contaminated margin and following the actual tendency to associate surgery to accelerated particle therapy [18], all implants had to be titanium free.

Surgery was performed under general anesthesia and under control of motor and sensory-evoked potentials with neuro-monitoring. In the first posterior surgical time, after median incision and exposure of the levels L1–L5, the vertebrae L1, L2, L4, and L5 were instrumented with composite polyether-ether-ketone (PEEK)/carbon fiber pedicle screws (Carbofix, Herzelyia, IL, USA). The transverse processes of L3 were resected and the lateral sides of the vertebra were detached from the psoas muscle, both manually and with the aid of a bipolar scissor, until the intervertebral discs L2/3 and L3/4 were identified and isolated. A laminectomy from L2–L4 was performed. L3 pedicles were partially removed

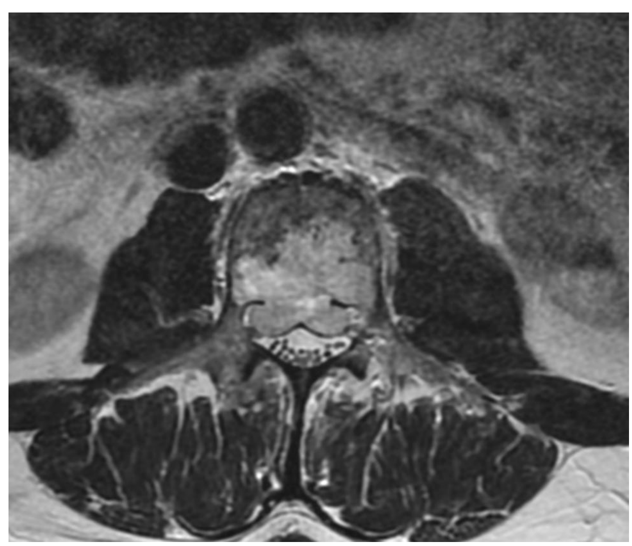


Fig. 1 MRI of the chordoma of L3. Sectors involved are 9–4 (body and both pedicles). Layers B, C, and D. The tumor is contained inside the vertebral body but involving the epidural space (layer D)

without entering the tumor and the pedicles of L2 and L4 were separated from the neural structures. Blunt spoon retractors were placed bilaterally along the lateral aspect of the L2–L3 and L3–L4 discs to allow for lateral annulotomy. The epidural tumor was found, limited by a very thin membrane and a delicate maneuver to release from the thecal sac started. Left L3 nerve root was not affected by the tumor, but the right nerve root was in close contact with the tumor in the foramen and was sacrificed for best margin and to allow safe removal of the vertebral body from the left side in the second surgical time. This step had been discussed with the patient, who accepted any possible functional loss to reduce the risk of local recurrence. After resection of the nerve root, the neuro-monitoring system recorded a reduction by 40% of the evoked motoric potentials in the right L3 innervation area. The right L3 segmental artery could also be identified and ligated. The annulus of L2/3 and L3/4 intervertebral discs were then incised, making sure that the left and right incisions coalesced posteriorly in the midline and then extended bilaterally in the annulus fibrosus as far anterior as possible, approximately two-thirds of the length of the vertebrae. To stabilize the spine, the right rod (composite PEEK/carbon fiber) was inserted. The dural sac was fully separated from the tumor and a polytetrafluoroethylene (ePTFE) mesh was placed anterior to the neural structures from L2 inferior endplate to L4 superior endplate to protect the dura during the second surgical time. The left rod (composite PEEK/carbon fiber) was also inserted after placing two reamers in the intervertebral spaces L2/3 and L3/4 under minimal distraction of the vertebrae; this is in order to avoid impingement of L3 vertebral body between L2 and L4 and thus to facilitate its removal. Figure 2 shows the surgical field at the end of the posterior surgical time. The posterior incision was sutured and the patient was repositioned in right lateral decubitus for the second surgical time.

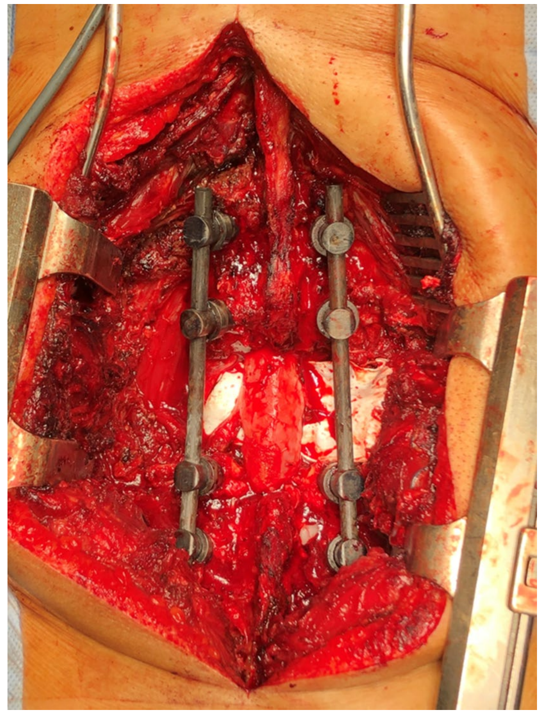


Fig. 2 Surgical field at the end of the posterior surgical time. The dural sac was exposed from L2 to L4 and the right L3 nerve root had been sacrificed. A layer of ePTFE mesh was positioned ventral to the dural sac from L2 to L4. The screw and rods were in place

After radiological identification of L3, the patient was re-draped taking care of including the posterior wound in the field in case simultaneous posterior access would have been needed (Fig. 3). An 8-cm, oblique incision over L3 was performed and the external and internal obliqui and transverse muscles were open in the direction of their respective fibers to access the retroperitoneal space and L3. The approach was performed with directional, pulsed electromyography (EMG) neuro-mapping of the lumbar plexus to detect and protect the neural tissue; the portion of the psoas anterior to the lumbar plexus was resected at the level of the index vertebra to provide wide exposure of the vertebral body. The ipsilateral segmental vessels were ligated, coagulated, and divided. The prevertebral retrovascular space was dissected and blunt retractors were passed in front of the L3 vertebra from disc to disc reaching the opposite side. The contralateral segmental vein was identified and coagulated and the cleavage plane was completed. The anterior portion of the

Fig. 3 Repositioning of the patient on right lateral decubitus. The level of L3 was identified after radiological control and marked on the skin. The wound from the first surgical time was included in the surgical field to allow quick posterior access if needed

L2–L3 and L3–L4 discs were cut longitudinally from the anterior longitudinal ligament in a posterior direction, side to side, with the protection of the anterior malleable blade, which allowed to safely complete the circumferential release of the L3 vertebral body. The body of L3 could be removed en-bloc with an angled, wide mouth, atraumatic forceps. The tumor mass was not breached (Figs. 4, 5). Bleeding from the residual left L3 segmental artery was identified and controlled with clips. The ePTFE mesh was removed. A custom-made composite PEEK/carbon fiber cage (Carbofix, Herzelyia, IL, USA) was filled with the autologous bone fragments obtained from the previous laminectomy and was positioned in the space left by L3 vertebral body. A composite PEEK/carbon fiber plate (Carbofix, Herzelyia, IL, USA) was then introduced, connected by composite PEEK/carbon fiber screws to the cage and to L2 and L4 vertebral bodies. The wound was closed after placing a subfascial wound drainage without negative pressure (Fig. 6). The total estimated blood loss during surgery was 2800 ml (2500 ml during the posterior approach) and the patient received six blood transfusions and two plasma transfusions. A schematic representation of the surgical steps is shown in Fig. 7a–g; the figures are positioned as the MRI scan section in Fig. 1 to facilitate orientation. After surgery, the patient was monitored for one night at the intensive-care unit and, since all vital parameters were stable, could be transferred to the ward on the first postoperative day. Mobilization began on the 2nd postoperative day: initially, we observed a weakness in the abduction of the right leg, which completely recovered within the 4th day after surgery. The patient was gradually able to walk without any aid and was discharged on the 11th postoperative day. Three months after surgery, we did not report any complication (Fig. 8).

The pathological analysis of the resected vertebra confirmed the diagnosis of chordoma and the resection margins were free of tumoral cells. On the side of the spinal canal, the margins were also free from neoplastic cells with a thin layer of fibrotic tissue separating the tumor from the neural structures. Due to the thin margin at epidural space, the patient was referred to medical oncologist for accelerated particle treatment. At the 1-year follow-up, the patient was in good health and presented no sensory or motoric deficits.

Fig. 5 Posterior view of the anatomical piece after removal. The pedicles, cut at their bases, are visible and the prominence of the intact tumor is patent

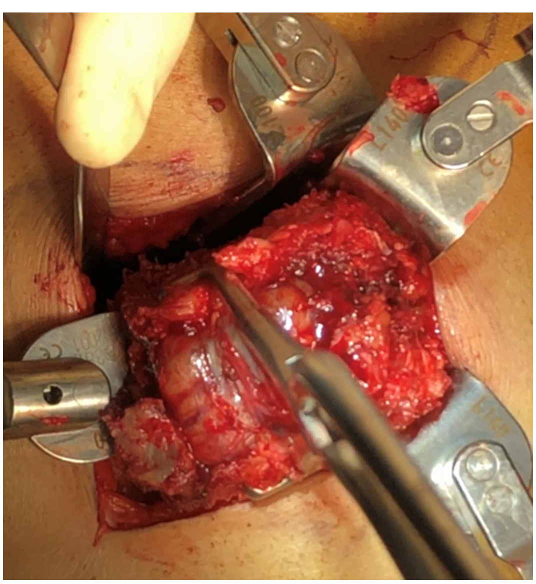


Fig. 4 Extraction of the vertebral body containing the tumor from the anterior approach

Fig. 6 The surgical field after wound closure

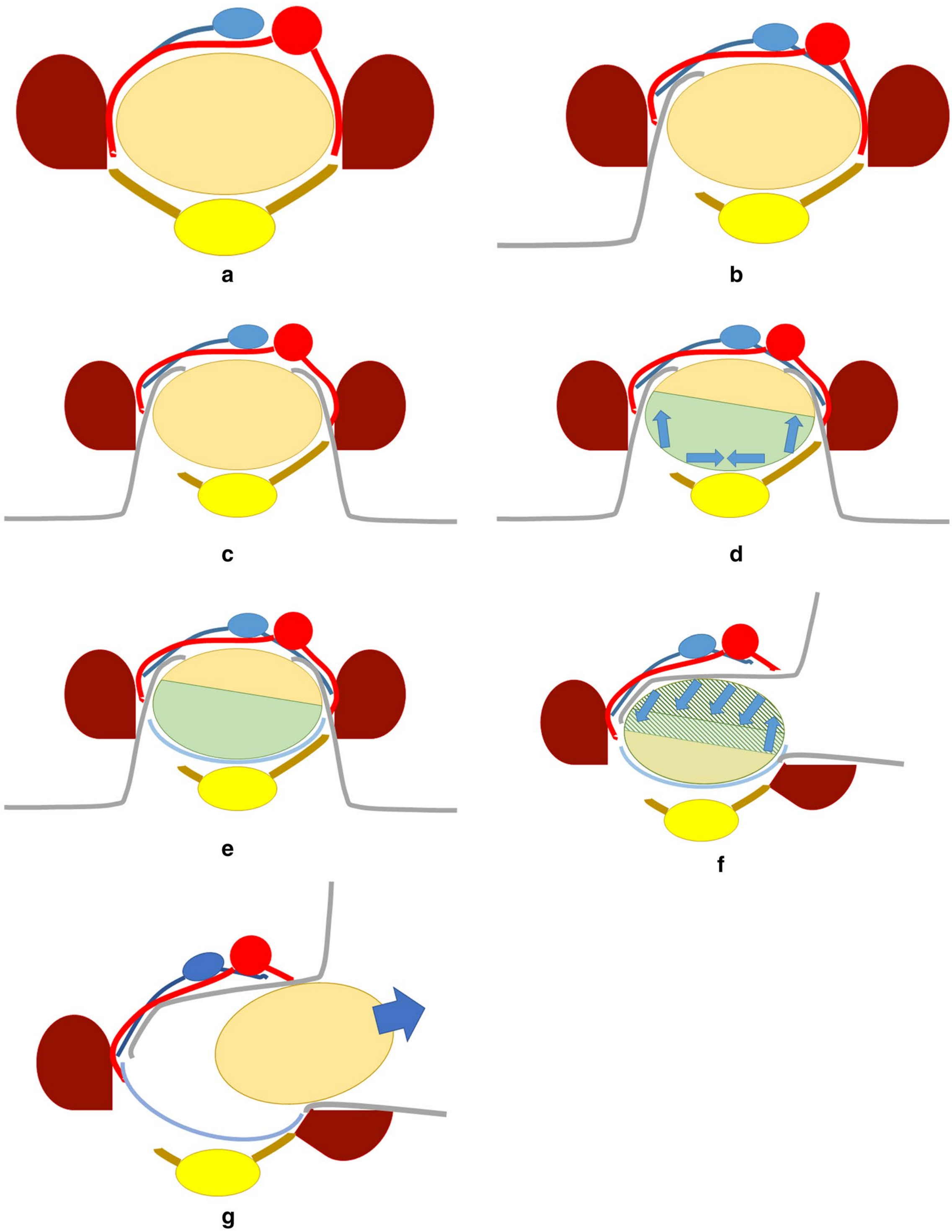
Discussion

To our best knowledge, this is the first report in the literature of an en-bloc resection performed via a combined posterior and mini-retroperitoneal approach for a lumbar chordoma with curative intent. It is well known since 30 years that en-bloc resection by only posterior approach distal to L1 is not advisable, even if the tumor is fully contained within the vertebral body, due to the risks connected with the blunt dissection of the vascular elements, which is not safely feasible as in the thoracic spine [11]. The standard approach to the ventral surgical time would usually be a retroperitoneal lumbotomy with a lateral incision that would have reached from T11–L5. The use of a minimally invasive approach has advantages for the patients, since it allows for a reduction in soft-tissue damage, blood loss, surgical time, and postoperative pain, often leading to a shorter postoperative hospital stay [16]. Blood loss was still considerable in this case—as in all en-bloc resection—due to the epidural bleeding when epidural tumor extension created an obstacle to the venous flow. Generally speaking, tumor patients may have a reduction in wound-healing capacity due to neoadjuvant radiotherapy, steroid therapy, chemotherapy, or cachexia [19], and the rate of surgical site infections can reach up to 25% in metastatic cancer patients [20]. Minimally invasive approaches also allow a quicker start of chemo- or radiotherapy in comparison to conventional open techniques [15]. The use of a less extensive approach with a consequent smaller incision targets this important issue, at least in the ventral time of the surgical procedure.

It is important to underline that a minimally invasive anterior approach can only be successful when the posterior wall of the vertebral body has been completely detached from all ligament, muscle, disc, and most importantly from the neural structures, to prevent any damage while removing the vertebral body. Hence, the use of an ePTFE mesh: to verify the separation between the vertebra and the spinal canal and to obtain a cleavage plan between bony and neural structure, including a continuous tumor-free shell around the tumor mass. Another important requirement is that the annulotomies made posteriorly proximal and distal to the affected vertebra are complete from side to side, and particularly joining each other in the midline. A separation between the lateral sides of the vertebra and the surrounding soft tissue should also be obtained during the posterior surgical time, again to facilitate the ventral surgical time. Since the surgeon cannot be certain that these two goals are achieved during the posterior surgery, the posterior wound should be accessible and prepped during the ventral surgical time. In this way, in case of connection between the posterior and lateral side of the vertebra and the surrounding structures, these can be addressed posteriorly by re-opening the wound.

Independently of the modality of the approach, all the reconstruction should be performed with composite PEEK/carbon fiber systems [21]: the posterior screws and rods, the cage, and the anterior plate with the screws. This titanium-free system allows for accelerated particle therapy [22, 23] to be performed as an immediate adjuvant in case the pathologist detects a violation of the margin, or the margin is considered too thin and at risk of seeding, or later in case of local recurrence.

This case report raises some questions. The sacrifice of L3 right nerve root did not result in a significant loss of function of the quadriceps, which returned to normal function few weeks after surgery. The literature on trans-psoas anterior interbody fusion suggests that the approach can cause dysfunction of the muscles and nerves [24, 25], leading to weakness of the hip flexors and potential damage to the lumbar plexus. In this case, the psoas muscle was completely transected on the left side. Despite this, the patient was still able to flex the hip and walk normally. Though this is an anecdotal observation, it suggests that the mechanism causing the aforementioned side effects of trans-psoas surgery is unclear. The second question raised is to what extent anterior minimally invasive surgery (MIS) is appropriate and in which cases it can be replicated with success. The far-lateral approach was initially described to treat degenerative disc disease, but with increasing experience, it has been successfully applied to a variety of clinical scenarios including spinal cord decompression, fractures, and spinal deformity [26–28]. MIS is reasonable only when the oncological principles can be respected to the same extent as in a standard approach. The decision must be taken combining the anatomical characteristics of the tumor and of the patient, and the surgeon's experience and ability. Performing lumbar, anterior minimally invasive resection (and delivery) is a more difficult procedure than implanting an interbody cage, with a greater variety of maneuvers and skills needed to achieve sufficient exposure and dissection through a reduced incision, bleeding control, safely performing extensive annulotomies, and extraction of the piece without disrupting the boundaries of the tumor. In the future, such procedures may become partially less demanding by developing specific instruments that are currently not available. Due to the anatomical proximity of vascular and nervous structures and of internal organs, complications can present: their resolution might be challenging given the restricted space available and considering that the approach does not allow two surgeons to look simultaneously into the field. Extensive vascular exposure may not be possible through an anterior minimally invasive approach. Endovascular preventive procedures might provide additional safety for these operations [29]. The third question is what should be the competencies of surgeons performing this procedure. Oncological spine surgery is by its nature multidisciplinary. This applies again to the current



case: the surgical team was composed by two senior surgeons, one with extensive oncological experience (SB) and one (PB) with solid background in complex reconstruction, including anterior MIS. This provided a unique environment that increased the ability to preserve the oncological and reconstructive principles of treatment, while reducing its aggressiveness using the anterior MIS approach. It is the perception of the authors that most surgeons expert in either oncological or mini-invasive surgery cannot improvise the knowledge and skills needed to safe and appropriately treat cases like this one with the technique shown.

This study does not come without limitations. It is a single case report. Being focused on details of a new surgical technique, the follow-up is not considered, but the

◂**Fig. 7** **a** Posterior surgical time. Axial view of the spine at the level of the upper disc. The segmental vessels have been represented, though they are in a different plane, more caudally, to show how they are handled. The vertebral arch has been removed. **b** Posterior surgical time. The right root has been ligated to improve the access to the right side of the vertebra. This is the least accessible side from the left anterior approach and needs complete separation. A lateral wall retractor is inserted to expose and dissect the lateral discs and wall from adjacent tissue. The segmental vessels have been clipped and cut. **c** Posterior surgical time. The left lateral wall retractor is inserted underneath the exiting root (from its axilla, without ligation of the root). **d** Posterior surgical time. The disc is cut under the sac from both sides beyond the midline and bilaterally in anterior direction. Due to the difficulty of confirming the complete anterior isolation of the vertebra in the lumbar spine, the release will be completed from the anterior approach. The disc division is carried out more anteriorly on the right side, due to the difficulty of reaching the right side from the anterior left approach. **e** Posterior surgical time. A sheet of ePTFE mesh (light blue) is placed between the vertebra and the dural sac to assure that the dissection is complete and to allow for easier identification of the plane during the anterior approach. **f** Anterior surgical time. Part of the psoas is excised (anterior to the lumbar plexus, identified by pulsed EMG) and the posterior portion is gently retracted posteriorly (only intermittently to avoid damage to the plexus). The left segmental vessels, and in some cases the contralateral ones as well, are ligated and divided. An anterior retractor goes around the vertebra to protect the disc incision on the opposite side. The remaining disc is incised from anterior to posterior (arrows) and the discotomy overlaps with the one performed from the posterior approach (shaded area), completing the release of the vertebral body. **g** The vertebral body is extracted

Fig. 8 Postoperative, standing X-ray in lateral projection

pathologist's report on margins confirmed the efficacy of the procedure. The margins were described as completely tumor free (wide/marginal). Though reduced blood loss is one of the benefits claimed for minimally invasive surgery, in this hybrid procedure, most of the blood loss happened during the posterior open approach and came from epidural bleeding. The procedure was performed by a team with extensive experience in both oncological and MIS reconstructive surgery and the patient had almost ideal conditions of tumor extension within bone boundaries, as the nerve structures were not involved and the tumor did not breach the anterior abdominal wall. It is not possible to establish to what extent this kind of techniques can be generalized to the majority of spine oncological teams. Furthermore, according to the basic criteria to perform en-bloc resection, the tumor extension and the involvement of surrounding anatomical structures must drive the selection of the best surgical technique to reach the oncologic target.

Conclusion

The case here reported showed how it is possible to perform an en-bloc vertebrectomy in the lumbar spine via an open posterior and mini-retroperitoneal anterior approach, maintaining tumor-free surgical margins. The authors also aimed to provide surgical instructions for colleagues wishing to perform this surgical approach in the future. Specific training both in oncologic surgery and in minimally invasive techniques is required for this complex surgical procedure. The approach shown in this case can be applied only to selected cases.

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Declarations

Conflict of interest Pedro Berjano: grants and personal fees from Nuvasive, personal fees from Depuy Sinthes, personal fees from Medacta, personal fees from Zimmer, personal fees from K2M, personal fees from Medtronic, and grants from Stoeckli Medical, from null, outside the submitted work; Alice Baroncini: none; Riccardo Cecchinato: personal fees from Nuvasive and personal fees from Medacta, outside the submitted work; Francesco Langella: none; Stefano Boriani: personal fees from Nuvasive and personal fees from Stryker, outside the submitted work.

Ethical approval Not required.

Informed consent The patient gave written consent to participation to treatment and publication of data.

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