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ORIGINAL ARTICLE

Predictors for surgical complications of en bloc resections in the spine: review of 220 cases treated by the same team

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Abstract
Purpose Identify risk factors, enabling reduction of the rate of complications and improve outcome in en bloc resection surgeries.
Methods A retrospective study of prospective collected data of 1681 patients affected by spine tumors treated from 1990 to 2015 by the same team.
Results A total of 220 en bloc resections that were performed on 216 patients during that period. Most of the tumors were primary—165 cases (43 benign and 122 malignant), metastases occurred in 55 cases. Median FU was 45 months (0–371). 153 complications were observed in 100 patients (46.2 %). 64 (30 %) suffered one complication, while the rest had two or more. There were 105 major and 48 minor complications. Seven patients (4.6 %) died as a result of complications. The combined approach, neoadjuvant chemotherapy and neoadjuvant radiotherapy were statistically significant independent risk factors for complications occurrence. 33 patients (15.2 %) suffered from local recurrence. Reoperations were mostly due to tumor recurrences, but also to hardware failures, wound dehiscence, hematomas and aortic dissection.
Conclusion The rate of complication is higher in multisegmental resections and when double combined approach is performed. Reoperations display greater morbidity owing to dissection through scar/fibrosis from previous operations and possibly from RT. Careful treatment planning and, in the event of uncertainty, referral to a specialty center must be stressed. The high risk of complications should not discourage surgeons from performing en bloc resection when needed. Most of the patients who sustain complications benefit from the better local control resulting from en bloc resection.

Keywords En bloc resection · Vertebrectomy · Complications · Spine tumors · Morbidity

Introduction

The morbidity of spine surgery as a whole is high and is well reported in the literature [1–10]. En bloc resections [11] are the procedures aimed at surgically removing a tumor in a single, intact piece, fully encased by a continuous shell of healthy tissue, which is defined as the ''margin'' and is considered to be of oncological value. These operations can also be performed in the spine [12–18], where anatomical and surgical constraints make them specifically technically demanding. Either combined surgical approaches or a widely enlarged single posterior must be planned for the complete removal of the tumor without violation of its margins. The requirement of a margin encasing the tumor can, at times, be met by resecting relevant anatomical structures [19–24] (pleura, dura, muscles, nerve roots, nerves, vessels, etc.). Intentional transgression of oncological principles [11, 16, 25] may be considered, the advantage in terms of reduced morbidity and better functional results being weighed against the higher risk of recurrence.

En bloc resection has proved effective in improving the prognosis of primary bone tumors of the spine [12, 25–29] and the quality of life of patients with some isolated

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metastases, such as renal cell carcinoma, lung [30–33] and thyroid cancer [34, 35]. The local control of the disease is markedly increased when margins are tumor free, where if an en bloc resection is achieved the local control rises to 92.3 % in giant cell tumor (GCT) [36], to 78 % in chordoma (CHO) [27] and to 82 % in chondrosarcoma (CHS) [28], compared with the local control achieved in the same studies by intralesional surgery: 72.2 % in GCT [30, 36] 22 % in CHO [27] and 0 % in CHS [28]. In a recent study, reporting a series of 103 patients, both marginal and intralesional resections were shown to be an independent risk factors for local recurrence with hazard ratio (HR) of 9.45 and 38.62, respectively [25].

The morbidity of en bloc resection in the spine, however, should always be considered in the decision-making process. In fact the risk of complications increases as the involvement of major spine surgery, long-duration surgical procedure multiple surgical approaches, tumor, and patients possibly immunosuppressed [37], all can be expected to affect the patient's quality of life and well being.

Perioperative treatments such as radiation therapy (RT) and chemotherapy improve oncological outcomes in some tumor types, but also possibly exacerbate the risk of local complications [5, 6, 38].

Only few reports dealing specifically with the complications and outcomes of en bloc resections in the spine have been published to date [25, 39, 40]. Some focusing on specific area of resection such as the cervical spine [41], sacrum [42, 43], while others focusing on specific tumor such as chordoma [41, 43], and metastatic thyroid carcinoma [34]. This paper discusses the complications, which have occurred in the experience of a single team, based on a series of 220 cases of en bloc resections in the spine. These findings include all data previously discussed trying to find statistically significant predictors.

Complications were divided into major and minor, as described by McDonnell et al. [4], and related to time of occurrence, tumor location, surgical procedures including the number of resected segments, previous treatment(s) and adjuvant therapy.

Materials and methods

From January 1990 to July 2015, 1681 consecutive patients with spine tumors were diagnosed and treated in the same institution. 220 en bloc resections were performed on 216 patients by the senior author and his team. All cases underwent full clinical radiographic and histological studies, and were classified according to the Enneking [11] and the WBB [44] oncological and surgical staging systems, respectively. Surgery was planned and conducted accordingly. From the beginning of the period, all available data were inserted into a purpose-built database for use in a prospective study.

The complications were divided into major and minor as described by McDonnell et al. [4]: any complication that appeared to substantially alter an otherwise full and expected course of recovery was considered to be a ''major'' complication; others were regarded as ''minor''. Complications were further classified as intraoperative, early postoperative (within the first 30 days following surgery), and late postoperative (occurring later than 30 days after surgery). Complications were also correlated with the type of resection and the surgical approach performed: single (posterior or anterior) approach or combined anterior and posterior approaches in the same surgical session.

Some patients were previously surgically treated (either open biopsy or a surgical attempt of tumor resection) in another medical facility and were then referred to the AA's institution for further treatment or due to recurrence of the tumor. These were grouped in the category ''contaminated cases'' (CC) for analysis. Conversely, the cases diagnosed and treated in full at the AA's institution were classed as ''non-contaminated cases'' (NCC). Patients were further divided based on neoadjuvant and adjuvant therapy.

Statistical analyses

Continuous variables were expressed as mean ± standard deviation, if Gaussian, or as median and 25th–75th percentile, if skewed. Normality of distribution was assessed by means of the Kolmogorov–Smirnov test. Categorical data were shown as absolute and relative frequencies.

A logistic regression analysis was applied to find predictors of complications, considering gender, age, staging, contamination, surgical approach and neoadjuvant and adjuvant therapy (chemical and radiation) as covariates. The multivariate model included only covariates with a P 0.10 in univariate analysis and was adjusted for location and number of resected levels. Calibration and discrimination of the multivariable model were evaluated by means of the Hosmer–Lemeshow test and the c-statistic, respectively.

A two-sided P value 0.05 was considered to be significant.

For all analyses, SPSS 23.0 statistical software was used (SPSS Inc, Chicago, Illinois).

Terminology for resections [11, 44]:

1. Intralesional excision: defined as piecemeal removal of the tumor was further subcategorized into:
   (a) Intracapsular—where tumor removal was incomplete, thus gross or histological remnants inside the tumor capsule could be expected.

(b) Extracapsular—where the whole tumor mass was removed together with the peripheral tissue (3–5 mm or more of healthy peripheral tissue).

2. En bloc resection: complex surgery aimed at removing en bloc the whole tumor mass, including a cuff of healthy tissue encasing the tumor. The histopathological evaluation of the resected specimen enabled en bloc resections to be further subclassified as:

   (a) Intralesional, if the tumor was violated, either by unplanned incidental violation of the margins, either by planned transgression to spare important neuro-vascular structures, thereby causing tumor spillage.
   (b) Marginal, if a very thin shell of normal tissue covered the tumor.
   (c) Wide, if a thick layer of peripheral healthy tissue, a dense fibrous cover (e.g., fascia), or an anatomical barrier not yet infiltrated (e.g., pleura), fully covered the tumor.

Results

From January 1990 to July 2015, 1681 consecutive patients with spine tumors were diagnosed and treated in the same institution. A total of 220 en bloc resections were performed on 216 patients during that period.

The study group consisted of 113 male and 103 female patients with an average age of 44.1 ± 18 (range 3–82 years). The median follow-up (FU) related to each procedure was 45 months (last clinical FU examination or until death: range 0–371 months). Follow-up was available for at least 24 months in 139 cases (63.2 %); 25 of the remaining 81 died less than 2 years after surgery, seven from complications and 18 from the disease. A total of 61 patients died from the disease. Considering the 220 procedures, 165 cases were performed in primary tumors (43 benign and 122 malignant), 55 in metastases. The location of the tumor was lumbar in 114 cases, thoracic in 95 and cervical in 11. A single (posterior or anterior) approach was adopted in 81 procedures, while 139 involved a combined anterior and posterior simultaneous approaches during the same anesthesia. No resection was staged in more than one operation.

With regard to the margins determined by the pathologist following the examination of the final specimen, 'wide' was obtained in 128 cases; 'marginal' in 61 patients, and 'intralesional' in 31 cases.

For the achievement of clear margins, neurological sacrifice was planned and performed after discussion with the patients in six patients. Four cord resections (CHS at T8, OGS—osteogenic sarcoma at T11, OGS at L1, and chordoma at L2—where the conus medularis had to be resected below T12), and two resections at the level of the cauda equina (OGS at L3, and chordoma at L3), two cases of dura resection (followed by transient paraplegia), and nerve root resections that were performed frequently. Neurological deficits that followed were not considered a complication as they were planned according to the oncological goal of complete tumor en bloc resection.

Other neurological deficits that occurred during and following the surgical resection, such as accidental dural tears, transient paraplegia following the manipulation of the cord during tumor resection, were considered as complications for analysis.

Despite the common concern of ligation related cord ischemia, and subsequent neurological deficit, no cases of such events were recorded, notwithstanding the ligature of the radiculomedullary artery running along the nerve root and feeding the Adamkiewicz. To that extent, in four cases a new A. was demonstrated by post-op angiogram. Later on postoperative angiogram was not performed any more. This figure corresponds to the experimental work published by Kawahara [45], demonstrating that the risk of cord ischemia is primarily connected with the number of nerve roots ligated.

A total of 153 complications after en bloc excision were observed in 100 out of 220 procedures (45.45 %). In 64 cases (29 %) one complication occurred; in 25 (11.3 %) two complications; in 6 (2.7 %) three complications; 3 (1.4 %) had 3 and 2 (0.9 %) had five complications (pneumothorax, hematoma, transient paraplegia, late aortic dissection causing complete paraplegia, and death in one case and pleural damage followed by pneumothorax and mediastinal hematoma with postoperative hyperthermia, and in late follow-up rod breakage without clinical significance in the other case. The patient is with no evidence of the disease at last follow-up of 64 months). Correlated complications were considered and added separately. All failures were analyzed according to severity, temporal distribution, contamination (i.e., previously treated cases) and surgical approach as described in the methods.

All complications were categorized according to temporal distribution and severity. These were further divided into seven groups according to the type of complication (Tables 1, 2). These groups included—vascular failure and bleeding, hardware failure, injury to adjacent structures during and following surgery, injury to the dural sac and neurological unplanned deficit, infections of soft tissue and wound problems, systemic morbidity (including cardiac, renal, respiratory and immunological systems), and hypercoagulable state related problems (including PE, and DVT).

Table 1 Major complications

	Vascular and bleeding	Hardware failure	Adjacent structures	Dura and neurological damage	Infections wound and soft tissue	Systemic—cardiac, renal, respiratory	Hypercoagulable state	Total
Intra	7	1	10	11	1	0	0	30
Early	7	1	2	12	12	15	5	54
Late	5	7	0	3	1	3	2	21
Total	19	9	12	26	14	18	7	105

Table 2 Minor complications

	Vascular and bleeding	Hardware failure	Adjacent structures	Dura and neurological damage	Infections wound and soft tissue	Systemic—cardiac, renal, respiratory	Hypercoagulable state	Total
Intra	5	0	2	6	0	0	0	13
Early	1	0	0	3	0	1	1	6
Late	0	22	1	1	4	1	0	29
Total	6	22	3	10	4	2	1	48

Severity

As described in the methods, complications were categorized as major and minor according to the McDonnell classification [4], these were further divided into seven groups (Figs. 1, 2).

Major

One hundred and five major complications were observed in 71 patients. The most relevant major complications were one intraoperative death due to injury of the vena cava, and three late dissections of the aorta wall, two of which were fatal.

Two myocardial Infarctions occurred in the postoperative course (uneventfully healed). Seven cases of hypercoagulable state were recorded, of them one pulmonary embolism (leading to death), five deep vein thrombosis and one subclavian thrombosis. In 19 cases, injury to blood vessels and bleeding occured. One patient who suffered from a massive intraoperative hemorrhage was stabilized by means of fluid and blood products infusions and hemodynamic controlling medications. Another patient suffered from factor XI def. and was treated with multiple drains and infusions.

Two transitory renal failures were related to intraoperative hemodynamic imbalance. A total of 14 wound and soft tissue problems were recorded, of them five deep infections and three surgical site infections were considered major. Six required surgical debridement and long-term multiple antibiotic treatment. An iatrogenic injury of the left ureter was recognized during surgery and repaired at the time of the primary operation. 26 cases of dural damage and neurological deficit were observed. 12 cases of

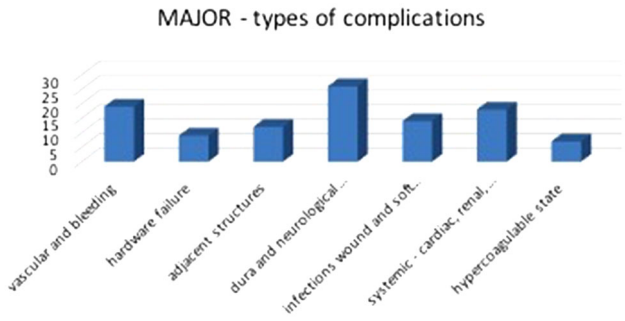

Fig. 1 Major complications—types distribution

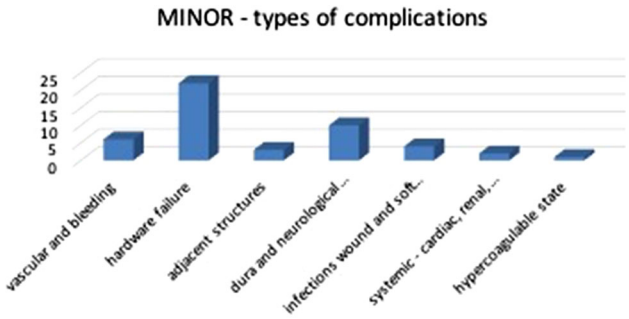

Fig. 2 Minor complications—types distribution

neurological deficit occurred, dural tears that were considered major occurred in ten cases, and CSF leak problems including meningocele were recorded in three cases. In one case, temporary postoperative paraplegia was caused by a significant postoperative hematoma; this patient fully recovered, but 8 months later developed paraplegia again due to the above-mentioned fatal aortic wall dissection. Another peculiar major complication was an ex-vacuo fronto-parietal subdural hematoma due to depletion of cerebrospinal fluid (an intraoperative lesion of the dura could not be repaired).

In nine cases hardware failure required revision of the posterior instrumentation.

Systemic problems occurred in 18 cases including the aforementioned renal failure, two cases of postoperative MI, and 13 cases of respiratory problems. Three hemothoraxes were treated with drains, of them one needed embolization. One case suffering from pleural effusion out of a total of eight cases needed surgical thoracoscopic drainage.

Overall, seven patients (4.6 %) died as a result of complications.

Minor

Forty eight minor complications were observed in 36 patients. Ten of these suffered dural tears and minor neurological damage, six dural tears were successfully repaired during the same procedure. Two patients had Horner syndrome diagnosed in the early postoperative period. In six cases, injury to blood vessels occured. Of them, injuries to the iliac vein and the vertebral artery in two separate patients were immediately repaired and had no sequel. Hardware failure occurred in 22 cases, all did not require further treatment during the entire follow-up period. In three cases, malposition of the hardware resulted in asymptomatic deformity. One patient complained of retro-grade ejaculation. Two cases of acute renal failure were successfully treated by medical therapy. In four cases scar and surgical approach complications occurred. One patient suffered from abdominal hernia following combined approach to the L2 vertebra. All other scar complications were treated locally without further medical sequel.

Temporal distribution

Intraoperative complications

Thirty major and 13 minor intraoperative complications were recorded. Major intraoperative complications were vena cava lesion leading to death, lesion of the aorta, massive hemorrhage from the epidural plexus, and dural tear unrepaired as the lesion was on the opposite side to that of the approach (two cases). Minor complications included malposition of the anterior cage, and dural and vascular injuries which were immediately repaired successfully.

Early postoperative complications

54 major complications and six minor complications were observed.

The major complications included a fatal massive pulmonary embolism and a postoperative paraplegia due to both a massive hematoma and hemothorax. Deep vein thrombosis, pneumothorax and tracheal lesions during intubation were reported among the minor complications.

Late postoperative complications

Twenty one major and 29 minor complications were recorded. The most severe cases were two aortic dissections, which occurred 3 and 8 months after surgery; one was fatal, while the other was successfully surgically treated.

Most major complications occurred in the early postoperative period, whereas most minor occurred in the late postoperative period (Figs. 3, 4 and 5).

Contamination

Forty eight patients (22.5 %) underwent 50 en bloc resection after unsuccessful previous treatment or open biopsy which had contaminated the epidural space and 168 patients were treated since the beginning in the AA's Institution undergoing 170 en bloc resections. Six out of 43 cases with primary benign tumors, 35 out of 122 with malignant tumors and nine out of 55 with metastases were admitted to our department owing to recurrence or progression of the disease. These were grouped in the ''contaminated cases'' (CC) category for analysis. Conversely, the 170 cases fully diagnosed and treated at the AA's

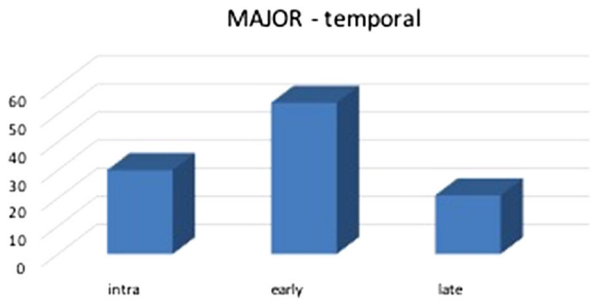

Fig. 3 Major complications—temporal distribution

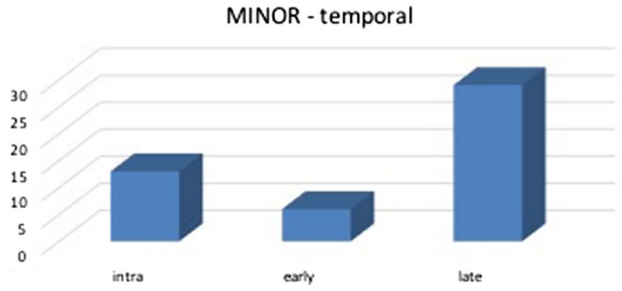

Fig. 4 Minor complications—temporal distribution

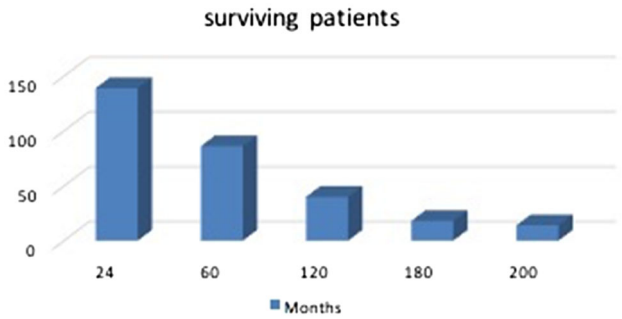

Fig. 5 Patient survival

Institution were included in the ''non-contaminated cases'' (NCC) category.

Of the 50 cases in the CC group, 28 (56 %) had at least one complication whereas in the NCC group, of the 170 NCC cases, 72 (42.35 %) suffered from at least one complication. A total of 48 complication occurred in these 28 cases, 39 major and nine minor. This is compared to a total of 105 complication occurring in the 170 NCC group, (66 major and 39 minor).

Surgical approach

Combined simultaneous anterior and posterior approaches were performed during the same operation [13, 15–17] in 139 cases, with two surgeons contemporarily working, while en bloc resection was achieved by means of a single posterior approach [12–14] in 81 cases.

Complications occurred in 26 (32.1 %) cases treated with a single approach, compared to 74 (53.24 %) treated by a combined approach.

It is noteworthy that the rate of complications was higher in patients that were operated by a combined simultaneous anterior and posterior approaches, than in patients that were treated using a single posterior approach (53.24 vs. 32.1 %, respectively). This difference in complications was statistically significant where the Odds ratio for complications when a combined approach was performed was 3.28 compared to a single approach. (P value 0.002).

Table 3 Complications analysis

Covariate	Multivariate analysis		
	OR	95 % CI	P value
Age	1.021	0.998–1.045	0.05
Male	0.722	0.368–1.417	0.343
Tumor type			
Benign	Reference	Reference	Reference
Malignant	2.56	0.96–6.84	0.06
Metastatic	1.95	0.625–6.17	0.255
Stage—Enneking	1.086	0.781–1.511	0.623
Contamination	1.267	0.549–2.925	0.579
Surgical approach	3.28	1.58–7.35	0.002
Number of levels res.	1.487	0.955–2.314	0.079
Complete vertebrectomy	0.857	0.393–1.868	0.698
Neoadjuvant CHT	4.25	1.339–14.29	0.01
Neoadjuvant RT	4.2	1.034–9.311	0.042
Adjuvant CHT	1.069	0.43–2.604	0.882
Adjuvant RT	1.91	0.724–5.07	0.19

Predictors of complications

The multivariate model used to predict complications included age, gender, oncological stage as described by Enneking, type of tumor (benign, malignant, metastatic), contamination, surgical approach (single or combined), number of levels resected, neoadjuvant and adjuvant chemo and radiotherapy treatment. The models calibration (Hosmer–Lemeshow test = 0.526, Chi-square 7.096, the Omnibus test of models coefficients—Chi-square 35.352, $P = 0$).

The combined approach (OR 3.28, $P = 0.002$), neoadjuvant chemotherapy (OR 4.25, $P = 0.01$) and neoadjuvant radiotherapy (OR 3.2, $P = 0.038$) were statistically significant independent risk factors for complications occurrence. Age was also statistically significant risk factor, however, the OR was irrelevant in this study group (OR 1.021, $P = 0.05$) (Table 3).

Other variables tested in the model—gender, type and staging of the tumor, the number of levels resected and adjuvant CHT, were not statistically significant risk factors for complications to occur.

When performing a multivariate model for predicting a major complication—the combined approach (OR 3, $P = 0.01$), neoadjuvant chemotherapy (OR 5.5, $P = 0.006$) and neoadjuvant radiotherapy (OR 4.2, $P = 0.022$) were still statistically significant risk factors, but also adjuvant RT (OR 3.01, $P = 0.042$) was statistically significant independent risk factor for the occurrence of a major

complication. In this model, age was also statistically significant risk factor, but with an irrelevant OR (OR 1.024, $P = 0.038$).

Local recurrence

A total of 33 patients (15.2 %) suffered from local recurrence. In a multivariate analysis, this was not shown to be a statistically significant independent risk factor for complications to occur.

Discussion

A review of a series of 220 consecutive cases treated with en bloc resection was performed for both risk factor stratification as well as an assessment of the various types and prevalence of failures and patient morbidity. All surgical procedures were performed in the same institution by the same team. These were done following full staging and oncological planning. This series of patients can be considered to represent a homogeneous series of cases.

It is commonly accepted that the morbidity of surgical procedures for spine tumors is related to both the altered anatomy secondary to the tumor growth, and the fibrosis caused by preoperative RT or previous surgery. It is also postulated that the medical status of the patient (affected by the disease as well as chemical or radiation treatment performed preoperatively), affects the body's ability to recover from major surgical procedure.

The peculiar and at times aggressive, surgical techniques required to achieve en bloc resection are expected to increase the rate of complications, as extratumoral resection requires the violation of anatomical barriers and the manipulation or sacrifice of vascular and nervous structures. Bleeding from the tumor's mass is not expected, as surgical excision is planned to be extralesional. It may, however, be caused by incidental tumor violation, damage to the tumor's feeding vessels, or accidental damage to the epidural plexus, all can lead to hemodynamic imbalance if not promptly treated. Manipulation of major vascular structures can cause bleeding, which may be fatal, particularly in revision procedures, where scar tissue and abnormal anatomy are encountered.

Following such long-duration surgeries, postoperative complications may include cardio-vascular, renal and pulmonary failures, but also early problems related to wound dehiscence or infections. Late complications may include mechanical failures, such as breakage or loosening of the complex's circumferential reconstructions. Local recurrences may reflect the failure of the oncological planning.

Accurate analysis of all the incidences is very difficult as most are multifactorial and may lead to other complications (e.g., hematoma after en bloc resection in the thoracic spine creates hemopneumothorax due to resection of the barrier for oncological purposes, and can cause paraplegia). The definition of a complication used in this study was an unplanned medical problem or damage that occurred during or following the surgical procedure. Therefore, in this review, the sacrifice of important structures performed for oncological purposes, was not considered to be complication.

Severity

The global rate of complications was quite high after en bloc resection: in 100 out of 220 cases (45.5 %) at least one complication occurred in the period reported. This rate was similar throughout the study's period. As the incidence of complications is considered to be mainly related to both, the complexity of the procedure, and the experience of the surgeon, it would be expected to improve throughout the years. However, as expected, more elaborate and complex procedures were performed in concordance with the team's experience and developed expertise.

Temporal distribution

Intraoperative complications were more related to manipulation of important and vital structures, the risk of injury being higher in patients who have already undergone surgery or previous RT (fibrous scar, tissue fragility).

Manipulation of the spinal cord, especially in the thoracic spine, should be done with extreme care. Thoracic root transection causes minimal postoperative problems, but allows an easier approach to the tumor's mass by reducing traction and manipulation of the cord. Dural tears are more likely when surgery is performed through the scar from a previous operation. Immediate suturing with either muscular graft coverage or other non-organic grafts generally leads to prompt and satisfactory healing. When water-proof suturing cannot be performed, CSF depletion may lead to further complications. Postoperative hematoma always forms whenever a large void is created by the tumor resection, and may cause immediate paraplegia and early deep infections.

Hemodynamic stability is the main intraoperative concern of anesthetists during en bloc resections, as in all long-duration operations. This can also affect the early postoperative course. In this series, myocardial infarction following a rapid decrease in intraoperative hemoglobin rate complicated two procedures, as an episode of paroxysmal tachycardia was observed; fortunately, all patients recovered during the following few months. A postoperative pulmonary embolism was fatal in one patient. Renal incompetence also followed incomplete control of

hemodynamics. Late complications can also be related to intraoperative problems, such as dissections of the aortic walls in patients who have previously undergone surgery or RT and in whom detachment of the tumor from the aorta is difficult. In such cases, an aortic bypass should be included in the surgical planning to prevent intraoperative injuries and late dissections. As a general rule, the preoperative planning should address such surgical limitations and pitfalls. At times these limitations might prevent the successful achievement of the oncological treatment planned, and a joint decision of the patient and the treating physician should be performed acknowledging the risks and outcomes of limited surgical treatment versus a dangerous complete resection.

Contamination/referred patients

A higher rate of complications was observed in the group of patients who underwent en bloc resection after open biopsy or previous treatment followed by recurrence. This, however, was not statistically significant when performing a multivariate analysis, nevertheless, the tendency still remained for higher complication rate in that group.

Surgical approach

Although en bloc resection by means of a single posterior approach seems less risky (OR 3.28 for complications using a combined approach, $P = 0.002$), it is likely that the more elaborate and complex procedures were perfumed using the combined approach. This higher risk of complications occurring in the combined simultaneous approach remained statistically significant in the multivariate analysis model, after adjustment of the model (including the number of levels resected as well as whether a complete resection of a vertebra was performed), both considered to be indirect parameters of the complexity of the procedure. This suggests that a combined approach has increased risk of complications irrelevant of the complexity of the procedure performed. To that extent, neither the number of levels resected nor the complete resection of a vertebra was shown to be an independent risk factor for complications in the multivariate model. Although both correlated with increased risk of complications when performing a correlation analysis.

Adjuvant therapy

Contrary to what was expected, the rate of complications in the group of patients who underwent adjuvant RT or CHT was not statistically significant higher when performing the adjustment of the multivariate model. One explanation might be that most patient did in fact receive an adjuvant treatment, thus this could not be demonstrated as an independent risk factor in these circumstances.

Nevertheless, adjuvant RT was shown to be a statistically significant independent risk factor for the occurrence of a major complication when comparing to minor and no complications, suggesting that although this treatment does not affect the rate of complications to occur, once occurring with adjuvant RT, there will be a major affect on the patient as described by McDonnell.

Hardware failures

En bloc resection involves not only resecting bone, but also muscle and ligaments, and sacrificing anatomical barriers. The consequent instability is therefore complete, and complex circumferential reconstruction is required [17, 46–48]. As this surgical technique is aimed at removing the tumor, long survival should be expected and planned for. Autogenous grafts and/or bone substitutes should be used to achieve spinal fusion. Chemotherapy and RT may affect the possibility of achieving fusion, and timing is critical. The reconstructive technique that was used in most cases included a posterior pedicle screws and rods, and an anterior column reconstruction construct filled with autogenous graft or bone substitutes [48]. This system failed in 31 (14 %) of our cases, although only in nine cases (4.09 %) did this failure was clinically significant, and required revision surgery. No failure of the anterior construct was observed.

Conclusions

The surgical techniques of en bloc resections are clearly described in the literature. Although there are few reports on large series, these surgical procedures seem to dramatically improve local control in spinal aggressive benign and low-grade malignant bone tumors. Oncologic criteria should guide the decision-making process regarding bone tumors of the spine [11–19, 25–28, 30, 31, 36–39, 44]. When en bloc resection is the procedure of choice, surgical planning should take into account not only the functional sacrifices required to meet oncological requirements, but also the intrinsic morbidity of these procedures. This study describes the incidence and type of complications recorded in a large single-center series of en bloc resections, and highlights the predictors of these events.

The results in terms of better prognosis and better local control [12–19, 25–28, 30, 31, 36, 39, 43] justify performing such highly demanding and risky procedures in aggressive benign and in low-grade malignant bone tumors.

The main risk factors identified on reviewing the series reported were:

- Manipulation of important and vital structures after previous surgery or radiation;
- Incomplete intraoperative control of hemodynamics;
- Double combined approach;
- Too short posterior fixation and lack of anterior support.
- Although radiation therapy does not increase the rate of complications, it was associated with the ones having major affect on the patient.

En bloc resections should be performed by specifically dedicated teams, including trained oncological surgeons and anesthesiologists. The decision-making process leading up to en bloc resection should consider not only the high morbidity as was reported in this study, but also the positive impact on local control and prognosis in aggressive benign and low-grade malignant tumors. In some isolated metastases from renal cell carcinoma, too, the clinical advantages in terms of quality of life and survival are considerable. Before deciding to reduce morbidity by adopting less aggressive surgery or by intentionally violating oncologically appropriate margins, the higher risk of local recurrence should be considered, and the consequent worsening of the prognosis.

The high risk of complications should not discourage surgeons from performing en bloc resection when needed, provided that it is technically possible. Most of the patients who sustain complications benefit from the better local control resulting from en bloc resection. Conversely, local recurrences, which mainly result from inappropriate surgery, negatively affect prognosis and may be associated with a higher risk of complications during subsequent revision surgery.

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Compliance with ethical standards

Conflict of interest None of the authors has any potential conflict of interest.

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