




Spinal Metastasis Surgery: A Proposal for a Predictive Model of Morbidity and Mortality*

Cirurgia em metástase vertebral: Proposta de modelo preditivo de morbimortalidade

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Abstract

Objective To develop a predictive model of early postoperative morbidity and mortality with the purpose of assisting in the selection of the candidates for spinal metastasis surgery.

Methods A retrospective analysis of consecutive patients operated for metastatic spinal disease. The possible prognostic preoperative characteristics were gender, age, comorbidities, tumor growth rate, and leukocyte and lymphocyte count in the peripheral blood. The postoperative outcomes were 30-day mortality, 90-day mortality and presence of complications. A predictive model was developed based on factors independently associated with these three outcomes. The final model was then tested for the tendency to predict adverse events, discrimination capacity and calibration.

Results A total of 205 patients were surgically treated between 2002 and 2015. The rates of the 30-day mortality, 90-day mortality and presence of complications were of 17%, 42% and 31% respectively. The factors independently associated with these three outcomes, which constituted the predictive model, were presence of comorbidities, no slow-growing primary tumor, and lymphocyte count below 1,000 cells/ μ L. Exposure to none, one, two or three factors was the criterion for the definition of the following categories of the predictive model: low, moderate, high and extreme risk respectively. Comparing the risk categories, there was a progressive increase in the occurrence of outcomes, following a linear trend. The discrimination capacity was of 72%, 73% and 70% for 30-day mortality, 90-day mortality and complications respectively. No lack of calibration occurred.

Keywords

- ▶ spine/surgery
- ▶ comorbidity
- ▶ lymphocytes
- ▶ morbidity
- ▶ mortality
- ▶ neoplasm metastasis
- ▶ postoperative complications

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Resumo

Palavras-chave

- ▶ coluna vertebral/cirurgia
- ▶ comorbidade
- ▶ linfócitos
- ▶ morbidade
- ▶ mortalidade
- ▶ metástase neoplásica
- ▶ complicações pós-operatórias

Conclusion The predictive model estimates morbidity and mortality after spinal metastasis surgery and hierarchizes risks as low, moderate, high and extreme.

Objetivo Desenvolver um modelo preditivo de morbimortalidade pós-operatória precoce com o intuito de auxiliar na seleção dos candidatos à cirurgia para metástase vertebral.

Métodos Análise retrospectiva de pacientes consecutivos operados por doença metastática vertebral. As características pré-operatórias consideradas possivelmente prognósticas foram: sexo, idade, comorbidades, velocidade de progressão tumoral e contagem de leucócitos e linfócitos no sangue periférico. Os desfechos pós-operatórios analisados foram: mortalidade em 30 dias e em 90 dias, e presença de complicações. Um modelo preditivo foi desenvolvido a partir de fatores independentemente associados a esses três desfechos. Testou-se então o modelo estabelecido quanto à tendência de prever eventos adversos, à capacidade de discriminação e à calibração.

Resultados Um total de 205 pacientes foram operados entre 2002 e 2015. A mortalidade em 30 dias e em 90 dias e a incidência de complicações foram de 17%, 42% e 31%, respectivamente. Os fatores independentemente associados a esses três desfechos, e que constituíram o modelo preditivo, foram: presença de comorbidades, tumor primário de progressão não lenta, e linfócitos abaixo de 1.000 células/ μ L. A exposição a nenhum, um, dois ou três fatores definiu as categorias do modelo preditivo: baixo, moderado, alto e de extremo risco, respectivamente. Comparando-se as categorias, houve aumento progressivo na ocorrência dos desfechos, seguindo tendência linear. A capacidade de discriminação foi de 72%, 73% e 70% para mortalidade em 30 dias, em 90 dias e incidência de complicações, respectivamente. Não ocorreu falta de calibração.

Conclusão O modelo preditivo permite estimar a morbimortalidade após a cirurgia para metástase vertebral e hierarquizar os riscos em baixo, moderado, alto e extremo.

Introduction

The surgical treatment for vertebral metastasis is related to a high incidence of postoperative complications;¹ therefore, it is controversial, and has been debated in the academic environment for decades.² Other forms of treatment, such as radiotherapy, have fewer adverse effects,³ and are becoming increasingly attractive, especially because the patients often do not reach twelve months of survival.⁴ The patient with metastatic spinal disease (MSD) is on average 60 years old, and has a health condition weakened by comorbidities such as immunosuppression and malnutrition.⁵

In cases of surgical treatment of MSD, postoperative complications occur in 17-51% of cases,^{1,6} and they often affect negatively the natural history of the disease, abbreviating the patient's already short survival. On the other hand, when considering surgery, there is scientific evidence on the benefits of this treatment, even with better results than radiotherapy alone,⁷ because it enables the direct intracanal decompression of the structures (resection of the tumor mass), as well as the mechanical stabilization of the spine by surgical fixation. These procedures may lead to maintenance/recovery of urinary function, reduction in pain, and recovery, in some cases, of the ability to walk.⁸⁻¹⁰

The anticipation of adverse events from surgery in cases of MSD and the prediction of the positive or negative evolution of the cases operated using predictive models (PMs) also

resulted in many researches. Several PMs are available in the literature, some of which help in patient selection, but the majority has the primary function of estimating patient survival time.¹¹ The authors did not find in the current literature any PM that would help estimate early morbidity and mortality after the surgical treatment of MSD. Thus, the objectives of the present study were to evaluate the clinical and laboratory parameters that influence early morbidity and mortality after the surgical treatment of MSD and determine, based on the multivariate analysis of these parameters, a PM that helps the attending physician estimate early postoperative morbidity and mortality in patients with vertebral metastatic lesions.

Materials and Methods

We conducted a retrospective analysis of a cohort of patients operated for MSD between January 2002 and December 31, 2015. The present study was approved by the Ethics Committee of the institution where it was performed. As this was a retrospective study, there was no need to apply the Informed Consent Form.

Inclusion Criteria

(1) Single and consecutive patients undergoing open surgery; and (2) presence of anatomopathological study confirming the diagnosis of metastatic vertebral malignant neoplasia.

Exclusion Criteria

(1) Primary surgery or revision in another institution; (2) incomplete medical record data; and (3) loss to follow-up.

Determination of possible prognostic risk factors

The authors considered the following preoperative characteristics as possible risk factors for the occurrence of negative outcomes in MSD:

1. male gender;
2. age \geq 70 years;
3. presence of at least one comorbidity from the list in **Box 1**.
The listed comorbidities were obtained by combining the significant comorbidities proposed by Charlson et al¹² and Elixhauser et al;¹³
4. primary tumor not considered slow-growing. The model developed by Tomita et al¹⁴ was adopted, in which breast, prostate and thyroid cancers are considered slow-progressing neoplasms. In this group, multiple myeloma and lymphoma were also considered slow-progressing tumors;
5. leukocyte count \geq 13,000 cells/ μ L in the peripheral blood; and
6. lymphocyte count $<$ 1,000 cells/ μ L in the peripheral blood.

Possible Outcomes for the Predictive Model of the Treatment for Vertebral Metastatic Disease

In order to elaborate the PM, the following outcomes were considered:

1. mortality 30 days after surgery;
2. mortality 90 days after surgery;
3. incidence of at least one complication.

Postoperative complications were those occurring within 30 days of the procedure, based on the definition of the World Health Organization (WHO).¹⁵ They were characterized and classified by the method of Rampersaud et al;¹⁶ only the major were included, and they were grouped into:

1. local/systemic;
2. infectious/non-infectious.

Box 1 Comorbidity index

- Diabetes
- Chronic lung disease
- Previous myocardial infarction
- Congestive heart failure
- Cardiac arrhythmia
- Pulmonary circulation disease
- Peripheral vascular disease
- Cerebrovascular disease
- Dementia
- Renal insufficiency
- Liver failure
- Connective tissue disease
- Coagulopathy
- Previous paralysis
- Peptic ulcer
- Acquired immunodeficiency syndrome

Predictive Model

Comparing the frequency of occurrence of outcomes in individuals exposed and not exposed to possible risk factors, the multivariate analysis determining the factors with statistical significance and the factors associated with all outcomes enabled the ranking of the risks as low, moderate, high and extreme. The PM was tested for trend of occurrence of events, capability of discrimination and calibration.

Statistical analysis

Continuous variables were dichotomized and treated as categorical variables. The Fisher and Chi-squared tests were applied for risk assessment. The analysis of mortality at 30 and 90 days postoperatively was performed separately for each point in time. The Kaplan-Meier method was used to elaborate survival curves. The final PM categories were compared for the trend of occurrence of events through the Chi-squared test. The discriminatory capacity and calibration of the final model were analyzed using the receiver operating characteristic (ROC) curve and the Hosmer-Lemeshow test respectively. Logistic regression models were applied to the groups of variables, provided that $p < 0.05$ in the bivariate analysis. The confidence interval was of 95% for all analyzes. The following software were used to perform the statistical tests: R (R Foundation for Statistical Computing, Vienna, Austria), version 3.3.1, and MedCalc (MedCalc Software, Oostend, Belgium), version 17.6.^{17,18}

Results

Patients

A total of 306 patients were submitted to surgery, and after the adoption of the inclusion and exclusion criteria, 205 patients were included in the study. The general characteristics of the studied patients are presented in **►Table 1**.

Possible Prognostic Risk Factors

A total of 114 patients (55%) were male; 48 patients (23%) were \geq 70 years old; 65 patients (32%) had 1 or more comorbidities; 81 patients (40%) had tumors that were not slow-growing; 40 patients (20%) had leukocytes \geq 13,000 cells/ μ L (mean of 9,700 cells/ μ L); and 51 patients (25%) had lymphocytes $<$ 1,000 cells/ μ L (mean of 1,600 cells/ μ L).

Possible Outcomes of Metastatic Spinal Disease Treatment in the Development of the Predictive Model

The mortality at 30 days was of 17% ($n = 36$), and at 90 days, it was of 43% ($n = 88$). The incidence of postoperative complications was of 31% ($n = 64$), and it is presented in **►Table 2**.

Statistical Analysis

►Tables 3 and 4 present a risk analytical study regarding the possible predictors of outcomes. We found that the characteristics that act as an independent risk factor for the occurrence of systemic complications are: age \geq 70 years

Table 1 General characteristics of the 205 patients who underwent surgery for vertebral metastasis

Variables	n (%)
Male gender	114 (55%)
Age (years), mean \pm standard deviation	58.9 \pm 13.3
Deaths before discharge	14 (7%)
Alive during data collection	12 (6%)
Approach	
Cervical/cervicothoracic	11 (5%)
Thoracic	70 (34%)
Thoracolumbar	71 (35%)
Lumbar/Lumbosacral	49 (24%)
Multiple	4 (2%)
Posterior approach	201 (95%)
Primary tumor	
Prostate	51 (24%)
Breast	43 (21%)
Multiple myeloma	26 (13%)
Unknown	20 (10%)
Uterus	12 (6%)
Other	53 (25%)
Comorbidities	
Diabetes	25 (12%)
Chronic lung disease	20 (10%)
Cardiac insufficiency	7 (3%)
Previous myocardial infarction	5 (2%)
Cardiac arrhythmia	4 (2%)
Other	13 (6%)

old (odds ratio [OR]: 2.44, $p < 0.05$); primary tumor that is not slow-growing (OR: 2.54; $p < 0.05$), and total lymphocyte count $< 1,000$ cells/ μ L (OR: 3.19; $p < 0.01$). Primary tumor that is not slow-growing is the only preoperative feature associated with surgical site infection (OR: 2.52; $p < 0.05$). Age ≥ 70 years old and primary tumor that is not slow-growing are independent risk factors for infectious complication (OR: 2.82; $p < 0.05$; and OR: 3.22; $p < 0.01$ respectively). After the multivariate analysis, the complication-related mortality was associated with age ≥ 70 years old (OR: 3.35; $p < 0.01$), presence of comorbidities (OR: 2.74; $p < 0.01$), and total lymphocyte count $< 1,000$ cells/ μ L (OR: 3.61; $p < 0.0001$). Death related to infectious complications, after the analysis of the multiple variables, correlates with age ≥ 70 years (OR: 2.61; $p < 0.05$), primary tumor that is not slow-growing (OR: 2.82; $p < 0.05$), and total lymphocyte count $< 1,000$ cells/ μ L (OR: 4.23; $p < 0.01$).

Predictive Model

► **Table 4** explains the independent risk factors for the outcomes of the present research. Those with statistical signifi-

Table 2 Incidence of complications after surgical treatment for vertebral metastasis

Variables	n (%)
Systemic	
Pneumonia	14 (6.8)
Death by unknown cause	11 (5.4)
Gastrointestinal bleeding	4 (2.0)
Respiratory failure	3 (1.5)
Renal insufficiency	2 (1.0)
Sepsis with urinary focus	1 (0.5)
Sepsis with unknown focus	1 (0.5)
Other	4 (2.0)
Subtotal	40 (19.5)
Local Complications	
Wound infection	20 (9.8)
Dehiscence	2 (1.0)
Hematoma	1 (0.5)
Neurological worsening	1 (0.5)
Subtotal	24 (11.7)
Infectious	36 (17.5)
Non-infectious	28 (13.7)
Grade III	19 (9.3)
Grade IV	45 (21.9)
Total	64 (31.2)

Note: According to Rampersaud et al,¹⁶ grade-III complication requires significant treatment (such as unexpected surgery or readmission, for example), increasing the hospital stay by more than 7 days and/or causing sequelae for more than 6 months. Grade-IV complication is one that results in death.

cance for the three outcomes were included in the PM, which is illustrated in ► **Box 2**.

► **Figures 1, 2 and 3** show the survival curves at 90 days postoperatively according to the characteristics used to develop the final PM. Exposure to none, one, two or three factors was the criterion that defined the categories of low, moderate, high and extreme risk respectively. ► **Figure 4** illustrates the incidence of early morbidity and mortality according to each risk category of the PM. ► **Figure 5** shows survival at 90 days postoperatively according to the four risk

Box 2 Predictive model

Risk factors	Present factors	Risk category
<ul style="list-style-type: none"> • Presence of at least one comorbidity • Primary tumor that is not slow-growing • Total peripheral blood lymphocyte count below 1,000 cells/μL 	0	Low
	1	Moderate
	2	High
	3	Extreme

Table 3 Bivariate analysis of preoperative characteristics as possible prognostic factors of early morbidity and mortality after surgical treatment for vertebral metastasis

Characteristic	n (%)	Odds ratio for mortality at 30 days (CI)	Odds ratio for mortality at 90 days (CI)	Odds ratio for incidence of complications (CI)
Sex				
Female	91	Ref.	Ref.	Ref.
Male	114	1.00* (0.48–2.06)	1.05* (0.60–1.83)	1.15* (0.63–2.10)
Age (years)				
< 70	157	Ref.	Ref.	Ref.
≥ 70	48	2.94*** (1.37–6.31)	2.08** (1.08–4.00)	3.13**** (1.60–6.14)
Comorbidities				
Absent	140	Ref.	Ref.	Ref.
Present	65	2.60*** (1.24–5.41)	2.87**** (1.57–5.27)	2.61*** (1.40–4.88)
Slow-growing primary tumor				
Yes	124	Ref.	Ref.	Ref.
No	81	2.21** (1.07–4.59)	3.79**** (2.10–6.85)	2.48*** (1.35–4.56)
Leukocytes (μL)				
< 13,000	165	Ref.	Ref.	Ref.
≥ 13,000	40	1.78* (0.77–4.08)	3.17*** (1.54–6.52)	1.81* (0.88–3.74)
Lymphocytes (μL)				
≥ 1,000	154	Ref.	Ref.	Ref.
< 1,000	51	3.06*** (1.44–6.52)	1.96** (1.03–3.72)	2.71*** (1.40–5.25)

Abbreviations: CI, 95% confidence interval; Ref., reference variable.

Note: Values of p : * if $p > 0.05$; ** if p between 0.05 and 0.01; *** if p between 0.01 and 0.001; **** if $p < 0.001$.

Table 4 Multivariate analysis of preoperative characteristics as possible prognostic factors of early morbidity and mortality after surgical treatment for vertebral metastasis

Characteristic	n (%)	Odds ratio for mortality at 30 days (CI)	Odds ratio for mortality at 90 days (CI)	Odds ratio for incidence of complications (CI)
Age (years)				
< 70	157	Ref.	Ref.	Ref.
≥ 70	48	2.73** (1.20–6.20)	2.06* (0.98–4.36)	3.15*** (1.51–6.59)
Comorbidities				
Absent	140	Ref.	Ref.	Ref.
Present [†]	65	2.33** (1.07–5.07)	2.60*** (1.33–5.12)	2.37** (1.21–4.65)
Slow-growing primary tumor				
Yes	124	Ref.	Ref.	Ref.
No [†]	81	2.56** (1.17–5.62)	4.30**** (2.23–8.30)	3.07*** (1.56–6.04)
Leukocytes (μL)				
< 13,000	165	Ref.	Ref.	Ref.
≥ 13,000	40	--	2.94** (1.29–6.70)	--
Lymphocytes (μL)				
≥ 1,000	154	Ref.	Ref.	Ref.
< 1,000 [†]	51	3.07*** (1.37–6.87)	2.19** (1.06–4.51)	2.84*** (1.37–5.85)

Abbreviations: CI, 95% confidence interval; Ref., reference variable.

Notes: [†] Characteristic included in the predictive model (PM) by the association with the three outcomes. Values of p : * if $p > 0.05$; ** if p between 0.05 and 0.01; *** if p between 0.01 and 0.001; **** if $p < 0.001$.

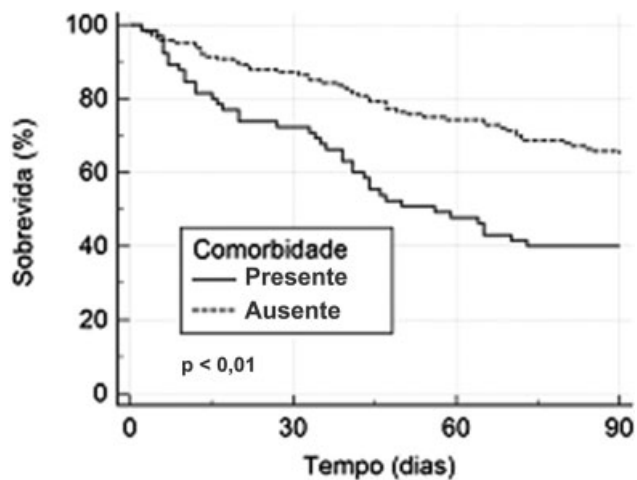


Fig. 1 Survival at 90 days postoperatively according to the presence of comorbidities.

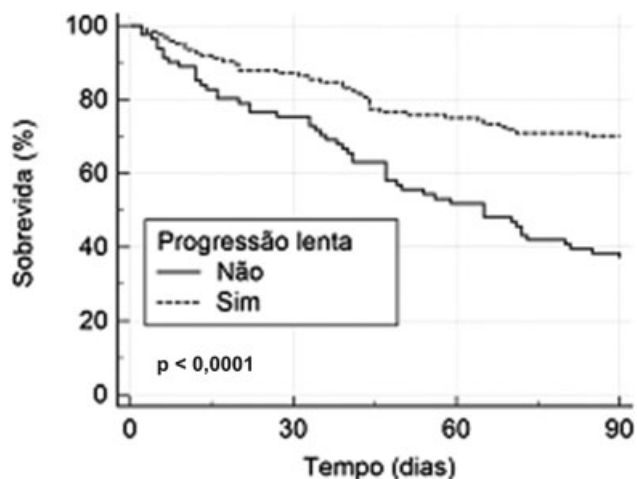


Fig. 2 Survival at 90 days postoperatively according to the velocity of tumor progression.

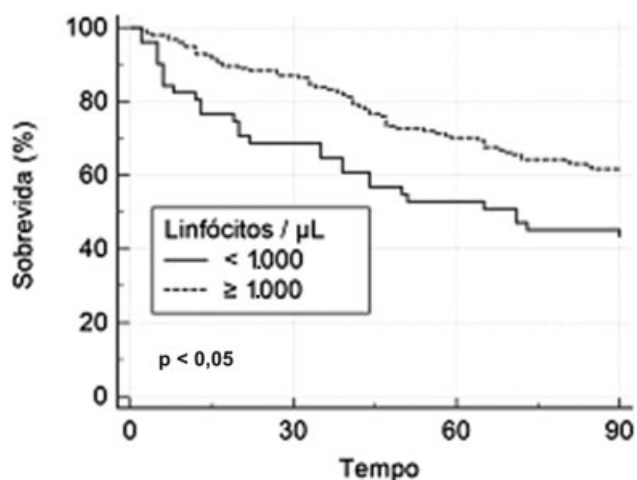


Fig. 3 Survival at 90 days postoperatively according to the preoperative lymphocyte count in the peripheral blood.

categories. Comparing the categories from lowest to highest risk, there was a progressive increase in the occurrence of outcomes, following a linear trend ($p < 0.0001$). The

same occurred when analyzing systemic complications ($p < 0.0001$), infectious complications ($p < 0.0001$), death from complication ($p < 0.0001$), death from infectious complication ($p < 0.0001$) and surgical wound infection ($p < 0.05$). The discriminatory capacity of the model, according to the ROC curve, was of 72% for the 30-day mortality, 73% for the 90-day mortality, and 70% for the incidence of complications. There was no evidence of lack of calibration by the Hosmer-Lemeshow test.

Discussion

The complications of MSD in relation to unfavorable surgical outcomes, including death, which is the worst of them, are in no way comparable to those obtained in the surgical treatment of most orthopedic diseases. In MSD surgery, 90-day mortality is important, and most authors agree that this time interval is the minimum expected to indicate a highly morbid and palliative procedure.¹⁹ However, there are few studies addressing this cutoff point in postoperative survival.²⁰

Preoperative clinical characteristics are supposed to exert greater influence on early surgical outcomes compared with long-term outcomes. Traditional PMs, such as the scoring system of Tokuhashi,²¹ focus more on features that are associated with mid- and long-term surgical outcomes, such as the presence of visceral metastases. Perhaps because of this, the Tokuhashi score only estimates events from 180 days after the procedure. More recently, Schoenfeld et al²⁰ showed the serum level of albumin as a strong risk factor for mortality within 30 days, even surpassing the rate of tumor progression. The present study, hoping to identify more significant prognostic factors that could positively alter outcomes within three months of the procedure, evaluates some clinical features that are less valued in previous studies, such as comorbidities and peripheral blood cell count.

Comorbidity rates are rarely addressed in MSD research. Patil et al¹ reported a 50% increased risk of complications from MSD surgery in patients with two comorbidities, as reported by Elixhauser et al.¹³ Arrigo et al²² noted an increased risk of up to five times in patients with two or more comorbidities mentioned by Charlson et al.¹² The present work shows that the presence of at least one comorbidity among those obtained by the combination of those comorbidities mentioned by Charlson et al¹² and Elixhauser et al¹³ represents an independent risk factor for early morbidity and mortality after metastatic spinal surgery. This is a risk factor not previously reported in the literature.

Secondary lymphocytopenia may have several etiologies, including malnutrition, infection, corticosteroid use, radiotherapy and chemotherapy. These conditions are common in MSD. Lymphocytopenia reduces the action of lymphocytes B, T and natural killers against bacteria, viruses and fungi, leaving the body susceptible to local or distant infections. Zinc and some vitamins play a role in cell maturation, and their deficiency may partly explain the lymphocytopenia presented by malnourished patients.²³ Although low lymphocyte count is an old nutritional marker²⁴ and a known factor of poor prognosis in cancer,²⁵ surprisingly, the literature review does not show

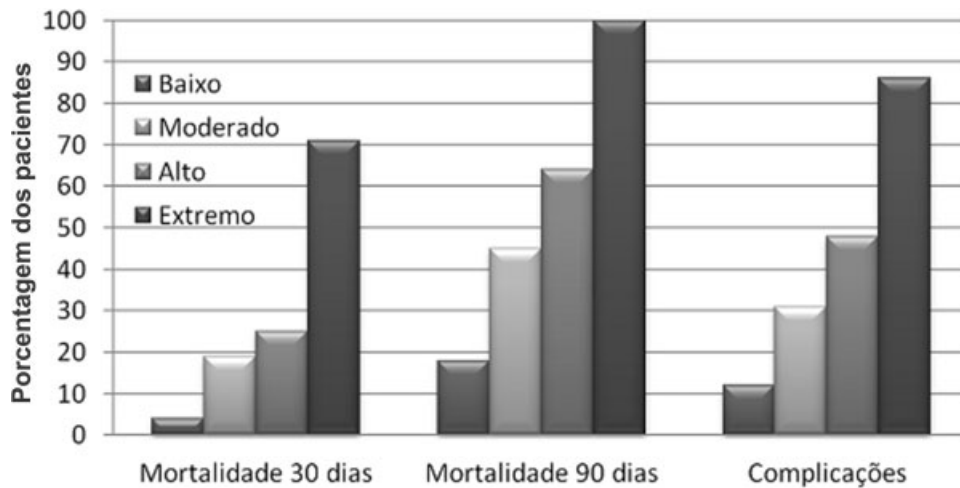


Fig. 4 Early morbidity and mortality after surgical treatment for vertebral metastasis, according to the proposed predictive model (PM).

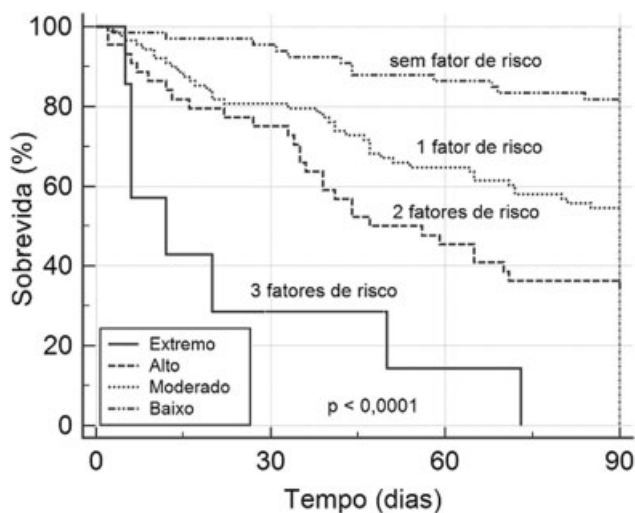


Fig. 5 Survival at 90 days postoperatively according to the proposed predictive model (PM).

preoperative lymphocytopenia as a risk factor for MSD surgery. Revised studies use a different cutoff point for the cell count ($1,500/\mu\text{L}$), which may explain the conflicting findings.^{5,26} On the other hand, in the current research, the total lymphocyte count $< 1,000/\mu\text{L}$ proved to be a strong risk factor. The presence of these data represents a significant increase factor in the early occurrence of complications and death. It was related to a nearly five-fold increased risk of death from infectious complications. In this series, one patient with total preoperative total lymphocyte count of $245/\mu\text{L}$ died due to sepsis by *Candida sp*, a rare causative agent of systemic infection.

Previous studies have shown that older patients have worse MSD surgical outcomes.^{26,27} In the present study, we identified that individuals aged 70 years and older have a 2.73-fold increased risk of 30-day mortality; 3.15 times more total complications; 2.44 times more systemic complications; 2.82 times more infectious complications; 3.35 times more incidence of death by complications; and 2.61 times more incidence of death from infectious complications. However, because it failed to predict the 90-day mortality, this feature was excluded from the final PM.

The results about the influence of the aggressiveness of the primary tumor in the incidence of complications and mortality at 30 and 90 days after surgery are not surprising. Several previous studies report worse prognosis in groups of patients with tumors with more aggressive histological types.²⁶

In the present work, a PM was proposed to estimate early morbidity and mortality in MSD that considers not only the aggressiveness of the primary tumor, but also the patient's systemic condition. (► **Box 2**). Laufer et al,²⁸ in their management algorithm, state that the patient's systemic condition is a decisive factor in the surgical decision-making. However, none of the many existing PMs in the literature consider the presence of comorbidities and the patient's immune capacity.¹¹ Only Ghori et al²⁹ refer to the influence on nutritional status by analyzing serum albumin, and they suggest this factor as a possible tool to estimate complications.

The proposed PM estimates, by category, the occurrence of unfavorable events within 90 days of surgery. In the present study, low-risk patients had the lowest postoperative morbidity and mortality rates, while patients in the extreme-risk category had the worst outcomes (► **Figures 4 and 5**). Future research could shed light on whether this PM is useful in guiding the therapeutic decision. It is believed that, due to its simplicity of application, this PM could be one of the first tools used to evaluate the patient with MSD.

The present research has several limitations, and undoubtedly needs future validation, especially in relation to the PM results. Due to the retrospective design, selection, measurement and susceptibility, bias may have occurred. The results may not be generalizable because the study was conducted in a single institution and on a typically heterogeneous sample.

Conclusion

Preoperative factors that enable the prediction of early morbidity and mortality for MSD are age ≥ 70 years, presence of at least one comorbidity of the specific index, primary tumor that is not slow-growing, leukocytes $\geq 13,000$ cells/ μL and total lymphocyte count $< 1,000$ cells/ μL . The proposed PM enables

the estimate of the morbidity and mortality of surgery in cases of MSD, and the ranking of the surgical risks as low, moderate, high and extreme.

Conflicts of Interest

The authors have none to declare.

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