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Non-Operative Management of Spinal Metastases: A Prognostic Model for Failure

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Abstract

Objectives: To describe patient-specific characteristics associated with non-operative failure leading to surgery.

Patients and Methods: We conducted a retrospective review of patients treated for spinal metastases from 2005–2017. We deemed patients as failures if they were treated non-operatively and then received a surgical intervention within one year of starting a non-operative regimen. We used multivariable Poisson regression to identify factors associated with non-operative failure. We conducted internal validation using bootstrapping with 1,000 replications.

Results: We identified 1,205 patients with spinal metastases, of whom 834 were initially treated non-operatively and constituted the analytic sample. Of these 77 (9%) went on to have surgery within 1-year of presentation and were deemed non-operative treatment failures. We identified vertebral body collapse and/or pathologic fracture (adjusted Risk Ratio [RR] 1.75; 95% Confidence Interval [CI] 1.11, 2.76) and neurologic signs or symptoms at presentation (RR 1.90; 95% CI 1.19, 3.03) as factors independently associated with an increased risk of non-operative failure. Platelet-lymphocyte ratio >155, a marker for inflammatory state, was also associated with an increased risk of failure (RR 2.32; 95% CI 1.15, 4.69). Failure rates among those with 0, 1, 2 or all three of these risk factors were 5%, 7%, 12% and 20%, respectively ($p=0.004$).

Conclusion: We found that 9% of patients with spinal metastases initially treated non-operatively received surgery within 1-year of commencing care. The likelihood of surgery increased with the number of risk factors. These results can be used in counseling and shared decision making at the time of initial presentation.

Keywords

spinal metastases; surgery; non-operative treatment; survival; ambulatory function; prognosis

Introduction

Due to advancements in surveillance and medical treatments for cancer, there are now more patients living with spinal metastases than ever before in history.^{1,2} Current estimates suggest that over 20,000 new diagnoses of metastatic epidural compression are made each year.^{1,3} The development of spinal metastases may portend increased risk for physiologic decline, neurological deterioration and mortality within the year of diagnosis.^{1,3–6}

While numerous investigations have shown benefit for both operative and non-surgical management of spinal metastases in select situations,^{1–5,7–14} several suggest a surgical approach may be more advantageous in terms of preserving ambulatory function.^{2,4,7,11,14} Surgery for spinal metastases is known to be associated with high rates of peri-operative morbidity as well as the potential for iatrogenic neurologic decline.^{5,6,8,9,11,12,13} Many patients will elect non-operative treatment in order to avoid peri-operative complications.¹ However, non-operative treatment may fail and patients who receive surgery following non-

operative management have been reported to be at increased risk of wound breakdown, infection, and construct failure.^{3,7} Therefore, it would be useful to identify patients who are at increased risk of failure of non-operative management at the time of presentation.

In this context, we sought to evaluate factors at presentation that were associated with the eventual need for surgery after non-operative treatment had been initiated. We performed this investigation using the medical records of patients treated at Brigham and Women's Hospital and Massachusetts General Hospital over the course of 2005–2017.

Patients and Methods

Data Source

We conducted this retrospective study using medical information contained in the Partner's Healthcare Data Repository (RPDR) and the electronic medical records of two tertiary academic centers. Data from these centers have been successfully utilized in the past to study the treatment of primary bone tumors, metastatic disease and outcomes following operative and non-surgical management of spinal metastases.^{6,15,16,17} We included patients 40–80 years old in this investigation if they were treated for spinal metastatic disease at one of our two tertiary care centers between January 1, 2005 and June 30, 2017. Chart abstraction was completed on August 1, 2018. We excluded patients with primary spinal tumors such as chordoma, or primary osteogenic sarcoma of the spine.

Data Elements

We abstracted medical records of all individuals meeting inclusion criteria and obtained socio-demographic characteristics, number of co-morbidities defined using the Deyo modified Charlson Co-morbidity index (CCI)¹⁸, body mass index (BMI), primary cancer diagnosis, and the location of spinal and extra-spinal metastases. We determined the presence of vertebral body collapse and/or pathologic fracture, spinal canal compromise (e.g. stenosis or nerve impingement from a metastatic process), ambulatory status, and spine-related symptoms at presentation for treatment. These factors were abstracted from the medical record as documented by treating oncologists, radiation oncologists, surgeons and/or radiologists. Vertebral body collapse was recorded when there was documented evidence of loss of height of the vertebral body due to the presence of spinal metastases. Pathologic fracture was recorded when an actual fracture was noted in the vertebral body, either through the metastatic process or adjacent to it in the compromised vertebral elements. To minimize the potential for misclassification, both vertebral body collapse and pathologic fractures were grouped together as a single variable. We abstracted laboratory values at presentation, including white blood cell (WBC) count, serum albumin and platelet/lymphocyte ratio (PLR), a marker of inflammation found to be predictive of outcomes in prior oncologic research.^{17,19,20}

Outcomes

Based on prior work, we defined the primary treatment approach as interventions received within the first 8-weeks following presentation with spinal metastases.²¹ Patients who received surgery in the first 8-weeks following presentation, with or without neoadjuvant

chemotherapy and/or radiation, were considered as having received a primary surgical treatment approach and were excluded from further consideration.²¹ We then recorded the type(s) of non-operative treatment received and the type of surgical approach in those who ultimately received a surgery for the same metastatic process within the first 365 days following presentation. In these situations where patients converted to a surgical intervention, we classified such individuals as having *failed non-operative management*. In line with prior research²¹, eligible surgeries consisted of stand-alone decompression, or decompression-fusion procedures, including corpectomy and fusion, as well as percutaneous instrumentation. Patients treated solely with vertebroplasty or kyphoplasty, or interventional pain procedures (e.g. radiofrequency procedures, image-guided injections, etc) were considered to be in the non-operative cohort. Individuals who received surgery at time points beyond the first year of treatment were also not considered to be failures. We established the threshold for failure at 1-year following presentation based on prior studies that have demonstrated that close to 50% of patients with spinal metastases will have died before reaching this time-point.^{3,6,13,21} We determined the rationale for surgical intervention in patients who failed initial non-operative treatment as documented by the treating surgeon, along with the number of days from presentation to the surgical event. We assessed survival at 6-months and 1-year following presentation. We ascertained mortality through chart review and the social security death index which is linked to the RPDR.^{6,17}

Variable Definition

We considered age (40–60 vs 61–80), sex, race (White vs non-White), BMI, CCI (2 vs 3), primary cancer diagnosis (breast or lung vs others), serum albumin ≥ 3.5 g/dL, WBC count ≥ 4.5 , PLR ≥ 155 , vertebral body collapse and/or pathologic fracture and neurologic signs or symptoms at presentation as documented by the treating oncologists, radiation oncologists, or surgeons (axial pain only/asymptomatic vs neurologic signs or symptoms [e.g sensory or motor changes, radicular pain, bowel and/or bladder dysfunction, paralysis]) as covariates. Laboratory cut-offs for albumin and WBC count were established based on existing literature^{6,9,19,20} while we established a PLR threshold by dividing this variable into quartiles and evaluating the association with non-operative treatment failure using chi-square testing.

Statistical Analysis

We used prior literature^{5,6,9,11,13} to identify candidate predictors of non-operative failure that we adjusted for in multivariable testing. These variables consisted of: patient age at presentation, sex, primary cancer, vertebral body collapse/pathologic fracture at presentation, and neurologic symptoms at presentation and PLR at presentation. We adjusted for confounding using a multivariable Poisson regression analysis. We also included ambulatory status at presentation and mortality at 2-months in the multivariable model, recognizing that early demise is a competing risk that would influence the opportunity to receive surgery following the initiation of non-operative care. We used Poisson rather than logistic regression because the latter yields odds ratios, which overstate risk ratios in situations such as this in which the prevalence of the outcome variable is non-trivial.²² We employed the c-statistic and the Hosmer-Lemeshow goodness of fit test²² to characterize discrimination and calibration, respectively, of the final predictive model. We performed

internal validation using a bootstrap analysis that employed repeat sampling with replacement (80% sample; $n=667$) and 1,000 replications. This approach to internal validation helps overcome the effects of influential outliers.²² We subsequently developed a risk score calculated as the sum of the independent risk factors associated with failure. Weighting was considered based on the relative risk of failure associated with each factor. We then assessed the association between the risk score and the frequency of failure. We set statistical significance at $p<0.05$ and RR and 95% confidence interval (CI) exclusive of 1.0 in all tests. We performed all analyses using STATA v15.0 (STATA Corporation; College Station, TX). This study received an exempt determination from our institutional review board.

Results

We identified 1,205 patients meeting eligibility criteria. Among these individuals, 371 received surgery as part of the primary intervention, leaving 834 patients who were initially treated with a non-operative approach to be included in this analysis. We found that 77 individuals (9%; 95% CI 7%, 11%) who initially received non-operative management underwent a surgical intervention within one year of presentation, meeting our definition of non-operative failure (Figure 1).

Within the entire cohort initially managed non-operatively ($n=834$), the average age was 57.4 (SD 9.8), 54% were female and 84% were White (Table 1). The average number of comorbidities was 2.5 (SD 0.99) and more than half of the cohort presented with additional extraspinal bone metastases at presentation. We identified lung metastases in 21% and liver metastases in 28%. The two most frequent primary cancer diagnoses were lung (25%) and breast (23%) followed by multiple myeloma/lymphoma (10%; Appendix 1). We classified 75% of the sample as independent ambulators at time of presentation, with 30% of the entire cohort demonstrating neurologic signs or symptoms to some degree. The association of quartiles of PLR with treatment failure in our study population demonstrated that PLR of 155 (lowest quartile) served as a threshold value, above which risk generally increased (Appendix 2).

A majority of the sample were initially treated with chemotherapy and radiation ($n=417$; 50%), while 237 (28%) received chemotherapy alone. Among those who eventually received surgery the average time from presentation to the surgical event was 124 days (SD 89; interquartile range 54–180). Neurological deterioration was responsible for the decision for surgery in 37 instances (48%), while intractable pain was cited in 22 cases (29%). The majority of surgical approaches were posterior ($n=59$; 77%) with decompression-arthrodesis procedures (including corpectomy) performed in 55 (71%). We determined 6-month mortality in the cohort to be 36%, with 51% deceased at 1-year following presentation.

We found that non-operative failures were more likely to have $PLR>155$ (87% vs 74%, crude RR 1.18; 95% CI 1.06, 1.31), vertebral body collapse and/or pathologic fracture (60% vs 46%, RR 1.29; 95% CI 1.06, 1.58), or neurologic signs or symptoms (44% vs 29%, RR 1.53; 95% CI 1.16, 2.01) at presentation (Tables 2 and 3). We did not observe a significant

difference in mortality at 6-months (30% vs 36%, $p=0.26$) and 1-year (51% vs 51%, $p=0.95$) between non-operative failures and patients who did not receive surgery.

Following adjusted Poisson regression analysis, we found that vertebral body collapse and/or pathologic fracture (adjusted RR 1.75; 95% CI 1.11, 2.76; $p=0.02$), neurologic signs or symptoms at presentation (RR 1.90; 95% CI 1.19, 3.03; $p=0.007$) and PLR >155 (RR 2.32; 95% CI 1.15, 4.69; $p=0.02$) were associated with an increased risk of non-operative failure (Table 4). As compared to patients with breast or lung metastases, those with metastases from other cancers demonstrated a higher risk of non-operative failure (RR 1.71; 95% CI 1.02, 2.89; $p=0.04$). The c-statistic of this final model was 0.74, indicative of moderate discriminative capacity, and there was no evidence of poor model calibration following the Hosmer-Lemeshow test ($p=0.91$). We determined that these results were robust in the bootstrap internal validation test (Table 5).

We developed a risk score to sum the clinical findings of vertebral body collapse and/or pathologic fracture, neurologic signs or symptoms at presentation and PLR >155. Because the relative risks associated with each risk factor was around 2, we did not assign differential weights to each risk factor in the risk score. Surgical rates among patients with 0, 1, 2 or all three of these risk factors were 5% (3/66; 95% CI 1%, 13%), 7% (17/240; 95% CI 4%, 11%), 12% (32/276; 95% CI 8%, 16%) and 20% (16/82; 95% CI 12%, 30%), respectively ($p=0.004$; Figure 2).

Discussion

The treatment of patients with spinal metastases is complex and frequently requires a multi-disciplinary approach.^{1,8,9,10} At the time of initial presentation, decision making regarding treatment is often informed by the anticipated length of patient survival, tumor characteristics, as well as structural instability and symptoms.^{1,2,4–14,21} In the wake of improvements in peri-operative medical management, the utilization of surgery as a treatment modality for spinal metastases has grown over the last twenty years.^{1,3, 21,23–26} Recommendations for surgery as part of the initial treatment strategy must balance the risks of the intervention against the capacity for the patient to derive long term benefit.^{1,3,6,9} Many treatment strategies consider surgery only in the event of precipitous neurologic decline or intractable pain refractory to other interventions, but this approach assumes that the benefits of a surgery will accrue to patients at any time.^{1,10,23}

Prior research has indicated that certain non-operative interventions, including radiation, immunotherapy and some types of chemotherapy may increase the likelihood of peri-operative morbidity, such as wound complications and systemic infection if surgery is performed after these treatments are received.^{3,7,25,26} Furthermore, in this already frail population the capacity to recover from an intervention performed for neurologic deterioration may be different from that of an elective procedure, where the patient can be medically optimized prior to surgery.^{1,3,14,23,25,26} Last, neurologic deficits precipitated by metastatic disease are not always reversible and spinal surgery has been found to be more effective at preventing neurologic decline as opposed to restoring function.^{3,14,23} In previous work conducted in a separate cohort of patients, Paulino-Pereira et al reported that

neurologic status was unchanged in 71% of patients following surgery and improved in 22%.²⁶ In the event of irreversible neurologic deterioration, especially when ambulation is affected, the risk of near-term mortality is known to increase.^{4,6,9} For example, in a series of patients with metastatic spinal cord compression, Lo and Yang reported superior function and survival for individuals who received operations prior to any neurologic deterioration as opposed to those who only underwent surgery following the development of motor deficits.¹⁴

Our adjusted analysis identified elevated PLR, vertebral body collapse and/or pathologic fracture, and neurologic signs or symptoms at presentation as factors associated with non-operative failure. Patients with none of these characteristics at presentation went on to receive surgery after initiating non-operative care only 5% of the time. In contrast, individuals with all three risk factors received surgery at a rate of 20%. Vertebral body compromise and the presence of neurologic symptoms likely herald the potential for spinal instability and/or precipitous neurofunctional decline within the first few months of treatment. As non-operative modalities have not been shown to improve spinal stability,^{2,4,7,8,14,23} patients who present with these characteristics may warrant consideration for surgery as a component of the initial treatment strategy.

The platelet-lymphocyte ratio (PLR) has been described as a marker of inflammation in prior studies on patients with cancer.^{17,19,20} This is presumed to result from decreased production of lymphocytes secondary to neutrophil activation.¹⁷ Thio et al found that higher PLR levels were associated with reduced rates of survival in individuals with skeletal metastases.¹⁷ An elevated PLR may signal immune-suppression through platelet activation, a more aggressive primary tumor, larger extent of osseous compromise within the spine, or greater involvement of neural structures, thus heralding greater risk of deterioration in the face of non-operative treatment.¹⁷ We are cautious in our interpretation of the influence of cancers other than breast or lung on receipt of surgery following non-operative care given the extensive heterogeneity encountered within this category of patients.

Our work was conducted using a large sample of patients treated between 2005–2017. The age of the cohort, symptoms at presentation, ambulatory function, manner of treatment and mortality rate are comparable to other investigations,^{4–14,16} which reinforces the generalizability of our results. As far as we are aware, this research is among the first to specifically consider factors associated with the failure of non-operative treatment in patients with spinal metastases.

We acknowledge several limitations, including the retrospective design and the fact we are restricted to consider factors regularly documented in the medical records at our hospitals. This limited our ability to utilize popular scoring systems for spinal metastases such as the Tokuhashi score²⁴, Tomita scale, or other measures of instability¹³. As a retrospective work, this effort also did not assess functional outcomes following surgery. Our designation of *non-operative failure* is specific to this investigation and does not take into account other factors outside of the need for a spine surgical intervention. We recognize that if criteria for *non-operative failure* were changed to include factors such as hospital admission for intractable pain, pain management interventions, and/or cement augmentation procedures,

the findings could differ. In addition, patients too sick to receive surgery would technically have *failed* non-operative treatment in this setting but would not be designated as failures in our analyses. If we assume that in both these groups (those who were too sick to undergo surgeries and those with other hospital admissions) the distribution of risk factors for failure differed from those observed in our analyses, the risk factors would be biased toward the null. Our findings should not be interpreted to mean that patients with characteristics for failure must receive a surgical intervention. As these characteristics are also indicative of an un-favorable disease pattern, decisions regarding the optimal treatment approach are best made on a case-specific basis.

We acknowledge that there are a broad range of cutoffs for delineating elevated PLR in cancer patients within the literature.^{17,19,20} These typically range from 150–300, and our selection of a value of 155 is based on the observed distribution within our study quartiles. The results may be influenced by the clustering of subjects in our region of New England and findings should be validated in other populations as a result. Finally, our determination of *failure* hinged on having surgery. As indications may vary across surgeons, institutions and regions this also urges validation among patients treated at other centers.

In conclusion, the findings presented here have immediate clinical application and are important for patients with spinal metastatic disease and their healthcare providers. Foremost, our data showed that approximately 1 in 10 patients who initiate non-operative management are likely to receive surgery within the first year of treatment. Second, an elevated PLR, neurologic symptoms, or the presence of a pathologic fracture and/or vertebral body collapse at presentation may serve as markers for failure of initial non-operative care. Patients who have multiple risk factors for failure could be counseled regarding the potential for non-operative treatment failure. Our results can also be used to facilitate shared decision making regarding the optimal treatment regimen at the time of initial presentation.

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Appendix

Appendix 2 -

The influence of platelet-lymphocyte ratio (PLR) evaluated in quartiles (PLR ≤155, PLR 155–243, PLR 244–392 and PLR >392) on the likelihood of non-operative treatment failure (% with 95% CI) in this study.

Appendix 1.

Distribution of primary cancer diagnoses within the cohort.

Primary Cancer (%)	834 (100)
Breast	193 (23)
Colon	37 (4)
Renal	39 (5)
Lung	207 (25)
Prostate	44 (5)
Thyroid	10 (1)
Other ^{&}	162 (19)
Head and Neck	16 (2)

Primary Cancer (%)	834 (100)
Multiple Myeloma/Lymphoma	84 (10)
Gastric Cancers	19 (2)
Melanoma	23 (3)

& - All primary cancers with sample size <10 in the cohort including carcinoid tumor, testicular cancer, hepatobiliary cancers, pancreatic cancer, skin cancers other than melanoma, urothelial tumors, uterine cancers, ovarian cancer, liposarcomas, leiomyosarcomas, osteosarcoma with extraspinal origin, poorly defined sarcomas, and unknown primary.

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Highlights

- We identified factors associated with non-operative failure in spinal metastases
- 9% of the population treated non-operatively received surgery within 1-year
- Risk factors for surgery included neurologic symptoms and pathologic fracture

Figure 1 –.
Flow diagram depicting the selection of patients who were included in this analysis.

Figure 2 –.

The influence of the number of risk factors (0, 1, 2, or 3) on the likelihood of non-operative treatment failure (% with 95% CI) in this study.

Table 1.

Demographic characteristics of patients treated primarily for spinal metastases with a non-operative approach. There were 834 patients in the total sample from which the proportions below are derived.

Characteristics	N(%) [@]
Age (mean, SD)	57.4 (9.8)
Female Sex (%)	450 (54)
White (%)	700 (84)
Body Mass Index (mean, SD)	27.2 (6.1)
Number of Co-morbidities (%)	
1–2	511 (61)
3–4	323 (39)
Primary Cancer (%)	
Breast	193 (23)
Lung	207 (25)
Other	434 (52)
Albumin >3.5g/dL (%) [#]	225 (27)
WBC Count >4.5 (%) ^{\$}	113 (14)
Platelet to Lymphocyte Ratio >155 (%) ^{&}	498 (60)
Lung Metastases (%)	173 (21)
Liver Metastases (%)	231 (28)
Additional Bone Metastases (%)	443 (53)
Vertebral Body Collapse/Pathologic Fracture (%)	396 (47)
Spinal Canal Compromise (%)	284 (34)
Ambulatory Status at Presentation (%)	
Independent Ambulator	626 (75)
Ambulatory with Assistance	147 (18)
Non-ambulator	60 (7)
Signs or Symptoms at Presentation (%)	
Axial Pain/Asymptomatic	581 (70)
Neurologic Signs or Symptoms	253 (30)

[@] - Except where otherwise specified.

[#] - There were 478 patients (57%) with albumin >3.5g/dL and 131 (16%) missing this variable.

^{\$} - There were 621 patients (74%) with wbc >4.5 and 100 (12%) missing this variable.

[&] - There were 166 patients (20%) with a ratio >155 and 170 (20%) missing this variable.

Table 2.

Demographic characteristics of patients who received a surgical intervention after initially being treated for spinal metastases with a non-operative approach compared to those who completed non-operative management without receipt of surgery.

	Non-operative	Operative	P-value
Number of Cases (%)	757 (91)	77 (9)	-
Age (mean, SD)	57.4 (9.9)	57.2 (8.9)	0.83
Female Sex (%)	414 (55)	36 (47)	0.18
White (%)	634 (84)	66 (86)	0.18
Body Mass Index (mean, SD)	27.1 (6.1)	27.5 (5.7)	0.44
Number of Comorbidities (%)			0.97
1–2	464 (61)	47 (61)	
3–4	293 (39)	30 (39)	
Primary Cancer (%)			0.03
Breast	181 (24)	12 (16)	
Lung	193 (26)	14 (18)	
Other	383 (51)	51 (66)	
Albumin < 3.5g/dL (%)	209 (28)	16 (21)	0.41
WBC Count < 4.5 (%)	103 (14)	10 (13)	0.31
Platelet to Lymphocyte Ratio >155 (%)	439 (58)	59 (77)	0.006
Vertebral Body Collapse (%)	350 (46)	46 (60)	0.02
Signs or Symptoms at Presentation (%)			0.006
Axial Pain/Asymptomatic	538(71)	43 (56)	
Neurologic Signs or Symptoms	219 (29)	34 (44)	

Table 3.

Factors associated with patients receiving surgical intervention after initially being treated with a non-operative approach.

	Non-operative	Operative	P-value	RR (95% CI)
Age (%)	-	-	-	-
Age 40–60	493 (65)	54 (70)	Ref	Ref
Age 61–80	264 (35)	23 (30)	0.38	0.86 (0.60, 1.22)
Biologic Sex (%)	-	-	-	-
Male	342 (45)	41 (53)	Ref	Ref
Female	414 (55)	36 (47)	0.18	0.85 (0.67, 1.09)
Vertebral Body Collapse/Pathologic Fracture at presentation (%)	-	-	-	-
Absent	407 (54)	31 (40)	Ref	Ref
Present	350 (46)	46 (60)	0.02	1.29 (1.06, 1.58)
Platelet to Lymphocyte Ratio (%)^{&}	-	-	-	-
Platelet to Lymphocyte Ratio ≤155	157 (26)	9 (13)	Ref	Ref
Platelet to Lymphocyte Ratio >155	439 (74)	59 (87)	0.02	1.18 (1.06, 1.31)
Primary Cancer (%)	-	-	-	-
Lung or Breast	374 (49)	26 (34)	Ref	Ref
Other	383 (51)	51 (66)	0.009	1.31 (1.10, 1.56)
Signs or Symptoms at Presentation (%)	-	-	-	-
Axial Pain/Asymptomatic	538(71)	43 (56)	Ref	Ref
Neurologic Signs or Symptoms	219 (29)	34 (44)	0.006	1.53 (1.16, 2.01)

Ref – Referent; RR – risk ratio; CI – confidence interval

[&] - Calculated from the total number of patients with a platelet to lymphocyte ratio recorded at presentation.

Table 4.

Results of the multivariable Poisson regression analysis regarding factors that were associated with patients receiving surgical intervention after initially being treated with a non-operative approach.[&]

Variable	RR	95% CI	P-value
Age	-	-	-
Age 40–60	Ref	Ref	Ref
Age 61–80	0.98	0.59, 1.62	0.93
Female Sex	0.92	0.56, 1.51	0.74
Vertebral Body Collapse/Pathologic Fracture at presentation	1.75	1.11, 2.76	0.02
Platelet to Lymphocyte Ratio >155	2.32	1.15, 4.69	0.02
Primary Cancer	-	-	-
Lung or Breast	Ref	Ref	Ref
Other	1.71	1.02, 2.89	0.04
Neurologic Signs or Symptoms at Presentation	1.90	1.19, 3.03	0.007

Ref – referent.

[&] - Effect sizes shown are derived from a multivariable Poisson model that adjusted for all factors above as well as ambulatory status at presentation and mortality within 2-months of presentation.

Table 5.

Results of the bootstrap multivariable Poisson regression analysis regarding factors that were associated with patients receiving surgical intervention after initially being treated with a non-operative approach.[&]

Variable	RR	95% CI
Age	-	-
Age 40–60	Ref	Ref
Age 61–80	0.98	0.56, 1.70
Female Sex	0.92	0.53, 1.58
Vertebral Body Collapse/Pathologic Fracture at presentation	1.75	1.06, 2.87
Platelet to Lymphocyte Ratio >155	2.32	1.01, 5.33
Primary Cancer	-	-
Lung or Breast	Ref	Ref
Other	1.71	0.95, 3.08
Neurologic Signs or Symptoms at Presentation	1.90	1.17, 3.09

Ref – referent.

[&] - Effect sizes shown are derived from a multivariable Poisson model that adjusted for all factors above as well as ambulatory status at presentation and mortality within 2-months of presentation.