Risk Factors for Wound-Related Complications Following Spine Surgery for Primary and Metastatic Spine

Main author: Doreen K
Co-author: Christine M

Key Words

- Spine
- Surgery
- Wound
- Complications
- Infection

Abbreviations and Acronyms

CI: Confidence interval

PNI: Prognostic nutritional index

SSI: surgical site infections

VTE: Venous thromboembolism

- **OBJECTIVE:** The study systematically reviewed the literature to investigate the risk factors for wound-related complications after primary versus metastatic tumour surgery**.**
- **METHODS:** Screening of English-language publications between 2013-2023 on primary and metastatic spinal tumours surgery was conducted. The pooled analysis was done, which compared the risk factors identified in the studies for both metastatic and primary spine, which were defined as patient-related factors and surgery-related factors.
- **RESULTS:** The search strategy identified 506, but only 20 studies were included after screening through inclusion and exclusion criteria. Out of the 20 studies, 17 studies were retrospective studies, 2 were systematic reviews, and 1 was an RCT study. Wound complications were associated with factors such as BMI, female sex, preoperative chemotherapy, smoking history, preoperative radiation, nutrition status, type of surgery, surgery duration, blood loss, preexisting conditions (like diabetes, hypertension) and medication. Holding these risk factors constant, the wound complications were higher for the metastatic spine than primary spine tumours, indicating that patients with metastatic spine tumours had a higher risk of developing wound complications after surgery than those with primary spine tumours.
- **CONCLUSIONS:** The risk factors associated with wound complications in metastatic tumours included BMI, blood loss, medication, age, higher blood loss, neurological deterioration after surgery, venous thromboembolism (VTE), smoking, preexisting patient conditions such as diabetes, nutrition status of patients, American Society of Anesthesiologists risk classification (ASA) greater than 2, ambulatory presence, nutrition status of patients and ambulatory presence, history of previous radiation, type of surgery, surgery duration and type of tumour. Risk factors for primary tumours included sacral procedures and the use of equipment when conducting surgery. Given these factors, wound complications were higher for metastatic spine than primary spine tumours.

INTRODUCTION

Cancer patients now have much longer median survival times thanks to advancements in the discipline of oncological therapy over the past few decades (Molina et al., 2016). The prevalence of metastatic illnesses among the global population is also rising as a result of this evolution. The spine hosts over 70% of the subsequent malignant skeletal symptoms (Molina et al., 2016). Chakravarthy et al.'s findings that 40% of cancer patients had spine metastases are consistent with this. The most prevalent osseous metastases and a significant cause of morbidity in cancer patients are spinal metastases (SM).

SM can substantially negatively influence patients' quality of life because it can induce pain and neurological damage in up to 14 percent of instances (Silva et al., 2021). The cervicothoracic junction (CTJ) is the site of around 10% of all spine metastases, and surgical management of these lesions frequently entails stabilization and instrumentation (Chakravarthy et al., 2023). According to Vargas et al. (2022), those suffering from metastatic spine tumours frequently require substantial reconstructive surgeries because stabilization or decompression is required to reduce discomfort and enhance neurological function. Pathological fractures, excruciating pain, and neurological abnormalities brought on by spinal cord impingement are the primary indications for surgical surgery (Molina et al., 2016). Notably, spinal metastasis surgery can have a substantial effect on cancer patients, perhaps reducing discomfort and significantly enhancing their quality of life. Although these surgical techniques have a significant risk of complications, they can be morbid (Vargas et al., 2022). According to Rigney et al. (2023), the timing of additional therapies for cancer and overall survival (OS) can be affected by the clinical outcomes following surgery for spinal metastases, depending on the emergence of comorbidities. According to Bauer, wound infection is the most frequent complication following surgery for metastatic spinal tumours.

Reports show that postoperative infections can occur in up to 30% of patients who have surgery for metastatic spine tumours, and these patients tend to experience more infections than those who have

Spine surgery for other reasons. In addition to a rise in the general population's growth-adjusted rate of surgical treatment for spinal metastases from 1.15 to 1.77 per 100,000 between 2000 and 2009, Yoshihara and Yoneoka observed an increase in the total in-hospital complication rate from 14.8 to 27.7 percent (Luksanapruksa et al., 2017). A postoperative wound infection that may necessitate revision surgery, wound vacuum, several debridement procedures, and plastic surgery intervention can greatly reduce the postoperative quality of life since metastatic spine tumour surgery is largely a quality-of-life operation (Vargas et al., 2022). Local problems, such as wound breakdown and surgical site infections (SSIs), are particularly likely to occur during tumour removal. This correlation has been linked to the use of adjuvant medicines in patients with tumours, the incidence of comorbidities, and complex situations (Schilling et al., 2020).

The contrast between primary and metastatic cancers is significant since each has a variety of clinically unique origins and distinct therapy approaches and results. Consequently, the aim of this study is to conduct a systematic review that compares the risk factors for wound-related complications following surgery for primary versus metastatic tumours.

Objectives and research questions

The objective of this study is to investigate the risk factors for wound-related complications after surgery for primary versus metastatic tumours. The research question is:

What are the risk factors for wound-related complications after surgery for a primary versus metastatic tumour?

METHODS

Introduction

The aim of this research is to examine the risk factors for wound-related complications after surgery for primary versus metastatic tumours. To address the research questions, the study uses a qualitative, systematic review that will assess prior research articles. The findings from all of the independent studies that will be incorporated into the systematic review will be narratively synthesized using content analysis. The author will adhere to the six standard procedures for writing a review article, which are the formulation of the study question and objective, the current literature search, the screening for inclusion, the evaluation of the primary study's qualities, the extraction of data, and the analysis of data (Xiao & Watson, 2019).

Research identification

The aim of this study is to examine the risk factors for wound-related complications after surgery for primary versus metastatic tumours.

Search strategy

The author conducted a literature search of peer-reviewed retrospective articles on clinical outcomes after operative spinal tumour treatment. Databases queried included Cochrane Library, Scopus, Web of Science, PubMed, Embase, and ClinicalTrials.gov. According to Hristidis, Papakonstantinou, and Gravano (2003), in major databases such as JSTOR and Scopus, a million scientific publications are added annually to the existing pool of research papers. This makes it increasingly difficult for researchers to identify the most relevant publication for their study. Using keywords and phrases helps narrow the search and saves time wading through millions of articles in a database. In the case of this study, the author used single words and key phrases such as metastatic spine and spine, surgical site infection, tumour, surgery, metastatic tumour, wound complications, and retrospective study. Figure 1 below displays the results of using the key phrases and boolean operators to produce 560 articles. Of the 560 papers initially screened, 208 were disqualified because 82 did not adhere to research requirements, and 270 were duplicates. 42 articles were chosen after the remaining articles were screened using the titles and abstracts. Due to their importance and the absence of full texts, the author ultimately decided to analyze 20 articles.

Exclusion and inclusion criteria

The papers included for evaluation in the study were screened by the author using exclusion and inclusion criteria. The inclusion criteria were articles published in English between 2013 and 2023 that are relevant to or address the study's question and were included in the screening criteria, that is, metastatic tumour surgical outcome studies, primary tumour surgical outcomes, and studies having both metastatic and primary tumours with a report of greater than 1 wound-related complication. Articles published before 2013 that cannot be fully accessed, are not published in English, and do not relate to or address the study question were excluded, such as nontumor spine surgery studies. The table below shows the PICOs used as an inclusion and exclusion criteria guide:

Table 1: PICOS Criteria

P: Population	Patients with Metastatic and Primary Spine Tumor
I: Phenomenon of interest	Spine surgery wound-related complications
Co: Context	Wound-related complications risk factors
S: Types of studies	Studies published between 2013 and 2023, available in full text, RCTs and retrospective studies

Quality assessment

For quality assessment, the eligible studies underwent the screening of abstracts and titles as per the predetermined exclusion and inclusion criteria. The remaining studies were subjected to full-text screening. Accordingly, the quality of the included studies was assessed based on the source's credibility, author credentials, methodology used in the original study, and the clarity and coherence of the findings. This quality assessment informed the weight given to each study in the overall analysis and conclusions drawn in this study. The methodological approach of this study ensures a systematic, comprehensive, and unbiased review of the existing literature, which is crucial for understanding the risk factors for wound-related complications in metastatic and primary spine surgeries.

Data extraction

Data was retrieved after the final papers chosen for the study were chosen. The factors or objectives of the study directed the data extraction strategy. The focus on data extraction was determined by the conclusions of each study and the strategy used to generate results. Accordingly, wound complications were categorized under surgical site infections (SSIs) and sterile wound dehiscence. SSIs were considered to be deep incisional, space/organ infection, and superficial incisional. To aid in identifying the risk factors, data specific to patients was collected, such as tumour type, age, smoking history, chemotherapy, sex, previous spine surgery, preoperative radiotherapy, instrumentation, and surgical approach. For studies that specifically focused on the risk factors, the author focused on their findings and conclusions to identify them. Below is an illustration of the data extraction method:

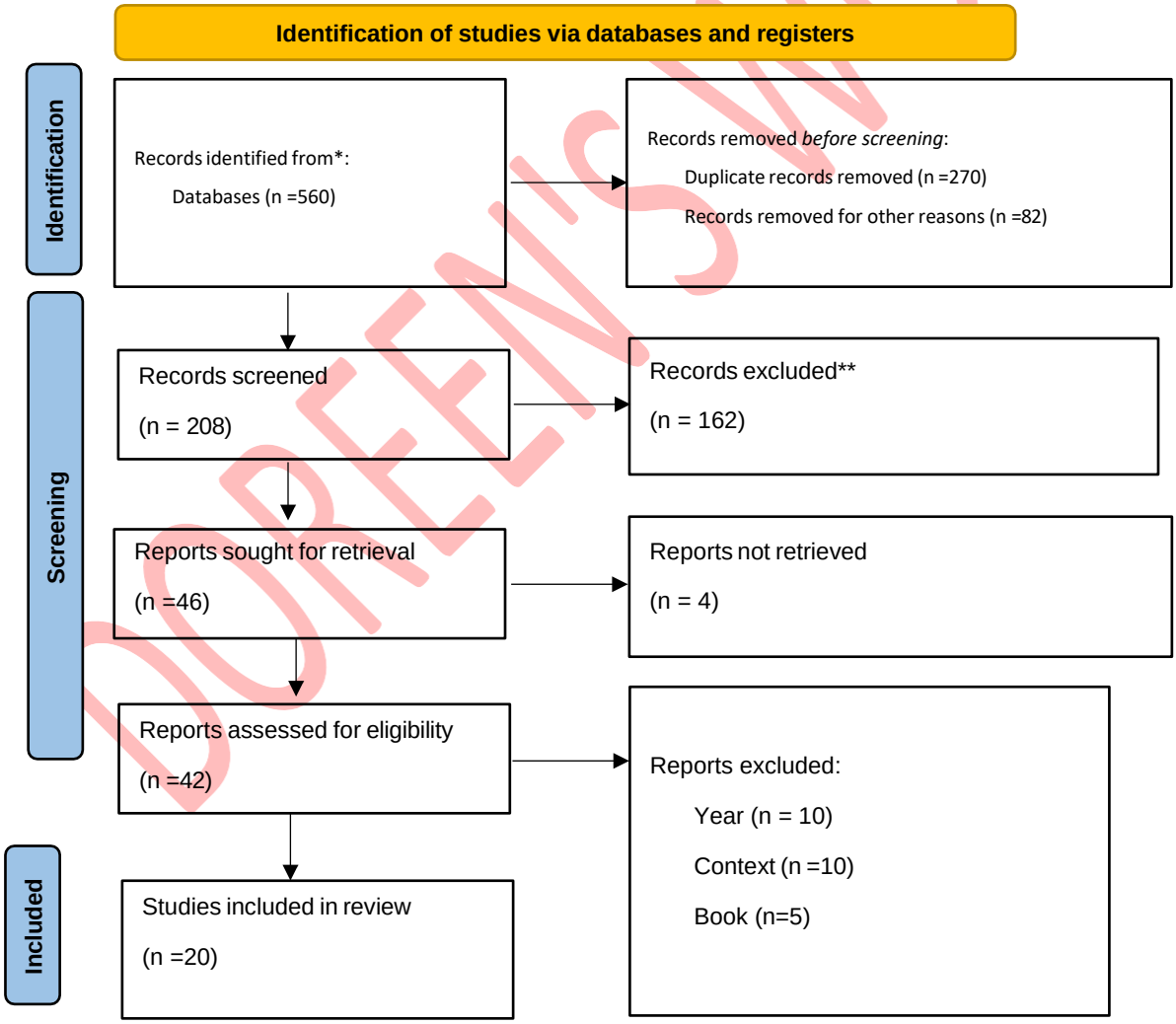

Figure 1: The PRISMA Diagram for reporting systematic reviews (source: Page et al., 2021).

Data analysis and presentation

The research used content analysis techniques to analyze the identified clinical study articles. This involved systematic and structured steps that were aimed at extracting meaningful insights from textual sources. The author followed six steps in analyzing the data using the content method. The researcher clearly outlines the research objectives. This was important to ensure that the analysis focused primarily on the relevant aspects of secondary data that captured the objective of the study (Selvi, 2019). The researcher then organized and cleaned the collected data to ensure it was in a format for content analysis. The data was segmented into manageable units to facilitate codding. The researcher read the data carefully to identify the coding scheme. Coding involved categorizing the content into relevant patterns or themes (Lindgren et al., 2020).

Once the author finished coding, he identified themes, patterns, and insights related to the risk factors for wound-related complications in metastatic and primary spine surgeries. Since the content analysis in this research also included numerical data or themes, the author performed a basic quantitative analysis that calculated percentages, frequencies, and other relevant measures that helped quantify the prevalence of a specific pattern. The content analysis findings were interpreted qualitatively, with a contextual explanation provided by the author.

RESULTS

This section presents the findings of the analysis of the selected articles. The presentation of findings is arranged in terms of themes. Here is the summary of the studies selected for analysis in this study.

Table 2: Summary of the clinical articles identified

Reference	Country	Tumor type	Study design	Sample size	Wound complications
Jarvers et al. (2021)	Germany	Spinal metastases	Retrospective study	237 patients (84 female, mean age 66 years, SD 11)	Forty-one patients (17.3%) had wound-related complications
Molina et al. (2016)	US	Spinal metastases	A systematic review of studies from 1980 to 2015	34 studies	27 percent mean for the rate of wound-related complications reported by the studies
Kumar et al. (2015)	UK	Spinal metastases	Retrospective study	98 patients	17.9 percent of patients included in the study
Chakravarthy et al. (2023)	US	Spinal metastases	Single-institution retrospective study	79 patients	The overall complication rate was 18.8% (6 patients with wound-related complication)
Rao et al., (2014)	Australia	Spinal metastasis	Retrospective study done between 2009 and 2012	8 patients with a mean age of 59 years (range, 36–72 years)	56 percent of patients had would-related complications
Vargas et al. (2023)	US	Metastatic spine	Retrospective review study between 2005 and 2017	205 patients	14.3 percent of the population had wound complications
Hersh et al. (2021)	US	Metastatic spine tumor compared to primary spine	Retrospective study done between 2013-2020	317 patients	56 patients had wound related
Rigney et al. (2023)	US	Metastatic spine	Retrospective analysis of consecutive patients who underwent surgery	154 individuals (39% female; mean [SD] age	15 of 48; (31.25%) developed wound-related complications

			for spinal metastases between 2014 and 2020	63.23 [13.14] years)	
Lei et al. (2019)	China	Spine metastases	A retrospective analysis	19	8.6 mean for wound-related complications
Kim et al. (2017)	South Korea	Spinal metastasis	RCT done between 2009 and 2013	18 patients	3 patients developed wound related complications after surgery
Sugita et al (2016)	Japan	Spinal metastases	Retrospective study comprising of patients who underwent IORT for the treatment of spinal metastases between August 2004 and June 2013.	279 patients	SSI occurred in 41 patients (14.7 %).
Schilling et al. (2020)	US	Spinal metastasis Primary spine tumours	Systematic review	5471	8.1 percent of the 1936 patients that underwent surgery for primary tumor 6.6 wound complication for
Sebaaly et al. 2018	Canada	Spinal metastasis	Retrospective analysis of a prospective collected data	297 patients	5.1 percent of the 297 had SSI (superficial SSI:113.4%; deep SSI: 1.7 %
Keam et al. (2014)	US	Primary spine tumors Spinal metastasis	Retrospective analysis done between 1999 and 2010	165 patients	24 patients developed wound related complications
Piper et al. (2017)		Spine metastases	Retrospective study done between 2012–2014	99,152 patients were included in this study	2.2% experienced at least one wound complication
Lee et al. (2014)	Korea	Spine metastases	Retrospective study	200 patients who underwent surgical treatment for spinal metastases	There were 8 (12.9%) postoperative complications in the en bloc group, 17 (20.7%) in the debulking group, and 8 (14.3%) in the palliative group (p = 0.016, chi-square)
Amelot et al. (2017)	France	Spinal metastases.	Multicentre prospective study	1,266 patients who were admitted for surgical treatments	33.3% in the >80, 23.9% in the 70-80, and 17.9% for patients <70 years
Wang et al. (2014).	US	metastatic spine tumours	Retrospective study done between September 1997 to February 2004	140 patients	Wound complications occurred in 16 patients (11.4%),

Silva et al. (2021)	Argentina	Spinal Metastases	Retrospective study	72 patients	4.2 percent of patients developed wound-related complications rate including wound-related complications
Luksanapruksa et al. (2017)	Thailand	Spinal Metastases	Retrospective analysis	76 patients	20.7 percent postoperative complications rate

Wound-related complications analysis results

This section presents the risk factors related to wound complications for metastatic spine and primary spine. The table below shows the summary of risk factors in terms of themes and sub-themes

Table 3: Summary of risk factors in terms of themes and sub-themes

Theme	Sub-themes
Patient-related risk factors	BMI, blood loss Medication Age Higher blood loss Neurological deterioration after surgery, venous thromboembolism (VTE) Smoking, Preexisting patient conditions such as diabetes Nutrition status of patients Ambulatory presence Ambulatory presence History of previous radiation
Surgery-related risk factors	Type of surgery Duration of surgery
Typo of tumour	Primary spine Metastatic spine

Risk factors related to patients

BMI, blood loss, preexisting conditions (like diabetes hypertension) and medication

The selected study analysis revealed that patient-related factors such as smoking, BMI, blood loss, and medication were among the most common risk factors for wound-related complications after surgery in spinal metastases. For instance, Jarvers et al. (2021) study The purpose of this study was to evaluate the factors associated with wound-related problems following surgical stabilization of spinal metastases, with a particular emphasis on the impact of postoperative RT and the timing of it. According to the research, patients who have wound complications following surgery are more likely to have an American Society of Anesthesiologists risk classification (ASA) >2, body weight issues ($p = 0.021$), are taking anticoagulant medication ($p = 0.045$), and have obesity (BMI > 30 kg/m2, $p = 0.018$). This suggests a connection between a higher risk of wound problems following surgery and patient-related characteristics such as body weight, obesity, and the type of medicine patients take before surgery. Additionally, post-spinal surgery complications have been linked to female sex, a history of smoking, preoperative irradiation, corticosteroid use, prior spine procedures, transfusion rates, postoperative delirium, dysphagia, and inadvertent durotomy (Jarvers et al., 2021).

Piper et al. (2017) conducted another study to identify preoperative factors independently linked to spine surgery patients' wound problems. These variables let the authors create a novel risk score for the study group that can be used to estimate a patient's risk of developing organ-space SSI, deep incisional SSI, superficial SSI, or dehiscence as wound complications. Accordingly, the study discovered that 2.2% of the 99,152 patients who were a part of it had at least one wound complication (dehiscence: 2.2%, superficial SSI: 0.9%, deep SSI: 0.8%, and organ space

SSI: 0.4%). Ten preoperative factors were revealed to be linked with wound complications by multivariate binary logistic regression testing: body mass index 30, smoking, female, chronic steroid usage, hematocrit 38 percent, infected wound, hospitalization status, emergency case, and surgery time >3 hours.

Kim et al. (2017) restricted their study group to individuals with thoracic spine metastatic tumours because these tumours can potentially compress the spinal cord and because the thoracic spine is often the location for bony metastasis. The efficiency of extra corpectomy was the study's main goal because posterior corpectomy can be carried out simultaneously with decompression using a single posterior longitudinal route to the thoracic spine. The results showed no discernible difference in the degree of recovery following surgery between the groups ($P > 0.05$). However, 5 occurrences of surgical complications were noted, including 1 case of pneumonia, 1 case of ileus, and 3 cases of wound complications (seroma and wound dehiscence), all of which were managed medically or surgically. Accordingly, increased blood loss was one of the risk factors linked to wound-related problems following procedures. In this instance, more blood was lost during surgery (2200 vs. 710 mL), and more postoperative complications, including pneumonia, wound issues, and infections, were seen in the corpectomy group. However, the study was unable to identify differences in the complication rate between the two groups due to the small number of patients it analyzed. The study also found that complications, especially those linked to wounds, were more likely in individuals with postoperative diseases, including diabetes (Kim et al., 2017).

Confirming the above study findings is a study by Wang et al. (2014). The results of this study also revealed an 11.4% wound infection rate and a median loss of blood of 1500 ml. This suggests that blood loss during surgery was a risk factor for wound-related complications among patients. According to a study by Sebaaly et al. (2018), smoking, having more spinal metastases, having a higher BMI, having worsened neurological function after surgery, and having a higher ASA score were all preoperative factors linked to an increased risk of surgical site infection (SSI). The incidence of SSI was raised by increasing intraoperative blood loss (intraoperative bleeding of 2000 ml) and increased numbers of fixated vertebrae. Only surgery duration (4 hours) and ASA 3 were discovered to be significant risk factors for the development of SSI when all of these variables were examined in a multivariate regression model.

Furthermore, Kumar et al. (2015), who focused on identifying the characteristics that increase the risk of wound infection during surgery for spinal metastases, discovered that lower albumin levels, the use of delayed or nonabsorbable skin closure materials, and the presence of neurological impairment all increased the risk of infection. There seems to be a correlation between low albumin levels, the existence of neurological impairment, and an elevated risk of infection.

Nonetheless, another patient-related factor associated with an increased risk of wound infection complications after surgery is venous thromboembolism (VTE), meaning patients with VTE reported a higher risk of infection than those without. According to the study results of Lee et al. (2018), in addition to the factors examined in the study, preexisting VTE raises the risk for complications of wounds, which may be related to the fact that patients with VTE are treated with anticoagulants, which slows the healing process. It is consistent with the strong association between anticoagulation and wound complications discovered in the current investigation.

Nutrition status of patients and ambulatory presence

A study by Rigney et al. (2023) evaluated how dietary status may affect unfavourable outcomes following surgery for metastatic spine cancers. There were 154 participants in the study, and 39% of them were female. The results showed that patients with normal nutritional status—as measured by the albumin-to-globulin ratio and the prognostic nutritional index (PNI)—had an improved prognosis compared to those with poor nutritional status and were significantly correlated with a lower risk of complications within 90 days (OR 0.93, 95% CI 0.85-0.98). According to the results, wound-related complications comprised the most frequent type of reported difficulty, occurring in 48 of 154 patients (31.2%) within the first 90 days following surgery (15 of 48; 31.25%). 11 out of 15 (73.33%) wound problems necessitated a second visit to the operating room for reclosure, incision, and drainage. There were two wound complications involving the cervical spine, nine wound problems involving the thoracic spine, and four wound complications involving the lumbar spine. Nine of the 15 people with wound problems were ambulatory (Rigney et al., 2023). This study's findings show a significant relationship between patients' nutritional status before surgery and their ability to be ambulatory afterwards. Accordingly, a high PNI value is linked to a lower risk of wound-related complications and vice versa, while being

ambulatory increases patients' chances of developing such complications.

History of previous radiation

Another risk factor that has been identified to increase wound complications is radiation effects. A study by Vargas et al. (2022) confirmed this assertion. The study aimed to compare the rates of wound complications in patients who underwent surgery for metastatic illness with either postoperative radiation, preoperative radiation, or no radiation. Despite the fact that the difference was not statistically significant, the results showed that 70 patients who had preoperative radiation and had undergone metastatic spine surgery experienced a greater rate of wound problems. This is due to the effects of radiation on human tissue, which alters its capacity to promote neovascularization and the recruitment of new cells necessary for effective postoperative healing. These reasons make a wound complication possible after surgery for a metastatic spine tumour. Accordingly, the study found that patients who had previously received radiation had a considerably greater prevalence of wound problems (32 percent) than patients who had previously undergone surgery and subsequent radiation (12 percent) (Vargas et al., 2022).

Similarly, a study by Sugita et al. (2016) found that preoperative treatment administration carries a substantial risk of SSI (wound complications). The results showed that 41 individuals (14.7 percent) had SSI. Significant correlations were found between the prognosis scores of Katagiri and Tokuhashi (P 0.05 for each), the postoperative Frankel scale score (P 0.01), the delivery of preoperative radiation (P 0.05), and postoperative performance status (P 0.05). Preoperative radiation administration was identified as a factor independently linked with SSI (P 0.05) by multivariate analysis employing those factors. The study came to the conclusion that preoperative radiation, postoperative ambulatory function, and patient outcome were risk factors for spinal metastases-related infection (SSI).

A study by Lei et al. (2019) also supports the idea that radiation performed before surgery is considered a substantial risk factor for surgical site infection (SSI) or wound complications. Two individuals reported wound-related complications (SSI), per the study's findings. Therefore, only patients who received preoperative irradiation prior to TES with a total radiation dosage >40 Gy experienced postoperative wound dehiscence. Additionally, the type of radiation used may affect the SSI risk.

In a different study, Keam et al. (2014) also found similar results for preoperative radiation treatment and wound complications following surgery for the metastatic spine. The authors of this study examined the rates of wound infection among patients who got preoperative radiation prior to spine surgery for metastases. Thirty-five patients underwent image-guided radiation (IGRT), and 130 patients got external beam radiotherapy (XRT) (r3 Gy/fraction). In contrast to the IGRT group, the 6-month cumulative incidence of wound complications for XRT was greater (17% vs. 6%, retrospectively). There was no significant distinction in wound complications between the IGRT and XRT groups (hazard ratio, 0.31, 95% confidence interval, 0.08–1.3; P = 0.11).

Age

Another risk factor for postoperative complications, including wound complications, is the age of patients. In this case, postoperative complications are more common in the elderly group. For instance, a study by Lau et al. (2013) found that age above 40 is an independent predictor of postoperative complications, particularly complications related to wounds. Patients between the ages of 40 and 65 were at an increased risk of complications compared to patients under the age of 40, and patients above the age of 65 were similarly at an increased risk of complications (OR, 5.17; 95% CI, 1.54–29.81).

Similarly, a study by Amelot et al. (2017) that examined surgery for elderly patients with metastatic spine tumours showed that the risk of postoperative complications, including wound-related complications, increased significantly with age (33.3% in the group of patients over 80 years old, 23.9% in the group of patients between 70 and 80 years old, and 17.9% for patients below 70 years ld). Conversely, a study by Kumar et al. (2015) discovered that the risk of wound infection is not significantly related to age. According to the study, the MUST score, age, low lymphocyte count, perioperative corticosteroid treatment, use of absorbable skin closure material, and other factors do not appear to affect the risk of infection.

Risk factors related to surgery

Duration of surgery

A study by Jarvers et al. (2021) discovered that neither the length of the procedure (p = 0.126), the number of vertebral bodies that were instrumented (p = 0.642), nor whether the intervention was carried

out using an open or percutaneous technique (p = 0.054) were significantly associated with the development of any wound complications. On the other hand, a study by Molina et al. (2015) discovered that the corpectomy group's longer operation duration was linked to postoperative complications such as infections and wound issues. The corpectomy group was shown to have a longer operation time (281 vs. 217 min) that was linked to postoperative complications such as infection, wound issues, and pneumonia. Concurring with this finding is the study of Chakravarthy et al. (2023), which revealed that patients were more likely to experience complications, such as wound-related difficulties if they stayed longer than the period allotted for the operation. Out of 6 patients who experienced wound-related issues, 2 did so as a result of the longer operation duration than those who received the procedure and had it finished in the allotted 179.2 minutes. Contrarily, Sugita et al.'s (2016) data reveal that the occurrence of SSI (wound complications) was not correlated with the length of the procedure or intraoperative blood loss.

However, Kumar et al. (2017) disagree with these findings, who found that the length of the surgery and other parameters have no discernible impact on wound-related complications (SSI). The results of the study showed that although patients who underwent hemilaminectomy were more likely to need revision surgery, other surgery-related risk factors, such as the length of the procedure, the number of instrumented levels, or the use of an open as opposed to a percutaneous approach, were not found to affect the occurrence of wound-related complications significantly.

Type of surgery

Taking into account patients' data and other factors post-operatively, Chakravarthy et al. (2023) also discovered that the greatest risk factor for problems following surgery, particularly wound-related issues, was instrumented fusion across the CTJ. In particular, the outcomes showed that all 58 patients had adjuvant radiation, with the median dose, fractions, and duration after surgery being 27 Gy, 3 fractions, and 20 days, respectively. Additionally, the average operating time, blood loss, and length of stay were 179.2 minutes, 600.5 ml, and 7.7 days, respectively. Instrumentation for lateral mass and pedicle screws was performed on all patients. 18.8% of patients experienced complications overall (6 with wound-related, 7 with hardware-related, 1 with both, and 1 with other). Another study by Sebaaly et al. (2018) found that while cervical surgery had the lowest incidence of SSI, with a mean infection rate of 5.1 percent for the 297 patients in the study, cervicothoracic surgery was linked to the greatest incidence.

A study by Rao et al. (2014) found that the goal of a minimally invasive method is to minimize the amount of muscle dissection necessary, which will lessen postoperative discomfort and hospitalization time. As there is less blood loss and less need for wound drainage in this situation, MIS is less likely to result in complications after procedures. The study also discovered that the percutaneous pedicle screws used in the least-invasive technique are more accurate. Additionally, the time that exposed and open wounds are exposed is shorter, potentially lowering infection rates, and the wounds are shorter, perhaps improving the safety of radiation. All of these elements may help people live better lives overall, which is crucial for those with lower socioeconomic status.

The postoperative infection rate was 3% in the MIS group against 16% in the open surgery group in research comparing open versus minimally invasive surgery (MIS) in 2015. The quicker wound healing in MIS patients allowed for an earlier start of radiotherapy to manage remaining local illnesses. Surgery for spinal metastasis patients carries a substantial (17.9%) risk of infection. Surgery at seven or more vertebral levels significantly raises the risk of infection (p 0.05). At the 5% significance level, it was discovered that the frequency of surgery was statistically substantially associated with a higher risk of wound infection.

Similarly, a study by Silva et al. (2021) supports Kumar et al.'s (2015) findings. According to the study's findings, MIS procedures for treating metastatic spine illness showed lower rates of wound complications than open techniques. The study concluded that MIS had reduced wound complication rates because MIS heals wounds and general wounds faster than open surgery, which is more resistant to wound breakdown brought on by radiotherapy. Additionally, since longer operating times are associated with greater blood loss and wound infection, blood loss and the need for transfusion are minimized in MIS operations thanks to the minimally exposed surgical corridor, despite lengthier operating times previously being a complaint of MIS technology due to the little exposure, operational times have decreased (Silva et al., 2021). These results imply that complex spinal metastases in cancer patients may be safely and successfully treated using MIS techniques.

Type of tumour (primary spine vs. metastatic spine)

The findings revealed that the type of tumour surgery is also a risk factor for wound complications, with operations for spinal metastases having a higher rate of wound infection compared to other spinal surgeries, such as the primary spine. This is demonstrated in a study by Luksanapruksa et al. (2017), who reported that, compared to other types of spine surgery, spinal metastasis surgeries had a greater likelihood of wound infection. Tumor surgery is an independent risk factor for SSI (OR, 6.2; 95% CI, 1.7–22.3). The existence of an iatrogenic dural rupture, the need for further operation during the same stay, diabetes mellitus, a lengthy procedure lasting more than four hours, and excessive blood loss over 3000 mL all raised the risk of developing a deep wound infection. The effect of original tumour type, location, and surgical method on the rate of wound infection, however, was not observed in any studies (Luksanapruksa et al., 2017).

Hersh et al. (2021) also showed that patients with metastatic spine tumours had a higher risk of wound complications compared to those with primary spines. The results did not specifically look at a cohort with prior radiation to the surgical site. Still, they suggested that patients with metastatic spine tumours had a lower risk of postoperative infection of the wound when a plastic surgery team conducted the closure. The cohort of patients undergoing closure by the plastic surgery service has a wound infection rate comparable to that of the majority of patients having wounds closed by spine surgeons, according to the study. The research finding indicates that referral to that service may be advantageous in reducing wound complication risks in patients with metastatic spine tumours who have previously received radiation to the surgical site because of the increased complexity and risk involved with patients who are referred to plastic surgery.

Another study by Schilling et al. (2020) found that the complication rate for the metastatic tumour cohort was 6.6 percent. Higher wound complication rates were linked to sacral procedures and the use of equipment in a pooled examination of primary malignancies. Higher complication rates were linked to the female sex, preoperative chemotherapy, smoking history, preoperative radiation, corticosteroid use, and prior spine surgery in the metastatic tumour population. With the addition of random-effects meta-analysis, instrumentation retained a statistically significant risk factor for primary cancers.

DISCUSSION

This study has established that spine surgery for metastatic bone lesions is associated with a significant risk for postoperative complications regarding the surgical wound site, resulting in longer hospital stays, unplanned reoperations, poor neurological outcomes, and significant morbidity compared to primary spine surgery.

The findings of this review established that wound-related complications (such as SSIs) are higher in spinal metastases than in primary spines. The risk factors that result in wound complications in these patients were categorized into three themes, including patient-related factors, surgery-related factors, and type of tumour (whether primary or metastatic spine) and of all the studies included, the risk of wound complications was reported in a sample of patients, indicating a fairly high incidence of wound-related infections for spine metastases. According to Finkelstein et al. (2003), surgery for metastatic spine tumours had an overall complication rate of 27%. As a result, the research has revealed somewhat high rates of both surgical complications and wound infection.

Patient-related factors

The study found that patient-related factors included BMI, blood loss, medication, age, higher blood loss, neurological deterioration after surgery, venous thromboembolism (VTE), smoking, preexisting patient conditions such as thromboembolisms (VTE), nutrition status of patients, ambulatory presence, nutrition status of patients, ambulatory presence, and history of previous radiation. These results are in line with those of the Olsen et al. (2003) study, which showed that surgical site infection (SSI) following spine surgery is a frequent complication that may raise treatment costs and increase morbidity and mortality. Based on the surgical technique, usage of instrumentation, patient variables, operative time, and whether the surgery is primary or revision, the SSI rates in spine surgery range from 2% to 15%.

Accordingly, the study found that the history of preoperative radiotherapy administration is significantly linked to wound complications and postoperative surgery for the metastatic spine, as four studies reported that it increases SSIs compared to patients who have not undergone radiotherapy before the surgery. This finding is supported by Lee et al. (2018), who found that, compared to individuals who waited longer, patients who started radiation

therapy within 21 days of surgery were more likely to experience wound problems. The study's findings convincingly demonstrated that RT can influence surgical wound healing pre-and post-operatively. Ionizing radiation, on the other hand, hinders fibroblast function and has a detrimental effect on their proliferation. According to Lee et al. (2018), this fibroblast depletion may be responsible for the side effects of radiation, including cutaneous atrophy, wound contraction, and a propensity for necrosis. The study's findings also support those of Jereczek-Fossa et al. (1998), who found that radiation administered prior to surgery decreases the initial leukocyte response, inhibits antibody formation, and makes wounds more susceptible to infection. The high rate of postoperative wound infection is caused by the fact that irradiated skin wounds are hypoxic and, hence, unable to fight off bacterial contamination. Furthermore, the study results are consistent with prior findings indicating postoperative radiotherapy (RT) is related to a decreased rate of wound infections compared to preoperative RT, such as those of Laohacharoensombat et al. (1997) and Berriochoa et al. (2016). Compared to patients who received radiotherapy before the surgery, Laohacharoensombat et al. (1997) only observed wound infection in one out of thirty patients who received RT 14 days after the surgery. When patients underwent RT within three months of surgery, Berriochoa et al. (2016) reported a low frequency of wound complications in their retrospective research. However, a number of studies support preoperative radiation. Similarly, Ghogawala et al. (2001), which further support the study's findings, revealed a wound complication rate of 46 percent when the operation was conducted 7 days after RT, as opposed to 20% when the procedure was performed > 7 days after RT. Notably, Ghogawala et al. found that patients who had previously had radiation had a much greater prevalence of wound problems (32%) than patients who had gone through surgery and subsequent radiation (12%). To reduce the rate of complications, such as wound complications after surgery, Lee et al. (2018) recommended waiting at least one week after RT before having surgery. Furthermore, this study's findings concur with Demura et al. (2009), who examined the overall infection rates in patients with metastatic spine tumour surgery. The rate of wound infection was much higher in the 22 patients who had received prior radiation (31.8%) than it was in the patients who had not (1.1%). In conclusion, preoperative exposure to radiotherapy increases the risk of wound problems and infections compared to radiotherapy administered after surgery, and the amount of time that passes after surgery before RT is also important. Also, the American Society of Anesthesiologists risk classification (ASA) greater than 2, higher blood loss, anticoagulant medication, neurological deterioration following surgery, patient nutrition status, smoking history, and prior spine operations were found to be major risk factors for wound complications, meaning they raise the likelihood of complications following the operation for metastases in the spine. This result is consistent with the Park et al. (2016) study of posterior cervical spine surgery, in which independent risk variables for postoperative SSI included hematocrit 33%, ASA class >2, BMI >35 kg/m2, chronic steroid use, and prolonged operation time. Other studies have discovered a connection between smoking and superficial, deep, and organ spaces (Sebastian et al., 2017). A study by Atkinson et al. (2016) supports this finding, as chronic hypertension and diabetes mellitus, two risk factors for SSI in spine surgery, were discovered to be insignificant in this study (Atkinson et al., 2016). Various definitions of these factors, the larger sample size utilized in this study, or alterations in demographic characteristics over time could all contribute to this disagreement. According to McPhee et al. (1998), who evaluated 53 patients who underwent 75 surgeries for spinal metastases and reported a wound dehiscence/infection rate of 20 percent (15/75 surgical sites), the study findings on BMI, nutrition status, and significant blood loss, among other patient-related characteristics, are linked to this study. Preoperative protein insufficiency and perioperative corticosteroid use were linked with variables for SSI in this study. Patients with lymphocyte count below 9.6103/mL on postoperative day 1 and white blood cell counts above 6.5103/mL on postoperative day 7 (sensitivity: 63%, specificity: 64%) or postoperative day 7 C-reactive protein levels above 5.0 mg/dL had higher rates of wound infection. 36 Additional major risk factors for spinal metastatic SSI were listed by Kumar and colleagues. They included low albumin levels, >7 levels of surgery, nonabsorbable sutures for skin closure, and the presence of neurological disability. However, the risk of SSI was unaffected by age, low lymphocyte count, absorbable skin closure material, or perioperative corticosteroid administration.

Age was positively associated with postoperative wound complications, as two studies revealed that wound complications are more common in older adults (above forty years) than in younger groups. Conversely, one study reported that age was not a risk factor for postoperative wound complications.

Surgery-related risk factors

The study findings established that surgery duration is linked to

postoperative wound-related complications and infections. Three studies reported that longer operation times are associated with postoperative complications, including wound complications and infections. Another surgery-related risk factor, according to the study findings, is the type of surgery. The study found that instrumented fusion, cervicothoracic surgery, and open surgeries had the highest risk factors linked to postoperative wound complications. However, minimally invasive surgery techniques were found to be less likely to cause postoperative wound infections. Four studies reported that postoperative infection rates, including wound infections, were lower in MIS compared to open surgery. Finally, the study findings revealed that the type of tumour surgery (primary spine vs. metastatic spine) is a risk factor, as two studies demonstrated spinal metastases having a higher rate of wound infection compared to other spinal surgeries such as the primary spine. However, one of the studies reported that plastic surgery for wound closure minimizes the risk of wound infections or complications compared to when spine surgeons close the spine. Thus, referral to that service may prove beneficial in managing wound complication risks in metastatic spine tumour patients with prior radiation to the surgical site.

These findings relate to the Hubertus et al. (2021) observational study of 238 patients with CTJ metastatic spine disease, of whom 68% underwent posterior-only surgery, 8% underwent anterior-only surgery, and 24 percent underwent a combination of anterior and posterior surgery. There were 8 incidences of hardware failure in their sample (18% surgical complications, 34% overall complications), 7 of which occurred in the posterior-only decompression and fusion group. The hardware failure rate in the posterior-only group was 4.3 percent (7 out of 164 patients). Likewise, Kanda et al. (2021) (46 total patients; 19 with CTJ lesions) showed a 24 percent complication rate, including wound problems and improved performance status, respectively, using a posterior-only technique. According to the scientists, a CTJ lesion indicates a chance of a bad outcome.

Study limitations

Bias is one of the potential limitations of this study. This is because the articles that could be openly accessed by the public, published in English, or included in this review were the only ones that were chosen for inclusion. Due to the fact that the topic of this review—risk factors for wound complications in metastatic and primary spines—is receiving more attention and that a lot of research has been conducted with a wealth of findings, the article samples chosen and included in this study were not exhaustive, hence leading to bias. Despite a thorough search of the literature, it is possible that some potentially relevant research was overlooked for this review. Additionally, choosing the literature sources may have involved subjectivity and bias. As a result, this study may include all relevant positive and negative findings, limiting the validity and applicability of the thesis's findings. Furthermore, it's possible that the study omitted some papers from the study's context published earlier than 2013, which would reduce the validity and trustworthiness of this study's conclusions. The reliability and validity of the thesis findings were increased by the authors' utilization of these studies to support the conclusions in the discussion section.

These findings are important and have implications for doctors and patients, as they reveal the risk factors that should be considered when conducting spine surgery to enhance outcomes. For instance, MIS should be preferred over open surgery; patients should avoid radiotherapy before undergoing surgery (they should be encouraged to undergo radiotherapy after the surgery); and they should also get some nutritional advice before undergoing spinal surgery to ensure their nutrition status is okay. Issues like BMI, preexisting conditions like diabetes, age, and smoking history should be considered, meaning patients with such factors need to be handled specially to minimize their postoperative complications, including wound infections. Also, surgeons should not avoid operating on elderly patients out of bigotry. Even though senior patients have lower survival rates and neurologic improvements than younger patients, operating on them is nevertheless challenging because, despite having acceptable ASA scores and functional levels, they frequently require emergency and palliative procedures. Age alone should not be a factor in deciding whether to operate or not, and when necessary, senior patients should not be excluded from surgery. As doctors plan for surgeries, this study's findings are important to patients and surgeons as they may be able to address modifiable hazards. The decision to pursue palliative surgeries or conduct cost-benefit evaluations of adjuvant therapies may be influenced by further information about the risks of wound complications.

CONCLUSION

This systematic review sought to identify risk factors for postoperative wound complications of the primary and metastatic

spine tumour surgical literature to help postoperative management of this vulnerable patient population. For each etiologic cohort, the study discovered distinct wound complication risk factors. This study established that the risk factors for wound complications in spine metastasis and primary spine surgery were patient and surgery-related. Accordingly, the risk factors associated with wound complications in metastatic tumours included BMI, blood loss, medication, age, higher blood loss, neurological deterioration after surgery, venous thromboembolism (VTE), smoking, preexisting patient conditions such as diabetes, nutrition status of patients, American Society of Anesthesiologists risk classification (ASA) greater than 2, ambulatory presence, nutrition status of patients and ambulatory presence, history of previous radiation, type of surgery, surgery duration and type of tumour. Risk factors for primary tumours included sacral procedures and the use of equipment when conducting surgery. Given these factors, wound complications were higher for the metastatic spine than primary spine tumours.

References

1. Amelot, A., Balabaud, L., Choi, D., Fox, Z., Crockard, H. A., Albert, T., ... & Mazel, C. (2017). Surgery for metastatic spine tumors in the elderly. Advanced age is not a contraindication to surgery. *The Spine Journal*, *17*(6), 759-767.
2. Atkinson, R. A., Davies, B., Jones, A., Van Popta, D., Ousey, K., & Stephenson, J. (2016). Survival of patients undergoing surgery for metastatic spinal tumours and the impact of surgical site infection. *Journal of Hospital Infection*, *94*(1), 80-85.
3. Berriochoa, A., Bennett, E., & Miller A. (2016). A comparison of oncologic and toxicity outcomes in patients receiving conventional external beam radiation therapy versus SB. *International Journal of Radiation Oncology* Biology* Physics*,96 (1), 113–114.
4. Carrera-Rivera, A., Ochoa-Agurto, W., Larrinaga, F., & Lasa, G. (2022). How-to conduct a systematic literature review: A quick guide for computer science research. *MethodsX*, 101895.
5. Chakravarthy, V. B., Hussain, I., Laufer, I., Goldberg, J. L., Reiner, A. S., Villavieja, J., ... & Bilsky, M. (2023). Cervicothoracic junction instrumentation strategies following separation surgery for spinal metastases. *Journal of Neurosurgery: Spine*, *1*(aop), 1-8.
6. Demura, S., Kawahara, N., Murakami, H., Nambu, K., Kato, S., Yoshioka, K., ... & Tomita, K. (2009). Surgical site infection in spinal metastasis: risk factors and countermeasures. *Spine*, *34*(6), 635-639.
7. Ferrari, R. (2015). Writing narrative style literature reviews. *Medical writing*, *24*(4), 230-235.
8. Finkelstein, J., Zaveri, G., Wai, E., Vidmar, M., Kreder, H., & Chow, E. (2003). A population-based study of surgery for spinal metastases: survival rates and complications. *The Journal of Bone & Joint Surgery British Volume*, *85*(7), 1045-1050.
9. Ghogawala, Z., Mansfield, F. L., & Borges, L. F. (2001). Spinal radiation before surgical decompression adversely affects outcomes of surgery for symptomatic metastatic spinal cord compression. *Spine*, *26*(7), 818-824.
10. Jarvers, J. S., Lange, M., Schiemann, S., Pfränger, J., Heyde, C. E., & Osterhoff, G. (2021). Risk factors for wound-related complications after surgical stabilization of spinal metastases with a special focus on the effect of postoperative radiation therapy. *BMC surgery*, *21*, 1-6.

11. Jereczek-Fossa, B., Jassem, J., Nowak, R., & Badzio, A. (1998). Late complications after postoperative radiotherapy in endometrial cancer: analysis of 317 consecutive cases with application of linear-quadratic model. *International Journal of Radiation Oncology* Biology* Physics*, *41*(2), 329-338.
12. Hersh, A. M., Pennington, Z., Schilling, A. T., Porras, J., Hung, B., Antar, A., ... & Sciubba, D. M. (2021). Plastic surgery wound closure following resection of spinal metastases. *Clinical Neurology and Neurosurgery*, *207*, 106800.
13. Hristidis, V., Papakonstantinou, Y., & Gravano, L. (2003). Efficient IR-style keyword search over relational databases. In *Proceedings 2003 VLDB Conference* (pp. 850-861). Morgan Kaufmann.
14. Hubertus, V., Gempt, J., Mariño, M., Sommer, B., Eicker, S. O., Stangenberg, M., ... & Meyer, B. (2021). Surgical management of spinal metastases involving the cervicothoracic junction: Results of a multicenter, European observational study. *Neurosurgical Focus*, *50*(5), E7.
15. Kanda, Y., Kakutani, K., Sakai, Y., Zhang, Z., Yurube, T., Miyazaki, S., ... & Kuroda, R. (2021). Surgical outcomes and risk factors for poor outcomes in patients with cervical spine metastasis: a prospective study. *Journal of Orthopaedic Surgery and Research*, *16*(1), 1-9.
16. Keam, J., Bilsky, M. H., Laufer, I., Shi, W., Zhang, Z., Tam, M., ... & Yamada, Y. (2014). No association between excessive wound complications and preoperative high-dose, hypofractionated, image-guided radiation therapy for spine metastasis. *Journal of Neurosurgery: Spine*, *20*(4), 411-420.
17. Kim, D. G., Ha, J. K., Hwang, C. J., Lee, D. H., Lee, C. S., & Cho, J. H. (2017). Is 1-stage posterior corpectomy more favorable compared with decompression with fusion to control thoracic cord compression by metastasis?. *Clinical Spine Surgery*, *30*(8), 350-355.
18. Kumar, S., Van Popta, D., Rodrigues-Pinto, R., Stephenson, J., Mohammad, S., Siddique, I., & Verma, R. R. (2015). Risk factors for wound infection in surgery for spinal metastasis. *European Spine Journal*, *24*, 528-532.
19. Kumar, N., Malhotra, R., Maharajan, K., Zaw, A. S., Wu, P. H., Makandura, M. C., ... & Wong, H. K. (2017). Metastatic spine tumor surgery: a comparative study of minimally invasive approach using percutaneous pedicle screws fixation versus open approach. *Clinical spine surgery*, *30*(8), E1015-E1021.
20. Laohacharoensombat, W., Wongwai, T., & Wajanavisit, W. (1997). Spinal metastasis: results of surgical management. *JOURNAL OF ORTHOPAEDIC SURGERY-HONG KONG-*, *5*, 3-10.
21. Lee, B. H., Park, J. O., Kim, H. S., Park, Y. C., Lee, H. M., & Moon, S. H. (2014). Perioperative complication and surgical outcome in Patients with spine metastases: retrospective 200-case series in a single institute. *Clinical Neurology and Neurosurgery*, *122*, 80-86.
22. Lee, R. S., Batke, J., Weir, L., Dea, N., & Fisher, C. G. (2018). Timing of surgery and radiotherapy in the management of metastatic spine disease: expert opinion. *Journal of Spine Surgery*, *4*(2), 368.
23. Lei, M., Yu, J., Yan, S., An, X., & Liu, Y. (2019). Clinical outcomes and risk factors in patients with cervical metastatic spinal cord compression after posterior decompressive and spinal stabilization surgery. *Therapeutics and Clinical Risk Management*, 119-127.
24. Lindgren, B. M., Lundman, B., & Graneheim, U. H. (2020). Abstraction and interpretation during the qualitative content analysis process. *International journal of nursing studies*, *108*, 103632.
25. Luksanapruksa, P., Buchowski, J. M., Zebala, L. P., Kepler, C. K., Singhatanadgige, W., & Bumpass, D. B. (2017). Perioperative complications of spinal metastases surgery. *Clinical spine surgery*, *30*(1), 4-13.
26. McPhee, I. B., Williams, R. P., & Swanson, C. E. (1998). Factors influencing wound healing after surgery for metastatic disease of the spine. *Spine*, *23*(6), 726-732.
27. Molina, C., Goodwin, C. R., Abu-Bonsrah, N., Elder, B. D., De la Garza Ramos, R., & Sciubba, D. M. (2016). Posterior approaches for symptomatic metastatic spinal cord compression. *Neurosurgical focus*, *41*(2), E11.
28. Olsen, M. A., Mayfield, J., Lauryssen, C., Polish, L. B., Jones, M., Vest, J., & Fraser, V. J. (2003). Risk factors for surgical site infection in spinal surgery. *Journal of Neurosurgery: Spine*, *98*(2), 149-155.
29. Park, S. J., Lee, C. S., & Chung, S. S. (2016). Surgical results of metastatic spinal cord compression (MSCC) from non–small cell lung cancer (NSCLC): analysis of functional outcome, survival time, and complication. *The Spine Journal*, *16*(3), 322-328.
30. Piper, K. F., Tomlinson, S. B., Santangelo, G., Van Galen, J., DeAndrea-Lazarus, I., Towner, J., ... & Vates, G. E. (2017). Risk factors for wound complications following spine surgery. *Surgical neurology international*, *8*.
31. Rao, P. J., Thayaparan, G. K., Fairhall, J. M., & Mobbs, R. J. (2014). Minimally invasive percutaneous fixation techniques for metastatic spinal disease. *Orthopaedic Surgery*, *6*(3), 187-195.

32. Rigney, G. H., Massaad, E., Kiapour, A., Razak, S. S., Duvall, J. B., Burrows, A., ... & Shin, J. H. (2023). Implication of nutritional status for adverse outcomes after surgery for metastatic spine tumors. *Journal of Neurosurgery: Spine*, *1*(aop), 1-11.
33. Saunders, M., Lewis, P. H. I. L. I. P., & Thornhill, A. D. R. I. A. N. (2007). Research methods. *Business Students 4th edition Pearson Education Limited, England*, *6*(3), 1-268.
34. Schilling, A. T., Ehresman, J., Huq, S., Ahmed, A. K., Lubelski, D., Cottrill, E., ... & Sciubba, D. M. (2020). Risk factors for wound-related complications after surgery for primary and metastatic spine tumors: a systematic review and meta-analysis. *World neurosurgery*, *141*, 467-478.
35. Sebaaly, A., Shedid, D., Boubez, G., Zairi, F., Kanhonou, M., Yuh, S. J., & Wang, Z. (2018). Surgical site infection in spinal metastasis: incidence and risk factors. *The Spine Journal*, *18*(8), 1382-1387.
36. Sebastian, A. S., Polites, S. F., Glasgow, A. E., Habermann, E. B., Cima, R. R., & Kakar, S. (2017). Current quality measurement tools are insufficient to assess complications in orthopedic surgery. *The Journal of hand surgery*, *42*(1), 10-15.
37. Selvi, A. F. (2019). Qualitative content analysis. In *The Routledge handbook of research methods in applied linguistics* (pp. 440-452). Routledge.
38. Silva, A., Yurac, R., Guiroy, A., Bravo, O., Ciancio, A. M., Landriel, F., & Hem, S. (2021). Low implant failure rate of percutaneous fixation for spinal metastases: A Multicenter retrospective study. *World Neurosurgery*, *148*, e627-e634.
39. Sugita, S., Hozumi, T., Yamakawa, K., Goto, T., & Kondo, T. (2016). Risk factors for surgical site infection after posterior fixation surgery and intraoperative radiotherapy for spinal metastases. *European Spine Journal*, *25*, 1034-1038.
40. Vargas, E., Mummaneni, P. V., Rivera, J., Huang, J., Berven, S. H., Braunstein, S. E., & Chou, D. (2022). Wound complications in metastatic spine tumor patients with and without preoperative radiation. *Journal of Neurosurgery: Spine*, *1*(aop), 1-6.
41. Wang, J. C., Boland, P., Mitra, N., Yamada, Y., Lis, E., Stubblefield, M., & Bilsky, M. H. (2014). Single-stage posterolateral transpedicular approach for resection of epidural metastatic spine tumors involving the vertebral body with circumferential reconstruction: results in 140 patients: invited submission from the Joint Section Meeting on Disorders of the Spine and Peripheral Nerves, March 2004. *Journal of Neurosurgery: Spine*, *1*(3), 287-298.
42. Xiao, Y., & Watson, M. (2019). Guidance on conducting a systematic literature review. *Journal of planning education and research*, *39*(1), 93-112.