Original Article Clinics in Orthopedic Surgery 2023;15:109-117 • https://doi.org/10.4055/cios22115

Trends in Survival and Surgical Methods in Patients Surgically Treated for Metastatic Spinal Tumors: 25-Year Experience in a Single Institution

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Background: This study aimed to examine trends in postoperative survival and surgical methods over a 25-year period in patients surgically treated for metastatic spinal tumors.

Methods: We performed a retrospective study of patients who underwent surgical treatment for metastatic spinal tumors between 1996 and 2020. For trend analysis, the study cohort was divided into three groups according to the year of surgery: 1996–2004, 2005–2012, and 2013–2020. A Kaplan-Meier survival analysis was performed to examine survival, and the log-rank test was used to compare the survival of the top six common cancers among the periods. The surgical methods were grouped and examined as follows: fixation only, palliative decompression and fixation, gross total removal and fixation, and total *en bloc* spondylectomy.

Results: This study included a total of 608 patients. There were 78 patients in 1996–2004, 236 in 2005–2012, and 294 in 2013–2020. Regarding the overall survival trend, the group 2013–2020 had a significantly improved survival as compared to the other two groups ($p < 0.001$). According to specific cancer sites, significant survival improvement was observed in patients with lung, kidney, and breast cancers ($p < 0.001$, $p < 0.001$, and $p = 0.022$, respectively). There were no significant changes in the primary sites of the liver, colorectum, or prostate. Regarding surgical methods, the proportion of gross total tumor removal declined, whereas the proportion of palliative decompression and fixation and fixation only procedures increased.

Conclusions: During the past 25 years, significant survival improvement was observed in patients with lung, kidney, and breast cancers. There was no improvement in survival in patients with liver, colorectal, and prostate cancers. In terms of surgical techniques, palliative decompression and fixation only procedures increased, while gross total tumor removal declined.

Keywords: *Metastatic spinal tumors, Trends, Survival, Surgical methods*

A worldwide increase in the number of cancer cases is accompanied by improved multidisciplinary treatment, which has led to increased life expectancy in patients with cancer.[1] General cancer mortality has been on the decline, and a general 5-year survival rate for all patients diagnosed with cancer is in the range of 70%.[2,3] The spine is one of the most commonly encountered locations for metastases and spinal metastases occur in approximately 5%–10% of primary cancer cases.[4,5] Spinal metastases are most commonly found in the thoracic spine and may be present as the initial manifestation of systemic malignancy in approximately 10%–20% of cases.[6,7]

An important predictor of the type of treatment for spinal metastasis is expected patient survival. There are multiple options for the management of spinal metastases, including surgical stabilization, decompression, radiotherapy, and chemotherapy. The treatment is aimed at controlling

Received April 6, 2022; Revised July 29, 2022;
Accepted August 2, 2022
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local tumors and improving quality of life.[8-10] The appropriate treatment modality should be decided based on each patient's general condition and expected survival to avoid excessive and insufficient treatment.[11,12] Surgical treatment can be considered on the basis of the patient's symptoms and related radiographic findings.[13] However, the general prerequisite for surgical intervention in patients with spinal metastases is an expected survival of > 3 months.[11,14]

There are multiple scoring systems that have been used to analyze the expected patient survival; the commonly used scoring systems were suggested by Tomita et al.,[15] Tokuhashi et al.,[16] and Bauer and Wedin[17] It is of paramount importance to understand spinal metastasis as not a local disease but one that has widespread systemic manifestations. While these scoring systems have been used to determine expected patient survival, it is important to understand the role of heterogeneity in primary malignancy and the lack of inclusion of modern treatment methodology in most of these scoring systems. Hence, it is important to understand the recent trends in survival in patients with spinal metastases with different types of primary malignancies. In addition, owing to recent advances in radiation therapy, the role of local control of metastatic tumors through radiation therapy has been emphasized.[18] Procedures involving extensive debulking such as corpectomy are not used as frequently as they were in the past, and the use of minimally invasive surgery, such as separation surgery to remove only the mass surrounding the cord, has increased.[19,20] However, there have been very few studies focusing on survival trends and the type of surgical management employed in patients with spinal metastases over a long period.

This study analyzed the trends in survival rates and surgical methods in surgically treated metastatic spinal tumors at a single institution over a period of 25 years. We aimed to investigate the management trends in these patients and determine any temporal association with an increase or decrease in a specific type.

METHODS

The study was approved by the Institutional Review Board of the Samsung Medical Center (No. SMC 2022-03-085). After obtaining a waiver of informed consent from the board, we performed a retrospective analysis of patients with biopsy-proven metastatic spinal tumors who underwent surgical treatment between January 1997 and December 2020 at the outpatient center.

The study cohort was divided into three groups for the trend analysis according to the year of surgery: arbitrarily nine, eight, and eight years in chronological order among 25 years of surgical results (January 1997–December 2004, January 2005–December 2012, and January 2013–December 2020). The indications for surgical treatment were carefully determined through a multilateral inter-department conference involving medical oncologists, radiation oncologists, radiology specialists, and spine surgeons. The indications for surgical treatment were as follows: (1) persistent pain despite conservative treatment; (2) neurological deterioration; and (3) potential neurological deficits associated with mechanical instability.

Four different surgical strategies were employed in the entire cohort: fixation only, palliative decompression and fixation, gross total removal and fixation, and total *en bloc* spondylectomy (TES). Patients who underwent percutaneous procedures such as vertebroplasty or kyphoplasty were excluded from the study. The surgical treatment method was determined based on the patient's symptoms and radiologic imaging findings, which indicated the extent of tumor invasion. In cases of pathological fracture or mechanical instability without neurological deficits, only spinal stabilization was performed. Spinal stabilization was performed with a pedicle screw and rod-based system, using a standard open or minimally invasive method. Tumor removal was performed in cases of metastatic cord compression causing neurological deterioration. Palliative decompression was defined as the removal of only the tumor surrounding the cord for symptom relief. The maximum removal of tumors that invaded the vertebral body and surrounding cord was defined as gross total removal. The extent of tumor removal was determined based on the patient's general condition and whether the primary malignancy was hypervascular or radioresistant. TES was performed in a young patient with a single metastasis, well-controlled primary cancer, and good general performance.

The patients underwent radiation therapy in the form of either external beam radiation or stereotactic radiosurgery. General demographic data for the patients in the cohort were collected, and trends in 30-day and 90-day mortality were identified. The most common primary malignancies were then chosen from the cohort, and their overall survival data were represented individually. Metastatic disease was labelled as synchronous when the spinal metastases were diagnosed within 3 months from the diagnosis of the primary malignancy and metachronous if otherwise.

Statistical Analysis

Demographic parameters were described as percentages

of the study cohort. Trends in 30-day and 90-day mortality were expressed as percentages and compared between the three decided time frames using the chi-square test. Overall survival was defined as the time from the date of diagnosis of spinal metastasis until death or the last follow-up for censored patients. It was expressed as a mean time, and further survival was expressed as a percentage according to the specific primary malignancy. The Kaplan-Meier graphs were used to depict overall survival, and the log-rank test was used to compare survival specific to the primary malignancy. These values were used to calculate the mean survival time for each primary malignancy. The various types of surgeries performed were expressed as proportions of the total procedures and depicted graphically in pie charts. Statistical analyses were performed using IBM SPSS ver. 25 (IBM Corp., Armonk, NY, USA). Statistical significance was defined as $p < 0.05$.

RESULTS

The final study cohort consisted of 608 patients who underwent surgical treatment for spinal metastasis at a single center. Men comprised 63.3% of the total cohort, and the mean age at the time of spine surgery was 58.1 years (range, 17.0–83.0 years). The most common site of metastasis was the thoracic spine in 58.2% of cases, followed by the lumbar and cervical spine. Six primary malignancies were noted in 72.5% of the entire cohort in the lung, liver, kidney, colorectal, breast, and prostate in decreasing order of frequency. Of these, lung cancer was the leading single cause of surgical management of spinal metastases, comprising approximately 169 cases (27.8%). While analyzing the time of detection of metastases, metachronous lesions were found to be much more common, accounting for 79.4% of the cases. The 2013–2020 group consisted of 294 patients (48.4%), followed by the 2005–2012 group with 236 (38.8%) and the 1996–2004 group with 78 (12.8%). The results are summarized in Table 1 for better understanding.

The overall survival data for the study cohort and the top 6 individual primary malignancies are summarized in Table 2. The mean overall survival time was 19.8 months (95% confidence interval [CI], 16.9–22.8 months), and the 6-month survival rate was 57.8%, further decreasing to 20.7% at 2 years. A total of 169 patients with metastatic lung cancer underwent surgery, and the mean survival for lung cancer was 12.6 months (95% CI, 9.6–15.6 months), whereas the 6-month survival rate was 49.8%. This decreased to 28.8% at 1year and 13.2% at 2 years. The mean survival of 60 patients with kidney cancer was approximately 22.9 months (95% CI, 16.7–29.0 months), and the 6-month survival rate was 79.7%, which decreased to a 1-year survival rate of 56.5% and a 2-year survival rate of 31.3%. Among the 6 cancers, colorectal cancer had the shortest survival time with a mean of only 6.1 months (95% CI, 4.4–7.8 months), and the 6-month survival rate was 30.0%, 1-year survival rate was 11.5%, and the 2-year survival rate further decreased to 3.5%. The highest 90-day mortality was found to be 37.0% with colorectal cancer. The highest survival rate was noted in cases of metastatic breast cancer, with a mean survival of 45.1 months (95% CI, 31.4–58.7 months), with 1-year and 2-year survival rates of 74.6% and 52.0%, respectively. Breast cancer con-

Table 1. Baseline Demographics

Characteristics	Value (n = 608)
Sex	
Male	385 (63.3)
Female	223 (36.7)
Age at spine surgery (yr)	58.1 (17.0–83.0)
Location	
Cervical	103 (16.9)
Thoracic	354 (58.2)
Lumbar	146 (24.0)
Sacral	5 (0.8)
Top six common primary cancer sites	440 (72.5)
Lung	169 (27.8)
Liver	101 (16.6)
Kidney	60 (9.9)
Colorectal	46 (7.6)
Breast	41 (6.7)
Prostate	23 (3.8)
Metastasis detection time	
Metachronous	483 (79.4)
Synchronous	125 (20.6)
Surgery year	
1996–2004	78 (12.8)
2005–2012	236 (38.8)
2013–2020	294 (48.4)

Values are presented as number (%) or mean (range).

Table 2. Overall Survival Data According to the Top Six Common Primary Cancer Sites

Primary cancer site	No. (%)	Mean month (95% CI)	6-Month survival rate (%)	1-Year survival rate (%)	2-Year survival rate (%)	30-Day mortality (%)	90-Day mortality (%)
All	608 (100)	19.8 (16.9–22.8)	57.8	37.7	20.7	3.5	21.4
Lung	169 (27.8)	12.6 (9.6–15.6)	49.8	28.2	13.2	6.5	30.2
Liver	101 (16.6)	21.7 (13.2–30.3)	59.4	37.1	14.0	1.0	14.9
Kidney	60 (9.9)	22.9 (16.7–29.0)	79.7	56.5	31.3	0	8.3
Colorectal	46 (7.6)	6.1 (4.4–7.8)	30.0	11.5	3.5	0	37.0
Breast	41 (6.7)	45.1 (31.4–58.7)	87.6	74.6	52.0	2.4	7.3
Prostate	23 (3.8)	30.6 (13.0–48.2)	65.2	41.9	37.3	0	13.0

CI: confidence interval.

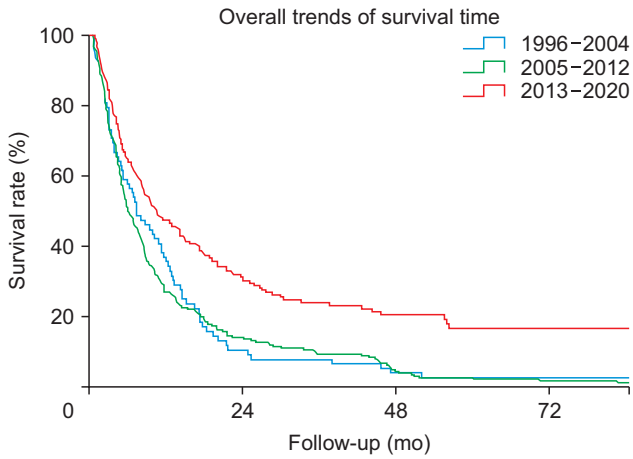

Fig. 1. The Kaplan-Meier survival curve shows significantly better overall survival in the 2013–2020 group than in the other 1996–2004 and 2005–2012 groups.

tributed the least to 90-day mortality among the groups, with a value of 7.3%.

Although there was no significant difference in the revised Tokuhashi scores between the three time frames, when we examined and compared the overall survival trend, it was found that the 2013–2020 group had significantly better survival rates than the other two groups (Fig. 1). Similarly, a significant improvement in survival rates was found in cases of lung, kidney, and breast cancers among the 2013–2020 group as compared to the 1996–2004 and 2005–2012 groups (Fig. 2). The remaining 3 primary cancers, namely, liver, colorectal, and prostate cancers, showed no significant improvements in survival trends when compared among the three time frames (Fig. 3, Table 3).

We compared 30-day and 90-day mortality between these three groups in terms of the percentage of the respective cohorts (Table 4). Overall, 30-day mortality decreased from 5.1% in 1996–2004 to 4.2% in 2005–2012 and finally to 2.4% in 2013–2020. However, this reduction was not statistically significant ($p = 0.349$). Similarly, the overall 90-day mortality increased marginally from 20.5% during 1996–2004 to 26.3% during 2005–2012 and finally decreased to 17.7% during 2013–2020. This reduction was not statistically significant ($p = 0.056$).

When comparing the different types of surgical procedures among the three time groups, it was evident that gross total tumor removal and instrumented fixation were the most common modalities used in the group 1996–2004 with 80.7% of cases, and palliative decompression with fixation was utilized in only 19.3% of the cases. The pattern changed in the next group (2005–2012), where palliative decompression with fixation and gross tumor removal with fixation were utilized in equal proportions of 46.6% of cases each. There was also minor utilization of fixation-only and TES methods in 4.4% and 2.4% of cases, respectively. The trend in the third group favored palliative decompression with fixation and fixation only, where both were utilized in about 62.6% of the cases. On the contrary, gross total tumor removal with fixation and TES was utilized in 37.4% of the cases (Fig. 4).

DISCUSSION

Predicting survival in patients with metastatic spinal disease is important because therapeutic studies largely depend on survival. Radical surgical treatment is reserved for patients with a better survival prognosis and more minimally invasive surgical management or radiotherapy is considered better for patients with a lower expected sur-

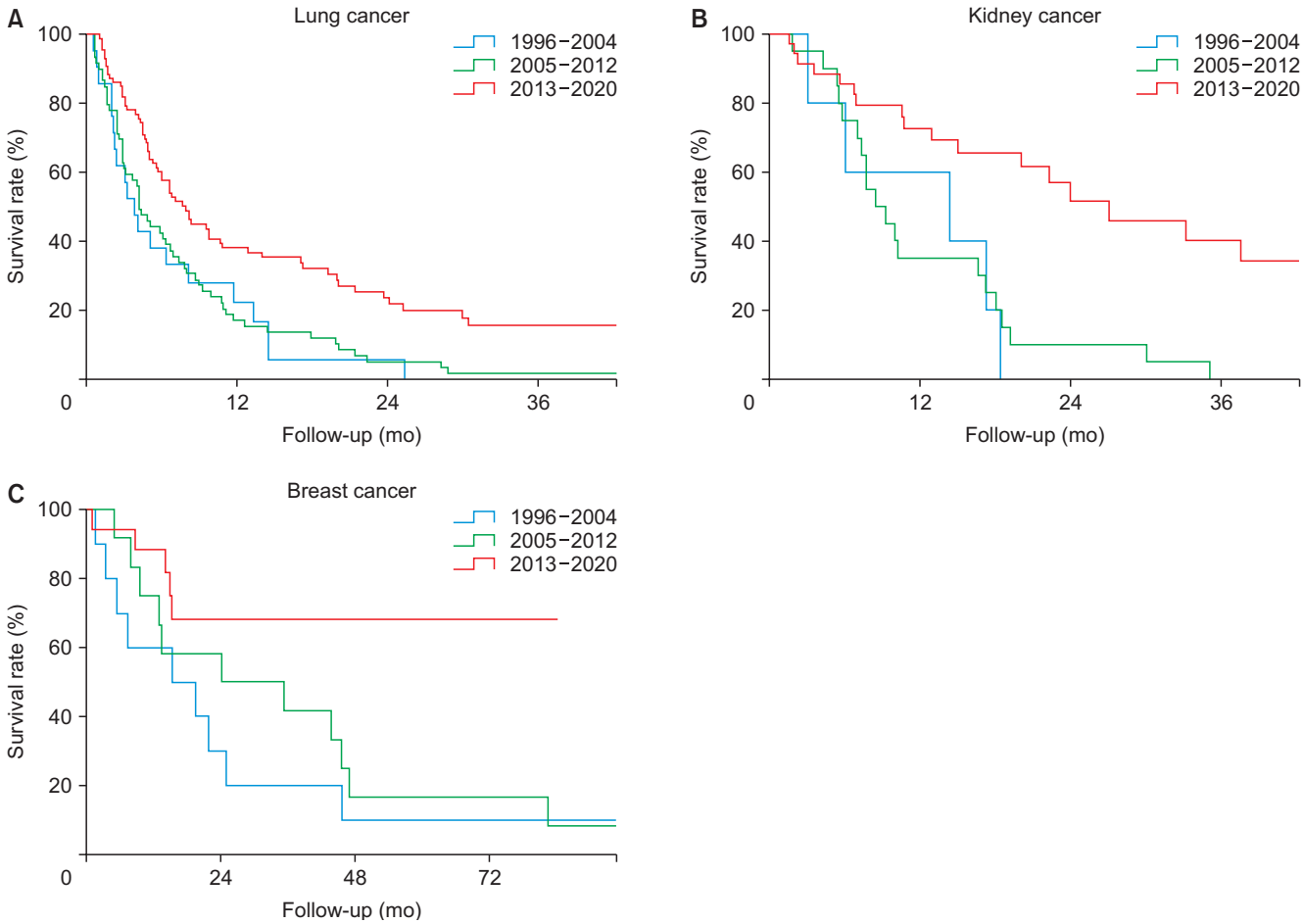

Fig. 2. The Kaplan-Meier survival curves show the significant improvement in survival trends in cases of lung (A), kidney (B), and breast (C) cancers among the top six common primary cancer sites.

vival.[16,21] The important factors considered by these scoring systems are the number of vertebral metastases, the primary site of malignancy, visceral metastases, Karnofsky performance status, and neurological status. However, these scoring systems have many disadvantages. The accuracy of some of these systems is low and decreases over time.[22,23] An underestimated life expectancy may lead to inadequate treatment of patients. A short life expectancy becomes an important limitation in offering radical surgical solutions and favors minimally invasive surgical management combined with radiotherapy.

Our study provides an opportunity to inspect the trends in the survival of patients undergoing surgery for metastatic spinal tumors at a single institution. Recent advancements in cancer screening, diagnostics, surgical management, and adjuvant therapy have translated into improved survival outcomes for patients.[3] There have been remarkable improvements in targeted systemic therapies aimed at specific mutations, hormonal therapy, and immune checkpoint inhibitors, which have been shown to extend survival.[24-26] Although there was no significant difference in the revised Tokuhashi score among the three groups classified by time period, this study demonstrated that survival recently improved. This means that as the survival of cancer patients has improved in recent years, the existing scoring system may underestimate the patient's life expectancy. In particular, we have noted significant survival improvements in patients with lung, kidney, and breast cancers with spinal metastasis over the last 25 years at our institution. This can also be accounted for by the fact that the general survival rate for primary cancers has also improved. A study by Rothrock et al.[2] has shown a 60% improvement in survival for patients with kidney tumors and metastases to the spine. Meanwhile, during the same period, the overall 5-year survival of kidney cancer patients improved from 57% to 74%. This is because a new therapeutic approach, such as anti-vascular endothelial growth factor, has shown good results in kidney cancer.[27]

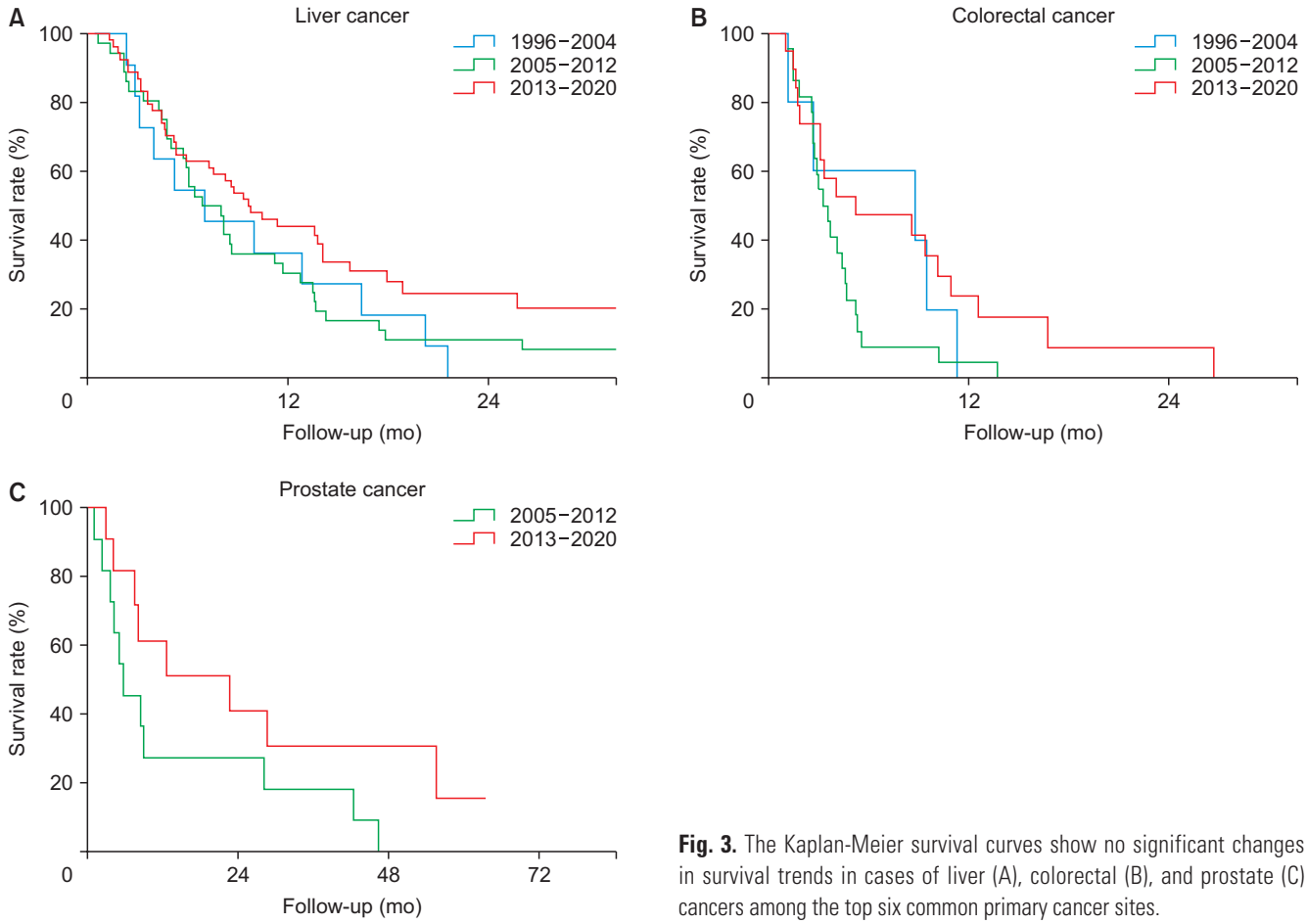

Fig. 3. The Kaplan-Meier survival curves show no significant changes in survival trends in cases of liver (A), colorectal (B), and prostate (C) cancers among the top six common primary cancer sites.

Table 3. Trends of Survival in the Top Six Common Primary Cancer Sites According to Three Time Frames

Primary cancer site	Mean month (95% CI)			*p*-value
	2013–2020	2005–2012	1996–2004	
All	26.1 (21.8–30.5)	13.2 (10.6–15.8)	13.5 (9.0–18.0)	< 0.001
Tokuhashi score	6.5 (6.0–7.1)	5.9 (5.5–6.2)	6.2 (5.9–6.5)	0.165
Lung	18.9 (12.8–24.9)	7.6 (5.5–9.8)	6.7 (3.8–9.6)	< 0.001
Liver	23.2 (13.5–32.9)	16.5 (6.4–26.7)	9.6 (5.3–13.8)	0.176
Kidney	32.8 (22.7–43.0)	12.2 (8.4–16.0)	11.8 (5.8–17.8)	< 0.001
Colorectal	8.3 (4.7–12.0)	4.1 (2.9–5.4)	6.7 (2.7–10.6)	0.095
Breast	60.9 (43.9–77.9)	36.0 (19.0–53.0)	24.9 (5.7–44.3)	0.022
Prostate	NC	14.2 (4.4–24.0)	27.0 (12.8–41.3)	0.067

CI: confidence interval, NC: not checked.

The same results have been noted with lung cancer, where mutation-targeted systemic therapy has been important to extending survival.[24] Adapted genotype treatments or hormonal therapy are actively used for breast cancer with good results.[27] As the main survival prognosis of spinal metastasis is determined by the effect of primary cancer

Table 4. Trends of 30-Day and 90-Day Mortality Rates According to the Year of Surgery

Surgery year	30-Day mortality (%)	90-Day mortality (%)
1996–2004	5.1	20.5
2005–2012	4.2	26.3
2013–2020	2.4	17.7
p-value	0.349	0.056

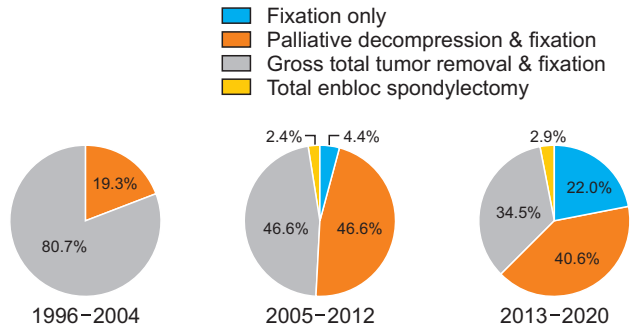

Fig. 4. Trends in surgical methods for metastatic spinal tumors according to the year of surgery.

treatment, our results showed that advances in medical oncology in the lung, kidney, and breast were superior to those in other cancers in the past decades. Therefore, survival improvement emphasizes the need for long-term outcome considerations in treatment decisions for patients with these cancers.

These developments have also been established in advanced radiotherapy techniques, in which high doses of radiation can be administered over small targets without collateral damage to the surrounding tissue. This is particularly important in the spine because of the proximity of neural structures. A modern concept introduced in the surgical management of metastatic spinal tumors has been "separation surgery," which basically denotes circumferential decompression of the spinal cord off the tumor tissue, using microsurgical techniques, just to create enough space without extensive debulking.[28] This allows for the delivery of high-dose radiation to the tumor tissue and minimal exposure to the spinal cord. There are also percutaneous stabilization techniques to stabilize the spinal column, which may be guided by navigation.[29-31] Taken together, these findings provide patients with a less radical surgical procedure, a limited duration of surgery, and less surgical trauma.[32] Separation surgery followed by stereotactic radiosurgery reduces local disease progression and gives good local control.[33] Thus, less invasive surgery was stated to be more beneficial than aggressive resection surgery for patients without a life expectancy of 2 years or more. This is also supported by the fact that our study demonstrated a trend towards less invasive methods of surgical management in the treatment of spinal metastases by demonstrating a decrease in the rate of gross total tumor removal. This is also supported by the study performed by Choi et al.[34] who reported a decreasing trend towards vertebrectomy and an increasing frequency of resection and instrumentation surgeries. This is largely made possible by advancements in systemic and stereotactic radiotherapy.

This study has certain important limitations. First, the cohort data were obtained from a single hospital and thus were likely to have a certain degree of bias. Second, the patient cohort consisted of multiple types of primary malignancies, and the types of adjuvant therapy available for each will be different. Hence, survival trends may not be uniformly applicable to all cancer types. Last, we did not include specific radiologic assessments, such as the spinal instability neoplastic score or Bilsky grade, when performing surgical procedures. However, it is important to note that the decision on surgical treatment for spinal metastasis was consistently made through a multilateral, interdepartmental conference. Surgical treatment is determined by the patient's clinical symptoms and radiologic findings, which indicate the extent of tumor invasion. Therefore, we did not specifically compare the spinal instability neoplastic score or Bilsky grade because the surgical indications, including radiographic assessment, were constant.

The current study has demonstrated favorable survival trends over the last 25 years among patients with lung, kidney, and breast cancers who underwent surgery at our institute for spinal metastases. No significant improvements were found in patients with spinal metastases from colorectal, hepatocellular, and prostate carcinoma among the top six causes. Therefore, primary tumors were an important predictor of survival in patients with metastatic spinal tumors. It was also noted that there was an increasing trend towards palliative decompression with fixation and minimally invasive fixation as compared to gross total tumor removal and TES, thus favoring less radical and invasive surgeries in the management of metastatic spinal tumors.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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