The Efficacy and Complications of Preoperative Embolization of Metastatic Spinal Tumors: Risk of Paralysis after Embolization

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Abstract:

Introduction: This study investigated the efficacy and complications of preoperative embolization for spinal metastatic tumors, focusing on the etiology of post-embolization paralysis.

Methods: We retrospectively reviewed the data of 44 consecutive patients with spinal metastases treated between September 2012 and December 2020. Intraoperative blood loss and postoperative transfusion requirement were compared between the embolization (+) and (−) groups. Complications associated with embolization were reviewed.

Results: Overall, 30 patients (68%) underwent preoperative embolization. All the patients in both groups underwent palliative posterior decompression and fusion. The mean intraoperative blood loss in the overall population was 359 ml (range, minimum-2190 ml) and was 401 ml and 267 ml in the embolization (+) and embolization (−) groups, respectively. Four patients (9%) (2 patients from each group) required blood transfusion. There were no significant between-group differences in blood loss and blood transfusion requirements. All 7 patients with hypervascular tumors were in the embolization (+) group. Two patients experienced muscle weakness in the lower extremities on days 1 and 3 after embolization. There were metastases in T5 and T1-2, and magnetic resonance imaging after embolization showed slight exacerbation of spinal cord compression. The patients showed partial recovery after surgery.

Conclusions: With the predominance of hypervascular tumors in the embolization (+) group, preoperative embolization may positively affect intraoperative bleeding. Embolization of metastatic spinal tumors may pose a risk of paralysis. Although the cause of paralysis remains unclear, it might be due to the aggravation of spinal cord compression. Considering this risk of paralysis, we advocate performing surgery as soon as possible after embolization.

Keywords:

Thoracolumbar spine, spinal metastasis, preoperative embolization, complication

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Introduction

Bone metastasis is a devastating condition that can negatively impact patients with advanced cancer, with patients experiencing limitations in the activities of daily living and reductions in quality of life. Bone metastasis commonly occurs in the spinal column. Surgical treatment is reportedly an effective treatment for spinal metastases. It is beneficial for resecting tumors, relieving pain, and improving neurological manifestations[1]. A randomized trial by Patchell et al. concluded that direct decompressive surgery plus postoperative radiotherapy is superior to radiotherapy alone in patients with spinal cord compression caused by metastatic cancer[2].

Surgical treatment for hypervascular spinal metastatic tumors can be complicated and technically demanding because of the potential for excessive or life-threatening blood loss during metastatic tumor excision. Further, it carries a risk of neurological deterioration. Hussain et al. reported that patients with metastatic spinal tumors in the thoracic spine have a high risk of postoperative blood transfusion, with a 30-day mortality rate of 8.3%. On the other hand, that rate in the cervical and lumbar spines were 5.1% and 2.6%, respectively[3]. Additionally, several studies have reported excessive bleeding during surgical interventions for metastatic spinal tumors.

Rapid advances in neuro interventions and spinal tumor

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embolization have enabled complex spinal surgeries for spinal metastasis with lower blood loss. Preoperative embolization of metastatic spinal tumors reduces blood loss and allows for more radical resection of the spinal tumor[4-8]. Moreover, a meta-analysis showed that intraoperative blood loss is lower in more recent studies than in earlier studies[9]. However, preoperative embolization has a potential complication of post-embolization paralysis[4,7,10]. Post-embolization paralysis can occur due to permanent occlusion of a feeding artery to the spinal cord. However, Murakami et al. suggested that surgeons may sacrifice up to 3 pairs of segmental arteries, even including the artery of Adamkiewicz (AKA), during total en bloc spondylectomy, if necessary[11].

Despite its negative impact, to our best knowledge, the cause of post-embolization paralysis has not been elucidated in detail. Therefore, this study investigated the efficacy and complications of preoperative embolization for metastatic spinal tumors, focusing on the etiology of post-embolization paralysis.

Materials and Methods

Study design and population

The institutional review board of our hospital approved this retrospective study that evaluated 76 patients who underwent surgical treatment for spinal metastasis in our hospital between September 2012 and December 2020. Among them, patients who underwent palliative decompression and instrumented stabilization using a single posterior approach were eligible.

After excluding patients who underwent only posterior decompression or total en bloc spondylectomy, the study included 44 patients with T1 to L5 vertebral involvement, candidates for preoperative embolization of metastatic vertebrae. Patients with paralysis, intractable pain, bowel and bladder dysfunction, and spinal instability were indicated for surgical treatment. Anterior debridement and decompression following laminectomy were performed using a posterior transpedicular approach when the tumor involved the vertebral body.

The progression of spinal metastasis was graded using Tomita's classification[12]. Physical status at the time of the surgery was evaluated using the American Society of Anesthesiologists (ASA) scoring system[13]. In this study, renal cell carcinoma and thyroid carcinoma were classified as hypervascular tumors[14]. Intraoperative blood loss was determined from the surgical records. Intraoperative and postoperative transfusion requirements within 72 h were reviewed from the medical records. None of the patients had comorbidities that could potentially influence intraoperative blood loss.

Preoperative embolization procedure

Preoperative tumor embolization was the most feasible way to reduce the risk of massive blood loss during surgery. Embolization was performed under local anesthesia using a femoral approach. Throughout the thoracic and lumbar levels, paired segmental arteries arising at each vertebral body level should be assessed, except for the upper thoracic spine, at which the superior intercostal arteries should be assessed in addition to the supreme intercostal arteries (arising from the costocervical trunk). Selective catheterization of the corresponding segmental arteries, including the 1 level above and below the tumor site, was usually performed. When the involvement of a feeding artery to the spinal cord was suspected during angiography, embolization was not performed at that artery.

Embolization-related complications were reviewed from the medical records. Embolization was performed on the same day as surgery in 20 patients, 1 day before surgery in 8 patients, and 3 days and 4 days before surgery in 1 patient each. Embolization used coils alone, gelatin sponge alone, and a combination of gelatin sponges and coils in 4, 11, and 29 patients, respectively. Preoperative embolization of metastatic spinal tumors is a routine procedure in our institution. It is performed for all eligible patients, particularly those with hypervascular tumors. Meanwhile, although preoperative embolization is considered effective for reducing intraoperative blood loss, it is not routinely performed. Such surgeries are typically performed in emergencies and limited by the availability of interventional radiologists.

Statistical analysis

Continuous variables were evaluated using nonparametric statistical analysis with the Mann-Whitney U test. Categorical variables were evaluated using Fisher's exact test or the chi-square test, as appropriate. All statistical analyses were performed using JMP software 15.1.0 for Windows (SAS Institute Inc., Cary, NC, USA). The threshold for significance was set at $P<0.05$.

Results

Among the 44 patients, 30 and 14 were male and female, respectively. The mean age at the time of surgery was 65.7 years (44-80 years). In total, 37 (84%) and 7 (16%) patients had metastasis involving the thoracic spine and the lumbar spine, respectively. There were 30 patients (68%) who underwent preoperative embolization (i.e., embolization [+] group). Table 1 shows the demographic dates of the patients in each group. The majority of metastases were in the prostate, lungs, and gastrointestinal tract. All 7 patients with hypervascular tumors were included in the embolization (+) group (Table 1). In total, 1-7 arteries were embolized per procedure (mean, 4.1 arteries). A total of 124 arteries were embolized in 30 patients in the embolization (+) group. During embolization, AKA or arteries with suspected AKA were identified in 5 patients (17%). These arteries were confirmed in left T10 in 2 patients and in left L1, right T9, and right L2 in one patient each. Embolization was not performed in these arteries. There were no significant differences in sex, age, location of metastasis, Tomita classification, and ASA

Table 1. Patient Characteristics.

	Embolization (−)	Embolization (+)	p
Number of patients	14	30	
Sex (male:female)	12:2	18:12	0.163
Age	63.2	66.5	0.585
Tumor (n)			
Breast	1	3	
Prostate	3	4	
Lung	4	10	
Thyroid	0	5	
Renal	0	2	
Gastrointestinal tract	4	3	
Multiple myeloma	1	0	
Others	1	3	
Hypervascular tumors:other tumors	0:14	7:23	0.078
Location of metastasis (n)			0.184
Thoracic	10	27	
Lumbar	4	3	
Tomita classification (n)			0.689
4	4	5	
5	3	11	
6	2	5	
7	5	9	
ASA score (n)			0.475
II	9	23	
III	5	7	

ASA, American Society of Anesthesiologists

Table 2. Surgical Treatments and Blood Loss.

	Embolization (−)	Embolization (+)	P
Instrumented segments	5.3±1.3	5.7±1.1	0.257
Decompressed segments	1.7±0.7	1.9±0.7	0.522
Operative time (min)	169±41	190±45	0.136
Blood loss (mL)	267±247	401±410	0.266
Blood transfusion (n (%))	2 (14%)	2 (7%)	0.581

score between the embolization (+) and (−) groups.

The mean intraoperative blood loss was 359 ml (range, minimum-2190 ml) in the overall population and was 401 ml and 267 ml in the embolization (+) and embolization (−) groups, respectively. Four patients (9%) required blood transfusion, including 2 patients in the embolization (+) group and 2 patients in the embolization (−) group. There were no significant between-group differences in blood loss, blood transfusion requirement, and operative time (Table 2). Intraoperative blood loss was higher in patients with hypervascular tumors than in those with other tumors (670 ml vs. 300 ml; p=0.013). Meanwhile, there was no significant difference in blood transfusion requirement between hypervascular tumors and other tumors (1 vs. 3; p=0.514). In patients who were not classified with hypervasclular tumors, there was no significant difference in intraoperative blood loss and blood transfusion requirement between the embolization (+) group and the embolization (−) group (320 mL vs. 267, mL, p=0.509; 1 vs. 2, p=0.544).

Muscle weakness in the lower extremities occurred in 2 patients on days 1 and 3 after embolization (Table 3). The metastasis was in T5 and T1-2, and the metastases originated from tongue cancer and gastric cancer, respectively. Although all patients showed partial recovery after surgery, they could not walk without assistance.

Case presentation (Fig. 1)

The patient was a 62-year-old man with tongue cancer (case 1, Table 3). He was scheduled for surgery because of spinal metastasis at the fifth thoracic vertebra, which compressed the spinal cord and caused difficulty in walking without assistance. On the day before surgery, the right T4, 5, and 6 intercostal arteries, the left T5 intercostal artery; and the supreme intercostal artery were embolized using a combination of gelatin sponge and coils. The following morning, the patient complained of weakness of the bilateral lower extremities, with a manual muscle test score of 1-2. Comparison of magnetic resonance imaging (MRI) scans af-

Table 3. Characteristics of the Patients with Paralysis after Embolization.

Case	Primary tumor	Day of operation*	Embolization	Embolic material	Location of tumor	Onset of post-embolization paralysis	Operation	Blood loss (ml)
1	Tongue cancer	Next day	Right T4, 5, and 6 intercostal artery; left T5 intercostal artery; and supreme intercostal artery	Gelatin sponge and coils	T5	Next day, muscle weakness of lower extremity (MMT 1-2)	Palliative decompression and instrumented fusion	50
2	Gastric cancer	3 days later	Bilateral costocervical trunk; T3, 4 intercostal artery	Gelatin sponge and coils	T1, 2	2 days later, muscle weakness of lower extremity (MMT 1-2)	Palliative decompression and instrumented fusion	680

*Day of surgery relative to the day of embolization.
MMT, manual muscle test

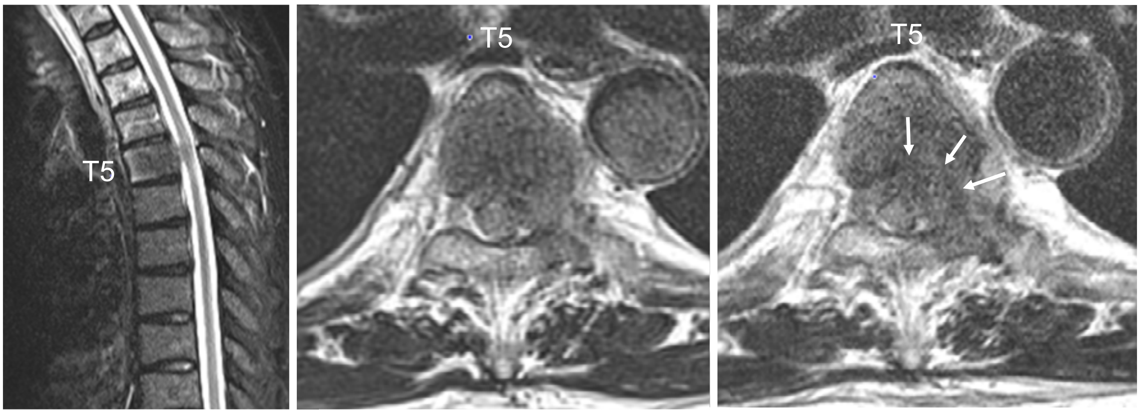

Figure 1. Left and middle: Preoperative magnetic resonance images (MRIs) taken 13 days prior to embolization of a patient with tongue cancer (Case 1, Table 3). A metastatic tumor at the fifth thoracic spine is compressing the spinal cord. Right: Axial MRI at the onset of paralysis after preoperative embolization of tumor. Comparison of MRI scans before and after embolization shows that the spinal cord compression appears to be slightly exacerbated after embolization (white arrows).

ter embolization and 13 days before embolization showed a slight exacerbation of the spinal cord compression after embolization. As such, posterior decompression and fusion surgery were performed on the same day, without any complications. The intraoperative blood loss was 50 mL, and blood transfusion was not necessary. The patient showed partial neurological recovery; however, he could not walk without assistance during follow-up.

Discussion

There were no significant differences in blood loss and blood transfusion requirements between patients who did and did not undergo preoperative embolization in the current series. The mean intraoperative blood loss in the overall population was 359 mL, and only 4 patients (9%) required blood transfusion. The blood loss in our series was relatively lower than in the previous studies. In the study by Cernoch et al., the mean intraoperative blood loss after embolization was 2300 mL[6]. Furthermore, Kato et al. retrospectively analyzed the efficacy of preoperative embolization of metastatic spinal tumors. They associated it with a significantly lower intraoperative blood loss (vs. without embolization: 520 mL vs. 1128 mL)[15]. Other studies reported similar findings of a significant decrease in operative blood loss and efficacy of preoperative embolization. However, the current study found no significant reduction in blood loss with preoperative embolization. The possible explanations for this result are as follows. First, more extensive surgery (i.e., aggressive circumferential resection of the metastatic tumor around the spinal cord) might have been performed in the embolization (+) group. Second, low intraoperative blood pressure and meticulous hemostasis during surgery, performed in all patients in both groups, favored a decrease in blood loss. Third, there was a predominance of hypervascular tumors in the embolization (+) group, possibly because we tried to perform preoperative embolization for hypervascular tumors as much as possible. These results indicate that blood loss is well controlled in the embolization group (+), as indicated by a mean blood loss of 401 ml. That preoperative embolization is effective to a certain extent. Quraishi et al. showed that greater embolization resulted in more blood loss, possibly due to a more extensive surgery, a rebound “reperfusion” phenomenon, or the presence of arteriovenous fistulae[8]. Thus, even in cases in which preoperative embolization is performed, it may be advisable to refrain from attempting aggressive tumor resection.

In the current series, 2 patients exhibited muscle weakness after preoperative embolization for a spinal metastatic tumor. The risk of neurological complications from preoperative embolization is <2% with experienced clinicians[5]. The AKA is the most dominant anterior radiculomedullary artery and is responsible for the arterial blood supply to the spinal cord from mid-thoracic to the conus medullaris. It typically originates from one of the thoracolumbar segmental arteries and connects to the anterior spinal artery. AKA is most common on the left side between T9 and L1[16,17]. Finstein et al. reported a case of post-embolization paralysis in a male patient with a giant cell tumor at T12 and L1, who underwent embolization of the T11 intercostal artery[10]. Although an apparent AKA was undetected during embolization, the patient had motor and sensory loss at the T12 level. Some authors suggested that small-sized particles for embolization might reach the lower thoracic portion of the anterior spinal artery through angiographically occult anastomotic pathways[4,10]. This indicates that physicians should be aware of the potential complications of spinal cord infarctions after embolization. Furthermore, Salame et al. reported that temporary occlusion with electrophysiological monitoring during angiography may improve the safety of permanent radicular artery occlusion[18]. Houten et al. performed a systemic literature review. They described neurological complications due to preoperative embolization of spinal metastasis[19]. They stated that a compromised spinal cord vascular supply or cranial stroke from reflux of embolic particles could cause neurological deficits. In this study, the two patients with neurological deficits had metastatic spinal tumors at T1 to 2 and T5 and underwent embolization without involving the feeding artery of the spinal cord. Thus, there was a low possibility of spinal cord infarction due to an occluded feeding vessel. Three cases of neurological deterioration, presumably due to tumor swelling after embolization, have been previously reported[20-22]. They were renal cell carcinoma metastasis at T3, giant cell tumor at L5, and thyroid carcinoma metastasis at the thoracic level. Although no radiographic assessment after embolization was described in these cases, tumoral swelling due to occlusion of the feeding artery, like any infarcted tissue, is presumed to have caused the neurologic deficits from an aggravated compression on the spinal cord[19-22]. In the present case, post-embolization MRI did not clearly show tumoral swelling; however, aggravation of spinal cord compression was suspected, and the possibility of spinal cord compression due to tumoral swelling could not be completely ruled out. The improved muscle weakness after surgical decompression, including in the past case reports, suggests that neurological deficits were caused by external spinal cord compression rather than by infarction. Paralysis due to AKA occlusion is likely to be complete and irreversible in many cases. In summary, the present study suggests that paralysis may occur after embolization, even if the embolized intercostal artery does not directly supply the spinal cord. Importantly, embolization of metastatic spinal tumors may pose a risk of paralysis. Although the cause of the paralysis remains unknown, it might be due to worsening spinal cord compression.

The optimal timing of embolization has been assessed in previous studies. Kato et al. recommended performing surgery on the same day of embolization to reduce intraoperative blood loss as much as possible[23]. However, other authors have concluded that a delayed operation does not influence the amount of blood loss[15]. Considering the risk of post-embolization paralysis, we strongly suggest performing surgery as soon as possible after embolization.

The current study has some limitations, including its retrospective nature, a small number of patients, various primary tumor types, and variations in surgical procedures, all of which may render it difficult to draw significant conclusions. Additionally, only one patient with post-embolization paralysis underwent MRI immediately after embolization. Despite these limitations, the findings robustly suggest that embolization carries a risk of post-embolization paralysis. Future prospective studies are needed further to elucidate the efficacy and complications of preoperative embolization.

Conclusion

Although there were no significant differences in blood loss and blood transfusion requirement between the embolization (+) and (−) groups, considering that all patients with hypervascular tumors were included in the embolization (+) group, preoperative embolization may have some positive effect on controlling bleeding. Preoperative embolization of metastatic spinal tumors has a risk of paralysis. Although the cause of paralysis remains unclear, it might be due to the aggravation of spinal cord compression. Considering this risk of paralysis, we advocate performing surgery as soon as possible after embolization.

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Ethical Approval: The institutional review board of Kobe City Medical Center General Hospital approved this study (Approval number zn200701).

Informed Consent: Informed consent was not required due to the nature of this study.

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