

# Preoperative Embolization of Spinal Metastatic Tumor: The Use of Selective Computed Tomography Angiography for the Detection of Radiculomedullary Arteries

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## Abstract:

**Introduction:** Preoperative embolization for metastatic spinal cord compression (MSCC) has a risk of spinal ischemia. This study aimed to assess the efficacy and safety of preoperative embolization in patients with MSCC and evaluate the use of computed tomography (CT) angiography for the detection of the radiculomedullary arteries (RMA).

**Methods:** This retrospective study included 20 patients (12 men and 8 women; median age, 66 years), who underwent preoperative embolization before a decompression surgery, which corresponded to 22 embolization procedures. The detection ability of RMA was evaluated using angiography and selective CT angiography. Surgical data including intraoperative blood loss and transfusion were also evaluated.

**Results:** Six RMAs were identified at the levels of affected vertebrae and one level above and below in the diagnostic spinal angiography. In addition to spinal angiography, adjunctive selective CT angiography allowed visualization of another five RMAs. Overall, 11 RMAs were identified in 9 patients. Preoperative embolization was successfully achieved in all patients. As regards complications related to embolization procedure, palsy exacerbated in one patient (4.5%), which improved postoperatively. During the surgical procedure, the mean intraoperative blood loss was 353.4±254.2 mL without intraoperative transfusion in all patients.

**Conclusions:** The present study showed small amounts of intraoperative blood loss without any severe complications related to preoperative embolization. Selective CT angiography was a useful technique to detect RMAs and contributed to the safety of preoperative embolization.

## Keywords:

metastatic spinal cord compression, preoperative embolization, Adamkiewicz artery, radiculomedullary artery, selective CT angiography

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## Introduction

Metastatic spinal cord compression (MSCC) is a serious problem in patients with advanced cancer that causes pain and neurologic impairment. Its incidence is 2.5%-10% of all patients with cancer<sup>1-4)</sup>. The demand for decompression surgery is increasing due to improved survival in patients with cancer<sup>1,2,5-8)</sup>, with decompression surgery for MSCC playing an important role in patients with long life expectancy by not only improving neurologic deficits but also effective pain relief and improved quality of life; however, decom-

pression surgery for MSCC is associated with massive intraoperative bleeding that can sometimes be catastrophic<sup>9)</sup>. Although preoperative embolization has been gradually used, it has been associated with the risk of spinal cord ischemia<sup>10-12)</sup>, where also, according to previous reports, preoperative embolization can reduce intraoperative blood loss especially in patients with hypervascular tumors<sup>10,13-19)</sup>. Therefore, radiculomedullary arteries (RMA) such as the Adamkiewicz artery should be detected to avoid nontarget embolization of the spinal arteries.

The usefulness of three-dimensional angiography (or com-

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puted tomography [CT] angiography) has been already reported in the treatment of intracranial aneurysm and intracranial/spinal arteriovenous fistulas<sup>20-23</sup>. Although it can clarify the angioarchitecture as well as surrounding anatomy, its utility has not been established in the procedure of preoperative embolization for MSCC.

Thus, this study aimed to assess the efficacy and safety of preoperative embolization in patients with MSCC and to evaluate the detectability of RMA in angiography with selective CT angiography.

## Materials and Methods

### Patients

Our institutional review board approved this retrospective study, which included consecutive patients who underwent preoperative embolization before palliative decompression surgery for MSCC from November 2017 to April 2020 at our institution. The need for additional informed consent for study inclusion was waived; however, informed consent for preoperative embolization and surgery was obtained from each patient.

A total of 70 palliative decompression surgeries for MSCC were performed during the same period, and preoperative embolization was performed in 20 patients (12 men and 8 women; median age, 66 [range, 48-87] years) that corresponded to 22 procedures. These cases were selected for the following reasons: (1) hypervascular tumor metastasis such as hepatic cell carcinoma and thyroid tumor; (2) expected large amount of metastatic mass resection for decompression (not only laminectomy and/or fixation). Conversely, preoperative embolization was not performed in patients with rapid progression of neurologic deficits to accelerate surgical decompression.

Primary cancers included lung cancer (n=5), hepatic cell carcinoma (n=3), thyroid cancer (n=3), colon cancer (n=3), cholangiocellular carcinoma (n=1), solitary fibrous tumor (n=1), rhabdomyosarcoma (n=1), uterine carcinosarcoma (n=1), esophageal cancer (n=1), and parotid gland cancer (n=1). Preoperative embolization for different spinal metastatic lesions was performed twice in one patient with hepatic cell carcinoma and one patient with uterine carcinosarcoma. Metastatic lesions occurred in the thoracic spine (n=17) and in the lumbar spine (n=5), and the mean number of vertebrae with tumor invasion was 1.5±1.0 (range, 1-5). The degree of tumor involvement and instability was assessed using the Epidural Spinal Cord Compression (ESCC) scale and Spinal Instability Neoplastic Score (SINS)<sup>24,25</sup>. Preoperative neurologic status was also assessed using the FRANKEL classification<sup>26</sup>. Patient characteristics are presented in detail in Table 1.

### Diagnostic angiography and detection of RMAs

At pre-procedure, the extent of vertebral metastasis was examined using any available imaging data including

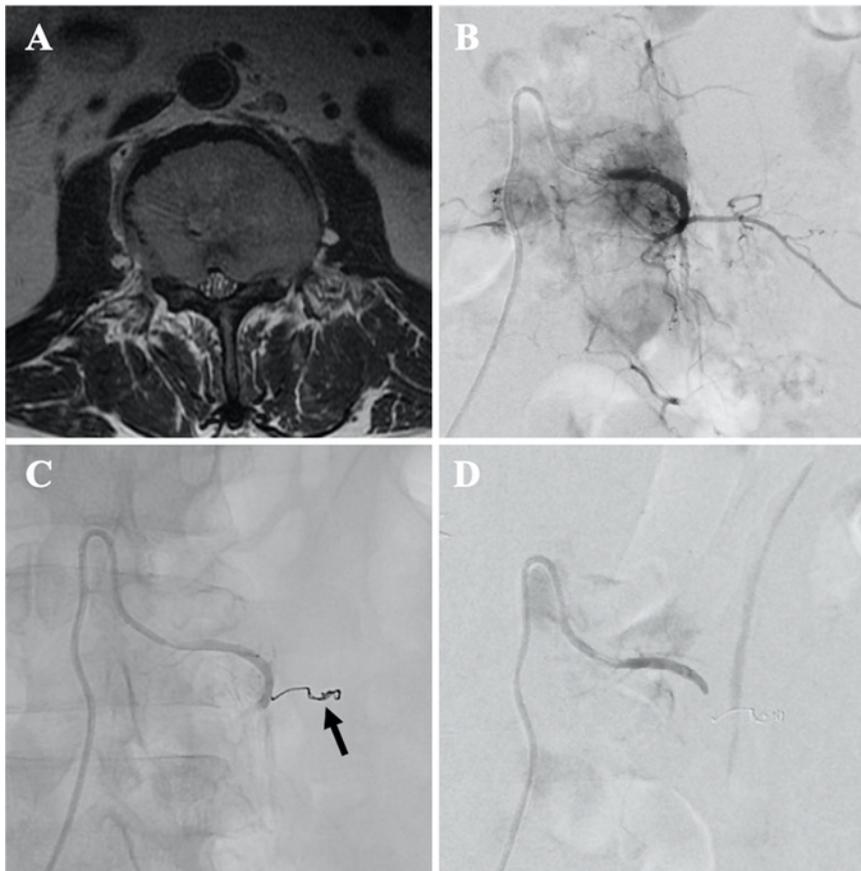
**Table 1.** Baseline Patient Characteristics.

Number of cases	22
Number of patients (male/female)	20 (12/8)
Median age in years (range)	66 (48–87)
Primary cancer (%)	
Lung cancer	5 (25%)
Hepatic cell carcinoma	3 (15%)
Thyroid cancer	3 (15%)
Colon cancer	3 (15%)
Cholangiocellular carcinoma	1 (5%)
Solitary fibrous tumor	1 (5%)
Rhabdomyosarcoma	1 (5%)
Uterine carcinosarcoma	1 (5%)
Esophageal cancer	1 (5%)
Parotid gland cancer	1 (5%)
Affected vertebrae level, thoracic/lumbar	17/5
Number of affected vertebrae±SD	1.5±1.0
ESCC scale, 1a/1b/1c/2/3	0/1/2/6/13
SINS, 0–6/7–12/13–18	4/16/2
Frankel classification, A/B/C/D/E	0/0/6/7/9
Preoperative hemoglobin (g/dL)±SD	12.2±2.5
Preoperative thrombocytes (×10 <sup>4</sup> /μL)±SD	20.9±7.4
Preoperative INR±SD	1.0±0.1
Preoperative radiation therapy (%)	11 (50%)

SD: standard deviation; ESCC: epidural spinal cord compression; SINS: spinal instability neoplastic score; INR: international normalized ratio

contrast-enhanced CT and/or magnetic resonance imaging (MRI) in all cases. In all cases, digital subtraction angiography (DSA) of spinal segmental arteries (intercostal arteries, subcostal arteries, and lumbar arteries) was performed at as well as one level above and below the affected vertebral levels using a 5-F Mikaelson catheter (Medikit's Angiographic Catheter, Medikit, Tokyo, Japan), where diagnostic spinal angiography was obtained before embolization using the hybrid CT/angiography system (IVR-CT, Infinix Celeve-i+ Aquilion PRIME, Canon Medical systems, Tochigi, Japan). Then, a coaxial 1.9-F microcatheter (ASAHI Tellus, Asahi Intecc, Aichi, Japan; or Canelian SI, Tokai Medical Products, Aichi Japan) was used to approach the feeding arteries and examine whether the spinal cord supply existed or not. If spinal cord supply could not be assessed using DSA due to prominent tumor blush or unclear image, selective CT angiography was performed. About 10-15 mL of iopamidol (iopamirone 300 mg/mL; Bayer Healthcare, Osaka, Japan) was administered using an automatic power injector at a rate of 0.6-1.0 mL/s during CT scanning (scanning parameter, 120 kV; 6.5 helical pitch [0.813 beam pitch], 0.5-mm section thickness) with 7-10 seconds delay from the initiation of contrast injection.

The spinal cord blood supply was diagnosed based on the depiction of RMAs that connected the anterior or posterior spinal artery.



**Figure 1.** A 51-year-old man with cholangiolocellular carcinoma. **A** T2-weighted images showed metastatic large tumor in the 3rd lumbar vertebra. The ESCC scale was graded as 3. **B** Selective angiography of the left 3rd lumbar artery revealed prominent tumor blush. **C** Redistribution of arterial flow with microcoils (arrow) was performed to protect normal branches distal to the feeding artery. **D** No residual tumor staining was confirmed after embolization with gelatin sponge particles. Then, the right 3rd and bilateral 2nd lumbar arteries were also embolized (data not shown).

### *Preoperative embolization*

All embolization procedures were conducted within 24 hours preoperatively. After the diagnostic spinal angiography, if the feeding arteries could not be approached directly, normal branches distal to the feeding artery were protected by microcoils before injecting gelatin sponge particles (Fig. 1), where the feeding arteries were embolized with these gelatin sponge particles (Spongel, LTL Pharma, Tokyo, Japan) and/or microcoils (Tornado Embolization Coil, Cook Japan, Tokyo, Japan). When the RMA was detected, embolization was not performed, or proximal embolization with microcoils was performed. Repeat angiography was obtained to assess residual tumor staining after embolization.

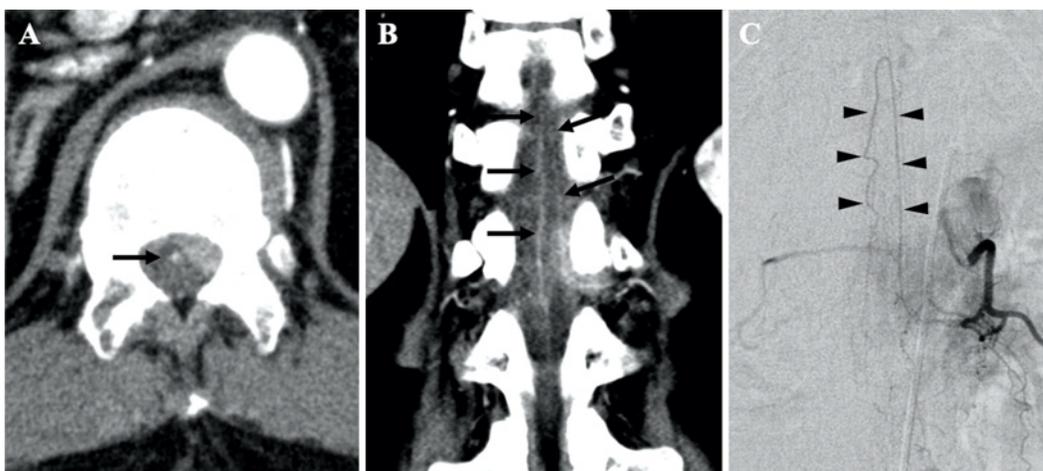
### *Surgical procedures*

All patients were operated via the posterior approach. Laminectomy was performed, and tumor was resected in a piecemeal fashion under the microscope until circumferential decompression of the spinal cord was achieved, following instrumentation that was performed using pedicle screws and rods across two or three levels above and below the affected

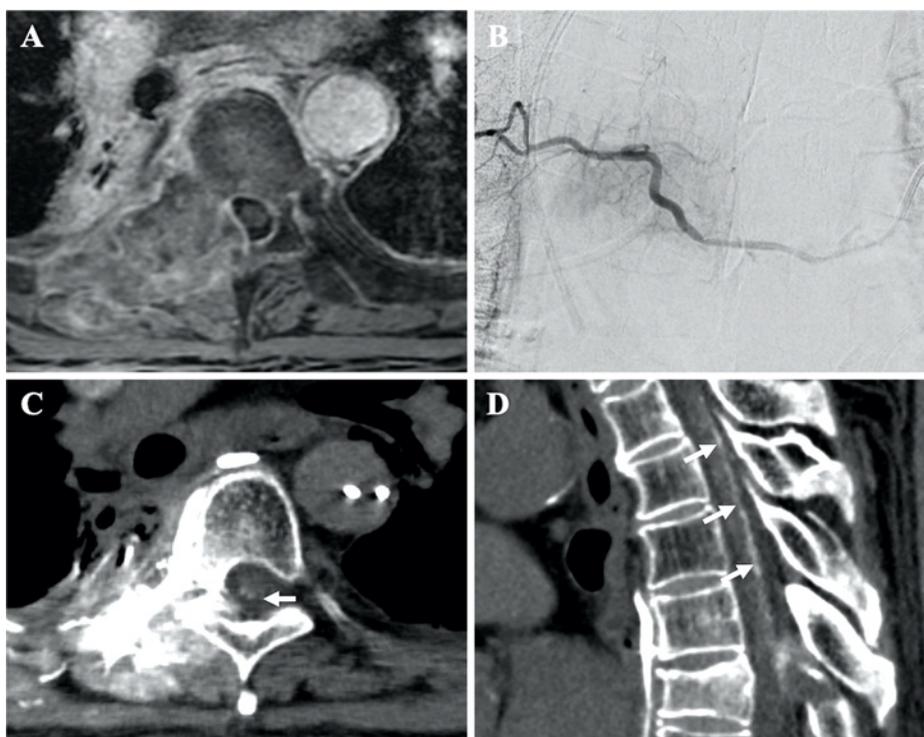
levels in all but one patient. With hemostatic agents based on gelatin-thrombin matrix (Floseal, Baxter Limited, Tokyo, Japan) being used in cases of bleeding, and a suction drain being placed after confirming hemostasis, in patients with anterior compression, pediculectomy and/or facetectomy was added to safely access the anterior aspect of the spinal cord. In one patient with recurrent metastasis after decompression surgery and radiotherapy, only tumor resection was performed. Estimated intraoperative blood loss, operation time, and amount of red blood cell (RBC) transfusions were obtained from anesthesiologist records.

### *Statistical analysis*

Categorical variables were expressed as number and percentages, and continuous variables as means and standard deviation. All patients were classified as either with or without RMA detection, and tumor characteristics were compared using the Fisher's exact test between the two groups. Surgical variables and complications were also assessed. All statistical analyses were performed using the IBM SPSS version 26 Statistics software (IBM Corp., Armonk, NY, USA).  $P$ -values < 0.05 were considered statistically significant.



**Figure 2.** A 53-year-old man with rhabdomyosarcoma. **A, B** Contrast-enhanced computed tomography depicted the great anterior radiculomedullary artery (the Adamkiewicz artery) and the anterior spinal artery in the arterial phase (black arrow). **C** Selective angiography of the left subcostal artery also showed the Adamkiewicz artery (black arrowhead). Embolization from the left subcostal artery was not performed.



**Figure 3.** A 68-year-old man with lung cancer. **A, B** No radiculomedullary arteries were detected on contrast-enhanced MRI and selective angiography of the right 7th intercostal artery. **C, D** The posterior spinal artery was detected using the selective computed tomography angiography from the right 7th intercostal artery (white arrow). Embolization with microcoils was performed, and no neurological deficit occurred after the embolization procedure.

## Results

### Detection of RMAs

In the diagnostic spinal angiography procedure, a total of 106 selective angiography from spinal segmental arteries were performed, and 6 of these identified RMAs (Fig. 2). In addition to spinal angiography, selective CT angiography visualized five more RMAs (Fig. 3). Overall, 11 RMAs sup-

plying the spinal cord were identified at the levels of affected vertebrae and one level above and below in 9 cases (Table 2, 3). Differences in any of evaluated items were not significant between cases with and without RMA detection (Table 4).

### Preoperative embolization

A total of 70 feeding arteries were identified in diagnostic angiography, and 63 of these that were not connected to the

spinal cord were embolized with gelatin sponge particles. In two cases with RMA connected to the posterior spinal artery, microcoils were used to embolize the segmental artery where the feeding artery branched because prominent tumor blush was observed in selective angiography, where seven feeding arteries arose from the same spinal segmental artery that also supplied RMAs. However, embolization was not performed in the other five cases. Eventually, preoperative embolization was successfully achieved in all cases. As a procedure-related complication, palsy exacerbated in one patient (4.5%). His neurologic status was C in FRANKEL classification and he could move his lower extremity against gravity before preoperative embolization procedure. Although RMAs were not detected in spinal angiography, he

could not move his lower extremity against gravity after embolization procedure. However, his neurologic status improved to D in FRANKEL classification and he could walk with a cane after decompression surgery. Results of preoperative embolization are presented in detail in Table 5.

**Surgical procedures**

The mean intraoperative blood loss and operation time were 353.4±254.2 mL and 258±45 min, respectively (Table 5). Intraoperative RBC transfusion was not needed in all patients, and the mean number of perioperative RBC transfusion units was 0.9±1.7. No serious surgery-related complications occurred. Postoperatively, neurologic status deterioration could be avoided in all cases (improved: n=9; stable: n=13).

**Discussion**

Several studies indicated the beneficial effects of preoperative embolization in reducing intraoperative blood loss in patients with MSCC<sup>10,13-19</sup>. In this study, the amount of intraoperative blood loss was 353.4±254.2 mL, which was much smaller than that of all previous reports describing preoperative embolization (618-2,350 mL), as well as that

**Table 2.** Evaluated Arteries in Diagnostic Angiography.

Evaluated artery	Right	Left	Total
Transverse cervical	0 (0)	1 (0)	1 (0)
Bronchial	0 (0)	1 (0)	1 (0)
Supreme intercostal	3 (1)	2 (0)	5 (1)
3 <sup>rd</sup> intercostal	2 (0)	3 (1)	5 (1)
4 <sup>th</sup> intercostal	3 (1)	4 (2)	7 (3)
5 <sup>th</sup> intercostal	4 (0)	3 (1)	7 (1)
6 <sup>th</sup> intercostal	4 (0)	3 (0)	7 (0)
7 <sup>th</sup> intercostal	5 (1)	4 (0)	9 (1)
8 <sup>th</sup> intercostal	5 (0)	6 (1)	11 (1)
9 <sup>th</sup> intercostal	4 (0)	3 (1)	7 (1)
10 <sup>th</sup> intercostal	3 (1)	3 (0)	6 (1)
11 <sup>th</sup> intercostal	4 (0)	5 (0)	9 (0)
Subcostal (12 <sup>th</sup> intercostal)	3 (0)	3 (1)	6 (1)
1 <sup>st</sup> lumbar	1 (0)	1 (0)	2 (0)
2 <sup>nd</sup> lumbar	2 (0)	2 (0)	4 (0)
3 <sup>rd</sup> lumbar	5 (0)	5 (0)	10 (0)
4 <sup>th</sup> lumbar	4 (0)	5 (0)	9 (0)
5 <sup>th</sup> lumbar	0 (0)	0 (0)	0 (0)
Total	52 (4)	54 (7)	106 (11)

The number of radiculomedullary arteries is shown in parentheses.

**Table 4.** Comparison of Tumor Characteristics Between Cases with and without RMA Detection.

Evaluated items	RMA (+) n=9	RMA (-) n=13	P value
Tumor vascularity (hypervascular)	11.1% (1/9)	38.5% (5/13)	0.33
Number of affected vertebrae (≥2)	33.3% (3/9)	15.4% (2/13)	0.61
Level of affected vertebrae (Th9-12)	33.3% (3/9)	30.8% (4/13)	>0.99
Number of feeding arteries (≥3)	55.6% (5/9)	76.9% (10/13)	0.32

RMA: radiculomedullary artery

**Table 3.** Detection of RMAs.

Case	Number of RMAs	Originated artery	Supply to spinal metastases	Spinal branch	Angiography	Selective CT angiography
1	1	right supreme intercostal artery	+	ASA	+	+
2	1	left 4 <sup>th</sup> intercostal artery	+	ASA	-	+
3	1	left 4 <sup>th</sup> intercostal artery	+	ASA	+	+
4	1	right 4 <sup>th</sup> intercostal artery	-	ASA	-	+
5	1	right 7 <sup>th</sup> intercostal artery	-	PSA	-	+
6	1	right 10 <sup>th</sup> intercostal artery	+	ASA	+	no assessment
7	1	left subcostal artery	+	ASA	+	no assessment
8	2	left 8 <sup>th</sup> intercostal artery	-	ASA	+	no assessment
		left 9 <sup>th</sup> intercostal artery	+	PSA	-	+
9	2	left 5 <sup>th</sup> intercostal artery	-	ASA	+	+
		left 3 <sup>rd</sup> intercostal artery	+	PSA	-	+
Total	11					

RMA: radiculomedullary artery, ASA: anterior spinal artery, PSA: posterior spinal artery

**Table 5.** Preoperative Embolization and Operation Data.

<i>Preoperative embolization data</i>	
Mean number of feeding arteries (range)	3.2 (2–6)
Mean number of embolized arteries (range)	3.0 (1–6)
Procedural time in minutes±SD	81±20
Complete embolization (%)	17 (77.3%)
Complication (%)	1 (4.5%)
<i>Operation data</i>	
Duration after embolization in hour±SD	16.2±4.5
Instrumented level±SD	4.3±1.8
Surgery time in minutes±SD	258±45
Mean intraoperative blood loss (mL)±SD	353.4±254.2
Mean number of intraoperative transfusions	0
Mean number of perioperative transfusions±SD	0.9±1.7
Serious complication	0

SD: standard deviation

reported in the meta-analysis of patients who did not undergo preoperative embolization (2,180 mL)<sup>9,10,13-19</sup>. Intraoperative transfusion could also be avoided in all cases. This excellent result was caused not only by preoperative embolization but also by multiple factors. First, this study included patients with non-hypervascular tumors, such as lung and colon cancer. Second, half of all patients underwent radiation therapy preoperatively, which might reduce tumor vascularity<sup>27</sup>. Third, careful tumor resection under the microscope and modern hemostatic agents would provide adequate control of hemorrhage<sup>11</sup>. While the indication for preoperative embolization remains controversial<sup>10-13,28</sup>, although some reports have suggested that preoperative embolization does not decrease blood loss especially in non-hypervascular metastatic spinal tumors, other reports have described its usefulness in the prevention of massive bleeding<sup>10,11</sup>. Therefore, its application should be decided considering various patient backgrounds.

While spinal cord ischemia is one of the most severe complications caused by disruption of spinal cord blood supply<sup>10-12</sup>, preoperative embolization carries certain complication risks with a frequency of 0%-8.5%<sup>10-13</sup>. In our study, one patient showed exacerbated palsy after the preoperative embolization. This patient showed severe spinal cord and nerve root compression in preoperative MRI, and the ESCC scale was graded as 3 (Fig. 1). In angiographic procedure, no RMAs were detected and his neurologic symptom improved after a surgical decompression. Therefore, this complication was thought to be caused by tissue edema due to embolization, not by spinal cord ischemia.

To avoid nontarget embolization of spinal arteries, the regional vascular anatomy including RMAs before and during embolization should be identified<sup>29</sup>. Our study identified 11 RMAs in 9 patients at the vertebral levels, which might be embolized and that meant nearly half of patients had potential risk of spinal cord ischemia in embolization procedure. In selective angiography, only half of RMAs could be detected. Large metastatic mass with destruction and tumor

blush of the vertebral body might result in poor diagnostic ability in two-dimensional angiography. Conversely, selective CT angiography showed excellent visualization of RMAs. It detected not only the Adamkiewicz artery, also known as the great anterior radiculomedullary artery, but also other RMAs that connected another anterior or posterior spinal artery. This study did not show significant differences in any of evaluated items between cases with and without RMA detection. These RMAs cannot be detected preoperatively without selective CT angiography.

In this study, the feeding artery that branched with RMA was embolized with microcoils in two cases, who showed no neurological deficits after the embolization procedure, where, when RMAs are detected, the feeding artery should not be embolized, because safety should be highly prioritized in the preoperative embolization procedure, with proximal embolization with microcoils maybe not causing spinal cord ischemia because of the vast network of spinal arterial anastomosis, nevertheless, embolization of the feeding artery should be carefully considered when spinal supply is detected. Therefore, even if it needs embolization, small gelatin particles or liquid embolic agents that can reach the more distal portion should not be used.

Several authors have already reported the usefulness of three-dimensional angiography, including cone beam CT angiography, to evaluate the angioarchitecture, such as intracranial aneurysm and intracranial/spinal arteriovenous fistulas<sup>20-23</sup>. The usefulness of selective CT angiography as adjunct to angiography even in preoperative embolization was emphasized for patients with MSCC, owing to evaluation of the metastatic tumor in the spine contributing not only to improved visualization of the vascular anatomy but also to optimal imaging displaying both detailed metastatic tumor and surrounding tissue volumetrically<sup>30</sup>.

Our study has several limitations. First, the sample size was relatively small. Second, patients who underwent surgery without preoperative embolization were not compared because selection bias could not be avoided. Third, in this study, selective CT angiography was obtained using the hybrid CT/angiography system. Further studies using cone beam CT angiography, a more common technique of acquiring volumetric data in the interventional suite, are expected<sup>31</sup>.

In conclusion, in this study, aside from the use of selective CT angiography in preoperative embolization, which was also shown in patients with MSCC, it was showed that small amounts of intraoperative blood loss without any severe complications were related to preoperative embolization. This technique is very helpful in detecting RMAs to prevent spinal cord ischemia.

**Conflicts of Interest:** The authors declare that there are no relevant conflicts of interest.

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**Author Contributions:** Shohei Chatani: Conceptualization, Data analysis, Writing-Original draft preparation

Shoichi Haimoto: Provision of data materials, Writing-Review & Editing

Yozo Sato, Takaaki Hasegawa, Shinichi Murata and Hidekazu Yamaura: Provision of data materials

Yoshitaka Inaba: Supervision

**Ethical Approval:** This study has obtained IRB approval from our institution and the need for informed consent was waived (Aichi Cancer Center Hospital IRB, approval code; 2018-1-343).

**Informed Consent:** For this type of study formal consent is not required. Consent for publication was obtained for every individual person's data included in the study.

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