Results of preoperative embolization for metastatic spinal neoplasms

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Object. Arterial embolization reduces blood loss in patients undergoing surgery for hypervascular spinal tumors. The objectives of this study were twofold: 1) to evaluate the role of magnetic resonance (MR) imaging in predicting tumor vascularity and 2) to assess the effectiveness of preoperative embolization in devascularizing these tumors.

Methods. Fifty-one patients with metastatic spinal neoplasms underwent angiography, preoperative embolization, and excision of the lesion between 1995 and 2000. The MR imaging studies were correlated with tumor vascularity on angiograms. Embolization was angiographically graded on a five-point scale ranging from no embolization (Grade A) to total embolization (Grade E). The embolization grade was correlated with intraoperative blood loss.

The mean age was 57 years, the male/female ratio was 1.2:1, and back pain was present in all patients. Metastatic renal cell carcinoma (30 cases) and thoracic spine involvement (33 cases) were most frequent. The positive predictive value of MR imaging in determining tumor vascularity was 77%, whereas the negative predictive value was 21%. Total embolization (Grade E) was achieved in 34 patients. A shared vascular pedicle between a radiculomedullary artery (RMA) and a tumor diminished the likelihood of complete embolization (p = 0.02). Small asymptomatic cerebellar infarctions were demonstrated in two cases. The mean intraoperative blood loss was 2586 ml. Following Grade D or E embolization, intraoperative bleeding was largely related to unembolized epidural veins.

Conclusions. Tumor histology and MR imaging findings are predictive of hypervascularity; however, hypervascular tumors may not be detected by standard MR imaging sequences. Superselective catheterization permits Grade D or E embolization in 80% of patients. Shared blood supply with an RMA is the most important factor precluding complete embolization.

Key Words • embolization • spinal tumor • metastasis • magnetic resonance
Preoperative embolization for spinal tumors

Magnetic Resonance Imaging

Magnetic resonance imaging of the entire spine was performed in all patients; studies included T₁- and T₂-weighted sequences, and STIR sagittal images, T₂-weighted axial images, T₁-weighted axial images, and images obtained before and after the administration of Gd–diethylene triamine pentaacetic acid (Omniscan; Novapharm, Princeton, NJ). Preembolization MR images obtained in 39 patients were reviewed by a staff neuroradiologist (E.L.) blinded to the histopathological diagnosis, clinical status, and angiographic findings. The vascularity of the tumor was predicted by assessing the MR images and correlated with that seen on angiograms. Tumors were classified as hypervascular if there were intratumoral or peritumoral flow voids, bright contrast enhancement, or evidence of intratumoral hemorrhage. Twelve patients were excluded because the MR images were acquired at other institutions and were either not available for review, did not contain adequate sequences to allow meaningful comparison, or the patient had undergone a surgical procedure at the pertinent level that precluded definitive determination of tumor vascularity.

Embolization Procedure

We conducted general medical clearance and analysis of hematocrit and blood chemistry (particularly blood urea nitrogen and creatinine levels), and patients fasted for 12 hours preceding the examination. All embolizations were performed after induction of general anesthesia, careful hemodynamic monitoring was conducted, and a Foley catheter and nasogastric tube were placed. Arterial access was established using a No. 5 to 7 French intravascular sheath placed within the common femoral artery. One patient with a cervical tumor required additional ipsilateral brachial artery cannulation for catheterization of tumor-supplying arteries from the ACT and DCT. With thoracic or lumbar tumors, angiography was initiated with an aortographic runoff. This involved placing a No. 5 French pigtail catheter (Cook Inc., Bloomington, IN) in the descending aorta, just above the level of interest, and slowly injecting 30 to 40 ml of full-strength contrast (8–10 ml/second) while performing a valsala maneuver. The contrast streamed along the back wall of the aorta, opacifying the segmental arteries. Following the aortic runoff, selective angiograms of segmental arteries supplying the targeted tumor and regional spine (typically, two levels above and below the lesion) were obtained. Studies were acquired in frontal projection by using high-resolution DS angiography with additional

### Clinical Material and Methods

**Patient Population**

Between 1995 and 2000, 458 patients with metastatic spinal tumors underwent surgery at Memorial Sloan–Kettering Cancer Center; in 51 of these patients preoperative tumor embolization was performed at New York–Presbyterian Hospital and New York University Hospital. A retrospective analysis of a prospectively maintained database of these 51 patients was performed. Table 1 provides a summary of tumor histologies and embolization-related features. The male/female ratio was 1.2:1, and the mean age was 57.1 years. Magnetic resonance imaging demonstrated spinal tumors in all patients, and all patients had a history of cancer. The thoracic spine was involved in 33 patients, lumbosacral spine in 13, and cervical spine in five. Vertebral body involvement was present in all cases. Epidural and paraspinal involvement was noted in 46 patients (90%) and 36 patients (71%), respectively. In 39 patients (76.5%) spinal involvement was restricted to one or two levels, whereas in 12 (23.5%) more than two levels were involved. All patients presented with moderate-to-severe back pain, with or without radicular pain, and 30 (59%) had undergone irradiation of the involved area. The Eastern Cooperative Oncology Group⁹ and ASIA¹³ grading systems were used to determine neurological status pre- and postoperatively.

The decision to perform tumor embolization was primarily based on the lesion’s histological features, either from previous personal or reported experience with specific spinal neoplasms, or on the known vascularity of the primary tumor.¹⁴ ¹⁵ ¹⁶ ¹⁷ ¹⁸ ²⁰ ²⁴ ²⁵ In 30 patients the metastases were from RCC. Other histological types included leiomyosarcoma (six patients), angiosarcoma (two patients), neuroendocrine tumor (five patients), follicular or papillary and thyroid carcinoma (three patients), and germ cell tumor, adenocarcinoma of unknown origin, breast, hepatocellular, and esophageal carcinoma (one patient each) (Table 1). Neuroendocrine tumors included one case each of pancreatic tumor, carcinoid tumor, and pheochromocytoma, and two cases of parangangiomas.

*AVS = arteriovenous shunt.

### Comparison of histological diagnoses and angiographic findings

<table>
<thead>
<tr>
<th>Tumor Type</th>
<th>No. of Cases (%)</th>
<th>Vascularity Grade (no. of cases)</th>
<th>Presence of AVS (no. of cases)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCC</td>
<td>30 (59)</td>
<td>Mild to Moderate: 5, Significant: 25</td>
<td>Significant: 17</td>
</tr>
<tr>
<td>sarcoma</td>
<td>8 (16)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>neuroendocrine tumor</td>
<td>5 (10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>thyroid cell carcinoma</td>
<td>3 (6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>breast</td>
<td>1 (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>liver</td>
<td>1 (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>esophagus</td>
<td>1 (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>germ cell tumor</td>
<td>1 (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>adenocarcinoma w/ unknown primary</td>
<td>1 (2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* *ASIA = arteriovenous shunt.*

**Comparison of histological diagnoses and angiographic findings**

**TABLE 1**

**Magnetic Resonance Imaging**

Magnetic resonance imaging of the entire spine was performed for spinal tumors; studies included T₁- and T₂-weighted sequences, and STIR sagittal images, T₂-weighted axial images, T₁-weighted axial images, and images obtained before and after the administration of Gd–diethylene triamine pentaacetic acid (Omniscan; Novapharm, Princeton, NJ). Preembolization MR images obtained in 39 patients were reviewed by a staff neuroradiologist (E.L.) blinded to the histopathological diagnosis, clinical status, and angiographic findings. The vascularity of the tumor was predicted by assessing the MR images and correlated with that seen on angiograms. Tumors were classified as hypervascular if there were intratumoral or peritumoral flow voids, bright contrast enhancement, or evidence of intratumoral hemorrhage. Twelve patients were excluded because the MR images were acquired at other institutions and were either not available for review, did not contain adequate sequences to allow meaningful comparison, or the patient had undergone a surgical procedure at the pertinent level that precluded definitive determination of tumor vascularity.

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stereoscopic, lateral, or magnified views as needed. Once tumor vessels were identified, guide catheters (for example No. 4 or 5 French RDC-A1 [Cordis; Miami, FL]) were used to cannulate the vessels. For cervical and upper thoracic lesions, the VA, ACT, and DCT bilaterally, and the ipsilateral supreme intercostal and external carotid arteries were injected. In cases of lumbar and sacral tumors, the local segmental, iliolumbar, internal iliac, median, and lateral sacral arteries were studied. Arterial-phase images were assessed for abnormal vertebral or paravertebral blush, arteriovenous shunts, origin of the RMA, and RPA supplying the ASA and PSA, respectively, and any angiographically demonstrated anomalies. Venous-phase images were studied for pattern of venous drainage and anomalies.

Guidewire-directed microcatheters from No. 1.7 to 2.5 French catheters (for example, Rapid Transit [Cordis]) were then used to catheterize the tumor vessels selectively (Fig. 1). The position of the microcatheter, contribution of catheterized vessel to the tumor, and safety of embolization with respect to neighboring radicular vessels was ascertained using DS angiography. Polyvinyl alcohol particles alone in nine (18%) were used, PVA, PFC, and Gelfoam powder (Pharmacia & Upjohn, Kalamazoo, MI) in two (4%), and PVA, PFC, and n-butyl-cyanoacrylate (Histocryl, Braun, Germany) in one patient (2%). In cases in which cervical tumors encased the VA, a 15 to 20-minute balloon occlusion test was performed, in which a coaxially introduced Endeavor balloon occlusion microcatheter (Boston Scientific) was inserted via a No. 6 French Envoy guide catheter (Cordis). Neurological signs or symptoms precluded sacrifice of the occluded vessel.

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TABLE 2

<table>
<thead>
<tr>
<th>Vascularity</th>
<th>Tumors (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MR predicted</td>
<td></td>
</tr>
<tr>
<td>angiographically documented</td>
<td></td>
</tr>
<tr>
<td>mild/moderate</td>
<td>4 (23)</td>
</tr>
<tr>
<td>significant</td>
<td>13 (77)</td>
</tr>
<tr>
<td>total</td>
<td>17 (44)</td>
</tr>
<tr>
<td>Not Hypervascular</td>
<td></td>
</tr>
<tr>
<td></td>
<td>19 (49)</td>
</tr>
</tbody>
</table>

Fig. 1. Artist’s rendering depicting the transaortic superselective cannulation of tumor vessel distal to radicular artery supplying the ASA arising from the same arterial pedicle.
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**Emboliization Grade**

Tumor vascularity was subjectively graded as mild, moderate, or significant based on comparison with the blush of an uninvolved adjacent VB (Table 2). Tumors were embolized if they showed moderate or significant tumor blush. In the event of a shared supply between the tumor and a radicular vessel, embolization was only performed if we could superselectively cannulate the tumor vessel distal to the common trunk. Tumor embolization was graded as follows: Grade A, not embolized; B, less than 50% devascularized and one or more remaining feeding vessels; C, 50 to 80% devascularized and one or more remaining feeding vessels; D, 80 to 95% devascularized and no remaining feeding vessels; and E, greater than 95% devascularized and no remaining feeding vessels (Table 3). Tumors located at noncontiguous levels that were not embolized or surgically treated were not included in the grading scheme.

**Surgical Procedure**

Operations were performed within 48 hours of embolization via anterior, posterior, or combined anterior–posterior approaches, depending on the location of maximal canal encroachment or paraspinal disease. Intraoperative blood loss was estimated by the anesthesiologist, and packed red blood cells were transfused to maintain the hemoglobin greater than 7.5 mg/dl.

**Statistical Analysis**

The frequency and percentages of patient-related characteristics and surgical procedures are reported. When applicable, chi-square and t-tests were used for associations. Linear regression was used to test for associations with intraoperative blood loss, number of days in the hospital, and duration of surgery as continuous variables. Overall survival was estimated using the Kaplan–Meier method. Survival time was defined from the date of surgery to the date of death or last follow-up visit. All probability values are two-sided, and a probability value of less than 0.05 was considered statistically significant.

**Results**

**Magnetic Resonance Imaging Findings**

All tumors evaluated were hypointense on T1-weighted images (39 patients) and hyperintense on STIR images (32 patients) (Fig. 2). Findings on T2-weighted sequences were more variable, with 17 tumors (44%) appearing hyperintense, 13 (33%) isointense, seven (18%) hypointense, and two (5%) indeterminate. Contrast enhancement

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**TABLE 3**

Summary of embolization grades, definition, and distribution

<table>
<thead>
<tr>
<th>Embolization Grade</th>
<th>Category</th>
<th>Elimination of Tumor blush</th>
<th>Tumor-Supplying Arteries</th>
<th>No. of Cases (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>not embolized</td>
<td>not embolized</td>
<td>not embolized</td>
<td>2 (4)</td>
</tr>
<tr>
<td>B</td>
<td>subtotal</td>
<td>≤ 50%</td>
<td>1 or more present</td>
<td>4 (8)</td>
</tr>
<tr>
<td>C</td>
<td>subtotal</td>
<td>50–80%</td>
<td>1 or more present</td>
<td>4 (8)</td>
</tr>
<tr>
<td>D</td>
<td>near complete</td>
<td>80–95%</td>
<td>none present</td>
<td>7 (14)</td>
</tr>
<tr>
<td>E</td>
<td>complete</td>
<td>complete</td>
<td>none present</td>
<td>34 (67)</td>
</tr>
</tbody>
</table>

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**FIG. 2.** Magnetic resonance images. A significantly hypervascular C-5 RCC metastatic tumor (arrowheads) involves the right half of the VB and lateral mass and extends into the paraspinal and epidural spaces. The lesion is hypointense on T1-weighted axial (upper) and hyperintense on sagittal STIR (lower) images with vascular flow voids within the tumor (arrows).
on T<sub>1</sub>-weighted images was noted in 11 tumors (28%); 14 tumors (36%) did not enhance. Contrast material was not administered in 14 patients (36%).

Based on the previously mentioned MR imaging criteria, the neuroradiologist predicted that 17 tumors (44%) were hypervascular, and 19 (49%) were not (Table 2). In three tumors (7%), a clear determination could not be made because of poor image quality. On angiography, among 36 patients in whom a clear determination of tumor vascularity could be made, tumors were graded as mild or moderately vascular in eight (22%) and significantly vascular in 28 (78%). Among the 17 patients in whom MR imaging predicted hypervascular tumors, angiography demonstrated mild or moderately vascular tumors in four (23%) and hypervascularity in 13 (77%). Among the 19 patients in whom MR imaging predicted that the tumors were not hypervascular, angiography revealed mild or moderate vascularity in four (21%) and hypervascularity in 15 (79%) (Table 2). Thus, MR imaging findings suggestive of hypervascularity were generally consistent with angiography. Conversely, MR imaging did not effectively rule out a hypervascular tumor in the absence of these findings.

**Angiography Findings**

The ASA was visualized during the diagnostic workup in 39 patients (77%) (Fig. 3), and not visualized in 12 (23%). Among 35 of 39 patients in whom the RMA supplying the ASA was visualized, it arose from the left in 23 (59%) and from the right in 12 (31%). One patient harbored a bilateral RMA at the T-9 level. In 12 patients (31%), the RMA arose from branches of the VA, DCT, or ACT. In nine patients (23%), the RMA originated from branches of a segmental vessel between T-4 and T-8, and in 18 patients (46%) the RMA originated between T-9 and L-3. The PSA, by contrast, was visualized in only 17 studies (33%) (Fig. 4). Among 15 of 17 patients in whom the RPA supplying the PSA was visualized, it arose from the left in seven (41%) and from the right in eight (47%). In two patients (12%), the RPA arose from branches of the ACT or DCT, in two (12%) from branches of segmental vessels between T-4 and T-8, and in 10 (59%) from branches of segmental vessels between T-9 and L-3 (Table 4).

**Arteriovenous Shunts**

An arteriovenous shunt was noted in 26 patients (51%) and subjectively graded as mild in 13 and significant in 13. Among patients with RCC an arteriovenous shunt was noted in 17 (57%) of 30 patients, whereas in three (38%) of eight harboring a sarcoma this finding was documented (Table 1). Those in the venous phase were not embolized. No significant association was observed between the presence of an arteriovenous shunt and intraoperative blood loss (p = 0.66).

**Embolization Procedure**

All embolization procedures were performed in a single session. One segmental vessel was embolized in 22 patients (43%), two segmentals in 17 (34%), and three or more segmentals in 11 (22%). Embolization was total (Grade E) in 34 (67%) patients (Fig. 5) and near total (Grade D) in seven (14%) (Table 3). Eight tumors were subtotally embolized (Grades B and C) and two tumors could not be embolized (Grade A). In 29 patients (57%), an RMA shared the same vascular pedicle as the tumor (Fig. 1). This shared blood supply was present in all 10 patients in whom Grade A, B, or C embolizations had been achieved. It was also present in 19 (46%) of the 41 patients in whom Grade D or E embolization was achieved. Patients in whom there was a shared blood supply had fewer complete embolizations (p = 0.02).

**Procedural Complications**

No major complications occurred as a result of embolization. No deaths occurred as a result of either the embolization or surgical procedures. In two patients MR imaging demonstrated small asymptomatic lacunar infarcts in the ipsilateral cerebellar hemisphere to the cervical tumors. The VA was not sacrificed in these patients and the tumor vessels came off of the ACT and DCT. In one other patient a delayed ASA territory infarction developed following surgery, and it is unclear whether this was related to the embolization.

**Surgical Procedure**

Operations were performed a mean of 1.4 days (range 1–8 days) after embolization. The tumors were approached from an anterior transcavitary route in 15 patients (29%), a posterolateral route in six (12%), and a combined approach in 30 patients (59%). Instrumentation was placed in all patients. The median intraoperative blood loss was 2600 ml for the entire cohort. Stratified by
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allowing more complete resection and a lower morbidity rate in patients with hypervascular tumors. The authors of previous reports have shown efficacy for renal and nonrenal spinal metastases such as melanoma, sarcoma, thyroid, breast, prostate, hepatic carcinoma, and neuroendocrine tumors such as paragangliomas.3,4,6,7,11,12,22–24,26 Although the procedure is associated with minimal morbidity when performed by experienced surgeons, the decision to use preoperative angiography and possible embolization needs to be carefully considered, because angiographic studies to define radicular vessels and/or the side of an optimal surgical approach are no longer de rigueur.2

In this study, the need for preoperative embolization was determined by tumor histology. The tumors were predominantly RCC and sarcomas, such as angiosarcoma and leiomyosarcoma. During the past 6 years, however, our experience has suggested a useful role for preoperative embolization when surgically treating other tumors such as follicular and papillary thyroid carcinoma, hepatocellular carcinoma, germ cell tumors, and neuroendocrine tumors such as paragangliomas. The arterial feeder vessels to these hypervascular tumors are large and accessible by superselective microcatheterization, making them amenable to embolization. Conversely, other hypervascular tumors such as multiple myeloma and melanoma are not as amenable to embolization because the predominant blood supply arises from a fine capillary network in the tumor, not from large segmental feeder vessels. Other common metastatic spinal tumors such as those from breast, colon, and lung carcinomas are relatively avascular, obviating the need for preoperative embolization.

Magnetic Resonance Imaging Findings

Hypointensity on T1-weighted images and hyperintensity on STIR images are sensitive markers for tumors and approximately half the tumors enhance with Gd–diethylenetriamine pentaacetic acid.3 Generally, a histological diagnosis is known or can be made by systemic workup and examination of a percutaneous needle biopsy sample of the spine or primary site. This allows one to use tumor histology as a guide to determining vascularity and the need for embolization. Signs on MR imaging may also be useful in predicting tumor hypervascularity.11,13,23 These signs include large flow voids representing blood vessels and bright contrast enhancement.11,27 Hypervascular tumors may also show signs of hemorrhage including hyperintensity on both T1- and T2-weighted sequences resulting from extracellular methemoglobin or hypointensity from the breakdown products of methemoglobin. The presence of one or more of these signs accurately predicted a significantly vascular tumor in 13 (77%) of 17 patients. Conversely, in 15 (79%) of 19 patients in whom MR imaging criteria suggestive of significant vascularity were absent, hypervascular tumors were demonstrated on preoperative angiography. Hence, we recommend preoperative angiography and possible embolization in the following instances: 1) tumors of known hypervascularity such as RCC, paraganglioma, thyroid carcinoma, and neuroendocrine tumors regardless of MR imaging findings; 2) tumors in which MR imaging findings are consistent with hypervascularity, regardless of tumor histology; and 3) tumors of unknown primary origin even in the absence of MR imaging findings consistent with hypervascularity.

Discussion

Tumor Histology

Preoperative embolization reduces tumor vascularity, surgical approach, the mean blood loss was 2400 ml for anterior approaches, 3100 ml for anterior–posterior approaches, and 850 ml for posterolateral approaches. This difference was not statistically significant (p = 0.33). Intraoperative blood loss increased in association with the duration of the procedure (p = 0.03). Thoracic (2300 ml) and lumbosacral tumors (3700 ml) tended to be associated with more blood loss than those of the cervical region (1500 ml) (p = 0.015). With Grades D and E embolized tumors, we noted most intraoperative bleeding to be derived from large unembolized veins.

Nineteen patients (37%) survived a mean 11.5 months (range 8.7–21.4 months) after surgery (95% confidence interval). Those still alive (31 patients [61%]) have been followed for a median of 2.6 months (range < 1–28 months). One patient has been lost to follow up. Patients stayed in the hospital for a mean of 17 days (range 5–76 days). Surgical wound breakdown occurred in two patients requiring reclosure following healthy granulation, and one patient suffered a local incisional wound infection that healed after drainage and antibiotic therapy.

Discussion

Tumor Histology

Preoperative embolization reduces tumor vascularity,
**Embolization: Technical Considerations**

The extent to which arterial feeding or regional segmental vessels and tumor blush, as well as subsequent intraoperative blood loss are eliminated, may be used to grade the success of embolization.3,4,7,11,18,22,24,25 Cervical tumors are generally supplied by branches of the ACT, the DCT, or the VA, whereas thoracic, lumbar, or sacral tumors generally derive their blood supply from thoracic or lumbar segmental arteries or branches of the iliolumbar arteries such as the median or lateral sacral arteries.18,22,24,26 Regardless of the spinal level, the bilateral segmental distribution of arterial supply to the vertebral axis produces a characteristic hemivertebra blush on arterial-phase angiograms. Adjacent uninvolved vertebrae generally retain their characteristic angiographic features, permitting objective comparison (Fig. 4). In addition, at times tumor arterial feeding vessels are large enough to be clearly defined by angiography. Thus, we graded the embolization by the amount of tumor blush and arterial feeding vessel elimination achieved. In Grades D and E embolizations, all tumor vessels that were angiographically visualized were embolized. In Grade D, small collateral vessels not accessible by superselective catheterization persisted and contributed to a small tumor blush. In Grades B and C embolizations, at least one tumor vessel persisted, but the degree of devascularization was less than one hemivertebra blush in the former, and slightly more than one hemivertebra blush in the latter. Embolizations were safely performed in 96% of the patients, and in 80% of patients, a Grade D or E embolization was achieved, which is comparable with other reported series.3,16,22,25

In our series, in 29 (57%) of 51 patients a tumor vessel and RMA shared the same blood supply; this was the most common reason for subtotal embolization (Grades A, B, and C). Angiographic identification and protection of RMA vessels is essential in reducing the risk of embolizing the spinal cord and avoiding catastrophic consequences.3,4,7,11,18,22,24,26 The RMA originates from the PSA, traverses the intervertebral foramen, pierces the dura mater, and joins the ASA at a characteristic hairpin bend (Fig. 3).17 The ASA is a slender midline vessel, approximately 0.5 to 1 mm in diameter.1,17,19 The artery of Adamkiewicz is the largest RMA supplying the cord from approximately T-8 to the conus medullaris, and it most commonly enters the spinal canal from the left between T-8 and L-4.1,17,19 The PSA is not as easily visualized on angiography. It is paired, smaller than the ASA in diameter, and more lateral in position (Fig. 4). The ASA and PSA extensively anastomose at the conus medullaris.

To avoid embolization of the ASA or PSA circulation, coaxial microcatheter techniques with superselective catheterization of tumor vessels are performed (Fig. 1). The microcatheter is positioned distal to the takeoff of the radicular vessels and adequate flow maintained to prevent reflux of PVA particles. Our embolization protocol relies on careful angiographic definition of radicular and tumor vessels, and it is performed after induction of general anesthesia to limit a patient’s discomfort and movement. Neurophysiological monitoring and provocative testing are used in some centers to identify the RMAs, but they are significantly limited. Neurological complications can occur even in the absence of significant signal alterations when using sensory or motor evoked potentials.21,22,24,25 Provocative testing with sodium amytal, lidocaine hydrochloride, or propofol is limited by significant shunting of blood from the spinal cord circulation into the tumor bed, as well as the high potential for false-negative results.3,7,8,16,21,24

Cervical tumors also demand special attention, because anastomoses between cervical arterial trunks increase the risk of cerebral or brainstem infarction.26 To avoid complications, prior to VA sacrifice or embolization we check the patency of the circle of Willis and the VA, and perform a balloon occlusion test after injection of a local anesthetic with careful neurological monitoring. If the patient remains asymptomatic, PFC is used to occlude the VA. Detachable balloons may also used, but these occlude only short segments of the vessel and may migrate or deflate.26

Polyvinyl alcohol particles with PFC were most commonly used for embolization in this series. Polyvinyl alcohol particles are inert, nonabsorbable, and water insoluble, occlude tumor vessels proximal to the capillary bed, and are ideal for embolizing most tumors.3,6,11,16,18,20,22,24,26 The particles are suspended in nonionic contrast material, which permits fluoroscopic visualization of their progress. Particles range in size from 45 to 500 μm.6,18 We tend to use larger particles (250–500 μm) when a shared blood supply is present or in patients who have previously undergone irradiation to decrease the chance of spinal cord and skin infarction, respectively. Embolized vessels generally recanalize over a 4 to 6–week period, and surgery is optimally performed within 1 or 2 days of embolization.3,11,18,20,24 metallic coils, such as PFCs, alone are not effective at reducing tumor vascularity.3,26 These are, however, valuable adjuncts to PVA embolization. Radicular vessels may be protected by placing PFC at their origin during PVA embolization of the tumor, or PFC may be placed in a segmental vessel following PVA embolization to prevent reflux of particles.3,16,18,24

<table>
<thead>
<tr>
<th>Category</th>
<th>No. of Cases (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASA</td>
<td></td>
</tr>
<tr>
<td>visualized</td>
<td>39 (77)</td>
</tr>
<tr>
<td>lt</td>
<td>23 (59)</td>
</tr>
<tr>
<td>rt</td>
<td>12 (31)</td>
</tr>
<tr>
<td>cervical/upper thoracic</td>
<td>12 (31)</td>
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<td>T4–8</td>
<td>9 (23)</td>
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<tr>
<td>T9–L3</td>
<td>18 (46)</td>
</tr>
<tr>
<td>ipsilateral/contiguous</td>
<td>2 (5)</td>
</tr>
<tr>
<td>noncontiguous</td>
<td>11 (28)</td>
</tr>
<tr>
<td>PSA</td>
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</tr>
<tr>
<td>visualized</td>
<td>17 (33)</td>
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<tr>
<td>lt</td>
<td>7 (41)</td>
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<tr>
<td>rt</td>
<td>8 (47)</td>
</tr>
<tr>
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<td>2 (12)</td>
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<td>T4–8</td>
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<tr>
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<tr>
<td>noncontiguous</td>
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</tr>
<tr>
<td>AVS</td>
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<tr>
<td>present</td>
<td>26 (51)</td>
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</table>

**TABLE 4**

Summary of angiographic findings
Complications of Embolization

Neurological complications occur in approximately 2% of patients following spinal angiography and local or systemic complications in 4 to 10%. Although some authors have reported no neurological complications after conducting preoperative embolization, others have reported complications such as transient or permanent quadriplegia or quadriparesis as well as aortic dissections in up to 8.5% of patients. In our series, there were no local or systemic complications. Asymptomatic neurological complications occurred in two patients in whom small asymptomatic, incidental cerebellar infarcts were demonstrated on cranial MR imaging performed after embolization of cervical tumors. In neither of these patients was the VA sacrificed, and it is possible that PVA particles refluxed into the vertebral circulation via ACT or DCT collateral vessels.

Impact of Embolization on Blood Loss

In our analyses we found no statistically significant association between the embolization grade and intraoperative blood loss. Nonetheless, more completely embolized tumors bled less at surgery, and their resection was thought to be more complete. Similar findings were reported by Jackson, et al., who demonstrated no statistically significant decrease in intraoperative blood loss but empirically believed that embolization facilitated the resection of RCC metastases. King, et al., also found no statistically significant difference in blood loss between embolized and unembolized tumors, but they discontinued surgery in three patients in whom embolization had not been performed because of uncontrollable hemorrhage. The overall blood loss when decompressing the epidural component of a paraganglioma was 3 L in our series. Following embolization, the 10 cm paraspinal and VB tumor was intralesionally resected with only a 300 ml blood loss. The findings of several other authors substantiate the effectiveness of preoperative embolization in decreasing intraoperative blood loss to a mean of 1 to 3 L, comparable with our results.\cite{3,6,7,11,18,20,22,24–26} Thus, the statistical findings in our study deserve further consideration. The lack of a control group and the small number of patients in each embolization category, especially the Grade A group (unembolized tumors) is a limitation. It is likely that we did not find a statistically significant difference between the various embolization grades simply because there were not enough patients.

Arteriovenous Shunts

An arteriovenous shunt is a major source of bleeding in patients in whom embolization has been performed. Transarterial embolization devascularizes the tumor but does not contend with the venous circulation. Although the presence of an arteriovenous shunt did not correlate statistically with intraoperative blood loss, our impression is that tumors with an arteriovenous shunt have significant intraoperative venous bleeding that is difficult to control. Thus, an experienced spine surgeon may encounter significant blood loss despite preoperative embolization of the main body of the tumor, in the process of carefully achieving the goal of maximum tumor resection and optimal spinal stabilization.

Conclusions

Hypervascular spinal metastases commonly originate from renal cancer, thyroid cancer, sarcomas, or neuroendocrine tumors, and they involve the thoracic spine with epidural and paraspinal involvement. Preoperative embolization should be considered in cases involving these tumors. In addition, metastatic tumors associated with
hemorrhage, flow voids, and contrast enhancement on MR imaging are also candidates for preoperative embolization. Radicular vessels can be visualized using careful angiographic techniques and may share a vascular pedicle with the artery-supplied tumor. This shared supply negatively affects the ability to devascularize a tumor totally. Superselective catheterization past this common pedicle, however, permits greater than 80% embolization in approximately 80% of patients. Preoperative embolization of metastatic spinal tumors is a safe adjunct to surgery for hypervascular tumors.

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References