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***BACKGROUND AND PURPOSE*: Corporectomy is an effective treatment for vertebral metastases; however, massive perioperative hemorrhage is often associated with this procedure. We compared preoperative particle, particle-coil, and coil embolizations of hypervascular spinal tumors prior to vertebral body replacement to determine which prevented perioperative hemorrhage most effectively.**

***METHODS*: The vertebral tumors of 59 patients were embolized prior to corporectomy. In 26 cases, only coils were used for the proximal occlusion of feeding segmental arteries. Twenty-four patients received a combination of polyvinyl alcohol (PVA) particles and coils, and nine tumors were embolized with particles alone. We compared intraoperative blood loss between the three groups and 10 other patients who did not undergo embolization prior to corporectomy.**

***RESULTS*: Estimation of intraoperative hemorrhage showed a median value of 4350 mL in patients without embolization, 2650 mL in cases of coil embolization, 1850 mL in cases of particle-coil embolization, and 1800 mL in cases of particle embolization. The difference between unembolized patients and those who underwent coil embolization was not statistically significant. Particle and particle-coil embolizations showed very similar results, and reduced hemorrhage significantly as compared to unembolized and proximal coil occlusion cases. Residual bleeding came from the venous system and the neighborhood of the embolized region.**

***CONCLUSION*: Particle embolization prior to corporectomy can reduce perioperative hemorrhage. The additional benefit of proximal coil occlusion of arterial feeders is questionable.**

Vertebral metastases of primary bone tumors can be treated surgically by vertebral body replacement procedures. Complete removal of the vertebral body has achieved superior decompression and long-term results in comparison to posterior laminectomy (1–4). Corporectomy, however, is an extensive operation requiring ventral and dorsal approaches for preparation, resection, and internal fixation of a vertebral segment. The vertebral body is replaced by bony implants, titanium baskets, or polymerizing substances (1–4). One disadvantage of these procedures is the risk of massive perioperative hemorrhage. In contrast to normal vertebra, most operated tumors, especially metastases from renal cell carcinoma (5), are strongly hypervascular. Life-threatening blood losses (5, 6) have been described in cases without preoperative embolization. Frequently mass transfusions become necessary. In a limited number of published series, authors recommend preoperative embolization to reduce bleeding complications for more feasible surgeries (4, 5, 7, 8). Most frequently, particles such as polyvinyl alcohol (PVA) and gelfoam (5, 6, 9–11) were used to occlude small tumor vessels and prevent diffuse bleeding from cut surfaces during preparation.

The purpose of this study was to compare the results of different embolization techniques and analyze the sources of intraoperative hemorrhage. A prior radiologic team at our clinic who started to embolize vertebral tumors in 1990 used mainly coils for proximal occlusion of the feeding segmental arteries. At that time, this type of proximal embolization could be expected to be ineffective in the prevention of perioperative hemorrhage (6, 8). Proximal coil occlusion was desired by the orthopedic surgeons, who found the preparation of the tumor easier when the arterial feeders were ligated preoperatively. A second reason for the use of coils was the fear of neurologic complication. The team who used coils eliminated the use of particles after noting a case of neurologic impairment during embolization with gelfoam powder. In this case, tran-

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sient paraparesis of the legs was probably caused by dislodgement of embolic material into a previously unidentified radiculomedullary artery originating at the level above the embolized segment. Coils could not migrate through intersegmental collaterals owing to their large diameter. Thus, the risk of ischemic complications appeared minimal provided that coils were not placed directly into arteries with proved spinal cord supply.

Consistent with previous findings concerning embolization of hypervascular bone tumors (6, 8), we found that proximal occlusion with coils was not adequate. Between 1993 and 1996 the current radiologic team tried to improve the efficacy of preoperative embolization by introducing a combined technique with particle embolization of the tumor periphery and coil occlusion of the main stems of the segmental arteries. We questioned the effectiveness of additional coil placement. Therefore, the use of coils has been eliminated since 1997, and we now perform embolizations with particles alone.

In this investigation of occluded vertebral tumors, we evaluate the effect of embolization technique on intraoperative blood loss, and describe the sources of major hemorrhage. Embolized cases are compared to a control group of patients who did not undergo preoperative embolization.

Methods

Sixty-nine patients (48 men and 21 women [aged 12–82 years; mean age, 54.2 years]) with vertebral tumors of the cervical, thoracic, or lumbar spine underwent vertebral body replacement between 1988 and 1998. In the initial phase of this study (1988 to 1990), 10 patients received preoperative spinal angiograms without embolization. After 1990, all 59 patients who underwent corporectomy underwent embolization before surgery. Two orthopedic surgeons performed these operations via a dorsal approach. The posterior elements of the vertebrae were removed, followed by dorsal stabilization. Patients were then turned on the table, and from a ventral approach, the vertebral bodies were resected and replaced by a titanium basket (n = 52) or a bone graft (n = 7). Afterward, anterior stabilization was performed. Bone grafts were mainly used in our initial cases of benign tumors and in the upper thoracic or cervical spine.

Four groups of patients were defined according to preoperative embolization technique. In 26 cases, a prior team of two general radiologists used only coils for proximal occlusion of arterial tumor feeders. Tumors in 24 patients were embolized with particles (gelfoam [n = 6]; PVA [18]) and coils, and nine tumors were occluded with PVA particles alone. The same neuroradiologist performed particle embolizations, except in four cases.

A historical control group of 10 patients, who underwent corporectomy prior to the introduction of transarterial embolization, had preoperative spinal angiograms only. Table 1 shows the histologic diagnoses of the spinal tumors in each subgroup of the 69 patients. In 54 cases, the spinal column was affected by metastases of different primary tumors that were frequently renal cell carcinomas and thyroid cancers. Fifteen cases showed primary bone tumors or tumorlike lesions. Only one vertebra was involved in 55 cases; 14 patients had tumor extension to 2 (n = 11) or 3 (n = 3) adjacent levels. The distribution of histologic diagnoses and tumor extension was comparable between the four subgroups (Table 1). The tumors were mainly located in the lumbar (n = 35) or the thoracic spine (n = 30). Cervical metastases were embolized and surgically removed in only four patients.

TABLE 1: Histologic Diagnoses

Entity	No Embolization	Coils	Particles + Coils	Particles
Total (no)	10	26	24	9
Renal cell carcinmoa	5	10	11	6
Thyroid cancer	1	3	2	...
Breast cancer	1	2	1	...
Prostate cancer	1	2	3	1
Unknown primary	...	1	1	...
Hepatocellular carcinoma	...	...	1	...
Melanoma	...	1	...	...
Malignant neurofibroma	...	...	...	1
Plasmocytoma	...	3	2	...
Hemangioma	1	1	2	1
Giant cell tumor	...	2	...	...
Aneurysmal bone cyst	1	1	1	...

Spinal angiograms and embolizations were performed within 24 hours of corporectomy to avoid revascularization. Arterial feeders and pathologic vascularization of the tumors were shown on selective spinal angiograms of the involved segments. In the thoracic and upper lumbar spine, additional localization of the artery of Adamkiewicz was performed to avoid damage of the spinal cord during embolization or corporectomy. In upper thoracic or cervical sites of metastases, the subclavian, vertebral, and carotid arteries as well as the thyreocervical and costocervical truncus were injected. Degree of hypervascularization as compared to normal vertebral blush was classified into two categories: 1) slight blush with normal caliber and number of feeders; and 2) strong blush with enlarged and increased number of arterial feeders from adjacent segments. Hypervascularization can result in arteriovenous shunting and large-caliber draining veins.

Segments were injected at disease level and a minimum of one level above and below the tumor. Angiography was followed by immediate embolization if an artery was involved in the tumor blood supply. For safety, segments with spinal cord vascular supply were not embolized. Flow control during particle embolizations was done by road map and control angiograms to identify the opening of ‘‘dangerous’’ collaterals to segments with radiculomedullary or radiculopial arteries. At the endpoint of embolization, complete exclusion of tumor vessels and hemostasis in cases of coil placement were documented by a final angiographic series. After embolization, the levels above and below the embolized segments were injected to show the reduction of tumor blush and additional collaterals.

In the coil group, all segmental tumor feeders and collaterals from adjacent segments were embolized with 0.018-inch platinum microcoils (Tornado, Cook Inc., Bloomington, IN) or 0.038-inch Gianturco coils (Cook Inc.) just distal to the origin of the supplying artery. In 15 of 26 cases it was necessary to use coaxial systems with microcatheters to achieve a stable catheter position for the placement of coils. In two cases, reembolization with particles was performed after incomplete corporectomy owing to hemorrhagic complications.

In combined embolizations six patients received gelfoam particles. In all other patients, medium-sized (150–250 μ) PVA particles (Contour, Target Therapeutics, Freemont, CA) were injected as selectively as possible into all arterial tumor feeders to occlude the small-sized vessels of the tumor periphery. Particle embolization was followed by coil occlusion of the main stems of the segmental arteries. In the particle group,

TABLE 2: Tumor Vascularization

Degree of Hypervascularization	No Emolization (n = 10)	Coils (n = 26)	Coils + Particles (n = 24)	Particles (n = 9)
Slight	3	7	6	2
Strong	7	19	18	7

only medium-sized PVA particles were applied superselectively without proximal coil occlusion. Coaxial microcatheters (Venture 2, Boston Scientific, Watertown, MA) were used for all particle-coil and particle embolizations.

Estimated blood loss was determined in all patients by the anesthesiologists, and comparisons were drawn between the subgroups. Estimated blood loss was calculated by adding the volume of blood from the suction apparatus and the amount of blood squeezed out of swabs and sheets. The nonparametric *U* test (Wilcoxon rank sum test) was used to determine statistical significance. Perioperative hemorrhage was compared between patients with involvement of a single vertebra (n = 55) and those with tumor extension to two (n = 11) or three levels (n = 3) as well as in patients with lumbar involvement (n = 35) versus those with thoracic involvement (n = 30). Intraoperative hemorrhage and feasibility of operation was evaluated subjectively by the orthopedic surgeon who also determined the sources of major hemorrhage (> 1500 mL).

Results

All tumors were hypervascular in comparison to the normal vertebral blush on selective spinal angiograms. Table 2 shows the classification of the degree of pathologic vascularization within the four subgroups of patients. Fifty-one of 69 tumors showed a strong hypervascularization. The rate of intensely vascularized processes is similar within the technical subgroups.

In the group of patients with coil embolization, a complete occlusion of all tumor feeders could be documented in 21 (81%) of 26 cases angiographically. Incomplete embolizations with a minor residual tumor staining (< 20%) were performed owing to spinal cord supply (n = 3) or inaccessibility of single hypoplastic or tortuous segmental arteries (n = 2). Particle-coil embolizations were performed completely in 20 (83%) of 24 cases. Three segments with proved spinal cord feeders and one branch from a vertebral artery were not embolized.

Particle embolizations of all tumor compartments were possible in seven of nine cases. One feeder carrying the origin of the artery of Adamkiewicz and one vertebral artery branch were not embolized. No major differences concerning the technical success rate and completeness of embolization could be detected between the three operators who were involved in spinal embolizations.

The graphic representation of intraoperative hemorrhage (Fig 1) shows the tendency toward lower blood losses in embolized patients, especially for patients who underwent particle or particle-coil embolization. Nonetheless, there was a wide range of dispersion of the single values within the different subgroups, and a considerable overlap between the results of the different techniques. Even in the particle-coil group, two patients had severe blood loss of 7200 ml and 8000 ml, respectively.

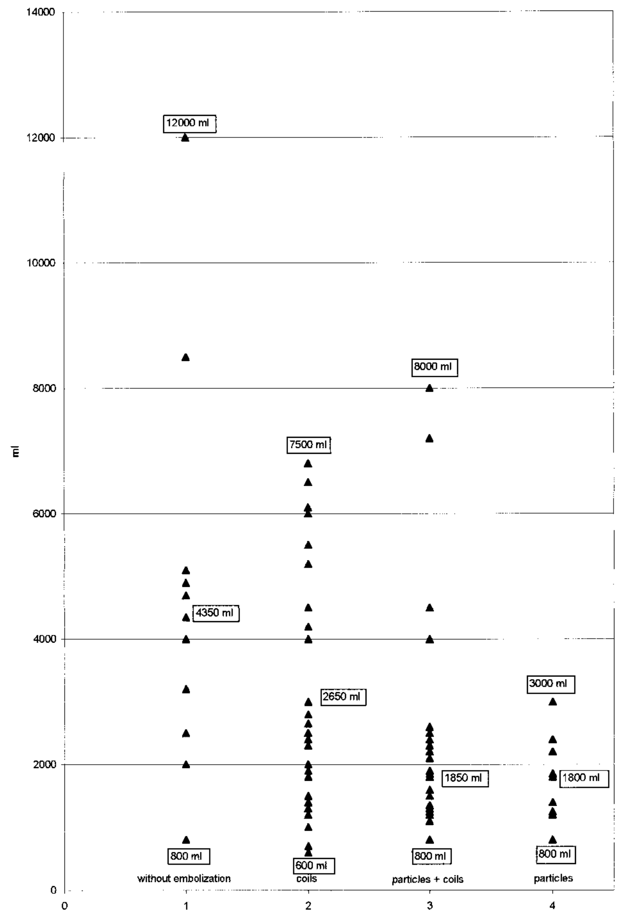
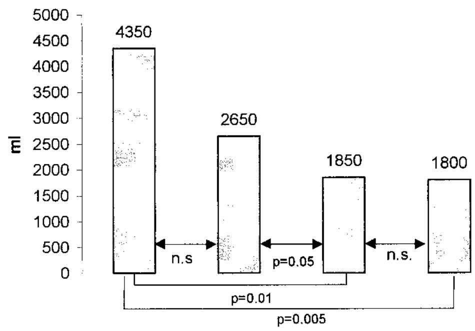


FIG 1. Diagram shows range of variation of intraoperative hemorrhage in corporectomy procedures according to embolization technique. Minimum, median, and maximum values of estimated blood loss are indicated for each group of patients.

The estimated median blood loss associated with perioperative hemorrhage was 4350 ml in the patients who did not undergo embolization, 2650 ml in the coil, 1850 ml in the particle-coil, and 1800 ml in the particle group (Fig 2). Cases of coil embolization tended to evince lower intraoperative hemorrhage than what occurred in patients who did not undergo embolization prior to surgery. The *U* test, however, proved no statistically significant difference between these two groups. Patients who underwent particle or particle-coil embolizations showed a significant reduction of intraoperative blood loss (particle [$P = .025$]; particle-coil [$P = .01$]). Significant differences between the coil vs particle ($P = .025$) and coil vs particle-coil ($P = .05$) groups were evident. No significant differences could be detected between patients with single-level (median, 2000 ml [n = 55]) and two- or three-level involvement (median, 2450 ml [n = 14]). The three cases with tumor extension to three adjacent levels showed higher blood losses (range, 4000–



	no embolization n = 10	coils n = 26	particles + coils n = 24	particles n = 9
median blood loss (ml)	4350	2650	1850	1800
mean blood loss (ml)	4770	3354	2379	1767
standard deviation (ml)	3299	2108	1844	687
no. of transfused blood units range/mean	0 - 16/ 7.2	0 - 13/ 5.9	0 - 13/ 3.7	0 - 6/ 2.6

FIG 2. Comparisons of estimated median blood loss and statistical significance (*U* test) of no vs coil (N.S.), coil vs particle-coil ($P = .05$), no vs particle-coil ($P = .01$), and no vs particle embolization ($P = .01$) are shown. No significant difference could be demonstrated between the two particle techniques. The table shows mean and median blood losses and the standard deviation. Additionally, the number of transfused units of packed red blood cells (300 ml each) is indicated.

6800 mL). The differences between cases with lumbar involvement (median, 2200 ml [n = 35]) and those with thoracic involvement (median, 2400 ml [n = 30]) were not statistically significant. There were also no significant differences between these patients within the different technical subgroups.

The table in Figure 2 shows the number of infused units of packed red blood cells according to the embolization technique. Infusion was lower for patients who received particle embolization than for the other two groups. Severe hemorrhage (> 2500 ml) occurred less frequently for particle (11% [n = 9]) and particle-coil (21% [n = 24]) than for coil (50% [n = 26]) embolizations or cases of no preoperative embolization (70% [n = 10]). The orthopedic surgeon's subjective evaluation asserted that all 10 patients who did not undergo preoperative embolization bled out of their tumor. In the coil group, 22 of 26 cases had residual hemorrhage from the tumor. The majority of tumors embolized with particles showed "dry" cut surfaces. Only six of 33 patients from both groups bled during the preparation of the tumor itself. The orthopedic surgeons also found considerable bleeding (> 1500 ml) from the tumor periphery in 16 of these 33 patients. Sources of hemorrhage were 1) cut surfaces within the normal spongiosa of the dorsal vertebral arch, 2) spongiosa of the normal adjacent vertebra during placement of the titanium basket, 3) enlarged arterial feeders in the surroundings of a highly vascularized neoplasm, and 4) epidural veins. Further intraoperative bleedings were independent from the tumor, and occurred during the access to the operation field. In each group, single operations were interrupted after dorsal preparation owing to life-threatening bleeding complications. Repeated angiography in a case of coil embolization showed revascularization through collateral channels (Fig 3). In a second operation, vertebral body replacement was completed successfully after reembolization particles.

During the initial phase of this experience (1988–1990), a radiologic team that preceded ours noted one occurrence of paraparesis in a patient who was embolized with gelfoam particles and coils at the L1 level on the right side. A small radiculomedullary artery supplying the anterior spinal axis was visible retrospectively at the level of T12 above the embolized segment. Dislodged material through unidentified intersegmental collaterals and blockage of the arterial input to the spinal cord was most likely caused by inadequate collateral supply. Fortunately, the symptom resolved completely within a few days. After that event, no major complications, especially neurologic impairment, were observed. In two cases, Gianturco coils deployed through an F5 diagnostic catheter dislocated out of the ostium of a segmental artery. Fortunately they went into muscle branches of the internal iliac arteries without any clinical consequences. When microcatheters were used, no coil dislocation was observed.

Discussion

Because the indication for vertebral body replacement operations is limited (2), the literature cites minimal data on associated bleeding complications (Table 3). This data and our own experiences (10 cases without preoperative embolization) show that larger amounts of blood loss occur more frequently when hypervascular tumors are resected. Perioperative blood losses between 4700 mL and 8300 mL, and occasionally even extreme values up to 15 L or 19 L may occur during vertebral body replacement in patients with highly vascularized lesions such as renal cell carcinoma (5, 6, 11, Table 3). A randomized comparison of intraoperative hemorrhage between cases with and without preoperative embolization is difficult to perform. Many orthopedic surgeons believe that vertebral body replacements became feasible with the introduction of modern embolization techniques. Today it may be impossible to establish a control group of patients who do not undergo preoperative embolization. In a retrospective comparative study, Olerud et al (5) found reduced average perioperative blood loss of 33% in patients who underwent particle embolization. According to our and other data of patients without embolization (6, 11, Table 3), one can also assume that preoperative embolization reduces introperative hemorrhage. Existing retrospective studies show estimated mean or median blood losses of 550–4300 mL (mean, 1832 mL) (5–7, 9–11). The amount of intraoperative hemorrhage may vary according to the vascularity of the tumor, the extent of the operation, and the

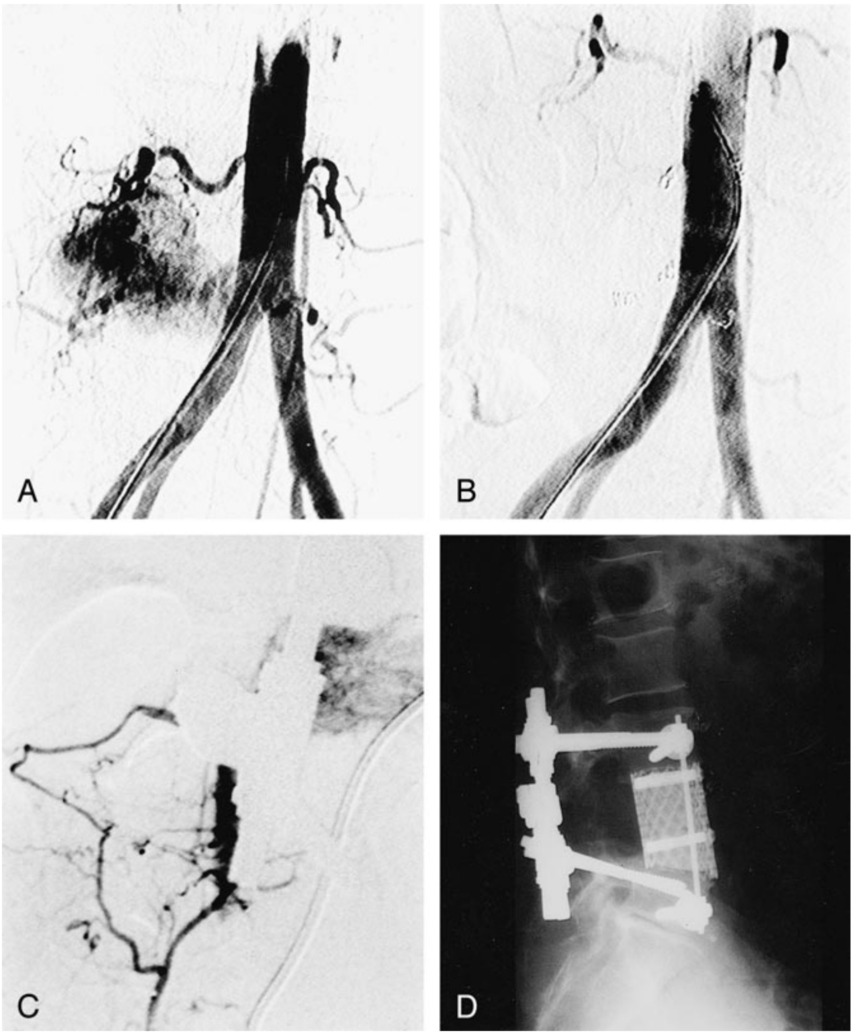


FIG 3. The stages of a patient with renal cell carcinoma who underwent corporectomy 24 hours after embolization are shown.

A, Abdominal aortogram shows an angiomatous pattern of vascularization. A strong tumor blush and enlarged feeding segmental arteries are visible.

B, No residual tumor staining is visible after coil embolization with occlusion of the segmental pedicles at the level of L4 and L5 on both sides.

C, Twenty-four hours after embolization, the corporectomy procedure had to be interrupted because massive hemorrhage (6800 ml) occurred during preparation and stabilization. A control angiogram showed revascularization of the tumor through collateral branches of the iliolumbar truncus. After reembolization with PVA particles, the vertebral body replacement could be completed in a second session with a blood loss of 2200 ml.

D, A radiograph of the lumbar spine shows the dorsal and ventral internal fixation and the titanium basket in place.

TABLE 3: Literature review: Blood loss in corporectomy procedures

Author	Cases (no.)	No Embolization	Embolization	Material
Broaddus, 1990	9		550 ml	collagen
Gellad, 1990	24	8750 ml	1850 ml	PVA, coils
Olerud, 1933	29	6200 ml	4300 ml	gelfoam, PVA
Boudghene, 1994	20	5900 ml	2800 ml	PVA
Smith, 1995	20		1871 ml	PVA
Breslau, 1995	14		1600 ml	PVA
Own results	59	4350 ml	2650 ml	coils
			1800 ml	particles
			1850 ml	particles + coils

fixation technique. Exact quantification of intraoperative bleeding is difficult to perform because the amount of blood remaining on swabs and sheets cannot be measured. Estimated values may vary between different surgeons or anesthesiologists. The number of infused blood units may also reflect the individual view of the anesthesiologist. For practical purposes, however, the estimation of hemorrhage seems to be accurate enough to introduce a quantitative parameter for the evaluation of the effect of embolization (5). Despite quantitative data, one cannot ignore the influence of bleeding as it relates to the feasibility of surgery. Not all bleeding sources can be influenced by transarterial embolizations. Major hemorrhage may occur during the access to the operation field, especially during the anterior approach (5). Future studies of blood loss should distinguish hemorrhage during access from bleeding during preparation and fixation of the vertebra. Our results confirm the orthopedic surgeon's subjective impression that perioperative hemorrhage was not mainly influenced by the location of the tumor in either the thoracic or lumbar spine. Surgery of several levels prolongs the procedure, and may increase blood loss.

Even coil occlusion of the segmental arteries showed a tendency toward reduced intraoperative hemorrhage in comparison to patients without embolization. The effect of proximal embolization, however, was moderate, and blood loss of more than 2500 mL occurred in 13 of 26 patients. These findings confirmed our expectation that coil embolization alone is not sufficient to ensure a safe operation of hypervascular lesions and limit the number of transfused blood units. Despite occlusion of all main vascular feeders, the reason for bleeding complications is early revascularization of the tumor through intersegmental collaterals (Fig 3C). This is especially true for many metastases from renal cell carcinomas showing an angiomatous tumor vascularization that may establish vascular channels within a few hours. The occlusion of smaller tumor vessels by means of small-particle embolization is mandatory. As opposed to coil embolization alone, additional particle embolization reduced intraoperative blood loss significantly to a median value of 1850 mL. The use of particles for the occlusion of small-tumor vessels is supported by most previous investigators (5, 6, 9–11). Blood losses in several other studies show a similar range to ours. In particular, Gellad (6), Breslau (9), and Smith (10) also achieved estimated mean or median blood losses lower than 2000 mL with PVA particles as the embolic agent. Blood losses reported by Olerud et al (5) are probably higher (Table 3) because only renal cell carcinoma metastases, with their high degree of hypervascularization, were included in the study. Another reason may be that the authors were using gelfoam particles for embolization. Smith (10) assumes that gelfoam particles are less reliable for the control of bleeding than PVA emboli of defined sizes. Larger particles or heterogeneous suspensions of different sizes may occlude pretumoral arterial branches before a complete filling of the vascular bed of the tumor can be achieved. If the tumor vessels are left open, early revascularization through collaterals may occur, which is similar to the findings in coil embolization. In other studies (12, 14), intraarterial ethanol injection was used without complications, but quantitative data about bleeding complications were not reported. The use of ethanol or other fluids as embolic agents in spinal tumors requires very experienced operators. Otherwise, it may be associated with increased rates of neurologic complications or skin and muscle necroses. The use of liquid embolic agents may be adequate if permanent vascular occlusion is desired. Liquid agents are not necessary for preoperative embolization.

After preliminary findings in a limited number of nine cases and a comparison with the results of other studies (6, 9, 10), we hypothesize that the additional use of coils after particle embolization shows no further benefit for the reduction of intraoperative hemorrhage. The placement of coils increases the cost and duration of the embolization procedure. The initial impression of our orthopedic surgeons that proximal occlusion of the segmental vascular pedicles makes preparation easier generally cannot be maintained after our experiences with particles. Coils may occasionally be useful for the protection of collaterals to a segment with proved spinal cord supply or for the occlusion of segmental arteries that are embraced by tumor masses, and this cannot be ligated during preparation. In addition to particle embolization, coils may inhibit rapid revascularization if the interval between embolization and the operation is delayed.

Our experience corresponds to previous findings (5, 6, 10) in that blood losses varied considerably for successful embolizations in the particle group (Fig 1). Massive intraoperative hemorrhage may occur even in patients with complete arterial embolizations after angiographic examination. Observations of the orthopedic surgeons confirm that injected particles reach their target and create ‘‘dry’’ cut surfaces within the tumor. Nonetheless, adjacent vascular structures, especially an increased number of enlarged arterial feeders and epidural and paravertebral veins, are sources of residual hemorrhage. A more aggressive and widespread particle embolization for the occlusion of collateral arterial supply, including the neighbor segments, can be considered. Hemorrhage from the venous system during access to the operation field, however, cannot be influenced by transarterial embolization of the vertebral tumor. Coil embolization must be very safe to avoid neurologic complications, and segmental arteries with spinal cord supply should not be occluded. Coils cannot migrate through intersegmental collaterals. With the use of particles, the risk of neurologic deficits also seems to be low and limited (10). Radiculomedullary and radiculopial arteries are part of anterior or posterior spinal cord circulation, and therefore must be identified; embolization of such segments should be avoided. Even proximal coil occlusion of such feeders is not justified in a purely preoperative procedure because there is a remaining risk of insufficient collateral supply to the spinal cord, especially when adjacent segments are embolized.

Careful interpretation of high-quality spinal angiograms, superselective catherization, and flow control during embolization must be performed to avoid neurologic complications (13–15). The risk of material dislodging through intersegmental anastomoses (14) may be particularly increased near the end of particle embolization. Frequent control angiograms should be performed to determine the complete filling of the tumor vascular bed and to avoid overembolization. Small-sized particles with diameters below 150 μ should not be used because they may cause blockage of the arterial input to the spinal cord at the level where collateral supply is either inadequate or does not exist. Smith (10) suggested lidocaine provocative testing before the injection of embolic material for the prediction of neurologic deficits. In our opinion, the results of lidocaine testing must be uncertain because in the preembolization phase, the flow is directed to the hypervascular tumor. Collateral branches to an adjacent segment, with contribution to the spinal cord supply, may suddenly open during the embolization process, and the consequences of such an event cannot be predicted from a preembolization test. Thus, angiographic analysis and clinical monitoring are the main instruments to ensure the safety of the procedure. As with the results of Breslau (9), we did not observe any procedurally related neurologic deterioration during embolization with calibrated, medium-sized PVA particles and careful neuroangiographic monitoring.

In conclusion, preoperative embolization of hypervascular spinal tumors is an effective tool to reduce intraoperative blood loss in corporectomy procedures. The effect of proximal coil occlusion of the segmental feeders alone is minimal and unpredictable. Medium-sized (150–250 μ) PVA particles with a defined range of diameters reduce intraoperative hemorrhage far more than cases with or without presurgical coil embolization. Preliminary results from a small series of nine patients proved no further benefit of additional coil placement. Particle embolization of tumor vessels remains the most important interventional tool to decrease hemorrhagic complications of vertebral body replacement, and it helps to increase technical feasibility and safety of often long-lasting surgical procedures. Nonetheless, not all sources of intraoperative bleeding can be controlled by means of arterial embolization. Difficulties in accessing the operation field and networks of venous structures and technical problems provide a small residual risk of massive hemorrhage even if the tumor itself is completely excluded from the arterial circulation.

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