Cervical vertebroplasty for osteolytic metastases as a minimally invasive therapeutic option in oncological surgery: outcome in 14 cases

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OBJECTIVE The treatment of cervical spinal metastases represents a controversial issue regarding the type, extent, and invasiveness of interventions. In the lumbar and thoracic spine, kypho- and vertebroplasties have been established as minimally invasive procedures for patients with metastases to the vertebral bodies and without neurological deficit. These procedures show good results with respect to pain reduction and low complication rates. However, limited data are available for kypho- and vertebroplasties for cervical spinal metastases. In an effort to add to existing data, the authors here present a case series of 14 patients who were treated for osteolytic metastases of the cervical spine using vertebroplasty alone or in addition to another surgical procedure involving the cervical spine in a palliative setting to reduce pain and restore stability.

METHODS Fourteen patients consisting of 8 males and 6 females, with a mean age of 64.7 years (range 44–85 years), were treated with vertebroplasty at the authors' clinic between January 2015 and November 2016. In total, 25 vertebrae were treated with vertebroplasty: 10 C-2, 5 C-3, 2 C-4, 2 C-5, 3 C-6, and 3 C-7. Two patients had an additional posterior stabilization and 5 patients an additional anterior stabilization. In 13 cases, the surgical approach was a modified Smith-Robinson approach; in 1 case, the cement was injected into the corpus axis from posteriorly. Patients with osteolytic defects of the posterior wall of the vertebral body did not undergo surgery, nor did patients with neurological deficits. Preoperatively, on the 2nd day after surgery, and at the follow-up, neck pain was rated using the visual analog scale (VAS).

RESULTS Twelve patients were examined at follow-up (mean 9 months). Neck pain was rated as a mean of 6.0 (range 3–8) preoperatively, 2.9 on Day 2 after surgery (range 0–5), and 0.5 at the follow-up (range 0–4), according to the VAS. The mean Neck Disability Index at follow-up was 3.6% (range 0%–18%).

CONCLUSIONS Anterior vertebroplasty of the cervical spine via an anterolateral approach represents a safe and minimally invasive procedure with a low complication rate and appears suitable for reducing pain and restoring stability in cases of cervical spinal metastases. Vertebroplasties can be combined with other anterior and posterior operations of the cervical spine and, in the axis vertebra, can be performed transpedicularly from posteriorly. Thus, in cases in which the posterior wall of the vertebral body is intact, vertebroplasty represents a less invasive alternative to vertebral replacement in oncological surgery. Prospective randomized trials with a longer follow-up period and a larger patient cohort are needed to confirm the encouraging results of this case series.

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KEY WORDS vertebroplasty; cervical metastasis; osteolysis; tumor; minimally invasive surgery

THE skeletal system is the third most common site affected by metastases, ranking after the lung and liver. The spine is involved most often; 70% of patients with metastasizing cancer show spinal metastases at the time of death. The thoracic and lumbar spine are most

frequently affected, whereas cervical metastases occur in 8%–15% of patients.^{11,21}

With the progress in cancer therapy and consequent increased life expectancy, the incidence of spinal metastases and the need to treat them also rise.^{20,43} In itself, the

ABBREVIATIONS NDI = Neck Disability Index; VAS = visual analog scale.

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patient's age does not represent a fundamental contraindication to a surgical procedure. On the contrary, in the presence of an indication, early surgical intervention is recommended because the rate of emergency surgery increases in patients with progressive tumor. It logically follows that in these progressive tumor cases, complication rates would rise and patient outcomes would be worse.¹

Different prognostic scores have been developed to help the physician in therapeutic decision making for patients with metastases of the thoracic and lumbar spine, taking into account the number of spinal metastases, the grade of malignancy, the primary site of the cancer, the patient's general condition, the presence or absence of neurological deficits, and the extent of other bony or visceral metastases.^{17,47,48} The literature shows that surgery can improve pain and quality of life in patients with spinal metastases.^{9,38}

Associations between the size and location of the metastatic lesion and the impending collapse of the vertebral body were statistically analyzed by Taneichi et al. to estimate the critical point of collapse.⁴⁶ Knowledge of the risk factors and the predicted probability of vertebral collapse is widely used when making a therapeutic decision regarding thoracic and lumbar spinal metastases.

To date, however, no studies have focused on the same issue in cervical spinal metastases; their treatment remains controversial in terms of the type, extent, and invasiveness of therapeutic interventions. Treatment options besides single, adjuvant, and neoadjuvant chemo- and radiotherapy include vertebrectomy with vertebral body replacement, spinal decompression surgery, and ventral or dorsal spondylodesis. The main objectives of cervical tumor treatment are pain reduction, stabilization of the cervical spine to avoid the collapse of vertebral bodies, and an improvement in or the preservation of life quality. In accordance with the primarily palliative therapeutic concept, together with multiple comorbidities and reduced life expectancy, the extent and invasiveness of surgical interventions should be as limited as possible.

Since Galibert and Deramond first described vertebroplasty in 1987, both kypho- and vertebroplasties in the lumbar and thoracic spine have been widely established as minimally invasive procedures for patients with metastases to the vertebral bodies and without neurological deficit.¹⁹ These procedures show good to very good results with respect to pain reduction and low complication rates.^{6,22,31} Besides the stabilizing effect of injected bone cement, it is well-known that the heat produced during cement polymerization damages tumor cells and leads to tumor necrosis.^{30,36,40} However, limited data on kypho- and vertebroplasties for cervical spinal metastases are available.

In an effort to add to existing data, we present a case series of 14 patients who were treated for osteolytic metastases of the cervical spine using vertebroplasty alone or in addition to another surgical procedure of the cervical spine. If necessary, we also performed hybrid operations with ventral or dorsal spondylodesis. Indications for surgery were osteolysis that was considered unstable and/or the presence of neck pain. Metastases were considered unstable if more than 50% of the vertebral body was af-

ected by the osteolysis. According to Taneichi et al., vertebrae of the lumbar and thoracic spine are associated with a dramatically increased risk of imminent pathological fracture if more than 50% of the vertebral body excluding the dorsal structures is affected.⁴⁶ If the pedicles are also involved, the risk increases if 20%–25% (lumbar) or 35%–40% (thoracic) of the vertebral body is osteolytic.

The vertebrae in this study that were treated with vertebroplasty showed, except in 1 patient (Case 11), no destruction of the dorsal structures, but more than 50% of the vertebral body was affected in every case.

Methods

Fourteen patients (8 males and 6 females) with metastatic disease of the cervical spine were treated using cervical vertebroplasty between January 2015 and November 2016 at our clinic. The indication for the surgical procedure was confirmed in each case by an interdisciplinary tumor board. The mean patient age was 64.7 years (range 44–85 years); the mean body mass index was 24.3 kg/m² (range 17.3–31.9 kg/m²). The primary tumor was myeloma in 10 cases, breast carcinoma in 2, and pulmonary cancer in 1. One patient had cancer of unknown primary origin at the time of surgery; histopathological examination during surgery revealed the presence of gastric carcinoma.

In total, 25 vertebrae were treated with vertebroplasty: 10 C-2, 5 C-3, 2 C-4, 2 C-5, 3 C-6, and 3 C-7. Two patients underwent additional dorsal stabilization and 5 patients additional ventral stabilization of the cervical spine. In 13 cases, the surgical approach was a modified Smith-Robinson approach; in 1 case, cement was injected into the corpus axis from posteriorly. Patients with osteolytic defects of the posterior wall of the vertebral body did not undergo vertebroplasty, nor did patients with neurological deficits.

In all cases, preoperative diagnostics included radiography, multislice CT, and MRI to detect possible spinal compression. Preoperatively, on Day 2 after surgery, and at the follow-up examination, pain was rated using a visual analog scale (VAS) with values from 0 (no pain) to 10 (maximum pain). At the time of follow-up, the Neck Disability Index (NDI) questionnaire was administered.^{41,50,51} On Day 2 after surgery and at the follow-up, anteroposterior and lateral radiographs of the cervical spine were obtained, as were multislice CT scans of the cervical spine in cases that were difficult to assess.

In 8 cases, single-level vertebroplasties were performed; patients in the other 6 cases received bone cement in multiple vertebrae. In 4 patients, the corpus axis was augmented with cement and an additional anterior odontoid screw was used to achieve more stability. Two patients underwent a hybrid operation with additional posterior stabilization of the upper cervical spine. In 1 case, vertebroplasties of C-2, C-3, and C-5 and a vertebrectomy of C-4 with vertebral body replacement were performed and an anterior plate from C-3 to C-6 was implanted. Five patients underwent kyphoplasties and/or spondylodesis with tumor decompression of the thoracic and lumbar spine, performed in the same operative session.

For the anterior operations, a modified Smith-Robinson approach to the cervical spine was used. The proce-

FIG. 1. Intraoperative fluoroscopic images, lateral projection, showing opening of the anterior vertebral body wall of C-3 with a drill (A), removal of the tumor mass and creation of a resection cavity using forceps (B), and the vertebral body filled with bone cement after the procedure (C).

cedure was performed in the operating room using a C-arm imaging system for biplanar control (Arcadis Orbic 3D, Siemens Healthcare). All patients were informed about the potential dangers of, the alternatives to, and the expected outcomes of the procedure and signed informed consent.

The course of the operation in the case of the vertebroplasties was as follows: After nasal intubation and the induction of general anesthesia, prophylactic single-shot antibiotic therapy (cefuroxime 1.5 g) was injected intravenously. The patient was placed supine with slight extension of the cervical spine in a head cup on the operating table, and the operating field was disinfected and draped. The correct cervical level was marked using a lateral radiograph, and the skin was incised horizontally left to the midline for approximately 2–4 cm, depending on the number of levels that needed to be reached. The platysma muscle was severed at the anterior border of the sternocleidomastoid muscle, and blunt dissection was performed with careful conservation of the esophageal-tracheal bundle and the carotid sheath. When the prevertebral cervical fascia was reached, under fluoroscopic control, a blunt dissector was used to mark the correct cervical vertebra. After confirmation of the correct level, the anterior cortical bone of the vertebral body was opened with a diamond drill. The soft tissue of the osteolysis was carefully removed from the vertebral body using forceps and a sharp spoon and was submitted for histopathological examination. Afterward, a Jamshidi needle (10-gauge, 150-mm length) was placed centrally with the tip in the cavity of the vertebral body; 9.4 ml of liquid methylmethacrylate monomer was mixed with 20 ml of methylmethacrylate polymer powder (Mendec Spine HV System, Tecres Medical). The high-viscosity bone cement was drawn into a 5-ml syringe and, after reaching the correct consistency, was carefully injected under low pressure into the vertebral body through the placed Jamshidi needle. The needle was pulled back slowly while the cement was injected to attain complete filling of the cavity. The injection was performed under intermittent biplanar fluoroscopic control to avoid leakage of the cement into the adjacent soft tissues, spinal canal, and vertebral artery. If multiple vertebrae were affected, each vertebral body was prepared and, one directly after another in quick succession, was filled with

cement. Subsequently, the needle was removed and the surgical site was irrigated with saline solution. A drain was inserted and the wound closed. Relevant steps of the procedure are shown in Fig. 1.

In Cases 3, 4, 13, and 14, the anterior odontoid screw was placed first and then the cement was injected through a hole drilled into the vertebral body of the axis. In Case 9, the vertebrectomy with vertebral body replacement was performed first and the holes for the anterior cervical plate (Reflex Hybrid, Stryker) were drilled. Then, bone cement was placed through the drilled holes into the vertebral bodies of C-2, C-3, and C-5, and the screws (and the plate) were quickly placed and tightened during the hardening time. In Case 11, a large osteolysis of more than half of the axis including the dorsal structures was present, so we decided to first perform a dorsal spondylodesis via a median dorsal standard approach from C-1 to C-4 (Synapse, DePuy Synthes). Subsequently, a Jamshidi needle was placed transpedicularly from the right side into the vertebral body of C-2 and the cement was injected under biplanar fluoroscopic control.

After the procedure, all patients were transferred to an intermediate care station for 1 night and were mobilized with a soft cervical brace, which was used for 10–12 days until wound healing was completed. Demographic and procedural data are summarized in Table 1.

Results

Twelve of 14 patients could be examined at follow-up. Four weeks after surgery, 1 patient with myeloma died of severe sepsis after the induction of chemotherapy; contact with another patient was lost. In all cases, the histopathological result confirmed the underlying primary tumor. In the patient with cancer of unknown primary origin (Case 11), we detected gastric adenocarcinoma.

We had 3 main surgical groups plus 2 other operations: 1) 1-level vertebroplasty (4 cases), 2) multilevel vertebroplasty (4 cases), and 3) vertebroplasty plus odontoid screw placement (4 cases). The mean surgery time for Group 1 was 46 minutes (range 35–55 minutes); for Group 2, 53 minutes (range 37–65 minutes); and for Group 3, 66 minutes (range 57–72 minutes). Two cases could not be classified into any of these surgical groups: Case 9 with 131

TABLE 1. Demographic and procedural data in 14 patients with cervical spinal metastases

Case No.	Age (yrs)/ Sex	Level of VP	Procedure	Cement per VB (ml)	Primary Origin	BMI (kg/m ²)	Op Time (mins)	Radiation Time for VP (sec)
1	74/M	C-2, C-3, C-4	VP plus pst transarticular fusion C1–2 (Magerl technique)	1.7, 1.9, 2.1	Myeloma	25.9	65 ventral, 85 dorsal	NA
2	72/M	C-2	VP plus dorsal thoracolumbar spondylodesis T10–L2	2	Myeloma	24.4	46 ventral, 135 dorsal	NA
3	44/M	C-2	VP plus odontoid screw	1.8	Myeloma	29.4	68	NA
4	69/F	C-2, C-3	VP plus odontoid screw	1.9, 2.3	Myeloma	25.6	72	NA
5	62/F	C-2	VP plus dorsal thoracic kyphoplasty T-4 & T-11	1.5	Breast cancer	27.6	46 ventral, 65 dorsal	NA
6	45/M	C-2, C-3, C-6	VP plus dorsal thoracolumbar spondylodesis T12–L3	1.4, 1.6, 2.4	Myeloma	17.5	61 ventral, 219 dorsal	NA
7	48/F	C-6, C-7	VP	1.9, 2.1	Breast cancer	21.2	37	10
8	74/M	C-7	VP plus dorsal thoracic kyphoplasty T-8, T-11, T-12 & dorsal lumbar spondylodesis L2–5	2.1	Myeloma	25.8	55 ventral, 223 dorsal	NA
9	76/M	C-2, C-3, C-5	VP w/ vertebrectomy C-4 & ventral plate C3–6	1.8, 1.9, 2.6	Myeloma	24.5	131	NA
10	62/M	C-3	VP	1.5	Myeloma	17.3	35	10
11	67/M	C-2	VP from dorsal plus dorsal spondylodesis C1–4	1.7	CUPO, later determined to be gastric cancer	23.8	113	NA
12	84/F	C-4, C-5, C-6, C-7	VP	1.8, 1.9, 1.9, 2.0	Pulmonary cancer	22.9	47	15
13	44/F	C-2	VP plus odontoid screw & dorsal lumbar kyphoplasty L-3	2.2	Myeloma	31.9	65 ventral, 31 dorsal	NA
14	85/F	C-2	VP plus odontoid screw	2.1	Myeloma	21.9	57	NA
Mean	64.7			1.9		24.26		11.7

BMI = body mass index; CUPO = cancer of unknown primary origin; NA = not available; pst = posterior; VB = vertebral body; VP = vertebroplasty.

minutes and Case 11 with 113 minutes. Case 4 matched 2 groups but was assigned to Group 3.

After normal wound healing, or 10 days postoperatively, patients could be started on local radiation or adjuvant chemotherapy. The minimally invasive nature of our procedure allows for a relatively short healing interval after surgery; thus, the risk of impaired wound healing is re-

duced, as compared to such risks with other more invasive techniques.

Neck pain preoperatively was 6.0 on the VAS (range 3–8); on Day 2 after surgery, 2.9 (range 0–5); and at follow-up, 0.5 (range 0–4). The NDI at follow-up was 3.6% (range 0%–18%). All patients could reduce their use of analgesic drugs or discontinue them.

The mean amount of bone cement used was 1.9 ml per vertebra (range 1.2–2.6). Radiologically, good cement distribution and filling of the resection cavity was demonstrated in all cases (Fig. 2), but 1 patient had cement leakage anterolaterally from the vertebral body of C-4 (Fig. 3) and another patient experienced cement leakage dorsally into the spinal canal, although it did not cause relevant stenosis (Fig. 4). Both cases were asymptomatic. Radiographic control images at follow-up showed unchanged implant positioning without adjacent fractures or instabilities. There were no other intra- or postoperative complications apart from the death of the patient in Case 10, which was not an immediate consequence of surgery. Esophageal or tracheal perforations, spinal or nerve root damage, and lacerations of the carotid artery and jugular veins were not observed. Thus, the total complication rate was 8% per vertebra and 14% per patient.

Neurological examination results for all patients were unchanged between the pre- and postoperative periods.

FIG. 2. Case 6. Preoperative sagittal CT scans showing large osteolytic defects of the C-2, C-3, and C-6 vertebral bodies and smaller lesions that were considered stable in C-4 and C-5 (A). Postoperatively, there was good cement distribution in the affected vertebrae (B).

FIG. 3. Case 1. Sagittal (A), coronal (B), and axial (C) CT scans showing left-sided anterolateral cement extravasation at C-4.

The mean follow-up was 9 months (range 2–20 months). Mean radiation time intraoperatively was 11.7 seconds in the 3 cases in which only cervical vertebroplasties were performed. In the other cases, data are not available because additional radiographs were obtained for the other procedures and only the total radiation time was documented. Clinical outcome parameters and complications are summarized in Table 2.

Discussion

Anterior vertebroplasty of the cervical spine represents a secure, minimally invasive procedure with a low complication rate for osteolytic metastases. It is effective for reducing pain and restoring stability, can easily be combined with other ventral or dorsal procedures of the cervical spine, and, in the axis vertebra, can be performed from posteriorly. Vertebroplasty of the cervical spine thus represents a minimally invasive alternative to the far more invasive vertebrectomy with vertebral body replacement and anterior spondylodesis. To perform the vertebroplasty, the posterior wall of the vertebral body should be intact to avoid potentially dangerous complications such as intraspinal leakage with a risk of high para- or tetraparesis.

Apart from the standard anterolateral approach, which was described by Southwick in 1957 and Smith and Robinson in 1958,^{42,44} different percutaneous approaches for cervical vertebrae C3–7 have been described in the literature. For the atlas and axis vertebrae, transoral, postero-

lateral, anterior retropharyngeal, and even percutaneous transdiscal approaches have been used for vertebroplasty.^{7,10,12,13,39,53} The standard anterolateral Smith-Robinson approach that we used represents secure surgical access to the anterior cervical spine and has the advantage of an initial incision of approximately 2–3 cm that can be easily extended to reach more than 1 or 2 cervical vertebrae. Vertebrae C-2 to T-1 can be easily reached via this anterior approach.

The 2 cement leakages in this study represent the only complications and fortunately were completely asymptomatic. Nevertheless, surgeons should be aware that even if the posterior wall of the vertebral body on the preoperative CT scan appears to be intact, epidural-intraspinal cement leakage could occur (Fig. 4). It could lead to compression of the upper spinal cord with consequent high tetraparesis or even a fatal outcome. Embolization of

FIG. 4. Case 11. Sagittal (A) and axial (B) CT scans showing intraspinal cement extravasation at C-2.

TABLE 2. Summary of clinical outcome data in 14 patients with cervical spinal metastases

Case No.	FU (mos)	Preop VAS	Postop VAS	FU VAS	FU NDI (%)	Complications
1	11	6	4	4	18	Asymptomatic cement leakage anterolat
2	20	8	5	0	2	None
3	9	7	3	0	2	None
4	9	6	3	2	0	None
5	14	6	4	0	4	None
6	6	3	0	0	0	None
7	11	6	3	0	0	None
8	7	6	3	0	0	None
9	6	7	5	0	4	None
10	NA	6	3	NA	NA	NA
11	5	7	5	0	10	None
12	7	4	1	0	4	None
13	5	5	2	0	0	Asymptomatic cement leakage dorsal
14	NA	7	0	NA	NA	NA
Mean	8.8	6	2.9	0.5	3.6	

FU = follow-up; NA = not applicable.

bone cement through the epidural or paravertebral venous plexus is also conceivable and could lead to a pulmonary embolism. This complication occurs relatively often in vertebroplasties and kyphoplasties of the thoracic and lumbar spine, with rates ranging from 2.1% to 26%.^{2,8,16,24,49,52} Embolization via the arterial circulation of the vertebral artery into the posterior brain circulation has been described in 1 case and led to cerebellar symptoms and lateral homonymous hemianopia after the vertebroplasty. Imaging in this case revealed an acute cerebellar and occipital infarction due to a cement embolism of the vertebral artery.³⁵ Furthermore, cement leakages into the neuroforamina with nerve root compression and into the cervical disc space can occur.¹⁵

To prevent cement leakage and embolization, the cement should have an adequate consistency, a high-resolution fluoroscopic device should be used, and, most importantly, the injection should be stopped immediately if leakage is recognized.³³

The rate of cement leakage for percutaneous vertebroplasty of the thoracic and lumbar spine has been reported as 41% up to 88%, and for percutaneous kyphoplasty, between 9% and 49%.^{23,27} For cervical vertebroplasty, cement leakage rates between 3% and 58% can be found in the literature, though the overall number of reported cases in the cervical spine is far smaller.¹⁵ It should be noted that in addition to leakage of the cement itself into the spinal canal, there is also a risk of tumor displacement into the canal when the cement is injected, which could also create spinal cord or nerve root compression. Consequently, if the tumor mass already extends into the spinal canal, injecting cement should be avoided.⁴

We performed low-pressure filling of the vertebral body and first resected the tumor mass using a sharp spoon or forceps before filling the resection cavity with cement, as described by Floeth et al.¹⁸ The risks associated with a conventional percutaneous pressure-directed technique are considered to be higher in terms of cement leakage and displacement of the tumor mass toward potentially dangerous structures, compared with the risks of the alternative low-pressure technique we used. In addition, evidence suggests that the use of high-viscosity bone cement may reduce the leakage rates in vertebroplasty and kyphoplasty, which is why we used it.^{3,26} Furthermore, possible ventral and ventrolateral cement leakages can be detected under direct vision and removed instantaneously after the injection, which is not possible in percutaneous procedures.

Volumetric studies of the cervical spine have determined the vertebral body volume of C-2 to be 6.3 ± 1.1 cm³, C-3 as 10.4 ± 1.9 cm³, C-4 as 10.5 ± 2.0 cm³, C-5 as 11.1 ± 2.1 cm³, C-6 as 12.4 ± 2.5 cm³, and C-7 as 15.4 ± 2.8 cm³.¹⁴ In our study, the volume of the vertebral body filled with bone cement at C-2 was, on average, 28.7% (total amount injected: number of cases = average amount per vertebral body; 18.1 ml: 10 = 1.81 ml); at C-3, 16.6% (9.2 ml: 5 = 1.84 ml); at C-4, 18.6% (3.9 ml: 2 = 1.95 ml); at C-5, 20.3% (4.5 ml: 2 = 2.25 ml); at C-6, 16.7% (6.2 ml: 3 = 2.07 ml); and at C-7, 13.4% (6.2 ml: 3 = 2.07 ml). In biomechanical studies of the thoracic and lumbar spine, it has been shown that the minimal amount of bone ce-

ment necessary to restore adequate stability or stiffness, respectively, ranges between 13% and 16% of the vertebral body volume.^{28,29,33} Similar studies of the cervical spine do not exist, to our knowledge. The amounts of cement used in the present study are therefore in line with the biomechanical recommendations for adequate stress distribution after vertebroplasty.

The duration of fluoroscopy for vertebroplasties alone was very limited in this minimally invasive technique, with an average of 12 seconds, which reduces the radiation exposure of the patient and medical personnel in the operation room. The amount of radiation exposure in percutaneous procedures of the cervical spine is not documented in the literature but is likely to be higher than in the technique we used.

Even though the patient sample and the operative procedures in our study were inhomogeneous, we can show that a short operation time can be achieved for single-level and multilevel vertebroplasties, as well as for vertebroplasties with an additional odontoid screw. The average surgery time of 46 minutes for single-level vertebroplasty is slightly lower than that described in the literature: Floeth et al. reported a surgery time of 51 minutes; Cianfoni et al., 60 minutes; Kordecki et al., 67 minutes; and Brage et al., using a transoral approach, 90 minutes.^{7,10,18,25} Comparable data do not exist for multilevel vertebroplasty and vertebroplasty with an odontoid screw; our average surgery times for the respective procedures were 53 and 66 minutes. Compared with the far more invasive and elaborate vertebrectomy with vertebral body replacement, which may have been an alternative because of the large bony defects encountered, these times still represent a relatively short period for the procedure.

Intraoperative blood loss was not monitored but was seen to be low for the vertebroplasties alone and, of course, higher when combined with other procedures involving the cervical spine.

The primary treatment goals of stabilization of the cervical spine and effective pain control were achieved in all patients. The preoperative pain value of 6.0/10 on the VAS was comparable to scores in other published studies, as were the postoperative values (2.9/10) at Day 2 after surgery and at the follow-up (0.5/10).^{5,18,32,37,45} We showed that this significant reduction in neck pain occurred despite having performed in the cervical spine additional dorsal procedures in 2 cases and additional ventral procedures in 5 cases.

We acknowledge the limitations of this observational study, such as the relatively short follow-up, the nonprospective study design, and the small number of treated patients. There was no control group because conservative treatment of the osteolysis had failed, patients had significant pain, and we considered the affected vertebrae to be unstable and at high risk for vertebral collapse.

Conclusions

Our study suggests that in selected patients with osteolysis of the cervical spine, vertebroplasty via an anterior approach and low-pressure cement application can be performed with immediate pain relief, a consequent reduc-

tion in analgesic drug use, and a low complication rate. The possibility of combining the technique with other procedures involving the cervical spine makes it a very practicable option in oncological surgery. In the future, prospective randomized trials will need to show whether the encouraging results of this case series can endure for a longer period in a larger patient cohort. In that event, it should be noted that the maximum time of follow-up would be limited by the palliative situation. Finally, it must be emphasized that in this palliative setting, an individual and interdisciplinary therapeutic concept should always be discussed among the surgeon, oncologist, radiation therapist, and patient.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Dreimann. Acquisition of data: Stangenberg, Viezens. Analysis and interpretation of data: Stangenberg. Drafting the article: Stangenberg. Critically revising the article: Viezens, Mende, Mohme, Dreimann. Approved the final version of the manuscript on behalf of all authors: Stangenberg. Statistical analysis: Stangenberg. Study supervision: Eicker, Dreimann.

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