alignant metastatic tumors of the upper cervical spine—even the atlantoaxial region of the vertebral column—are uncommon.4,5,7 The origins of these metastatic tumors are mainly breast, lung, and prostate neoplasms, or they are part of hematopoietic disorders such as multiple myeloma or lymphoma. Destruction of the lateral articular mass of C-1, the odontoid process, and the vertebral body of C-2 can lead to pathological fractures, progressive subluxation, and spinal cord compression. Given the relatively wide midsagittal diameter of the spinal canal at the level of C1–2, neurological deficits are rarely present, although severe neck pain as a leading symptom is caused by cervical instability. Patients with neurological symptoms due to spinal cord compression or instability are the main candidates for surgery.

The clinical management of C-2 metastatic lesions includes open surgery, radiotherapy, vertebroplasty, and external immobilization. The approach most frequently used for C-2 ventral tumors is transoral exploration, tumor removal, and dorsal occipitocervical fixation. In these cases, ventral epidural tumorous propagation of the tumor may be observed and treated with vertebroplasty combined with posterior occipitocervical fixation.

**Object.** Metastatic spinal tumors of the atlantoaxial region are quite uncommon, and surgery is challenging. The aim in this study was to evaluate the safety and efficacy of transoral or transpedicular vertebroplasty combined with posterior fixation in C-2 metastatic disease.

**Methods.** The authors collected from a hospital database all cases of C-2 metastatic tumor treated in the period from January 2009 to December 2012. Cases with histologically confirmed metastatic disease were included, but those with epidural tumor propogation and signs of spinal cord compression were excluded.

**Results.** Five patients (3 females, 2 males) with osteolytic C-2 metastasis were eligible for this study. In 3 cases a purely posterior approach was taken to perform a dorsal open C-2 biopsy and transpedicular vertebroplasty followed by posterior occipitocervical fixation. In the other 2 cases a transoral C-2 biopsy and vertebroplasty were performed in combination with dorsal occipitocervical fixation during the same operative session. Patients were followed up with regular fluoroscopy, MRI, and CT studies as well as neurological examinations. During an average follow-up of 13 months (range 8–19 months), no surgical or neurological complications were associated with this combined approach. In all cases spinal stability and pain reduction were detected. The average pain score according to the visual analog scale was 3.5 after surgery (range 2–5); before surgery, the average score was 7 (range 6–8). The average volume of polymethylmethacrylate injected was 4 ml. The body and dens of the C-2 vertebra was filled more than 60% for each patient.

**Conclusions.** In this small series, simultaneous intraoperative transoral or transpedicular vertebroplasty and dorsal occipitocervical fixation proved to be a safe and effective treatment for patients with osteolytic C-2 metastatic tumors. These techniques may provide excellent pain relief and improvements in quality of life. The true value of these combined techniques should be evaluated in larger series.

**Key Words** • axis • C-2 • metastatic tumor • occipitocervical fixation • transoral • transpedicular • vertebroplasty • cervical spine

---

**Abbreviations used in this paper:** PMMA = polymethylmethacrylate; VAS = visual analog scale.
Treatment of C-2 metastatic tumors with vertebroplasty and fixation

C-2 vertebral body or vertebral body collapse can lead to spinal cord compression at the level of the atlantoaxial spine. Surgical treatment is difficult, because the procedure itself requires an experienced medical background and carries the risks of infection and failure of bone healing due to poor clinical conditions and comorbidities. In cases of C-2 tumors without current epidural tumor propagation, occipitocervical fixation is recommended, especially in those cases where developing compression fracture with signs of instability or imminent pathological fracture is threatening. New combined surgical techniques can provide stable fixation of the atlantoaxial junction with a lower intraoperative risk for the patient. Adjuvant radiotherapy and/or chemotherapy may also be options for treating these patients.

For osteolytic C-2 vertebral body and/or dens metastatic tumors without epidural tumor propagation, vertebroplasty is an alternative treatment option. The aim of cement infiltration is to provide mechanical support, reduce pain, and prevent pathological fracture and collapse of the vertebral body. Verteoplasty can be combined with posterior fixation.

The purpose of this retrospective study was to evaluate the safety and efficacy of simultaneous intraoperative transoral or transpedicular vertebroplasty and posterior occipitocervical fixation in cases of C-2 metastatic disease.

Methods

Within our hospital database, we searched for cases of C-2 metastatic tumor in the period from January 2009 to December 2012. We included only those patients with histologically confirmed metastatic disease but excluded those with epidural tumorous propagation and signs of spinal cord compression. We included patients of any age and either sex. During physical examination, all patients were asymptomatic neurologically and had severe neck pain. Solitary C-2 metastasis and the absence of spinal cord compression were confirmed on preoperative spinal MRI. The mean age was 58.2 years (range 43–74 years). According to the histological results of biopsies, metastases originated from breast cancer in 2 cases, lung cancer in 2 cases, and multiple myeloma in 1 case, corresponding to the primary malignancy. The average follow-up was 13 months (range 8–19 months).

All patients undergo meticulous oncological examination. The primary tumor is histologically identified through percutaneous biopsy or direct surgical removal of the primary lesion. All patients receive combined oncological therapy according to the actual treatment protocol for their concomitant systemic disease. A multidisciplinary oncoteam consisting of a neurosurgeon, spine surgeon, interventional radiologist, oncologist, and radiation therapist evaluates the patient. In cases of solitary osteolytic C-2 tumors, we perform vertebroplasty and long (C0–5) posterior fixation in patients with signs of imminent or developing vertebral body collapse and instability, in good clinical and stable oncological condition, and with a long life expectancy and low surgical risk.

A halo device provides immobilization of the cervical spine preoperatively. All patients undergo fiber-optic intubation, followed by the induction of general anesthesia for the entire surgical procedure. The transoral biopsy and vertebroplasty procedures are performed in the Neurointerventional Lab using a digital subtraction angiography unit (GE LCV +). Patients are then immediately transported to the operating room for posterior fixation. Transpedicular vertebroplasty is performed in open surgery using a surgical C-arm image intensifier (BV Pulsera, Philips Medical Systems). The transoral and transpedicular tumor biopsies are intended to verify the histology of the known metastatic disease.

Vertebroplasty is performed under fluoroscopic guidance to avoid any complications during cement injection. Our method of avoiding perivertebral intravenous cement penetration, a potential complication especially during the free-hand approach, is real-time imaging. According to our experience, the transpedicular polymethylmethacrylate (PMMA) injection seems to be an appropriate method mainly for the treatment of C-2 metastatic osteolytic lesions and more caudal vertebral bodies. The existence of intrapedicular tumor does not affect our decision. Transoral PMMA injection is suitable for the treatment of both dens and C-2 vertebral body lesions. A posterior approach to the dens is very difficult and dangerous; hence, it is not recommended.

Patients are followed up with regular fluoroscopy, MRI, CT, and neurological examinations immediately after the operation and 6 months thereafter. The halo fixation device is removed after the first postoperative CT examination.

Results

Five patients (3 females, 2 males) with osteolytic C-2 metastasis were eligible for study (Figs. 1 and 2). The mean age was 58.2 years (range 43–74 years). According to the histological results of biopsies, metastases originated from breast cancer in 2 cases, lung cancer in 2 cases, and multiple myeloma in 1 case, corresponding to the primary malignancy. The average follow-up was 13 months (range 8–19 months).

Two patients underwent transoral C-2 biopsy and vertebroplasty and dorsal occipitocervical fixation (Figs. 3–5) at the same operative session. In the remaining 3 cases, dorsal open C-2 tumor biopsy and transpedicular

Fig. 1. Preoperative sagittal CT reconstruction scan showing osteolytic C-2 vertebral body and spino-pal process lesions (multiple myeloma).
Vertebroplasty were done in combination with C0–5 posterior occipitocervical fixation using an occipital plate, screws, and rods (Figs. 3, 5, and 6; Axon, CerviFix, Synthes GmbH Switzerland; Vertex Select, Medtronic Sofamor Danek USA Inc.).

The incidence of postoperative cervical pain was lower than that for preoperative pain. The preoperative visual analog scale (VAS) score was 7 (range 6–8), whereas the postoperative score was 3.5 (range 2–5). On postoperative neurological and radiological follow-up, no surgical or neurological complications had developed with respect to the combined approach to the atlantoaxial region of the spine.

The average volume of PMMA injected was 4.0 ml (range 3.1–5 ml). The amount of PMMA injected was measured intraoperatively, by calculating the remaining volume in the syringe (Table 1). Average filling of the body and dens of the C-2 vertebra was more than 60%. This calculation was based on postoperative CT scans, using a multiplanar reconstruction on Osirix 3.9.2 software (www.osirix-viewer.com) on a Mac Pro workstation (Apple Inc.).

No cement leakage into the spinal canal or paravertebral region was detected except in 1 case, in which a small amount of cement appeared in the C1–2 joint but with no clinical significance. Cement leakage into the spinal canal or paravertebral region during injection mostly depends on the integrity of the vertebral endplates, destruction of the vertebral discs, and posterior wall of the vertebrae. To avoid unexpected cement extravasation, we evaluated interruption of the endplate and posterior wall on preoperative CT. In addition, during high-viscosity cement injection, we used continuous radiography, alternating between anteroposterior and lateral views (Figs. 4 and 6).

Transorally treated patients complained of some pharyngeal discomfort and pain, which remained temporary complications. No dural tear was detected, nor was any sign of local infection. Early mobilization in the halo device was allowed.

The halo fixation device was removed after the first postoperative CT examination on the 3rd postoperative day. Control CT scans proved correct positioning of the PMMA and the occipitocervical fixation screws (see Figs. 8–10) in all of the cases. We excluded spinal instability with regular postoperative CT scans and radiographs (Figs. 7–10). There was no evidence of C-2 vertebral body collapse, hardware failure, or kyphosis.

**Discussion**

The most mobile section of the spinal column is the atlantoaxial articulation. At the same time, it has the least stability. The craniospinal junction (occiput-C1-C2 complex) is responsible for 60% of cervical rotation and about 45% of cervical flexion-extension. Most atlantoaxial stability is provided by the transverse ligament of C-1, the odontoid process, and the lateral articular mass of C-1 and C-2. Osteolytic destruction of these structures leads to instability and atlantoaxial subluxation.

Painful limitation of neck and head motion, especially rotation, may be the first and, in most cases, the only clinical sign of upper cervical metastases, even the atlantoaxial spine. Patients suffering from primary malignances of the lung, breast, prostate, or kidney and neck pain should undergo radiological examinations to reveal early metastatic lesions.

Immobilization and irradiation therapy of the affected spine region can alleviate early symptoms. Ra-
Treatment of C-2 metastatic tumors with vertebroplasty and fixation

diotherapy can reduce the pain after 10–14 days, with a maximum effect after 2–5 months. The possible complication of radiotherapy is delayed bone reconstruction, which may increase the periprocedural risk of vertebral collapse. Chronic and supplementary use of an external collar also affects quality of life. In previously treated cancer patients, the repetition of radiotherapy is not recommended. Moreover, radiotherapy may not be the best choice for patients with a poor overall prognosis and shortened life expectancy. The percutaneous injection of PMMA into osteolytic vertebral metastases is a well-tolerated and effective treatment, even in patients with a poor general condition. The injected bone cement prevents pathological fracture, compression of the involved vertebra, and pain, as reported in the literature.

Surgical treatment is indicated if atlantoaxial instability or an epidural tumor mass and consequent spinal cord compression are detected to prevent or resolve serious neurological complications and to maintain quality of life. The survival of patients with metastatic spinal disease depends on the stage and level of control of the underlying systemic disease, but quality of life can be improved with surgical interventions. Most patients with C-2 metastatic lesions have other affected vertebral bodies. Ventral, epidural propagation of a C-2 vertebral body tumor requires transoral exploration and tumor resection for spinal cord decompression and prevention of neurological complications. Screw-rod fixation is recommended for patients with atlantoaxial tumor and current or developing instability to achieve maximum biomechanical stability. However, metastatic tumors of the C-2 vertebral body and the odontoid process are very difficult to resect via the posterior midsagittal approach. Transoral exploration of the atlantoaxial region is difficult and potentially risky. The narrow and limited operative field makes anterior fixation very difficult. The most frequent complications of the transoral approach are wound healing failure, infection, retropharyngeal hematoma, and even leakage of CSF.

Combining the dorsal pedicle screw-rod fixation technique with transoral/transpedicular PMMA injection is a treatment option for patients with osteolytic C-2
metastatic tumors without epidural propagation. The risk of cement leakage into the spinal canal is lower if the posterior wall of the infiltrated C-2 body is intact. Besides the vertebroplasty, transoral puncture of the C-2 vertebral body provides the possibility of needle biopsy for histological proof of the metastatic tumor.

According to our experience, transpedicular PMMA injection is appropriate mainly for the treatment of C-2 vertebral body metastatic osteolytic lesions, whereas transoral PMMA injection is suitable for the treatment of both the dens and C-2 vertebral body lesions. The posterior approach to the dens is very difficult and dangerous; hence, it is not recommended. The vertebroplasty provides ventral support for the atlantoaxial junction, preventing pathological fracture of the dens and compression of the C-2 vertebral body.

Continuous oncological care is provided to our patients. Vertebroplasty and posterior fusion are recommended primarily for those in good clinical condition with a stable oncological status and an acceptable or a long life expectancy. Despite oncological care, there is still the possibility of disease progression, which leads to the destruction of crucial elements, such as the atlantoaxial articulation or the lateral mass of C-1, which is responsible for stability in this region. Because of tumorous destruction of the C-2 pedicles and vertebral body, the insertion of transpedicular screws at this level is very difficult or even impossible, and a “floating” C-2 vertebra may develop. Besides possible tumorous destruction, the potential presence of osteoporosis must also be dealt with. Osteoporosis is frequent not only in the elderly, but also in postchemotherapy patients.

The subaxial cervical lateral mass screws have reduced pullout resistance compared with the C-2 transpedicular or C-1 lateral mass screws. Our selected cancer patients are quite vulnerable in terms of cervical instability due to the tumorous and potentially osteoporotic structure that is exposed to high rotational and sagittal movements. Extended posterior (C0–5) fixation is highly recommended to achieve the maximum and most durable stability.

Given our experience with solitary osteolytic C-2 tumors, we performed vertebroplasty and long (C0–5) posterior fixation in patients with signs of imminent or developing vertebral body collapse and instability, in good clinical and stable oncological condition, and with a long life expectancy and low surgical risk. We excluded patients with epidural tumorous propagation and signs of spinal cord compression.

Cancer patients with long survival times tend to have severe atlantoaxial instability. Progression is caused by the destruction of the atlantoaxial articulation elements. It is very important to take these factors into consideration before performing a shorter posterior fixation (C1–3). Because of additional tumoral infiltration and the progression of instability, this shorter posterior fixation might later become insufficient (mainly the floating C-2 segment) and reoperation could be required. That would be a high-risk procedure and would carry a lot of potential complications due to hardware failure, scar tissue, and poor healing conditions as a result of radiotherapy and/or chemotherapy.

As a consequence, shorter (C1–3) fusion with vertebroplasty is considered for patients with C-2 osteolytic tumor who have a shortened life expectancy, decreased surgical suitability, and again no epidural propagation or vertebral body collapse and only minimal signs of atlantoaxial instability. These patients will not reach the metastatic stage when significant destruction of atlantoaxial articulation elements would develop. In these patients, less invasive surgery seems reasonable.

Vertebroplasty and shorter (C1–3) fusion is between

Table 1: Summary of characteristics in 5 patients with C-2 metastatic tumor

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Primary Tumor</th>
<th>Approach of Vertebroplasty</th>
<th>Amount of PMMA Injected (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43, F</td>
<td>breast</td>
<td>transpedicular</td>
<td>3.1</td>
</tr>
<tr>
<td>2</td>
<td>52, F</td>
<td>breast</td>
<td>transpedicular</td>
<td>3.4</td>
</tr>
<tr>
<td>3</td>
<td>74, F</td>
<td>lung</td>
<td>transoral</td>
<td>4.2</td>
</tr>
<tr>
<td>4</td>
<td>48, M</td>
<td>lung</td>
<td>transpedicular</td>
<td>5.0</td>
</tr>
<tr>
<td>5</td>
<td>47, M</td>
<td>myeloma multiplex</td>
<td>transoral</td>
<td>4.5</td>
</tr>
</tbody>
</table>

![Fig. 8. Postoperative sagittal (A), axial (B), and coronal (C) CT reconstruction scans showing the injected PMMA in the C-2 vertebral body.](image-url)
vertebroplasty alone and vertebroplasty with C0–5 posterior fixation.

The true value and efficacy of these combined techniques and varieties of posterior fixation should be evaluated in larger series with a longer-term follow-up.

Although the current study was based on a small sample size, the clinical and radiological results are very promising and suggest that the combined technique appears suitable to treat C-2 metastatic osteolytic lesions. Larger studies are required to confirm these results.

Conclusions

Simultaneous intraoperative transoral or transpedicular vertebroplasty and dorsal occipitocervical fixation was found to be a safe and effective treatment for patients with osteolytic C-2 metastatic tumors in selected cases.

These techniques may provide excellent pain relief and improvements in quality of life. The true value of these combined techniques should be evaluated in larger series.

Disclosure

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 to the study and manuscript preparation include the following: Conception and design: Papp, Szikora, Banczerowski, Marosfői. Critically revising the article: Szikora, Banczerowski. Administrative/technical/material support: Marosfői.

References