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► **To cite this version:**

Frédéric Clarençon, Eimad Shotar, Evelyne Cormier, Kevin Premat, Mehdi Drir, et al.. Transoral vertebroplasty for the C1 lateral mass. *Journal of Neurointerventional Surgery*, 2020, 12 (9), pp.879-885. 10.1136/neurintsurg-2020-015853 . hal-03015755

**HAL Id: hal-03015755**

**<https://hal.sorbonne-universite.fr/hal-03015755v1>**

Submitted on 20 Nov 2020

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# Transoral Vertebroplasty for the C1 Lateral Mass: Single Center Experience

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## **Abstract**

### *Background*

Osteolytic lesions of the atlas (C1) are challenging to treat by vertebroplasty due to the vicinity of the vertebral artery (VA) and of the spinal cord.

Our objective was to present our experience of transoral vertebroplasty (TOV) for osteolytic lesions of the lateral mass of the atlas.

### *Methods*

Retrospective cases series involving 15 consecutive patients (9 males, 6 females, mean age: 63y) who underwent transoral vertebroplasty for the treatment of an osteolytic lesion of the lateral mass of the atlas. Among the osteolytic lesions, 10/15 (67%) were bone metastases from various cancers; 4/15 (27%) were lesions related to multiple myeloma and one lesion (6%) was an aggressive hemangioma.

All the transoral vertebroplasties were performed under general anesthesia and in most cases (10/15; 67%) in a hybrid angio-suite combining a C-arm flat panel and CT-scan. The remaining 5 patients were treated under biplane fluoroscopic guidance.

### *Results*

Vertebroplasty of the lateral mass of C1 through a transoral route was feasible in all cases. Significant pain relief was obtained in most cases (1 month average decrease in numeric rating scale [NRS]:  $4.9 \pm 4.1$ ). No major complication was recorded. In 7/15 cases (47%), a cement leakage surrounding the C1 lateral mass was seen; none of these leakages had a significant clinical consequence. No additional spine surgery was required in any of the patients.

### *Conclusion*

Our experience shows that TOV of osteolytic lesions of the lateral mass of the atlas is feasible and seems safe and effective in terms of pain relief and bone stabilization.

### **Abbreviations and acronyms:**

**AP:** anteroposterior; **DSP:** dose-surface product; **ICA:** internal carotid artery; **IRB:** institutional review board; **NRS:** numeric rating scale, **PMMA:** polymethyl metacrylate, **RFA:** radiofrequency ablation, **TOV:** transoral vertebroplasty, **VA:** vertebral artery.

**Key words:** Vertebroplasty, transoral, C1, atlas

## **Introduction**

The C1 vertebra (*aka* the atlas) has a specific anatomic configuration, compared to the other vertebrae of the human body. Indeed, the atlas presents a circle shape with 2 masses located laterally, which bear the skull through the joints with the occipital condyles. This bearing role of the lateral masses of the atlas explains the unstable characteristic of the osteolytic lesions involving this region of C1.

In addition to its specific anatomy, the atlas is surrounded by critical nervous and vascular components: the medulla oblongata-spinal cord junction, the C1 and C2 nerve roots, the distal aspect of the cervical internal carotid artery (ICA) and the vertebral artery (VA), which surrounds laterally and posteriorly each lateral mass of C1.

Transoral route has been described several years ago for vertebroplasties of C2 lesions.<sup>1 2</sup> Only scant data, mainly case reports<sup>3 4</sup>, are available in the literature on the feasibility, safety and effectiveness of vertebroplasty for C1 lesions, either by transoral<sup>4 5</sup> or alternative routes.<sup>3 6</sup>

The purpose of this study was to report the authors' experience of transoral vertebroplasty (TOV) for lesions involving the lateral mass of C1 in terms of safety and pain relief.

## Materials and Methods

### *Study design:*

Retrospective monocentric case series.

### *Patients' demographic and lesions' characteristics:*

From 2012 to 2019, all patients who underwent a TOV for a C1 lesion at a single Institution were included in a prospectively filled database. Clinical demographics (age, sex, underlying disease) as well as lesions' characteristics (pathological origin, osteolytic/mixed or osteoblastic pattern) were systematically recorded. All patients were treated for unstable lesions of C1 lateral mass. Instability was defined as an osteolysis involving more than 50% of the volume of the C1 lateral mass or cortical bone lysis or fracture of the C1 lateral mass.

Two patients of this cohort have already been reported previously in an article describing the early experience of the authors in TOV of C1 lesions. <sup>5</sup>

Five patients of the present study have also been already reported through a study presenting the authors' experience in cervical vertebroplasty (from C1 to C7), reporting the safety and effectiveness of 140 cervical vertebroplasty procedures. <sup>7</sup>

### *Procedure descriptions:*

All patients were treated under general anesthesia in supine position using an oral intubation with a reinforced oral tube. Ten out of the 15 patients (66.7%) were treated in a hybrid angiosuite, combining a flat panel C-arm and a 16-rows CT scan (Myabi, Siemens) (**Fig. 1**). The remaining 5 patients (33.3%) were treated under biplane fluoroscopic guidance (Artis Q, Siemens). All patients were treated according to a technique previously described by our team. <sup>5</sup> Briefly, a Boyle-Davis mouth gag was positioned in order to expose the posterior aspect of the pharyngeal mucosa. Disinfection with Betadine (povidone iodine, Meda Pharma, Soina, Sweden) oral antiseptic solution was then performed. After the induction of the anesthesia, 1 g intravenous cefazolin (or other broad spectrum antibiotic) was injected in order to reduce the infection risks. An 11G bone needle (Thiebaud, Margencel, France) was

positioned and advanced gently in the lateral mass of C1 to treat, under fluoroscopic guidance (Fig. 1). The satisfactory positioning of the bone needle was checked by a CT acquisition (in patients treated in a hybrid angio suite) or by a cone-beam CT acquisition (in patients treated in a by-plane angio-suite). In 73.3% of the cases (11/15), a compliant protection balloon was navigated in the V3 segment<sup>8</sup> of the vertebral artery (VA) ipsilateral to the lesion from a 6F guiding catheter positioned in the VA, via a femoral access. This balloon protection was temporarily inflated under full IV anticoagulation to prevent retrograde cement migration in the VA ipsilateral to the lesion via the arterial feeders. Finally, low viscosity polymethyl metacrylate (PMMA) bone cement (Biomet V; Biomet UK Ltd, Bridgend, UK) was injected through the bone needle under anteroposterior (AP) and lateral fluoroscopic guidance. In each case, the volume of cement injected in the lateral mass of C1 was recorded. Total duration of the procedure as well as X-Ray doses (dose-surface product [DSP] in  $\mu\text{Gy}\cdot\text{m}^2$ ) delivered to the patients were collected for patients treated only for a C1 lesion (patients treated during the same session for another location were excluded).

### *Safety:*

Complications were systematically collected and graded using the CIRSE and SIR complication guidelines.<sup>9</sup> Briefly, this classification is a 6 scales grading system evaluating the severity of the complication; grade 4 being a complication causing a permanent mild sequelae, grade 5 being a complication causing a permanent severe sequelae and grade 6 corresponding to death.

All patient underwent AP and lateral projection plain X-Ray at the end of the procedure, and an unenhanced CT. On post-procedure imaging, lesion's filling with the PMMA bone cement was evaluated. Bone cement leakages were systematically recorded as well, and were divided into 1) anterior soft tissue leakage, 2) vascular leakage, 3) C0-C1 joint leakage and 4) C1-C2 joint leakage.

### *Clinical outcome:*

Clinical follow-up was evaluated 1 month after the C1 TOV through a follow-up consultation with the physician who performed the procedure. Pain relief was evaluated on the Numeric Rating Scale (NRS). Occurrence of a delayed complication (i.e.: infection, delayed hematoma, delayed neurological complication,) was systematically recorded as well. In case of persistent pain, pain worsening or occurrence of neurological symptoms, new imaging work-up was performed (contrast enhanced CT and/or MRI) to depict any recurrence/progression of the treated lesion. Late clinical follow-up, including NRS evaluation, was assessed by a phone interview.

#### *Systematic review of the literature:*

A systematic review of the literature focused on the safety and effectiveness on vertebroplasty for C1 lesions was performed according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines <sup>10</sup>. The different studies were analysed using combinations of terms in title, abstract, keywords and free text, until 1st September 2019. The selection was focused only on articles dealing with C1 vertebroplasty. The search was performed on MEDLINE via PubMed, Embase via Ovid and Cochrane central database via CENTRAL with advanced search builder. The following terms and synonyms were used: cervical, vertebroplasty, atlas and C1. Additionally, references from the publications obtained were checked to add relevant studies. Two investigators (\*\*\*) performed this systematic review of the literature on C1 vertebroplasty.

Animal studies, surgical series, non-relevant studies and non-English written series were then excluded (**Fig. 2**). Risk of bias was evaluated by both reviewers using the Newcastle–Ottawa Quality Assessment Form for Cohort and Case-control Studies. <sup>11</sup>

#### *Ethical statement:*

Our local institutional review board (IRB) approved the study protocol. The need for patients' informed consent for retrospective analyses of records and imaging data was waived by our IRB. This work adheres to the World Medical Association Declaration of Helsinki.

*Statistical analysis:*

Continuous variables were reported as means  $\pm$  standard deviations (SD). The normality of the distribution was checked using a Shapiro-Wilk test. Comparison between pre and post-treatment NRS was performed using a Student-t test. All tests were calculated using Stata software (Stata/IC 13.1 for Mac; StataCorp LP, College Station, TX, USA); p values less than 0.05 were considered statistically significant.



## Results

### *Patients' demographic and lesions' characteristics:*

From 2012 to 2019, 15 consecutive patients (9 males, 6 females; mean age:  $63 \pm 12.9$ , range: 38-84 y) underwent a transoral vertebroplasty for an osteolytic lesion of the lateral mass of C1 at a single Institution (*Patients' demographics and lesions' characteristics are summarised in Table 1*).

Most of the lesions (10/15 [67%]) were bone metastases from various cancers; 4 patients (27%) had a C1 lesion from a multiple myeloma; 1 patient (6%) had a biopsy proven aggressive hemangioma.

Seven lesions (46.7%) were located in the left lateral mass of C1; 8 lesions (53.3%) involved the right lateral mass of C1. In 3/15 cases (20%), cementoplasty of the ipsilateral occipital condyle was performed during the same procedure; using the same transoral route. In one case (6.7%) an additional vertebroplasty of the C2's dens was performed during the same procedure.

None of the patients had presurgical spine fixation.

Average cement volume injected was  $1.5 \pm 0.9$  ml. Average DSP was  $5234.6 \pm 4675.7$   $\mu\text{Gy.m}^2$  (range: 485-11968). Mean duration of the procedure was  $117.2 \text{ min} \pm 38.7$  min (range: 60-180).

### *Safety:*

No major complication was recorded. One (6.7%) minor complication (grade 1 in the CIRSE-SIR grading scale <sup>9</sup>) was recorded in a patient (Patient # 13) who experienced a retropharyngeal mild hematoma after the procedure, responsible for a transient dysphagia. The symptoms spontaneously resolved without any specific treatment.

Bone cement leakages were depicted on immediate post-procedure CT acquisition in 7/15 cases (47%). In 3/7 cases (43%), the cement leakage was located in the retropharyngeal space; in 4/7 cases (57%) in the C1-C2 joint. One patient (Patient # 11) had cement leakage in both the retropharyngeal space and the C1-C2 joint. None of the patients had cement leakage in the C0-C1 joint. One

**Table 1. Patients' demographics and lesions' characteristics**

Patient nb	Treated lesions	Side	Lesion type	Underlying disease	PreTx NRS	Post-Tx NRS	Cement leakage
1	C1	L	Osteolytic	Pancreatic Kc	9	NAv	0
2	C1	L	Osteolytic	Hemangioma	10	0	0
3	C1	L	Osteolytic	Multiple myeloma	4	3	0
4	C1	L	Osteolytic	Thyroid Kc	10	0	0
5	C1	L	Osteolytic	Lung Kc	5	NAv	Uvula
6	C1	L	Osteolytic	Multiple myeloma	4	0	0
7	C1 + occipital condyle	R	Osteolytic	Lung Kc	6	0	Anterior soft tissue
8	C1 + occipital condyle + axis dens	R	Osteolytic	Breast Kc	6	2	C1-C2 joint
9	C1	R	Osteolytic	Breast Kc	2	NAv	C1-C2 joint
10	C1 + occipital condyle	R	Osteolytic	Multiple myeloma	0	0	0
11	C1	R	Osteolytic	Lung Kc	0	0	C1-C2 joint and anterior soft tissue
12	C1	R	Osteolytic	Lung Kc	8	NAv	Anterior soft tissue
13	C1	R	Osteolytic	Multiple myeloma	9	0	0
14	C1	L	Osteolytic	Lung Kc	5	4	C1-C2 joint
15	C1	R	Osteolytic	Lung Kc	8	2	0

**Nb** indicates number, **F**: female, **M**: male, **L**: left, **R**: right, **Kc**: cancer, **PreTx**: pre-treatment, **Post-Tx**: post-treatment, **NRS**: Numeric rating Scale, **NAv**: not available



patient (Patient # 7) had a cement peak released during the removal of the bone needle, which was removed manually from its proximal aspect in the oral cavity. In another patient (Patient # 5), a drop of cement was released in the uvula during the removal of the bone needle, which was removed under fluoroscopic guidance using a supple biopsy forceps ([Fig. 1](#) and [Video 1](#)).

No delayed complication of any kind was reported. No infectious complication was recorded. No patient reported any dysphagia at follow-up.

#### *Pain relief/follow-up:*

Mean pretreatment NRS was  $5.7 \pm 3.3$ . At 1 month, 4 patients (27%) were lost to the follow-up. In the 11 remaining patients (73%), mean NRS at 1-month clinical follow-up was  $1.5 \pm 1$ . Mean NRS decrease between pretreatment and 1 month follow-up was  $4.6 \pm 3.9$  ( $p = 0.0002$ ). Late clinical follow-up (i.e. > 1 month) was available in 53% of the patients (8/15); 4/7 (57.1%) patients with no late clinical follow-up were deceased from their tumour disease and 3/7 (42.9%) were lost to the follow-up. Average time interval between treatment and last clinical follow-up was  $41.2 \pm 39.8$  months. Average NRS at last follow-up was  $1.1 \pm 1.46$  and was not significantly different from the one at 1 month ( $p = 0.86$ ).

Imaging follow-up was available in 10/15 patients (66.7%), with an average time interval of  $16 \pm 23.7$  months. One case of post-TOV C1 lesion local progression was depicted (Patient # 12). No further local treatment on the C1 lesion was performed due to general progression of the lung cancer, that eventually lead to death 2 months after the C1 TOV.

None of the patients required a surgical fixation in the aftermath of C1 TOV.

#### *Systematic review:*

The systematic review of the literature depicted 15 C1 vertebroplasty (28 in total, including the patients reported in the present study).<sup>3-6 12-17</sup> According to the Newcastle-Ottawa grading scale<sup>11</sup>, the quality of the articles was poor for all the 11 series/case reports included in the systematic review. Two C1 vertebroplasties were performed via a posterior route (13.3%); 4 via a lateral route (26.7%); 1 via an anterior route (7.7%) and 8 via a transoral approach (53.3%) (21 [75%] including the patients of this study) (**Table 2**).

The underlying diseases responsible for the C1 osteolytic lesions were available in 14 cases in our systematic review (27 cases including our study). Most of the treated lesions were bone metastases from various neoplasms (10/14 cases [71.4%]; 19/27 cases [70.4%] including this study).

C1 vertebroplasties, regardless the route chosen, were feasible in all cases. Procedures were performed under fluoroscopic guidance only in 2/15 cases (13.3%) (2/28 cases; 7.1%, including our study); under CT guidance only in 5/15 cases (33.3%) (5/28; 17.9%, including our study); under both CT and fluoroscopic guidance in 6/15 cases (40%) (14/28 cases; 50%, including our study). It is noteworthy that in 10/14 cases (all in our centre) combined CT-fluoroscopic guidance was performed in a hybrid angio-suite, combining a CT and a C-arm flat panel. Finally, imaging guidance was fluoroscopy associated with cone-beam CT in 1/15 cases (6.7%) (6/28 cases; 21.4%, including our series). Neither major nor minor complication was reported in the literature. Including the present series, only one minor complication was recorded (1/28; 3.6%) (transient retropharyngeal hematoma).

Cement leakages were observed in 4/15 cases (27%) in our systematic review of the literature (11/28 [39.3%] including this study). None of the cement leakage reported in the literature (and in our series as well) were responsible for any clinical symptoms. It is noteworthy that one case of cement migration along the course of the V3 segment of the VA has been reported, without any neurological symptoms.<sup>3</sup> No other such vascular cement leakage was reported in the literature. Protection of the VA to prevent cement leakage was reported in 3/15 in the literature (with 2 patients from our cohort previously reported<sup>5</sup>). None of the patients previously reported out of our cohort had such use of protection balloon. In one case<sup>6</sup>, to prevent the risk of cement leakage

into the VA, due to its vicinity with the treated lesion, occlusion of the V3 segment of the VA by coils was performed; the patient having a contralateral VA with a satisfactory calibre.

All the cases of vertebroplasty for C1 lesions were associated with pain relief. No case of delayed fracture of the treated lesion was recorded, according to our systematic review of the literature.



**Table 2. Systematic review of the literature on C1 lesion vertebroplasty/cementoplasty**

Authors	Year	Journal	Nb of cases	Lesion type	Route	Guidance	Clinical complication	Pain relief	Cement leakage	VA protection	Comment
Wetzel SG et al <sup>5</sup>	2002	Spine	1	Metastasis	Percutaneous; posterolateral	Fluoroscopy	No	Yes	Atlanto-occipital joint	Occlusion V3 segment / coils	-
Huegli RW et al <sup>11</sup>	2005	Cardiovasc Intervent Radiol	1	Metastasis	Percutaneous, lateral	CT and fluoroscopy	No	Yes	No	No	Tx of C4 during the same session
Anselmetti GC et al <sup>14</sup>	2009	J Vasc Interv Radiol	1	Metastasis	Percutaneous, lateral	CT	No	Yes	No	No	-
Masala S et al <sup>15</sup>	2011	Clin Orthop Relat Res	3	Metastases	Transoral	CT and fluoroscopy	No	Yes	NM	NM	-
Cianfoni A et al <sup>2</sup>	2012	Spine J	1	Metastases	Percutaneous; posterolateral	CT	No	Yes	Yes, along V3 segment VA	No	-
Guo WH et al <sup>12</sup>	2012	Pain Physician	2	Metastasis and hemangioma	Percutaneous, lateral	CT	No	Yes	Little extraosseous reflux leakage	No	-
Clarençon F et al <sup>4</sup>	2013	Spine	2	Metastasis and hemangioma	Transoral	CT and fluoroscopy (hybrid angio suite)	No	Yes	No	Protective balloon in V3 segment (50%)	-
Yang JS et al <sup>16</sup>	2015	Spine J	1	Metastasis	Percutaneous anterior	Fluoroscopy	No	Yes	No	No	-
Kavakebi P et al <sup>3</sup>	2017	Acta Neurochir	1	NM	Transoral	CT and fluoroscopy	No	NM	Minor, lateral soft tissue	No	-
Wright CH et al <sup>13</sup>	2017	J Neurosurg Spine	1	Lymphangiomatosis	Transoral	CT	No	Yes	No	No	Tx clivus and C2 during same session
Bundy JJ et al <sup>18</sup>	2018	J Vasc Interv Radiol	1	Multiple myeloma	Transoral	Fluoroscopy and cone-beam CT	No	Yes	No	No	Associated RFA



Present study *	15	Metastases, multiple myeloma and hemangioma	Transoral	CT and fluoroscopy or bi-plane fluoroscopy cone-beam CT	Transient dysphagia in 1 case	Yes	Yes, in 47% of the cases	Protective balloon in V3 segment (73.3%)	-
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**NM** indicates non-mentioned, **CT**: computed tomography, **V3**: third segment of the vertebral artery, according to Fischer <sup>8</sup>, **VA**: vertebral artery, **Tx**: treatment, **RFA**: radiofrequency ablation. \*: 2 out of the 15 cases already reported by Clarençon F et al (Spine. 2013). <sup>5</sup>



## Discussion

This series involving 15 consecutive patients showed the feasibility of TOV; indeed, no procedure failure was recorded. It also suggests the safety of TOV since no major and only one minor transient procedure-related complications were recorded.

Only scant data are available on the safety and effectiveness of TOV for C1 lesions. Compared to open surgery (mainly tumour removal associated with occipitocervical fusion), which remains the criterion standard for the treatment of C1 osteolytic lesions<sup>18</sup>, the potential of percutaneous treatments is that they are less invasive, reducing the risk of major blood loss (especially in hypervascularized metastases or aggressive hemangiomas) and that they have a lower infectious risk. Different routes have been described for the treatment of C1's lateral mass lesions. The first case of C1 vertebroplasty has been published in 2002 by Wetzel SG et al.<sup>6</sup> The authors performed a vertebroplasty for a C1 osteolytic metastatic lesion from a parotid adenocarcinoma. In this case report, postero-anterior route was chosen, under fluoroscopy guidance, with satisfactory results in terms of pain relief and bone stabilization. Afterwards, lateral<sup>12 19</sup>, then anterior<sup>17</sup> approaches have been proposed for cementoplasties of C1 lateral masses, with good results. The first TOVs for C1 lesions described in the literature were 3 cases, included in a series of 62 cervical VPs, reported by Masala S et al<sup>16</sup> in 2011. No technical issue was reported in these first 3 cases; satisfactory pain relief was obtained at follow-up in all cases.

In total, including the 15 cases reported in our study, 28 cementoplasties of C1 have been reported so far<sup>3-6 12-14 16 17 19 20</sup>, including 21 transoral vertebroplasties. No complication, either infectious or neurological has been reported with this technique.

Transoral route appears to be a safe approach since it decreases the risk of VA wound during the positioning of the bone needles. Indeed, the V3 segment of the VA has a course laterally, then posteriorly to the lateral mass of C1. In our opinion, lateral and postero-anterior approaches, even with cautious CT guidance, expose to a too high risk of VA wound during the bone needle positioning due to the course of the VA laterally, then posterior to the lateral mass of C1. We also believe that the anterior percutaneous approach is less convenient, since it requires a very accentuated

ascending course, which may not be feasible in patients with a short neck or with prominent clavicles. The only risk of the transoral approach regarding vascular wounds is the possibility of a retropharyngeal course of the ICA. <sup>21</sup> Such variation of the cervical ICA course should thus be carefully studied on the pretreatment imaging work-up. We reported in our case series only one minor complication (6.7%), which consisted in a mild retropharyngeal hematoma that spontaneously resolved without any sequelae.

We acknowledge a potential risk of bone infection with the TOV, since bone needle is inserted through the oral cavity, which is known to contain a lot of bacteria. However, with oral cavity disinfection and by administering an IV antibiotic with a broad spectrum, we think that this risk remains very low. It is noteworthy that, even reporting a disinfection of the oral cavity in all cases, no injection of antibiotics was reported in the previously published cases. IV antibiotics injection during vertebroplasty is part of our regular protocol and we think it may help in reducing infectious complications that, even very rare <sup>22</sup>, may be observed after PV.

Cement leakages were observed in 47% of the cases in our study. Most of them (57%) were located in the C1-C2 joint. However, none of them were responsible for any clinical symptoms.

In our case series, we used a protection balloon in 73.3% of the cases. The use of protection balloon was left at the discretion of the operator. We used such protection balloon for two purposes. First to see the course of the vertebral artery under fluoroscopy due to the radiopaque characteristic of the microguide wire on which the balloon was navigated. Second, the balloon was inflated temporarily during the PMMA injection through the bone needle to prevent the risk of retrograde PMMA leakage from the lesion to the vertebral artery and thus to avoid the risk of cement embolism in the vertebrobasilar system.

Interestingly, one case of radiofrequency ablation (RFA) associated with cementoplasty has been reported, with satisfactory results in terms of safety and effectiveness. <sup>20</sup> Such technique may be valuable to reduce the risk of local recurrence. However, it should be kept in mind the RFA may be challenging in such location, and is associated with a significant risk of nervous thermal lesions (nerve

root, spinal cord).<sup>23</sup> Additionally, even if the imaging follow-up was not available in all patients (available in 10/15 patients; 66.7%) we depicted only one local progression (1/10; 10%) in the patients treated in our study.

Clinical effectiveness (bone stabilization and pain relief) was observed in all cases in our series. In the literature, pain relief was observed in all cases as well. No secondary fracture of the treated lesion was recorded in the literature, as observed in our series. However, it should be mentioned that a publication bias, inherent to case reports and short case series, may be responsible for an under-reporting of major complications and poor outcomes.

#### *Limitations of the study*

The main limitation of our case series is its monocentric and retrospective nature. Additionally, the number of patients included in this work was relatively low (15 patients). However, it should be mentioned that C1 lateral mass is not a frequent location of bone metastases or multiple myeloma. Moreover, all the cases were performed by very experienced interventional radiologists, in modern angio-suite facilities (hybrid angio-suite or bi-plane angio-suite). Thus, these results may not be generalizable. Finally, no comparison with a criterion standard (open surgery) was performed in this study.

## **Conclusion**

Transoral vertebroplasty for the treatment of osteolytic lesions of the lateral mass of the atlas seems feasible, safe and effective in terms of pain relief and bone stabilization. Larger series are warranted to confirm these preliminary results on 15 patients.

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## Figure Captions

### Figure 1.

Patient with left C1's lateral mass metastatic osteolytic lesion from a lung cancer. **A.** and **B.** CT scan; axial slice (**A**) and coronal reconstruction (**B**) in bone windowing, showing the osteolytic lesion of the left lateral mass of C1 (asterisk). **C.** Periprocedural picture showing the positioning of the bone needle via a transoral route after exposing the posterior wall of the pharynx by means of a Boyle-Davis mouth gag. **D.** and **E.** Plain X-Rays in anteroposterior (AP) (**D**) and lateral (**E**) projections showing the satisfactory positioning of the bone needle (white arrow). Note the course of the protection balloon in the V3 segment of the left vertebral artery (VA) (double black arrow). **F.** Control unenhanced CT-scan in bone windowing, after the positioning of the bone needle. Satisfactory positioning of the bone needle's tip in the metastatic lesion is confirmed (white arrow).

After the injection of the polymethyl metacrylate (PMMA) bone cement in the lesion, during the removal of the bone needle, a cement fragment released in the uvula was depicted. It was decided to remove it with a supple biopsy forceps. **G.** Lateral fluoroscopic view during the removal of the bone cement fragment located in the uvula (white arrow) with the biopsy forceps (double black arrow). **H** and **I.** Plain X-Rays after the cement fragment removal (**H**, AP and **I**, lateral projections). Satisfactory filling of the lesion is demonstrated, without residual cement leakage. **J.** Photograph of the removed cement fragment, side by side with a 10 cents coin.

**Video 1.** Live fluoroscopy in AP projection during the removal of the bone cement fragment released in the uvula.

### Figure 2.

PRISMA flow chart.

Builder search:

*For PubMed, the search was organized as follows:*

```
("vertebroplasty"[MeSH Terms] OR "vertebroplasty"[All Fields] OR "kyphoplasty"[All Fields]) AND ("neck"[MeSH Terms] OR "neck"[All Fields] OR "cervical"[All Fields]) OR (("vertebroplasty"[MeSH Terms] OR "vertebroplasty"[All Fields]) AND "atlas"[All Fields]) OR (("vertebroplasty"[MeSH Terms] OR "vertebroplasty"[All Fields]) AND "C1"[All Fields]) AND "1950/01/01"[PDAT] : "2019/09/01"[PDAT]
```

*For the Cochrane library, the search was organized as follows:*

```
'vertebroplasty' AND 'cervical' OR 'cementoplasty'
```

