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CLINICAL INVESTIGATION NON-VASCULAR INTERVENTIONS

Preventive Vertebroplasty for Long-Term Consolidation of Vertebral Metastases

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Abstract

Introduction To evaluate the long-term consolidation of vertebral metastases (VM) after preventive vertebroplasty (PV) and to report risk factors of pathological fracture despite PV.

Materials and Methods Files of 100 consecutives cancer patients referred for PV of VM were retrospectively analyzed. We enumerated 215 VM at the time of the PV procedure (T0): 138 VM were considered at risk of pathological fracture and had PV (treated-VM), and 77 VM were not cemented. We compared the VM characteristics using the spine instability neoplastic score (SINS) at T0 and the rate of pathologic fracture between treated-VM and untreated-VM using Kaplan–Meier method. We analyzed risk factors of pathological fracture despite PV using treated-VM characteristics and quality of cement injection criteria.

Results Despite a lower SINS value at T0 ($p < 0.001$), the rate of pathological fracture was significantly higher among untreated-VM compared to the treated-VM, (log-rank, $p < 0.001$). Major risk factors of fracture among treated-VM were: SINS value ≥ 8 ($p < 0.012$), mechanical pain ($p = 0.001$), osteolytic lesion ($p = 0.033$), metastatic vertebral body involvement $> 50\%$ with no collapse ($p < 0.001$) and unilateral posterior involvement by the vertebral metastasis ($p = 0.024$), Saliou score < 9 ($p = 0.008$), vertebral metastasis filling with cement $< 50\%$ ($p = 0.007$) and the absence of cement's contact with vertebral endplates ($p = 0.014$).

Conclusion PV is long-term effective for consolidation of VM and must be discussed at the early diagnosed. Quality of cement injection matters, suggesting that techniques that improve the quantity and the quality of cement diffusion into the VM must be developed.

Keywords Vertebroplasty · Preventive · Metastasis · Consolidation · Stabilization · Fracture

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Introduction

The spine is the most common site of bone metastases. These metastases can result in pathological fractures that are associated with a significant deterioration of the quality of life and even with high risk of death [1].

Vertebroplasty is a minimally invasive technique that consists in percutaneous injection of cement, polymethylmethacrylate, into the vertebral body. Palliation provided by vertebroplasty is well established in the literature. It significantly reduces pain after procedure [2], and this analgesic effect persists for several months [3, 4]. The main mechanism is related to the stabilization of the fracture thanks to the cement which acts as glue and fixes the bone fragments.

In patients with vertebral metastases (VM), another objective of vertebroplasty is the restoration of vertebral body strength in order to prevent pathological fractures, pain and neurological complication. Many ex vivo studies have demonstrated the biomechanical effects of bone metastasis on the spine [5] and the efficiency of vertebroplasty to restore mechanical behavior of vertebrae [6]. However, clinical interest of preventive vertebroplasty (PV) remains to be demonstrated, especially on long-term follow-up.

The aim of this study was to evaluate the long-term consolidation of VM after PV and to report risk factors of pathological fracture despite PV.

Materials and Methods

This single-center study retrospectively reviews records of all patients treated with vertebroplasty between January 2005 and January 2016 in our interventional radiology department. Pre-specified inclusion criteria were patients treated with vertebroplasty in order to prevent pathological fracture and with a minimal follow-up of 12 months after the procedure. Exclusion criteria were vertebroplasties performed for benign tumors, osteoporosis and or for palliation of pathological fractures that already demonstrated a vertebral body collapse over 50%.

All patient files were discussed at tumor board. According to the multidisciplinary tumor board recommendation, PV was recommended for VM considered at risk of fracture (treated-VM) and no treatment was recommended for VM not considered at risk (untreated-VM).

Techniques

Interventional radiologists performed all PV during a short hospital stay. PV was performed either under conscious sedation or general anesthesia according to the performance status, the number of VM treated and the association with thermal ablation during the same procedure. Cone beam CT or CT scan guidance was used for insertion of 11G or 13G needle into the vertebral body. For lumbar vertebrae, a pedicular approach was used. For thoracic vertebrae, a trans-costovertebral or lateral approach was used. For cervical vertebrae, an anterolateral or trans-oral approach (for C2) was used.

According to the oncologic status and to the tumor board recommendation, local destruction of the VM was performed in association with PV, either using radiotherapy (before or after vertebroplasty) or using thermal ablation (cryotherapy or radiofrequency ablation, during the same procedure, immediately before the vertebroplasty).

Outcomes Analysis

The primary objective was to compare the rate of pathological fracture between the treated-VM and the untreated-VM using the Kaplan–Meier method. Fractures were defined on CT scan by decrease of vertebral height $> 20\%$ or change of vertebral kyphosis angle.

The secondary objective was to report risk factors of pathological fracture despite PV. For these purposes, we enumerated the number of VM and their characteristics at the time of the PV (T0) using 3D images acquired at the beginning of the procedure (CT scan or 3D cone beam CT). We evaluated the quality of the cement injection after PV using 3D images acquired at the end of the procedure and using the first post-op CT scan. We also reported the rate of pathological fracture at one year among all VM (treated-VM and untreated-VM) present at T0 and the progression of the bone metastatic disease (defined by appearance of new vertebral lesion or an obvious increase in metastasis size) at 1 year using all cross-sectional spine imaging performed from T0 and the last follow-up.

For patients characteristics, age, sex and primary cancer were collected. For VM characteristics, we used the spine instability neoplastic score (SINS) [7] (Fig. 1) and its different components: level, mechanical pain (defined by increased pain during physical activity), bone lesion quality, vertebral body collapse, posterolateral involvement of spinal elements). For the quality of cement injection, we used the Saliou score (Fig. 2) [8], the rate of VM filling with cement (0%; $< 50\%$ and $> 50\%$) and the presence of a discal leakage and the contact of cement with both vertebral endplates. We also reported the sagittal spinopelvic and regional alignment by measuring the vertebral body collapse at the treated level, the vertebral kyphosis, the regional kyphosis, the lumbar lordosis or thoracic kyphosis on the final 3D images acquired at the end of the procedure. For patients who experienced a pathological fracture

during the follow-up, we repeat these measures on the last CT scan available (Fig. 3).

We report the rate of fracture of non-pathological vertebrae, adjacent to the treated-VM.

Finally, we reported the number of adverse events (AE) related to vertebroplasty using the CTCAE V5.0 (Common Terminology Criteria for Adverse Events). A grade 1 is an asymptomatic or mild symptomatic AE for which an intervention is not indicated. A grade 2 requires minimal, local or noninvasive intervention. A grade 3 is a severe or medically significant but not immediately life-threatening AE, requires hospitalization, prolongation of existing hospitalization or limiting self-care activity of daily life. Grade 4 has life-threatening consequences and needs urgent intervention. A grade 5 is the death.

Fig. 2 Saliou score

Statistic Analysis

Statistical analysis was performed using SPSS 23.0 software package for Windows. Continuous variables between fractured or non-fractured groups were studied using a logistic regression. For nominal variables, the Chi-squared test ($\chi 2$) was used.

Fig. 1 Spinal instability neoplastic score (SINS)

Component		Score
• Location		-
	Junctional (O-C2; C7-T2; T11-L1; L5-S1)	3
	Mobile spine (C3-C6; L2-L4)	2
	Semi-rigid (T3-T10)	1
	Rigid (S2-S5)	0
• Mechanical Pain		-
	Yes	3
	Not mechanical pain	2
	Pain free lesion	1
• Spinal alignment		-
	Subluxation / translation	4
	De Novo deformity (kyphosis / lordosis)	2
	Normal	0
• Bone lesion		-
	Lytic	2
	Mixed	1
	Blastic	0
• Vertebral body collapse		-
	>50%	3
	<50%	2
	No collapse with > 50% involved	1
	None of the above	0
• Posterolateral involvement		-
	Bilateral	3
	Unilateral	1
	None of the above	0

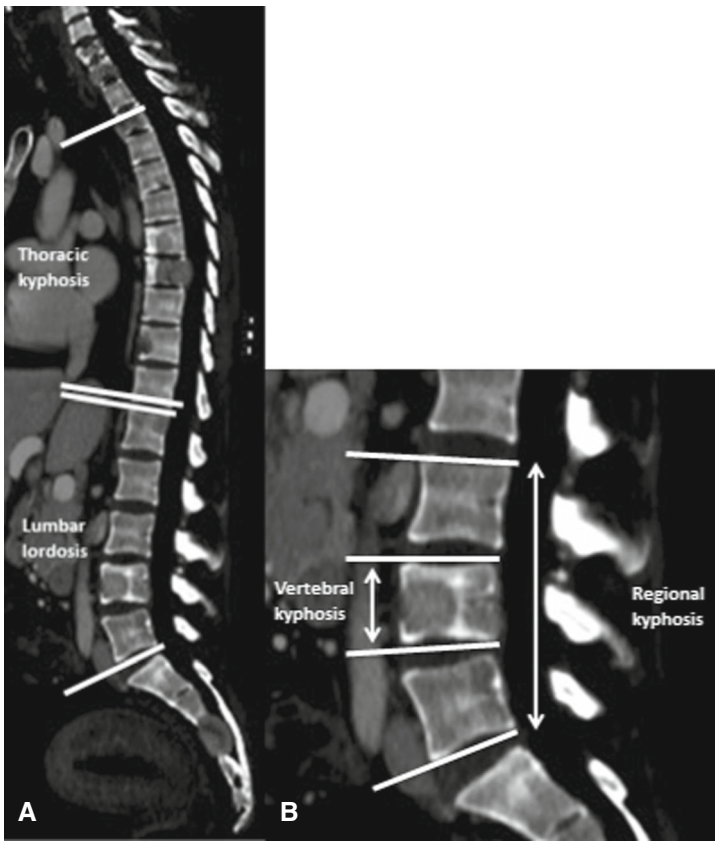


Fig. 3 Sagittal vertebral static measures

A Global sagittal vertebral static measures

Thoracic kyphosis : angle formed by the upper endplate of T4 and the lower endplate of T12

Lumbar lordosis : angle formed by the upper endplate of L1 and the lower endplate of L5

B Regional sagittal vertebral measures

Regional kyphosis : angle formed by the upper endplate of the overhead vertebra and the lower endplate of the bottom vertebra

Vertebral kyphosis : angle formed by the upper and the lower endplate of the concerned vertebra

The cumulative incidence of fracture of treated level was estimated from the date of vertebroplasty to the date of fracture. We estimated probabilities of fracture with the Kaplan–Meier method. Patients without fracture were censored on the dates of last follow-up if death had not occurred. When the p value was less than 0.05, the analysis was evaluated to be significant. All clinical and radiographical data were collected by a single observer.

Results

Between January 2005 and January 2016, 573 consecutive patients had vertebroplasty in our department and were screened for eligibility (Fig. 4). One hundred patients met the inclusion criteria and were included for analysis. Among the excluded patients, 299 had a follow-up under 12 months, 72 concern treatment of vertebral metastases already fractured, 92 had vertebroplasty for osteoporotic fractures, and 10 were treated for benign lesions. Baseline parameters of the population studied are summarized in Table 1.

Among the 100 patients included, we enumerated a total of 215 VM at T0. One hundred and thirty-eight VM were considered at risk of pathological fracture at tumor board and therefore consolidated with PV (treated-VM). Seventy-seven VM were not considered at risk, and no preventive consolidation was performed (untreated-VM). Baseline parameters of treated- and untreated-VM are summarized in Table 2. At T0, treated-VM had a SINS value significantly higher compared to the untreated-VM (5.8 ± 2.0 versus 4.5 ± 1.0, $p < 0.001$). There was no other difference between treated- or untreated-VM, namely for levels (junctional spine, mobile spine, semirigid or rigid spine) or bone lesion quality (osteolytic, mixed or blastic). During the follow-up, frequency of radiation therapy at the level concerned was not significant between the two groups. The

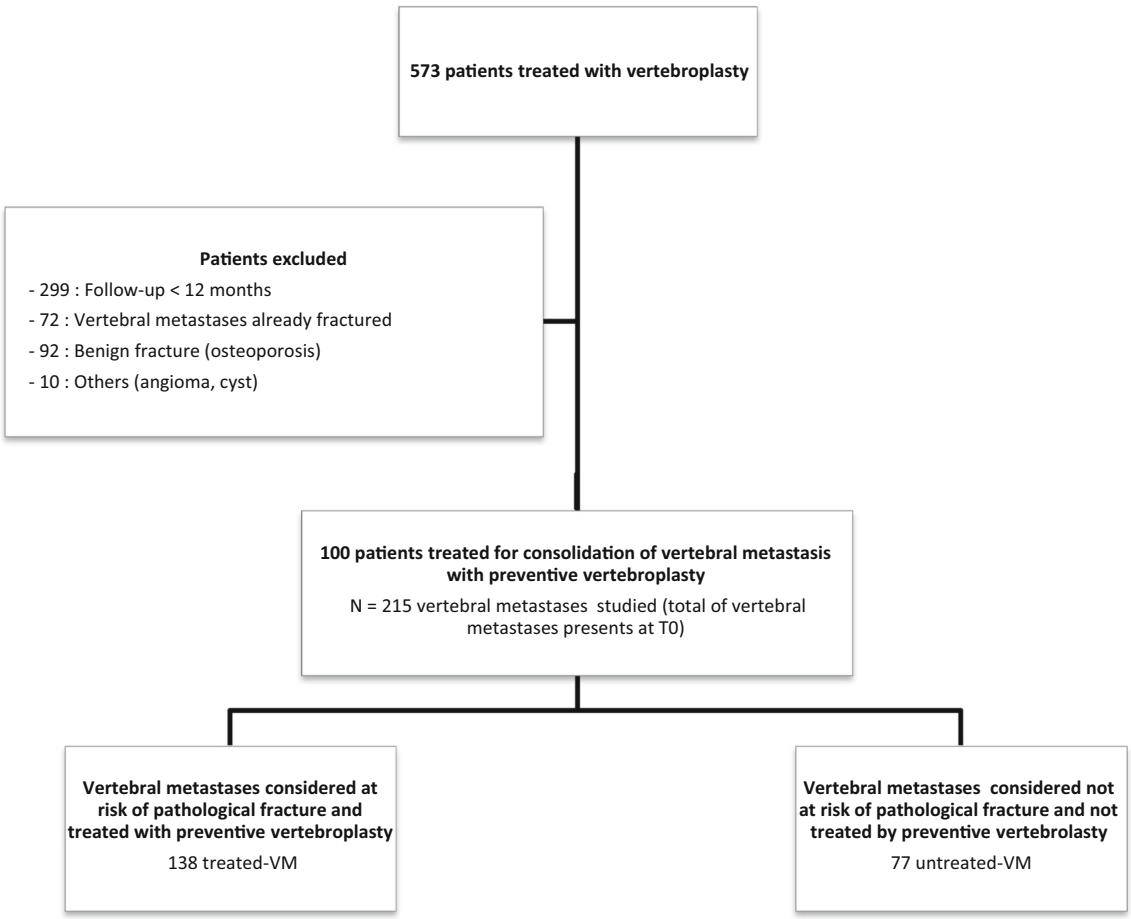


Fig. 4 Flow chart

Table 1 Population treated parameters

100 patients treated for consolidation of vertebral metastasis (VM) with preventive vertebroplasty (PV)	
Age (years)	53.7 (13.7)
Sex	
Female	61%
Male	39%
Primitive cancer	
Breast	35%
Kidney	10%
Thyroid	8%
Lung	7%
Other	40%
215 VM at time of PV (T0)	
Considered at risk fracture	
Yes	138 (64.2%) (treated-VM)
No	77 (35.8%) (untreated-VM)
Follow-up after T0 (years)	3.1 (2.1)

Data are mean (SD) or number (%)

mean number of treated-VM per patient was 1.4 (from 1 to 7). Seventy-one patients (71%) had only a single PV.

No serious complications were observed during the procedures (grades III–V, CTCAE). Three patients presented postoperative radiculalgia secondary to a cement leakage requiring local infiltration of corticosteroids (grade II, CTCAE).

After a mean follow-up of 3.1 ± 2.1 years, the rate of pathological fractures was 11.6% among all the VM diagnosed at T0 (25 pathological fractures among 215 VM). These fractures occurred after a mean delay of 705 days ± 690 days after T0, and 3 of them resulted in neurological complications requiring surgery and/or radiotherapy.

Despite a lower SINS value at T0, the rate of pathological fracture was significantly higher among the untreated-VM, 1 year after T0 (13.0% vs. 2.2%, $p = 0.002$), 2 years after T0 (17.9% vs. 3.6%, $p = 0.001$) and at the end of the follow-up (20.8% vs. 6.5%, $p = 0.003$). Six months after T0, the rate of pathological fracture was higher in the untreated-VM but not significantly (3.9% vs. 0.7%, $p = 0.132$). Figure 5 is the Kaplan–

Table 2 Vertebral metastases (VM) parameters at time (T0) of preventive vertebroplasty (PV)

	Treated-VM	Untreated-VM	*p* value
n	138	77	
SINS	5.8 (2.0)	4.5 (1.0)	< 0.001
Level			
Junctional (C1-C2, C7-T2, T11-L1, L5-S1)	48 (34.8%)	32 (41.5%)	NS (0.377)
Mobile spine (C3-C6, L2-L4)	41 (29. 7%)	22 (28.6%)	NS (0.877)
Semirigid (T3-T10)	49 (35.5%)	23 (29.9%)	NS (0.652)
Rigid (S2-S5)	0	0	NS (1)
Bone lesion quality			
Osteolytic	71 (51.4%)	45 (58.4%)	NS (0.399)
Mixed	64 (46.4%)	30 (39.0%)	NS (0.364)
Blastic	3 (2.2%)	2 (2.6%)	NS (1.000)
Spinal alignment			
Subluxation/translation	0	0	NS (1)
De Novo deformity (Lordosis/Kyphosis)	0	0	NS(1)
Normal	138 (100.0%)	77 (100.0%)	NS (1)
Pain			
Mechanical	37 (26.8%)	0	< 0.001
Not mechanical	61 (44.2%)	0	< 0.001
Pain free lesion	40 (29.0%)	77 (100.0%)	< 0.001
Vertebral body involvement			
> 50% collapse	0	0	NS (1)
< 50% collapse	0	0	NS (1)
No collapse with > 50% body involved	50 (36.2%)	0	< 0.001
None of the above	88 (63.8%)	77 (100.0%)	< 0.001
Posterolateral involvement			
Bilateral	3 (2.2%)	0	< 0.001
Unilateral	31 (22.5%)	0	< 0.001
None of the above	104 (75.3%)	77 (100.0%)	< 0.001
Local destruction			
Radiotherapy	52 (37.7%)	20 (26.0%)	NS (0.111)
Thermal ablation	31 (22.5%)	0	< 0.001
Pathological fracture rates after T0			
At 6 months	1 (0.7%)	3 (3.9%)	NS (0.132)
At 1 years	3 (2.2%)	10 (13.0%)	0.002
At 2 years	5 (3.6%)	13 (17.9%)	0.001
At the end of follow-up (3.1 ± 1.1)	9 (6.5%)	16 (20.8%)	0.003

Meier curve reporting the fracture-free survival between the two groups ($p < 0.001$).

The risk factors of pathological fracture despite PV are reported in Tables 3 and 4. A SINS value ≥ 8 (OR = 6.3, $p < 0.012$), a mechanical pain (OR = 11.295, $p = 0.001$), an osteolytic lesion (OR = 8.280, $p = 0.033$), a vertebral body involvement > 50% with no collapse (OR = 6.898, $p = 0.011$) and a unilateral posterior involvement by the vertebral metastasis (OR = 5.067, $p = 0.024$) were characteristics of vertebral metastases associated with a significant increased risk of pathological fracture despite PV. A Saliou score < 9 (OR = 8.334, $p = 0.008$), a vertebral metastasis filling with cement < 50% (OR = 7.396 $p = 0.007$) and the absence of cement's contact with vertebral endplates (OR = 4.876, $p = 0.014$) were characteristics of cement injection quality associated with a significant increased risk of pathological fracture despite PV.

Pathological fracture rates according to the SINS and the Saliou score relative to the untreated vertebral metastases are reported in Fig. 6. The risk of pathological fracture for VM with SINS ≥ 8 was not significantly different between treated-VM and untreated-VM ($p = 0.426$). It was significantly lower for VM with SINS < 8 among the treated-VM

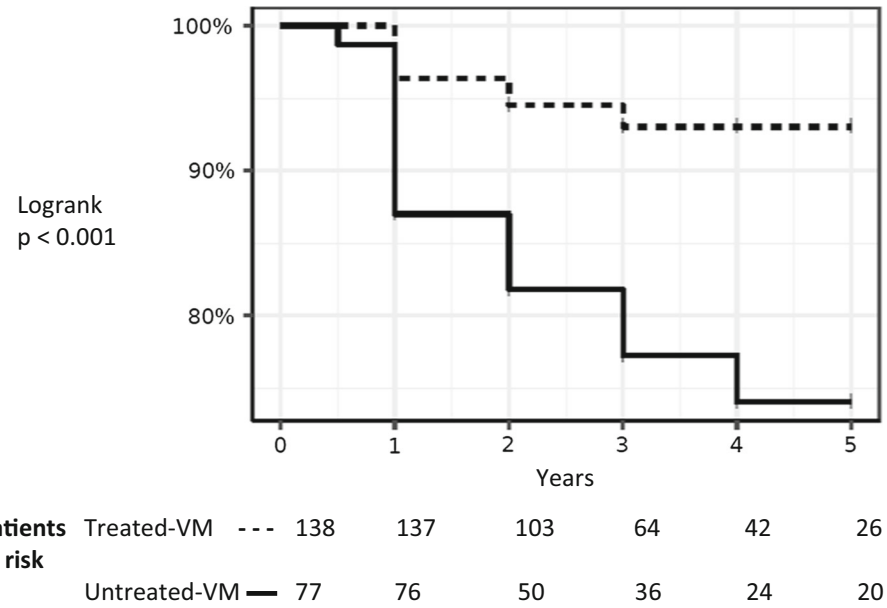


Fig. 5 Fracture-free survival Kaplan–Meier curve

compared to untreated-VM (3.6% vs. 20.8%, $p < 0.001$). The risk of pathological fracture for treated-VM with a Saliou score < 9 was not significantly different with untreated-VM ($p = 0.886$). It was significantly lower for VM with a Saliou score ≥ 9 (3.1% vs. 20.8%, $p < 0.001$).

One year after the PV, rate of pathological fracture for treated-VM with a SINS < 8 was 0.0%, and this rate was 7.7% for treated-VM with SINS ≥ 8 (33.3% if Saliou score was < 9 and 4.3% if ≥ 9).

We did not find any statistical risk of pathological fracture despite PV associated with thermal ablation performed during the same procedure nor for radiotherapy performed at the same level (Table 4).

Progression of the bone metastatic disease at 1 year was not associated with a significant risk of fracture despite PV.

Sagittal alignment of spine before intervention was not associated with statistical risk of fracture despite PV.

For patients suffering from pathological fracture despite PV, we noticed variations of spinal deformity between the final 3D images acquired at the end of the procedure and the last CT scan. The mean regional traumatic angulation was $6.8 \pm 7.1°$, the mean difference of thoracic kyphosis was $13.0 \pm 18.8°$, and the mean difference of lumbar lordosis was $10.6 \pm 8.1°$) (Fig. 7).

We observed only 4 fractures (1.73%) of non-metastatic adjacent vertebral body to treated-VM.

Discussion

Survival of metastatic patients increased over the past years but is very heterogeneous according to the primary tumor. The median overall survival for bone metastatic disease in patients with prostate cancer is 24 months [9], whereas this median survival is 5 months in lung cancer [10]. The preventive consolidation of bone metastases appears as a prime challenge with an objective to decrease the occurrence of pathological fractures and resulting pain.

Several radiological and clinical classifications have been used to predict pathological fractures. In this study, we have chosen the SINS score. This score is a highly reliable, reproducible and valid tool to classify spinal metastases in two groups: stable or instable [11], and could help operator to select patients for preventive consolidation in the absence of any other guidelines.

The rate of pathological fracture was lower in the treated-VM at 6 months after the procedure, but not significantly (0.7% vs. 3.9%, $p = 0.132$). This can be explained because the SINS was higher among the treated-VM compared to the untreated-VM (5.8 vs. 4.5, $p = 0.008$) at T0, and this result was consistent with the recommendation of our tumor board to consolidate VM considered at risk of fracture. However, the rate of fracture was significantly lower among the treated-VM after 1 year ($p = 0.002$) or 2 years ($p = 0.001$) after the vertebroplasty, and at the end of the follow-up ($p = 0.003$).

To our knowledge, these results are unpublished in the literature. Many studies have focused on analgesic effects of vertebroplasty for spinal metastases, but no study has been conducted on long-term follow-up of stabilized vertebrae and secondary fracture rate. In addition, most of the studies focus on the treatment of fractured metastases and not on their preventive stabilization.

According to the literature, a SINS ≥ 8 requires surgical stabilization, especially before a palliative radiotherapy treatment [12]. In our study, we demonstrated that the risk

Table 3 Risk factors of pathological fracture despite preventive vertebroplasty (PV) (part 1)

	No pathological fracture	Pathological fracture	*p* value
138 treated vertebral metastases (VM)	129 (93.5)	9 (6.5)	
Age (years)	53.6 (13.8)	55.1 (11.9)	NS (0.740)
SINS	5.7 (2.0)	7.6 (1.2)	0.007
Level			
Junctional (C1-C2, C7-T2, T11-L1, L5-S1)	47 (36.4%)	1 (11.1%)	NS (0.160)
Mobile spine (C3-C6, L2-L4)	36 (27.9%)	4 (44.4%)	NS (0.283)
Semirigid (T3-T10)	46 (35.7%)	4 (44.4%)	NS (0.723)
Rigid (S2-S5)	0	0	NS (1)
Pain			
Mechanical	30 (23.3%)	7 (77.8%)	0.001
Not mechanical	59 (45.7%)	2 (22.2%)	NS (0.298)
Pain free lesion	40 (31.0%)	0	NS (0.058)
Bone lesion quality			
Lytic	61 (47.3%)	8 (88.9%)	0.033
Mixed	62 (48.1%)	1 (11.1%)	0.039
Blastic	6 (4.6%)	0	NS (1)
Spinal alignment			
Subluxation/Translation	0	0	NS (1)
De Novo deformity (lordosis/kyphosis)	0	0	NS (1)
Normal	129 (100%)	9 (100%)	NS (1)
Vertebral body involvement			
No collapse with $> 50\%$ body involved	43 (33.3%)	7 (77.8%)	0.011
No collapse with $< 50\%$ body involved	86 (66.7%)	2 (22.2%)	0.011
Posterior involvement			
Bilateral	3 (2.3%)	0	NS (1)
Unilateral	26 (20.2%)	5 (55.6%)	0.027
None of the above	100 (77.5%)	4 (44.4%)	0.041

Data are mean (SD) or number (%)

of pathological fracture for treated-VM with SINS ≥ 8 is not significantly different with an untreated-VM, suggesting that surgical consolidation remains the gold standard for these VM with high risk of pathological fracture. However, the risk of pathological fracture was significantly lower for VM with SINS < 8 among the treated-VM compared to untreated-VM, suggesting that vertebroplasty is effective to restore the vertebral strength and that PV should be discussed at the early diagnosed of VM, before the SINS is ≥ 8. Among the SINS component, the worst prognostic factors are the mechanical pain before procedure, the osteolytic characteristic of the metastases and a vertebral body involvement over 50%. Surprisingly, level of vertebroplasty does not affect the success rate in our study. However, some authors have reported that junctional spine (T11-L1, L5-S1) [13] is more risky because of the biomechanical stresses at these levels.

On the other hand, the quality of cement injection is another key point to decrease the risk of pathological fracture despite PV. Based on our results, we enumerate criteria for effective consolidation with vertebroplasty: a Saliou score ≥ 9, a rate of vertebral metastasis filling with cement over 50% and cement diffusion in contact with both upper and lower vertebral endplates.

In our study, no pathological fracture was observed in treated-VM with a Saliou score over 14. On the other side, we found no statistical difference between the rate of pathological fracture among the treated-VM and the untreated-VM when the Saliou score after PV was < 8. We can hypothesize that bipedicular approach during PV or techniques such as kyphoplasty or stentoplasty could be of interest for stronger preventive consolidation by increasing the quantity of cement injected and improving the diffusion of cement inside the vertebral body.

Table 4 Risk factors of pathological fracture despite preventive vertebroplasty (PV) (part 2)

	No pathological fracture	Pathological fracture	*p* value
Sagittal alignment before intervention (degree)			
Vertebral kyphosis	5.4 (4.6)	4.6 (4.0)	NS (0.565)
Regional kyphosis	15.6 (16.8)	16.8 (12.2)	NS (0.771)
Lumbar lordosis	38.5 (11.5)	42.8 (12.0)	NS (0.488)
Thoracic kyphosis	39.8 (15.0)	37.8 (13.3)	NS (0.818)
Local destruction of the VM			
Thermal ablation before	28 (21.7%)	3 (33.3%)	NS (0.419)
Radiotherapy before	22 (17.1%)	1 (11.1%)	NS (0.620)
Radiotherapy after	27 (20.9%)	4 (44.4%)	NS (0.114)
Progression of VM at 1 year (RECIST)	71 (55.0%)	8 (88.9%)	NS (0.078)
Quality of the cement injection			
Saliou score	13.1 (3.3)	9.3 (2.7)	0.001
VM filling with cement			
> 50%	90 (69.8%)	2 (22.2%)	0.007
< 50%	39 (30.2%)	7 (77.8%)	0.007
Endplates contact of cement	103 (79.8%)	4 (44.4%)	0.014

Data are mean (SD) or number (%)

Kyphoplasty consists in the injection of cement into cavity created by balloon dilatation. This technique appears as a tool for optimal filling of the metastatic vertebra, reducing the risk of fracture or cement leakage [14, 15]. It could be used for VM with a high SINS or a predictable low Saliou filling score. Nevertheless, few studies have been published about and balloon dilatation inside VM remains questionable in terms of vascular cells embolism [16]. Stentoplasty refers to the insertion of vertebral implants in the vertebral body associated with cement injection. This technique has been developed for the management of osteoporotic fractures with the goal of prolong restoration of the vertebral height [17, 18]. Their use on VM has not been studied for the moment and significantly increases the price of the procedure.

Interestingly, thermal ablation (cryotherapy and radiofrequency) or radiotherapy is not associated with an increased risk of fracture. This result may be explained by the fact that PV counterbalances the bone loss secondary to local treatments of VM, usually considered as a risk of secondary fracture.

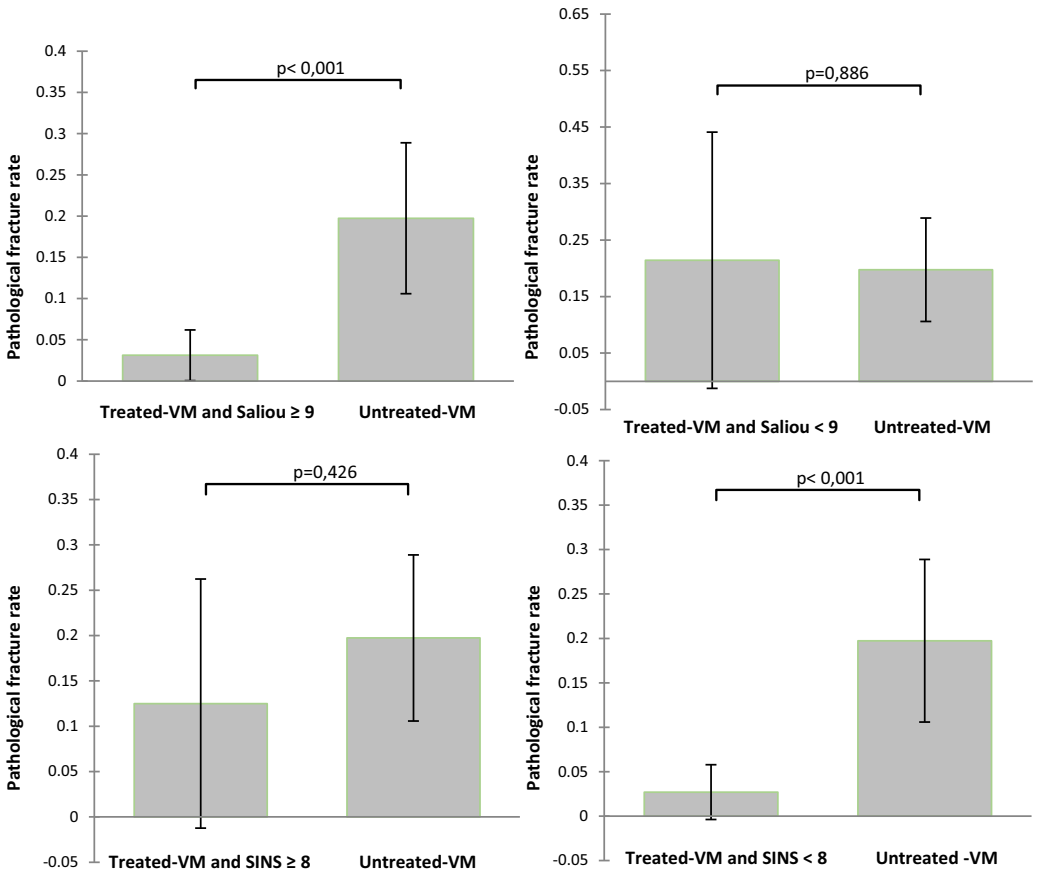
We demonstrated that the sagittal vertebral static and the regional spinal static angulations were not significantly modified, even in case of pathological fracture in treated-VM. The mean regional post-fracture angulation was lower than 15° among treated-VM. The absence of significant change in regional spine angulation is a very important element. Secondary kyphosis occurring as a result of vertebral compression leads to a change in the distribution of forces on the spine, especially on adjacent vertebrae [19]. This is greatly accentuated in case of osteoporosis [20]. On the other hand, many reports indicated correlation between pain and functional restrictions with a post-traumatic regional angulation exceeding 20° [21] or 30° [22]. It can therefore be expected that vertebroplasty, even in case of fracture, is a good technique to prevent the domino effect [23]. Respect of this sagittal balance is associated with a greater quality of life in middle-aged and elderly people [24].

We noticed a very small number of fractures in adjacent vertebral bodies regardless of period of follow-up. We observe only 4 fractures of adjacent vertebral bodies (1.73%) to a treated-VM. Thus, it is much lower than the incidence of new vertebral compression fracture of cemented vertebrae for osteoporotic fracture (20% in a retrospective study with a mean follow-up of 20 months [25]). It can suggest that a systematic vertebroplasty of adjacent vertebrae to the secondary lesions is unnecessary. In an Italian ex vivo study, results demonstrated that after vertebroplasty of a L4 VM, the stress of a non-osteoporotic L3 lower endplate model increased by 1.33% and does not change relevantly for L5 upper endplate. In contrast, when prophylactic vertebroplasty was simulated in the osteoporotic model, the stress of L3 lower endplate increased by 16.0% [26].

Limitations

Methodological limitation of this study includes its retrospective, single-arm and single-center design.

The number of patients is relatively small. However, one hundred consecutive patients represent the biggest cohort



		Fracture rates				
		Number of VM	at 6 months	at 1 year	at 2 years	End of follow-up
SINS <8	Treated-VM	112	0	0	2 (1.8 %)	4 (3.6 %)
	Saliou score <9	12 (10.7 %)	0	0	2(16.7 %)	3 (25.0 %)
	Saliou score ≥9	100 (89.3 %)	0	0	0	1 (1.0 %)
SINS ≥ 8	Treated-VM	26	1 (3.8 %)	2 (7.7 %)	4 (15.4 %)	5 (19.2 %)
	Saliou score <9	3 (11.5 %)	1 (33.3 %)	1 (33.3 %)	1 (33.3 %)	1 (33.3 %)
	Saliou score ≥9	23 (88.5 %)	0	1 (4.3 %)	3 (13.0 %)	4 (17.4 %)

Data are numbers (%) and rates

Fig. 6 Rates of pathological fractures according to the SINS and Saliou scores

published on preventive consolidation in cancer patients with VM and with a follow-up more than 1 year. We believe that a long-term follow-up has become an essential parameter given improvement of cancer patient's life expectancy.

In our study, the risk of fracture despite PV is relatively low, 6.5%. Indeed, the rate of fracture despite vertebroplasty published in the literature can be very high, beyond 30% [27] in osteoporotic vertebrae, suggesting that most treated vertebral metastases were not associated with severe osteoporosis in our patients. Another bias could be the exclusion of patients with a follow-up lower than 12 months. We can hypothesize that our patients have a long life expectancy and thus a better overall condition and less susceptible to severe osteoporosis. This bias could explain the small number of fractures at the adjacent vertebrae and the absence of sagittal deformity. Osteodensitometries were not available for all patients included in our retrospective study but should be an important point to focus on for future studies on preventive consolidation of vertebral metastases.

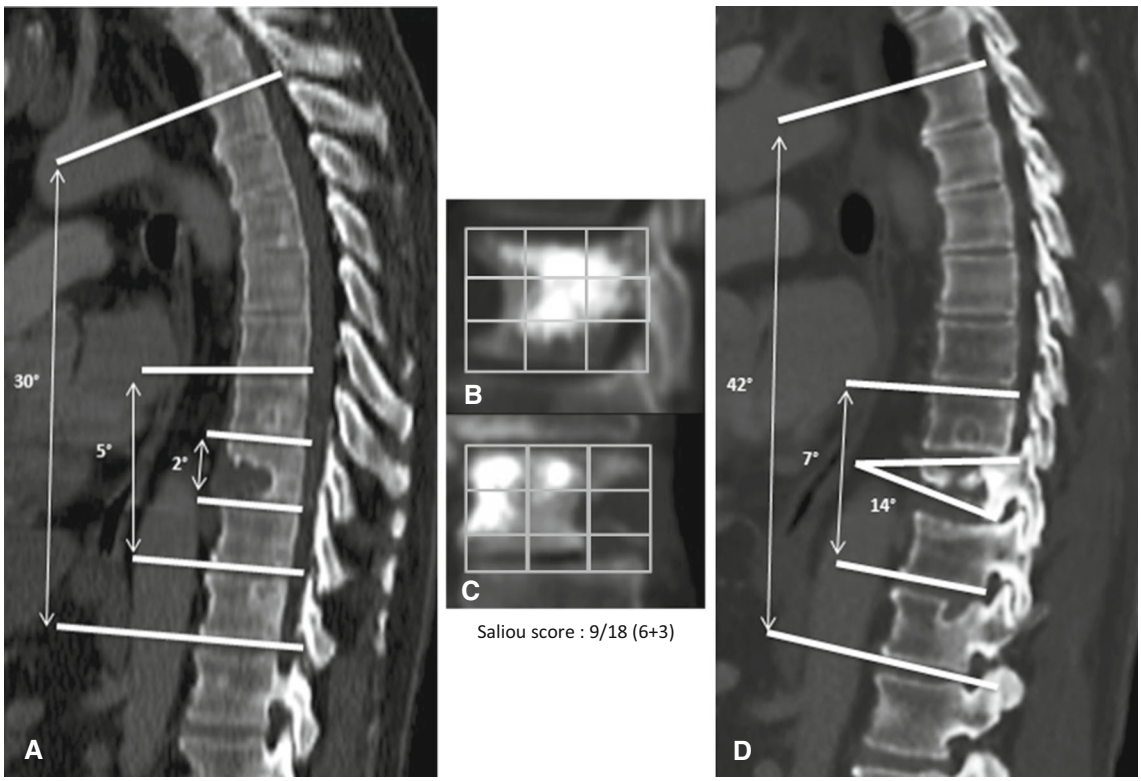


Fig. 7 Example of pathological fracture for a treated-VM, Saliou score and sagittal vertebral static measurements

Conclusions

Vertebroplasty is long-term effective for preventive consolidation of VM. Best results are obtained for vertebral metastases with SINS lower than 8, suggesting that vertebroplasty must be discussed at the early diagnosed. In addition, quality of the cement injection matters, suggesting that techniques that improve the quantity and the quality of cement diffusion into the vertebral body must be developed and evaluated for better preventive consolidation of vertebral metastases.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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