Percutaneous vertebroplasty: the radiologist's point of view

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Summary

Introduction: Vertebral compression fractures (VCFs), usually caused by osteoporosis, is a disabling pathology associated with back pain, low quality of life and high costs.
We report a retrospective study of 852 patients who underwent Percutaneous Vertebroplasty (PVP) in our department, for treatment of refractory back pain caused by osteoporotic vertebral fractures.
Objectives: To evaluate the safety and the helpfulness of the PVP in vertebral osteoporotic fractures treatment and, particularly on durable pain reduction, mobility improvement and analgesic drugs need.
Materials and Methods: Follow-up analysis was made through a questionnaire filled by the patients before and after PVP (1-6 months), designed to measure pain, ambulation capacity, ability to perform activities of daily living (ADL) and analgesic drugs administration.
Results: A statistically significant difference between visual analogue scale (VAS) values before and after treatment has been observed. No difference between VAS values were observed at 1 and 6 months post-treatment period. The treated vertebrae number did not influence post-treatment VAS values during all the follow-up. Ambulation capacity and the ability to perform ADL have been improved following PVP. Patients also reported significant reduction in administration of medications after PVP.
Conclusions: PVP is a safe and useful procedure in painful osteoporotic VCFs treatment, able to reduce pain, improve patients mobility and decrease analgesic drugs need.

KEY WORDS: osteoporosis, vertebral compression fractures, percutaneuos vertebroplasty.

Introduction

Vertebral Compressive Fractures (VCFs), defined as a 20% or an at least 4 mm height reduction of the vertebral body, occur when the axial and rotational load exceed the resistance offered by the vertebra (1).
The most common causes of vertebral fractures are osteoporosis and malignant bone lesions.
Primary osteoporosis is responsible of 85% of all VCFs while secondary osteoporosis and malignant bone lesions are the cause of the remaining 15% (1,2,3).
VCFs usually become evident due to severe back pain, which can dramatically reduces patient's quality of life. Other symptoms associated with VCFs include functional limitations, depression, disability, height loss caused by vertebral collapse, spinal instability and, in many cases, kyphotic deformity that could compromise lung capacity. In addiction, patients with VCFs have a 1,6% risk of mortality compared to age-matched controls without VCFs (1,4,5).
The first choice treatment options of VCFs include medical therapy associated to rest, eventually to bracing and, in the case of osteoporosis-induced fractures, to specific drugs like biphosphonates (5).
In patients that don't respond to the conservative treatments interventional radiology techniques, Vertebroplasty and Kyphoplasty, may be used (6).
Percutaneous Vertebroplasty (PVP), described first by Galibert and Deramound in 1987, consist of percutaneous injection of bone cement (Polymethylmethacrylate-PMMA) within a collapsed vertebral body, in order to obtain a vertebral body stabilization and pain relief (1,8,18).
This technique has rapidly reached standard of care in medically refractory painful VCFs treatment. The purpose of this study is to evaluate effectiveness and usefulness of PVP in a large number of patients with symptomatic osteoporotic VCFs (1,6,7,8).

Materials and methods

Patients selection

All eligible patients must undergo an accurate clinical-anamnestic evaluation in order to confirm the role played by the VCF in pain and disability.
Instrumental investigations included plain radiographic exam, CT and/or MRI were performed in all patients before the procedure (7).
Radiographs exam in two orthogonal projections demonstrates the presence and fracture localization (8).
MR allow to assess the presence of edema on T2-STIR weighted sequences, index of acute compression fractures, that could be a predictive factor of a favourable response to procedure (9) (Figure 1 a-b). In patients with a normal vertebral segment between two collapsed vertebrae we decided to execute an 3T MR Spectroscopy evaluation on this vertebra. When Spectroscopy imaging demonstrated an increase in the saturated fats and a decrease in the apparent diffusion coefficient (ADC), we performed a prophylactic PVP (Figure 2 a-b) (10).
CT scans, prior vertebroplasty, evaluates the integrity of the posterior somatic wall and assess eventual posterior fragments displacement. Furthermore, CT allows measurement of the pedicular diameter, which may influence the size of the needle chosen for puncture especially in the more gracile thoracic vertebral pedicles (10,11).

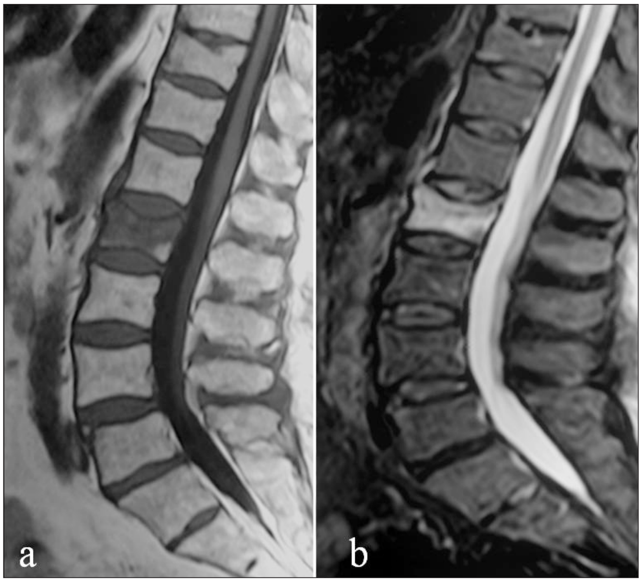

Figure 1a, b - MR Sagittal T1 and T2-STIR weighted sequences show an acute L2 vertebral compressive fracture.

In case of chronic fractures in which pain doesn't improve or patients that can't perform MR exam, bone scintigraphy should be performed (12).

Technique

Patients were carefully informed about benefits and risks concerning the procedure; informed consent was required. In order to minimise the risk of bleeding, laboratory exams with assessment of blood coagulation profile (INR, PTT, PT) was made and anticoagulation therapy was discontinued if administrated before the procedure.
Prior the procedure patients undergo cardiological and anaestesiological evaluations, since the intervention is carried out under local anaesthesia.
In addiction, large spectrum antibiotical coverage (2 g vial of endovenous Glazidin), gastroprotective drugs (20 mg vials of endovenous Antra) and corticosteroids (20 mg vials of endovenous Urbason) are administered for prophylactic purposes before the treatment.
Procedure was performed under Fluoroscopic or combined Fluoroscopic-CT guidance in angiography suite (Figure 3 a-b). The combined guide is prefered in thoracic upper vertebrae related to their small pedicles.
While in case of cervical vertebrae the supine position is preferred, patients undergoing the procedure for the treatment of thoracic or lumbar VCFs are positioned prone.
After localizing under fluoroscopy the vertebra to be treated and its pedicles, subcutaneous and periosteal administration of a local anesthetic is performed. A small incision is then followed by the insertion of a 11-13 Gauge bone biopsy needle (13,14).
The classic transpeduncolar (mono or bilateral) access is preferred in the case of thoracic and lumbar vertebrae due to its major safety, while for upper thoracic vertebrae a costo-vertebral access is used because of the small sized pedicles (14).
Needle is advanced through the pedicle, with an anterior, medial and caudal trajectory until the anterior 2/3 of the vertebral body is reached (15) (Figure 4 a).
A PMMA mixture injection into the vertebral body (mean 2,5 ml) is undertake after careful imaging confirming location of the trocar/s into the antero-medial portion of vertebral body (Figure 4 b).
Cement injection was executed on lateral view with continuous fluoroscopic monitoring, paying attention at the posterior margin of the vertebral body and to the epidural space (16) (Figure 4 c).
Procedure time is approximately 30-40 minutes per level of Vertebroplasty (17).
Post-procedure control was performed under CT scan or spinal X-Rays. All patients remained motionless for four hours after the procedure and are discharged usually on the following day (18).

Patient population

From February 1999 to April 2009, 852 patients were submitted to our department to PVP for painful osteoporotic VCFs, refractory to medical therapy for a period of three weeks.
The vertebrae to be treated were located in the thoracic segment

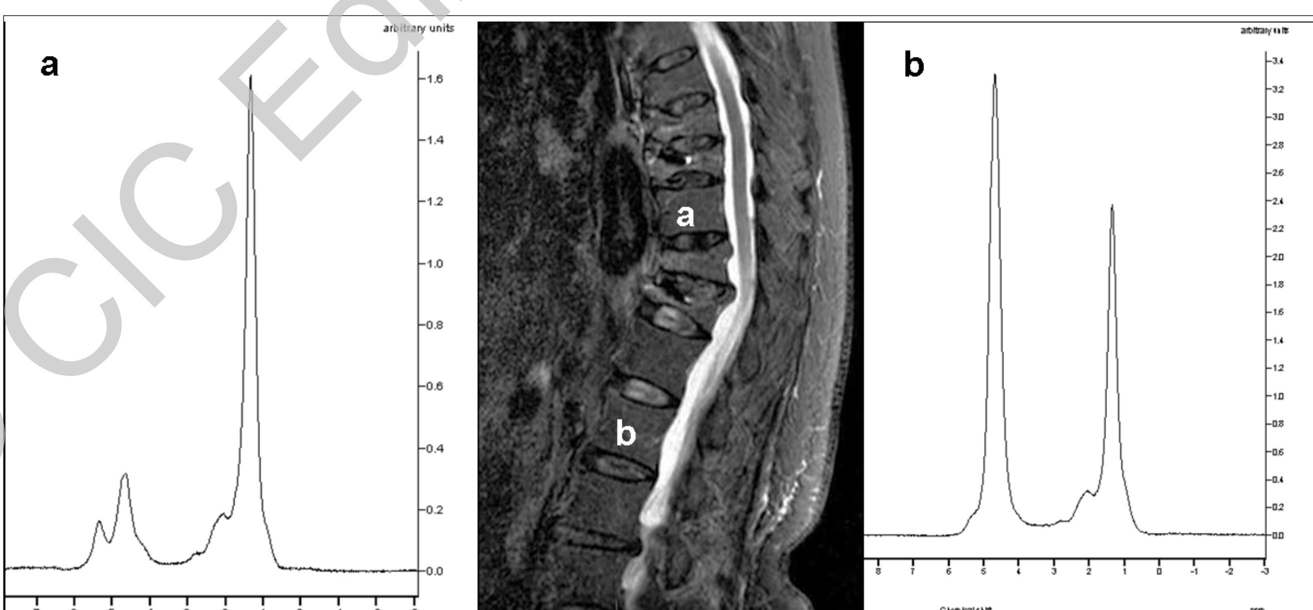

Figure 2 a, b - 3T-MR Spectroscopy analysis. **a**) spectral analysis in normal vertebral segment between two collapsed vertebrae (FF 72.4%) and **b**) spectral analysis in the distant control vertebral body (FF 61%).

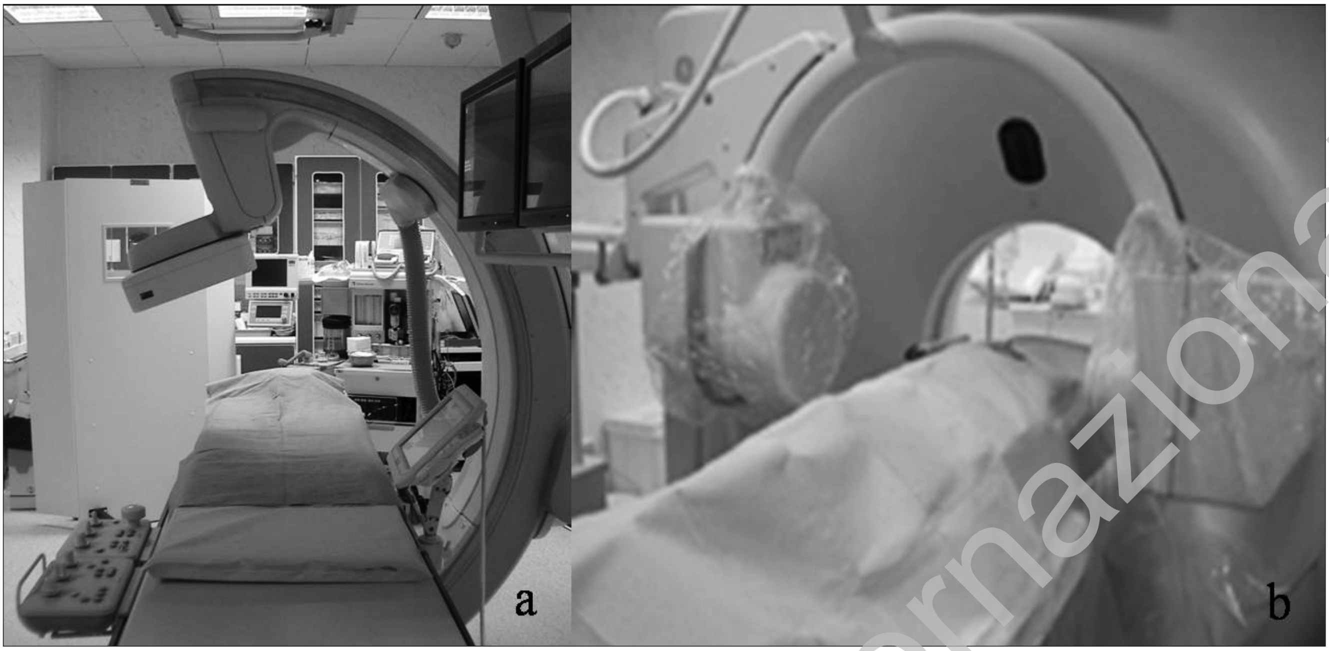

Figure 3 a, b - Fluoroscopic or combined CT -Fluoroscopic guidance.

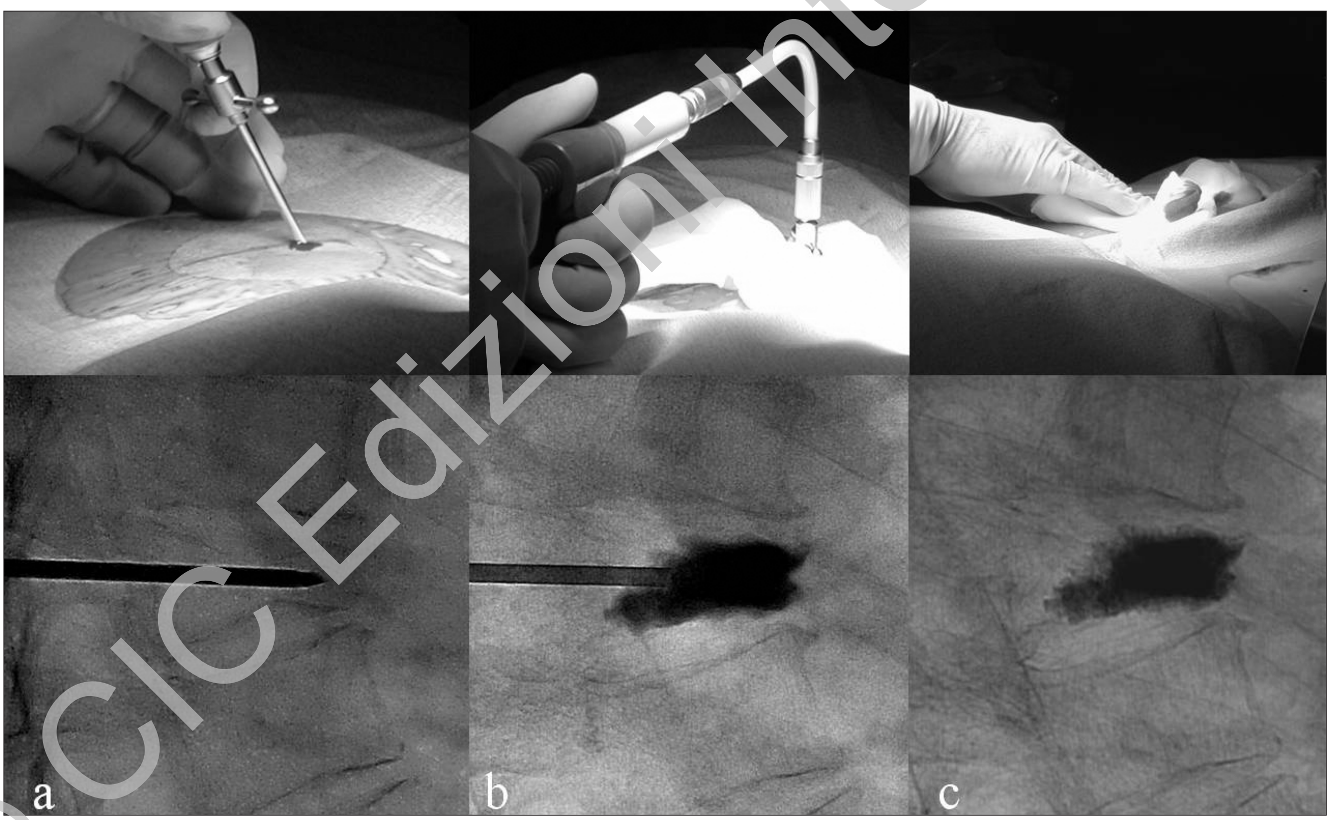

Figure 4 a-c Vertebroplasty treatment. Sequential fluoroscopic images in lateral projections: **a**) a 13 G biopsy needle positioning with a transpeduncolar approach **b**) Injection of bone cement (PMMA) into the vertebral body **c**) Post-procedure fluoroscopic control with an homogeneous PMMA distribution inside the vertebral body.

(544 vertebrae), in lumbar segment (811 vertebrae) and sacral segment (22 vertebrae).
The mean age of our population was 73 years (range 47-89).
Contraindication to PVP included response to medical treatment, systemic infections, presence of radicular symptoms or neurologic deficits and spinal stenosis.

Outcome measures and statistical analisys

Pain and functional degree were evaluated in all patients using a self-assessment questionnaire submitted before and 1-6 months after the procedure, designed to measure pain, ambulation capacity, ability to perform activities of daily living (ADL) and

Table I - Ambulation, ADL and use of analgesics during the follow-up period.

Evaluation parameters	Pre-PVP	Post-PVP	
		1 month	6 months
Ambulation	N (%)	N (%)	N (%)
Normal without pain	0 (0.0)	693(81.3)	495 (58.1)
Normal with pain	78 (9.2)	159 (18.7)	345 (40.5)
Limited with pain and/or brace	504 (59.2)	0 (0.0)	12 (1.4)
Wheelchair	135 (15.8)	0 (0.0)	0 (0.0)
Bedridden	135 (15.8)	0 (0.0)	0 (0.0)
ADL			
Able to execute without pain	0 (0.0)	523 (61.4)	357 (41.9)
Able to execute with mild pain	12 (1.4)	302 (35.4)	449 (52.7)
Able to execute with pain	161 (18.9)	27 (3.2)	23 (2.7)
Able to execute with severe pain	426 (50.0)	0 (0.0)	23 (2.7)
Not able to execute	253 (29.7)	0 (0.0)	0 (0.0)
Medication			
No analgesics	12 (1.4)	690 (81.0)	403 (47.3)
FANS	103 (12.1)	58 (6.8)	81 (9.5)
Oral narcotic (when needed)	230 (27.0)	104 (12.2)	368 (43.2)
Scheduled oral narcotic	507 (59.5)	0 (0.0)	0 (0.0)
Total	***852 (100.0)***	***852 (100.0)***	***852 (100.0)***

analgesic drugs administration. The Visual Analogue Scale (VAS) 10.0 cm long, was used for pain evaluation; the patient was asked to assign a score to the questionnaire 10.0 cm long strip, based on its subjective perception of pain, ranging between 0 and 10, where 0 corresponds to the pain absence while 10 represent the maximum pain never felt.

The ambulation was evaluated with a five point scale: 1= normal, without pain; 2= normal with pain; 3= limited with pain or brace using; 4= wheelchair; 5= bedridden.

The ability to perform the activities of daily living (ADL) was always measured with a five point scale: 1= able to execute ADL without pain; 2= to execute ADL with mild pain; 3= to execute ADL with pain; 4= to execute them with a severe pain; 5= not able to execute ADL because of pain.

The analgesic drug engagement was finally described as follows: 1= no analgesics; 2= anti-inflammatory not steroid drugs (FANS); 3= oral narcotic analgesics when needed; 4= oral narcotic analgesics with established doses and time (scheduled oral narcotic).

Patients were also asked about overall improvement of status after the procedure, and, during the interview, all patients were requested to contact us if conditions changed.

Quantitative data (ages, VAS) were showed as ± DS (range) average, while the qualitative data were showed as MN (%).

Subgroup analysis was performed to asses the differences of pre- and post-procedural pain and also by number of treated vertebrae. Mann-Whitney test was used to check differences on numerical data between two groups and Kruskal-Wallis test were used to check differences between more than two groups. All p values were two-tailed and a value less than 0.05 was considered statistically significant.

Results

On 852 patients, 440 treatments were executed on a single vertebra, 312 on two, 87 on three and at last 13 on more than three vertebrae for a total of 1377 vertebrae (544 thoracic vertebrae, 811 lumbar and 22 sacral).

A monolateral transpedicular approach was used in 1226 of 1377 treated vertebrae (89%) and bilateral in 41 (3%) vertebrae. Bilateral approach was used when it was not obtained satisfactory and homogeneous cement distribution in the vertebral body.

Costo-vertebral approach has been used for 110 thoracic vertebrae (8%).

All procedures were successfully executed without major complications. Instead we observed a reduced percent of minor technical complications (4,8% of patients), principally constituted by PMMA leakage within disk and para-vertebral veins, always asymptomatic and with not therapy requirement.

Table II - VAS during the follow-up period and according to the number of the treated vertebrae.

	Pre-PVP*	1 month*	6 months*
1 vertebra†	8.6 (7.2-9.6)	1.3 (0.0-2.1)	1.2 (0.3-2.1)
2 vertebrae†	8.9 (7.0-9.3)	0.8 (0.0-1.9)	1.8 (0.0-3.4)
> 2 vertebrae†	8.1 (7.4-9.4)	0.8 (0.0-3.0)	2.0 (0.6-3.8)
General-VAS‡	**8.7 (7.3-9.5)**	**1.1 (0.0-2.6)**	**1.5 (0.3-3.0)**

*No statistically significant difference has been observed between groups (number of treated vertebrae) during every step of the follow-up period (pre-PVP, 1 month and 6 months: Kruskal-Wallis test, p-values NS)

† Statistically significant differences has been observed between pre-PVP and all the other follow-up periods (for each group of treated vertebrae: Mann-Whitney test, all p-values <0.001), but no statistically significant differences has been observed between the post operative follow-up periods (Kruskal-Wallis test, p-values NS)

‡ Statistically significant differences has been observed for the General-VAS between pre-PVP and all the other follow-up periods (Mann-Whitney test, p<0.001), but no statistically significant differences has been observed between the post operative follow-up periods (Kruskal-Wallis test, p=.0.8)

The results of questionnaire on the functional state and the analysis of VAS were reported in Tables I and II. A statistical significant difference between VAS values before treatment and in during follow-up (p value <0.001) was found. Are not reported differences between VAS values at 1 and 6 months post-operative clinical examinations. Number of treated vertebrae didn't influence post-treatment VAS values and during all follow-up.
In addiction most patients reported a significant improvement in their ambulation and in their quality of life after the procedure and during all the follow-up. Patients also reported significant reduction in administration of medications as a result of pain relief after PVP.

Discussion

Osteoporosis is a progressive, systemic disease that results in low bone mineral density and weakened bone micro-architecture. Patients with osteoporosis are susceptible to develop vertebral fractures that are a major cause of morbidity and disability in elderly populations (1,2,3,19).
The National Osteoporosis Fundation estimated that over 200 million individuals are at risk of osteoporosis-induced fractures and the spine represent the most frequently affected localization. Only in Europe 438.750 VCFs are diagnosed every year. The VCF lifetime risk is 16% for women and 5% for men, and the incidence of osteoporotic fractures is anticipated to increase fourfold worldwide in the next 50 years. An estimated 25-50% of morphometric VCFs are clinically symptomatic (20).
The clinical symptoms associated with VCFs include severe back pain, limited spinal mobility, height loss, deformity and disability. These symptoms diminish physical efficiency and adversely effect the quality of life due to the higher occurrence of social isolation (21,26).
Hyper-kyphosis of the thoracic spine or loss in lumbar spine lordosis are associated with a reduction in the size of abdominal and thoracic cavities, which can seriously compromise gastrointestinal and pulmonary functions respectively (25,26).
The morphologic and structural alteration of a fractured vertebral body increases the risk of fracture of the vertebrae above and below; in 20% of these patients such condition is verified within the first year from diagnosis. In addiction, both painful and asymptomatic fractures are associated with morbidity and mortality increased rate (1,6%) with respect to age match controls (22,23).
For these reasons, the already high socio-economic expenditures of VCFs, are destined to significantly increase. Such high costs are due to the high number of days of hospitalization (an average of 10-30 days /patient), to the pharmacological and physical therapy, and to long-term nursing.
Currently in European Community the osteoporosis fracturative pathology costs are higher than 31 billions and are designed to reach a value equal to € 76 billions within 2050 (24).
The current medical and surgical therapies do not adequately diminish pain and the disability deriving from VCFs. The surgical treatment is considered to be highly invasive and frequently contraindicated for diffuse osteoporotic bone instability. Medical therapy is limited to pain control, bracing and bed rest, a therapy that itself can be dangerous, especially in an elderly patient. In fact, in addition to well-known risk of pulmonary embolism and pneumonia, elderly patients rapidly lose bone and muscle mass when bed rest is used as therapy (25).
For many patients these therapies are not effective, so during last 15 years new minimally invasive treatments, such as PVP and Kyphoplasty, have been developed to manage VCFs.
PVP is a therapeutic image-guided procedure that involves injection of radio-opaque cement into a painful collapsed vertebral body, in effort to relieve pain and provide vertebral stability (26,27).
Kyphoplasty ,a recent evolution of PVP, employs balloon catheters inflated with contrast agent to restore the morphology of the collapsed vertebral body and reduce kyphosis before stabilisation with bone cement (28).
This study proves that PVP offers a significant and immediate pain reduction associated with an important clinical improvement. Pain relief and ability to perform ADL, has been stable during all follow-up period and independent from number of treated levels (1,2,25,26).
Moreover patients reported significant reduction of drug therapy after PVP.
These results were obtained within a very short hospital stay and with few adverse effects: all the patients were discharged the day following the procedure. This is of particular interest because most patients treated with PVP are elderly and frail.
Our success might be attributed to strict evaluation of clinical indications, pre-procedural evaluation with MRI, good quality fluoroscopic equipment and operators hyper-specialization expertise.
A fundamental role in these minimally invasive procedures is also played by bone cement.
There are two main kinds of bone cement: polymer cements and calcium posphate cements (28).
The role of both is to fill, provide adhesion and stabilize fractures. Polymers are the most used due to their safety and efficacy. Their use is based on the polymerization of methylmethacrylate (MMA) into polymethylmethacrylate (PMMA), a compound better known as plexiglas while calcium posphate cements take advantage of chemical reactions based on the solubility of reagents and products.
When tricalcium phosphate and calcium phosphate are mixed with water they rapidly precipitate in the form of hydroxyapatite forming a hard compound at body temperature (29).
Hydroxyapatite is biocompatible material which is believed to form *in vivo* new bone without volume loss.
The disadvantages of this cement consist in the difficulty of injecting it at high pressure inside the vertebral body and the characteristics of its reabsorption which, in osteoporotic patients, may cause bone weakening (30).
Furthermore, data in literature report that this kind of cement may be less resistant than polymer cements and too fragile to be used in major treatments (31).
In our experience, PVP for the treatment of painful VCFs is a safe and useful procedure able to induce pain reduction, patient mobility improvement and decrease in analgesic drugs need.

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