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CLINICAL INVESTIGATION

Percutaneous Vertebroplasty and Bone Cement Leakage: Clinical Experience with a New High-Viscosity Bone Cement and Delivery System for Vertebral Augmentation in Benign and Malignant Compression Fractures

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Abstract The aim of this study was to assess the feasibility of and venous leakage reduction in percutaneous vertebroplasty (PV) using a new high-viscosity bone cement (PMMA). PV has been used effectively for pain relief in osteoporotic and malignant vertebral fractures. Cement extrusion is a common problem and can lead to complications. Sixty patients (52 female; mean age, 72.2 ± 7.2) suffering from osteoporosis (46), malignancy (12), and angiomas (2), divided into two groups (A and B), underwent PV on 190 vertebrae (86 dorsal, 104 lumbar). In Group A, PV with high-viscosity PMMA (Confidence, Disc-O-Tech, Israel) was used. This PMMA was injected by a proprietary delivery system, a hydraulic saline-filled screw injector. In Group B, a standard low-viscosity PMMA was used. Postprocedural CT was carried out to detect PMMA leakages and complications. Fisher's exact test and Wilcoxon rank test were used to assess significant differences ($p < 0.05$) in leakages and to evaluate the clinical outcome. PV was feasible, achieving good clinical outcome ($p < 0.0001$) without major complications. In Group A, postprocedural CT showed an asymptomatic leak in the venous structures of 8 of 98 (8.2%) treated vertebrae; a discoidal leak occurred in 6 of 98 (6.1%). In Group B, a venous leak was seen in 38 of 92 (41.3%) and a discoidal leak in 12 of 92 (13.0%). Reduction of venous leak obtained by high-viscosity PMMA was highly significant ($p < 0.0001$), whereas this result was not significant ($p = 0.14$) related to the disc. The high-viscosity PMMA system is safe and effective for clinical use, allowing a significant reduction of extravasation rate and, thus, leakage-related complications.

Keywords Vertebroplasty · Cement leakage · Spine · Vertebral fracture · Polymethylmethacrylate · Osteoporosis · Bone metastases

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Introduction

Percutaneous vertebroplasty (PV) consists of the injection of polymethylmethacrylate (PMMA) into a collapsed vertebra in order to obtain pain relief and mechanical strengthening of the vertebral body. Galibert and Deramond proposed this procedure for the treatment of aggressive vertebral hemangiomas of C2 [1], and at present, it is used extensively worldwide in osteoporotic and malignant vertebral fractures when conventional therapies are not effective or not well tolerated. Although, clinically, PV is a relatively safe and effective procedure for back pain treatment, several studies have reported some major complications that can lead to paraplegia and death [2–11]. The most often described complications concerned pulmonary embolism, soft tissue damage, and nerve root compression related to leakage of bone cement [12–19]. Bone cement leakage is detected very

frequently in vertebroplasty, as it is seen to occur in 38% [20] to 72.5% [21] of patients with vertebral metastases, in 59.5% [22] to 65% [23] of patients with osteoporotic vertebral collapse, and in 81% of treated patients [24] when computed tomography (CT) is carried out after PV. Even if this frequent minimal leakage is well tolerated or asymptomatic in the large majority of patients, cement extravasation is the main source of clinically relevant complications, depending on the site and volume of leakage.

PMMA symptomatic leakages are, in some astonishingly reported cases, related to poor technique, where initial extravasation is not detected and injection not suspended, thus allowing extensive endocanalar cement perfusion [25] or massive lung embolization [12]; when PV technique and radiological equipment are optimal, leakages are due to the low viscosity of PMMA [26, 27]. To reduce PMMA leakages, some authors have proposed technical optimization and implementation such as vertebral venography [28, 29], gel-foam embolization [30], and kyphoplasty [31–33], but the results were not conclusive. Even if minor complications related to venous leakages in the posterior epidural plexus, such as radicular pain, can be successfully treated [34], a technical improvement to reduce these leakages is necessary. Adequate patient selection and accurate imaging in the hands of skilled operators remain the major points for minimizing the risk of complications. Baroud and coworkers demonstrated the linkage between the viscosity of the injected cement and leakages [35]. In their experimental model, cement leakage ceased completely when its viscosity was very high. However, this study concluded that no delivery system in clinical use could inject such a highly viscous cement.

Even the above conditions regarding the venous leakage of PMMA cannot always be avoided or predicted by the sort of fracture in the treated vertebra [9, 36]. The high rate of minimal and asymptomatic venous leakage, which can expose patients to the risk of major complications, led us to verify whether PV is feasible and safer using a very high-viscosity PMMA. The studied high-viscosity bone cement is a special new formulation of PMMA designed for injection through a proprietary delivery system. This cement reaches a constant putty-like viscosity immediately after mixing, without waiting a few minutes as in other PMMA cements, and remains at a constant high viscosity, and consistently injectable for 8–10 min before it solidifies. This high-viscosity cement can be injected using 11-, 13-, and 15-G needles as well as a side-firing needle which enables directional cement injection. Cadaveric laboratory testing showed that in two excised vertebrae fractured with a chisel, injection of common PMMA resulted in leakage through the defect, while high-viscosity cement maintained a spherical filling configuration confined to the vertebral body, with no leakage.

Materials and Methods

Study Population

Written informed consent was obtained before study inclusion from all patients in accordance with the national legislation and the Declaration of Helsinki. As the high-viscosity PMMA was CE approved for PV, institutional medical ethics committee approval was not required for this study.

From February 2006, 60 patients underwent PV on 190 painful collapsed vertebrae not responding to conventional therapy (fractures aged from 3 to 24 months; mean, 6.9 ± 5.5 months). MRI and plain radiographs were evaluated before PV to assess correct indications to the procedure and to plan the levels to treat; up to seven vertebrae (1/30; 3.3%) were treated in the same sessions when MRI vertebral hyperintensity on T2-weighted sequences (Fig. 1) was concordant to focal pain evocated by clinical examination.

Patients were randomized and divided into two homogeneous groups: in Group A, 30 patients (24 female and 6 male; age, from 56 to 84 years; mean, 71.3 ± 7.8 years) underwent PV on 98 vertebrae (39 dorsal and 59 lumbar; from D6 to L5), whereas in control Group B, 92 vertebrae (47 dorsal and 45 lumbar; from D4 to L5) were treated in 30 patients (28 female and 2 male; age, from 54 to 84 years; mean, 73.2 ± 6.4 years). Respectively, in the two groups 23 of 30 patients (76,6%) had osteoporotic vertebral fractures, 5 of 30 patients (16,6%) suffered from malignant fracture, 1 of 30 (3.3%) from multiple myeloma, and 1 of 30 (3.3%) from two symptomatic angiomas (Tables 1 and 2). In 12 of 46 osteoporotic patients (7 in Group A and 5 in Group B), multiple vertebral collapses were caused by high-grade osteoporosis induced by continued and long-lasting corticosteroid therapy.

Procedural Technique

All procedures were performed using a C-arm angiographic unit (Advantx Tilt-C; GE Medical Systems, Milwaukee, WI) with the patient in the prone position. Vertebroplasty was always performed under sterile conditions and IV antibiotics (1 g of vancomycin hydrochloride; Abbott SpA, Campoverde di Aprilia, LT, Italy) was administrated 3 days before and 5 days after the procedure. Patient pressure, heart rate, and oxygen saturation were monitored during the whole procedure. PV was always performed in local anesthesia by injecting 2 ml of 2% lidocaine hydrochloride (Lidosan; Industria Farmaceutica Galenica Senese, Monteroni d'Arbia, Siena, Italy) both at skin level and deep to include the periostium of the pedicle. An 11-G (125 vertebrae; 65.8%) or 13 G (65 vertebrae; 34.2%) beveled vertebroplasty needle was used in either a monolateral (188 vertebrae; 98.9%) or a bilateral (2 vertebrae; 1.1%) approach; the pathway was

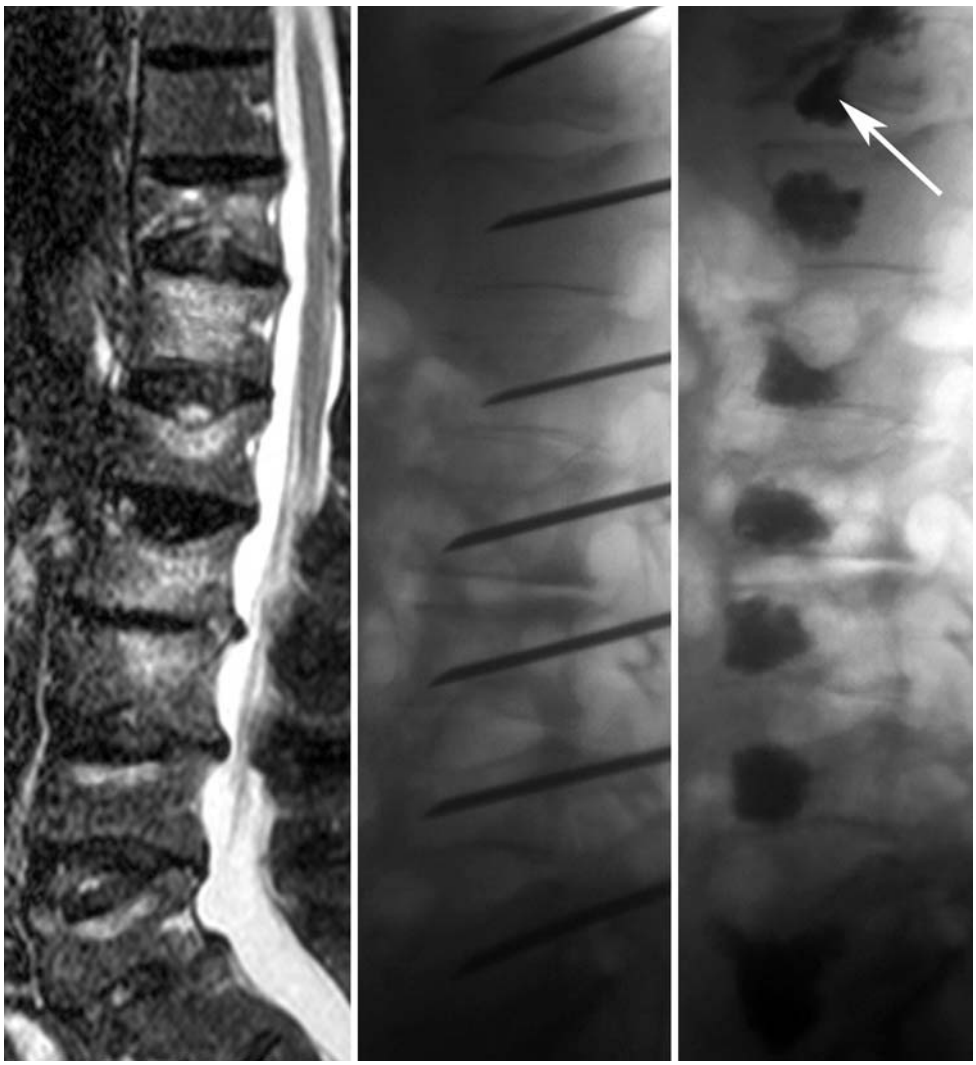

Fig. 1 MR T2-stir-weighted sequences identified hyperintensity in multiple levels that were concordant with clinical pain in a patient with steroid–induced osteoporosis. Up to seven levels were treated in one session, with a good clinical outcome and without complication (a discoidal leak occurred in D11; white arrow)

transpedicular in the lumbar spine and parapedicular intercostovertebral in the dorsal tract.

A core biopsy was always performed coaxially, using an 18-G through-cut needle (Magnum, Bard Inc., USA), to ensure the etiology of the fracture. Vertebral venography was not used following reports in the literature demonstrating no significant differences in frequency or amount of extravasation and no differences in clinical outcome between venography and no venography [28, 29].

In Group A patients PV was performed using a high-viscosity PMMA with a specially designed delivery system (Confidence Type I; Disc-O-Tech, Israel). According to the manufacturer's specifications, after 1 min of mixing of the liquid monomer into the powder polymer (containing 30% barium sulfate for optimal fluoroscopic visualization), the cement shows the consistency of Plasticine (Fig. 2). The delivery system consists of a hydraulic saline-filled screw injector with a long connection tube allowing the operator's hands to be out of the X-ray beam during the injection (Fig. 3). The reservoir containing the cement is then distally Luer-lock connected to 11- and 13-G proprietary vertebroplasty needles and proximally to the delivery system (Fig. 4). In patients in control Group B, PV was carried out with standard low-viscosity PMMA (Mendec Spine; Tecres, Sommacampagna, Italy) CE approved for vertebroplasty with a screw injector (CementoSet; Optimed, Germany).

Considering our previous clinical experience and the data in the literature on the filling volume and clinical outcome ratio [37, 38], from 1 to 3.5 ml (mean, 2.5 ± 1.1 ml) of cement was injected in the anterior two-thirds of each treated vertebra.

After the procedure all patients remained supine in bed for 1 h and had 6 h of clinical observations, then was discharged from the hospital.

Study Design

In each treated patient, CT scans with two-dimensional reconstruction (LightSpeed16; GE Medical Systems, Milwaukee, WI, USA) was performed 1 h after PV to

Table 1 Group A high-viscosity PMMA case summary

No.	Pt	Age	Gender	Pathology	Treated levels	Total	VAS pre	VAS post	Osw pre (%)	Osw post (%)	Venous leak	Levels	Discoidal leak	Levels
1	PS	67	M	Osteoporosis	L3–L4	2	5	0	20.0	4.0	Yes	L3	No	–
2	SM	68	F	Osteoporosis	D9–D10	2	10	0	57.7	4.4	Yes	D9–D10	No	–
3	GR	70	F	SI osteoporosis	D8–D9–D10–D11–D12	5	10	1	75.5	11.1	No	–	Yes	D12
4	MT	77	F	Osteoporosis	D12	1	10	0	80.0	4.4	No	–	No	–
5	NG	63	F	Osteoporosis	L5	1	7	0	44.0	2.0	No	–	Yes	L5
6	DS	76	F	Osteoporosis	L2–L3	2	9	1	64.4	6.6	No	–	Yes	L3
7	CM	72	F	Osteoporosis	L2–L3–L4–L5	4	8	0	55.5	6.6	No	–	No	–
8	SA	81	F	Osteoporosis	L1–L2	2	8	0	44.4	8.8	No	–	No	–
9	FA	72	F	SI osteoporosis	D12–L1–L2–L3–L4–L5	6	9	0	71.1	11.1	No	–	No	–
10	AD	84	F	SI osteoporosis	D11–D12–L1–L2–L3–L4	6	10	1	77.7	13.3	No	–	No	–
11	CM	67	F	SI osteoporosis	D11–D12–L1–L2–L3	5	9	2	88.8	22.2	No	–	No	–
12	BN	61	M	Osteoporosis	L3–L4–L5	3	7	0	30.0	2.0	No	–	No	–
13	BG	74	F	SI osteoporosis	D8–D9–D10–D12–L1–L2	6	9	2	80.0	20.0	No	–	No	–
14	BA	82	M	SI osteoporosis	D11–D12–L1–L2–L3–L4–L5	7	9	1	73.3	8.8	No	–	Yes	D11
15	BO	78	F	Osteoporosis	L2–L3–L4	3	10	0	77.7	2.2	No	–	No	–
16	DG	79	M	SI osteoporosis	D12–L1–L2–L3–L4–L5	6	8	1	66.6	4.4	No	–	Yes	L2
17	LG	56	F	Osteoporosis	L5	1	6	0	35.5	2.2	No	–	No	–
18	BR	76	F	Osteoporosis	L1–L2	2	10	0	77.7	2.2	No	–	No	–
19	RM	80	F	Osteoporosis	D12–L1–L3	3	9	0	62.2	4.4	No	–	No	–
20	DM	72	F	Osteoporosis	D12–L1	2	9	1	64.4	8.8	No	–	No	–
21	BM	83	F	Osteoporosis	D10–D11	2	7	0	44.4	4.4	Yes	D11	No	–
22	BE	73	F	Osteoporosis	D12–L2–L3	3	8	0	48.8	2.2	Yes	L2–L3	No	–
23	AC	68	F	Osteoporosis	D10–D11–D12	3	7	1	40.0	11.1	No	–	No	–
24	AG	71	F	Angioma	D12–L4	2	7	1	46.6	8.8	No	–	No	–
25	PM	65	F	Breast Ca MTS	D11–L3–L4–L5	4	9	1	71.1	15.5	No	–	No	–
26	BM	60	F	Breast Ca MTS	D8–L3–L4	3	10	2	82.2	20.0	No	–	No	–
27	ME	65	F	Breast Ca MTS	D6–D7–D8–D9–D10	5	8	1	57.7	8.8	Yes	D10	No	–
28	PI	78	M	Lung Ca MTS	L3	1	8	0	66.6	8.8	No	–	Yes	L3
29	AG	56	F	Colon Ca MTS	L2–L3–L4	3	9	0	56.0	10.0	Yes	L4	No	–
30	GL	64	M	Myeloma	D7–D8–D9	3	6	0	30.0	4.0	No	–	No	–

Note: PMMA, polymethylmethacrylate; Pt, patient; SI, steroid induced; MTS, metastases; CA, cancer; VAS, Visual Analog Scale; CT, computed tomography; Osw, Oswestry Back-Pain Index

Table 2 Group B low-viscosity PMMA case summary

No.	Pt	Age	Gender	Pathology	Treated levels	Total	VAS pre	VAS post	Osw pre (%)	Osw post (%)	Venous leak	Level(s)	Discoidal Leak	Level(s)
1	CA	68	F	SI osteoporosis	D7–D8–D9–D10–D11–D12–L4	7	10	1	80.0	6.6	Yes	D8–L4	Yes	D12
2	CE	69	F	SI osteoporosis	D12–L1–L2–L3–L4–L5	6	9	1	57.7	6.6	Yes	D12–L1	Yes	L3
3	AQ	73	F	Osteoporosis	D9–D10–D11	3	10	1	64.4	8.8	No	–	Yes	D10
4	CR	73	F	Osteoporosis	L4–L5	2	6	0	35.5	2.2	Yes	L4	Yes	L5
5	GI	78	F	SI osteoporosis	D7–D8–D9–D12–L1–L2–L3	7	6	1	56.0	8.8	Yes	D8–D12–L1–L3	Yes	D9
6	RM	73	F	Osteoporosis	D12–L1	2	10	2	77.7	20.0	Yes	L1	Yes	D12
7	VA	73	F	Osteoporosis	D12–L1	2	10	0	80.0	6.6	Yes	D12	No	–
8	CL	79	F	Osteoporosis	D12–L3	2	8	2	64.4	22.2	No	–	No	–
9	CE	79	F	Osteoporosis	L1–L2–L3–L4	4	4	1	30.0	2.2	Yes	L1–L2–L3	No	–
10	GC	77	F	SI osteoporosis	D10–D12–L1–L2	4	9	0	77.7	2.0	Yes	D12–L1	No	–
11	GM	75	F	SI osteoporosis	D11–D12–L1	3	8	3	66.6	20.0	Yes	D11–L1	No	–
12	LL	65	F	Osteoporosis	D12–L2	2	7	1	55.5	4.4	No	–	Yes	L2
13	MG	69	F	Osteoporosis	D12–L1	2	10	0	80.0	2.0	Yes	D12	No	–
14	MI	73	F	Osteoporosis	D10–D11–L2	3	8	2	73.3	22.2	Yes	D10	No	–
15	MB	79	M	Osteoporosis	L1–L2–L3–L4	4	9	0	77.7	2.2	Yes	L1–L2–L3	No	–
16	MT	71	F	Osteoporosis	L1–L2–L3–L4	4	8	1	66.6	11.1	No	–	Yes	L1–L3
17	MT	64	F	Osteoporosis	D12–L1	2	10	0	73.3	2.2	Yes	L1	No	–
18	NA	82	F	Osteoporosis	D11–D12–L1	3	9	0	77.7	2.2	Yes	D12	No	–
19	OM	80	F	Osteoporosis	D9–D10	2	8	2	71.1	22.2	Yes	D10	No	–
20	OG	72	F	Osteoporosis	D12	1	9	0	80.0	4.4	Yes	D12	No	–
21	PA	67	F	Osteoporosis	D11	1	8	0	66.6	2.2	Yes	D11	No	–
22	RR	77	F	Osteoporosis	D21–L1	2	8	1	71.1	4.4	Yes	D12	No	–
23	SR	84	F	Osteoporosis	L2–L3–L4	3	8	0	73.3	2.2	Yes	L2	No	–
24	SM	68	F	Angioma	D12–L1	2	8	0	71.1	2.2	No	–	No	–
25	DB	67	M	Lung Ca MTS	L1–L2	2	10	2	77.7	11.1	Yes	L2	No	–
26	DC	82	F	Breast Ca MTS	D8–D9–D10	3	10	2	80.0	20.0	No	–	Yes	D9
27	CA	54	F	Breast Ca MTS	D8	1	6	0	56.0	4.4	Yes	D8	No	–
28	FC	75	F	Colon Ca MTS	D4–D5–D6–D7–D8	5	7	1	66.6	8.8	Yes	D8–D10	Yes	D9
29	CC	72	F	Breast Ca MTS	D11–D12–L2–L3	4	8	3	66.6	22.2	Yes	L2	Yes	D11
30	GV	77	F	Myeloma	D11–D12–L1–L5	4	7	1	55.5	4.0	Yes	D11–D12–L5	No	–

Note: PMMA, polymethylmethacrylate; Pt, patient; SI, steroid induced; MTS, metastases; CA, cancer; VAS, Visual Analog Scale; CT, computed tomography; Osw, Oswestry Back-Pain Index

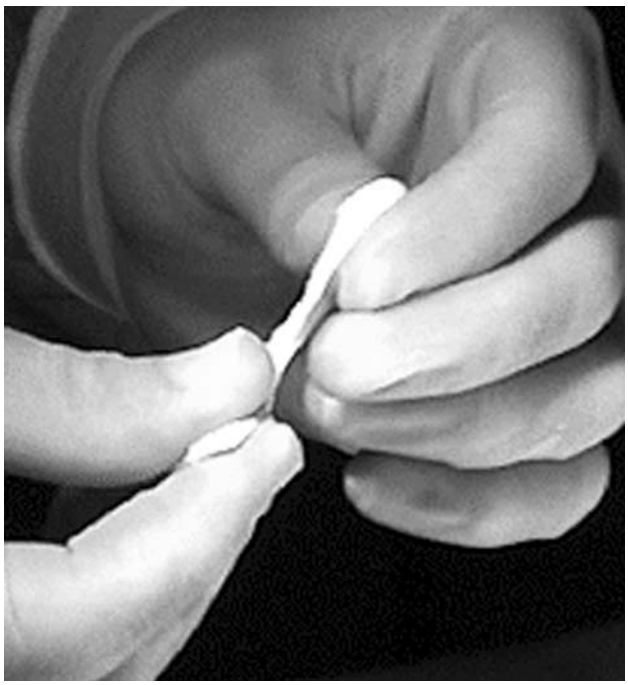

Fig. 2 After mixing, the high-viscosity bone cement showed the consistency of Plasticine (putty-like)

identify bone cement extravasation. Postprocedural CTs were examined by two experienced radiologists (not by the operator) from two different radiology centers, and allowed precise evaluation of vertebral cement perfusion, PMMA leakages, and needle pathways and possible complications (Fig. 5). When a venous leak was detected, CT scan of the lungs was carried out to evaluate the possibility of PMMA embolism. Blinded data about PMMA leakages on every treated vertebra were collected by another radiologist.

The 11-point (0, no pain, to 10, worst possible pain) Visual Analog Scale (VAS) [39] and the Oswestry Self-Evaluation Disability Questionnaire [40] were compiled by the anesthesiologist before PV, 7 days after the procedure, and after 6 months; a clinical interview follow-up was performed every month during a 6-month period.

Statistical Analysis

The Wilcoxon paired signed rank test was used to evaluate significant differences ($p < 0.05$) on clinical pain regression on the VAS and Oswestry disability questionnaire in each group and the Student paired *t*-test to investigate differences in clinical outcome between the two groups. Fisher's exact test was conducted to evaluate differences in PMMA leakages between Group A and Group B and to compare the results of Group A to other published series.

Statistical studies were performed using Graphpad Instat software (GraphPad Instat version 3.0b for Mac;

Fig. 3 The long connection tube allows the operator's hand to be out of the X-ray beam during injection

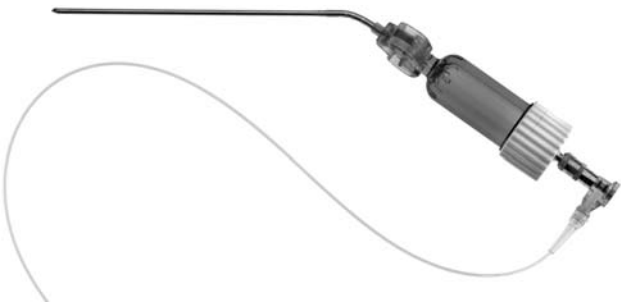

Fig. 4 The reservoir containing high-viscosity PMMA is Luer-lock connected to the vertebroplasty needle and to the saline-filled screw injector

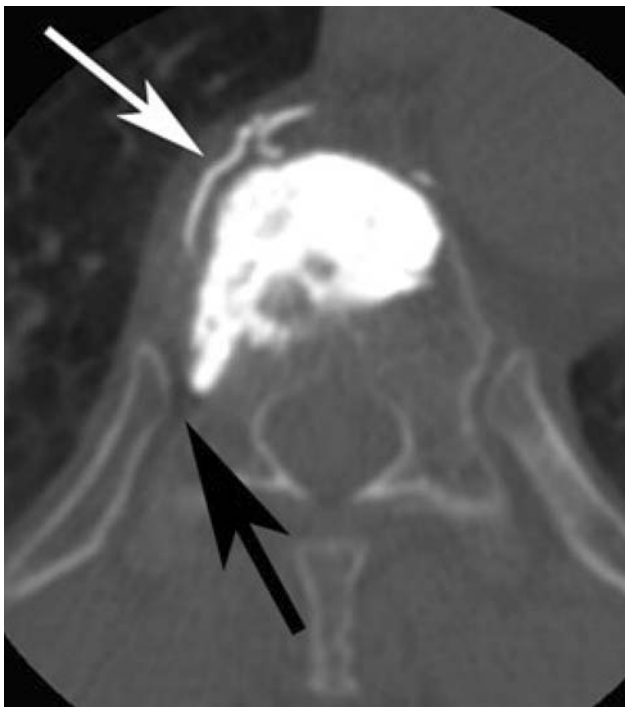

Fig. 5 Postprocedural CT scan precisely detected small venous leakages (white arrow) as well as the correct needle pathway (black arrow)

GraphPad Software, San Diego, CA, USA; http://www.graphpad.com) [41].

Results

Clinical Outcome

PV was feasible in all patients without any early or delayed complications, achieving a good clinical outcome; in Group A the mean VAS score before PV of 8.4 ± 1.4 improved significantly, to a mean of 0.5 ± 0.7 at the end point after the procedure (two-tailed $p < 0.0001$, Wilcoxon signed rank test). In Group B the mean VAS of 8.3 ± 1.5 preprocedure dropped to 0.9 ± 0.9 postprocedure ($p < 0.0001$). Patients' quality of life, evaluated by the Oswestry Disability Self-Evaluation Questionnaire, also improved ($p < 0.0001$) significantly in the two groups, from a mean index of 59.7% ± 18.0 to 8.1% ± 5.6% (Group A) and from 67.7% ± 12.5% to 8.7% ± 7.6% (Group B). No differences in clinical outcome were noted between the two groups ($p = 0.05$, paired t-test).

Two patients in Group A (6.6%) and one patient in Group B (3.3%) suffering from osteoporosis (nos. 7 and 15, Table 1; no. 10, Table 2) reported a new fracture within 2 months of the first procedure on the contiguous above vertebra; they were all successfully retreated without any complication. No statistical difference in new fracture rate was demonstrated between the groups.

PMMA Leakages

No symptomatic cement leakages occurred in the two groups. In Group A, a minimal asymptomatic venous leak was detected on postprocedural CT in 6 of 30 patients (20%) and in 8 of 98 treated vertebrae (8.2%). In two of six patients fluoroscopy did not detect the venous leakage that CT showed after the procedure due to the high sensibility of CT as previously demonstrated [24, 42]. PMMA leakage into the disc occurred in 6 of 30 patients (20%) and on 6 of 98 treated levels (6.1%); they were all demonstrated on procedural fluoroscopy. Considering the different pathology, 4 of 23 osteoporotic patients (17.4%) reported a venous leak in 6 of 77 (7.8%) treated vertebrae, whereas a venous leak occurred in 2 of 6 (33.3%) malignant patients on 2 of 19 (10.5%) levels. Two symptomatic angiomas, treated in the same patient, did not show any leakage. A discoidal leak was observed in 5 of 23 osteoporotic patients (21.7%) in 5 of 77 vertebrae (6.5%) and in 1 of 6 patients (16.6%) with malignancy in 1 of 19 (5.3%) vertebrae. Cement vertebral perfusion assumed a spherical configuration in osteoporosis (Fig. 6), whereas deposition was more diffuse and irregular in metastases (Fig. 7).

In Group B, postprocedural CT demonstrated an asymptomatic venous leak in 24 of 30 patients (80%) and on 38 of 92 treated vertebrae (41.3%). PMMA into the disc was detected in 11 of 30 patients (36.6%) and 12 of 92 vertebrae (13%). Nineteen of 23 osteoporotic patients (82.6%) had a venous leak on 30 of 71 (42.3%) levels; a venous leak occurred in 5 of 6 (83.3%) malignant patients on 8 on 19 (42.1%) levels, whereas no leak was observed in the two symptomatic angiomas. A leak occurred into the disc in 8 of 23 osteoporotic patients (34.8%) in 9 of 71 vertebrae (12.7%) and in 3 of 6 cancer patients (50%) in 3 of 19 (15.8%) vertebrae. In one osteoporotic patient in this group, CT showed small asymptomatic PMMA emboli in the left lung.

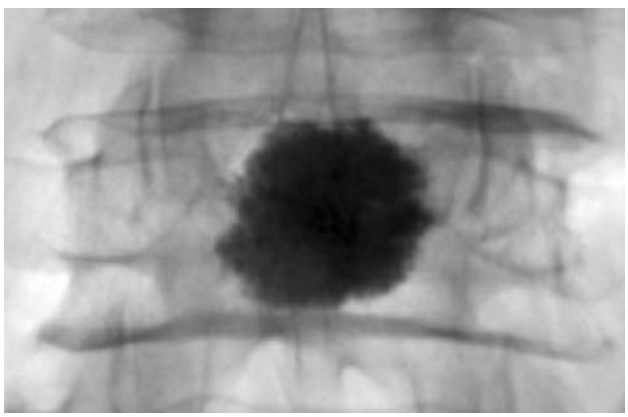

Fig. 6 High-viscosity PMMA perfusion assumed a spherical configuration in the osteoporotic-treated vertebra

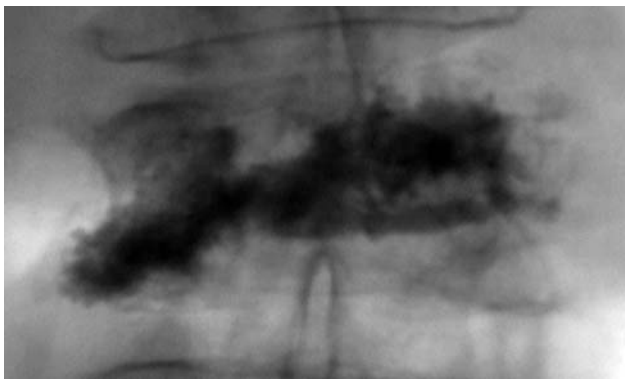

Fig. 7 In malignant vertebral fracture, high-viscosity PMMA perfusion was more diffuse and irregular

Data Analysis

Comparison of data showed a statistically highly significant difference ($p < 0.0001$, Fisher's exact test) of venous leakages between patients treated with high-viscosity cement (Group A) and patients in Group B. On the other hand, this difference was not significant concerning leakages into the disc ($p = 0.1374$) (Table 3).

Venous leakages detected in osteoporotic vertebrae in Group A were also compared to other published series (Table 4) where postprocedural CT was carried out to assess vertebral PMMA perfusion and leak-related complications [23, 24, 30, 42–44]. The Confidence bone cement and delivery system showed a statistically significant difference (p value from 0.0303 to <0.0001, Fisher's exact test) compared to all previous studies concerning venous leakages; this difference is statistically significant ($p = 0.0303$) even if PV, performed with standard low-viscosity bone cement injection, is performed by preinjection gelfoam embolization [30]. If leakage into the disc is analyzed, the high-viscosity cement system showed a statistically significant reduction ($p = 0.0069$) from that reported by Jung and collaborators [44] but did not demonstrate any statistically significant differences from PV performed with standard bone cement by Bhatia et al [30] and Perez-Higueras and coworkers [43] ($p = 0.2126$ and $p = 1.0000$, respectively).

Discussion

This study investigated whether PV is feasible and whether the rate of cement leakage can be reduced by means of a high-viscosity, specifically designed, bone cement. In the majority of patients (23/30; 76.6%) treated with high-viscosity PMMA, the underlying cause was osteoporosis and the demographic characteristics report elderly patients (71.3 ± 7.8 years), with female prevalence (24/30; 80%);

Table 3 CT-detected PMMA leakages: comparison between Group A and Group B

Group	No. of pts	Treated vertebrae	Venous leaks	Fisher's exact test[a]	Discoidal leaks	Fisher's exact test[a]
A: high-viscosity PMMA	30	98	8/98 (8.2%)	$p < 0.0001$ (RR = 0.20)	6/98 (6.1%)	$p = 0.1374$ (NS)
B: standard PMMA	30	92	38/92 (41.3%)		12/92 (13.0%)	

Note: PMMA, polymethylmethacrylate; pts, patients; RR, relative risk; NS, nonsignificant

[a] Two-tailed p-value

Table 4 CT-detected PMMA leakages in osteoporotic patients: comparison between current series and data from the literature

Study [ref. no.]	No. of pts	Treated vertebrae	Venous leaks	Fisher's exact test[a]	Discoidal leaks	Fisher's exact test[a]	Complications
Current series: Group A (high-viscosity PMMA)	23	77	6/77 (7.8%)		5/77 (6.5%)		None
Bhatia et al. (2006) [30]	25	49	11/49 (22.4%)	$p = 0.0303$	7/49 (14.2%)	$p = 0.2126$ (NS)	None
Jung et al. (2006) [44]	59	85	26/85 (30.5%)	$p = 0.0003$	19/85 (22.3%)	$p = 0.0069$	None
Schmidt et al. (2005) [24]	21	29	26/29 (89.6%)	$p < 0.0001$	NR	NA	2 surgical decompression
Yeom et al. (2003) [42]	49	76	58/76 (76.3%)	$p < 0.0001$	NR	NA	28 leakages into the spinal canal
Perez-Higueras et al. (2002) [43]	13	27	16/27 (59.2%)	$p < 0.0001$	2/27 (7.4%)	$p = 1.0000$ (NS)	2 neuritis
Cortet et al. (1999) [23]	16	20	13/20 (65.0%)	$p < 0.0001$	NR	NA	None

Note: PMMA, polymethylmethacrylate; pts, patients; NR, not reported; NA, not applicable; NS, nonsignificant

[a] Two-tailed p-value

the same distribution is applicable to control Group B. The reason for testing the new high-viscosity cement was that such demographic characteristics are also found in most of the series reported in the literature, and to date, painful osteoporotic vertebral collapse not responding to conservative therapy is the main indication for PV [23, 26, 28, 45–47]. The good clinical outcome achieved by this minimally invasive procedure and the wide distribution of digital fluoroscopy and CT are increasing PV performance worldwide. These have led to PV's being employed even at hospitals where the procedure is not performed daily. Although PV is generally safe, even well-trained physicians [9, 45–49] and high-quality imaging cannot prevent PMMA leakages, thus the patient is virtually exposed to a risk of serious complication. Furthermore, PV can be very dangerous, independent of the cement used, if proper technique is not applied [10, 12, 19, 25] or patient selection is inadequate [5]. As a consequence of these dramatic reports, the risk of potential leakage and their complications often prevents clinicians from offering the procedure to their patients.

Bhatia and coworkers [30] recently demonstrated that significant PMMA leakage reduction can be achieved by embolization with gelfoam preinjection; this is an easy and well-known method for interventional radiologists but it can be unfamiliar to orthopedics, neurosurgeons, and anesthesiologists who also perform PV; on the other hand, the high-viscosity PMMA system does not substantially change the technique of PV. The link between the viscosity of the bone cement and leakage was recently demonstrated by Baroud and coworkers, however, they concluded that delivery of high-viscosity cement may approach or exceed the human physical limit of injection forces [35]. However, the hydraulic cement delivery system enables the introduction of constant high-viscosity cement immediately after mixing the cement components during a 8- to 10-min injection. Use of a system with high-viscosity PMMA demonstrates, in our experience, a highly significant reduction of extravasation into the vein and, consequently, into the systemic venous circulation. This difference was demonstrated to occur in comparison to standard PV with low-viscosity vertebroplasty-designed bone cement ($p < 0.001$) but also when gelfoam embolization preceded standard PV ($p = 0.0303$). Although all detected leakages were asymptomatic and high-viscosity PMMA did not change patients' clinical condition at all compared to low-viscosity PMMA, in our opinion, a reduced PMMA leakage rate makes PV a safer procedure.

Finally, our data show that a relative (statistically not significant) reduction in the rate of leakages into the disc was achieved by use of high-viscosity PMMA. In an osteoporotic vertebral fracture the leak into the disc more frequently occurs through an intravertebral vacuum cleft or through a perforation of the endplate created by the needle tip [50]. Although this event is not related to serious complications and does not affect the clinical outcome [50], it could increase the risk of a new fracture in the contiguous vertebra [51]; in our series two patients in Group A and one patient in Group B who reported a new vertebral fracture did not show any leak into the disc during the first treatment. Our results did not show a statistically significant difference between the two groups ($p = 0.1374$) or from results reported by Bhatia and coworkers [30] ($p = 0.2126$) and Perez-Higueras et al [43] ($p = 1.000$). Jung et al [44] reported a rate of 22.3% discoidal leak in 85 osteoporotic treated levels that are more similar to the 77 vertebrae treated in our series with the high-viscosity system, where the rate of 6.5% shows a significant difference ($p = 0.0069$).

As application of the high-viscosity PMMA system does not substantially change the technique of PV as it is routinely performed by different physicians, in our opinion, it should be considered to reduce the rate of asymptomatic leakages and, consequently, the risk of complications related to cement extravasation. If PV is performed at centers where it is not part of the daily routine, the Confidence system could avoid further complications, usually due to limited experience of the operator in correct evaluation of the consistency of standard PMMA before injection and in manual syringe PMMA injection.

A limitation of this study could be that the same experienced operator used to avoid complications even with low-viscosity cement tested the high-viscosity PMMA; only a multicenter randomized study can assess whether physicians with different degrees of experience can also achieve this reduction in leakages.

Conclusion

This study has demonstrated that utilization of high-viscosity PMMA (the Confidence system) during routine PV is safe and feasible and can significantly reduce venous cement leakage without any substantial changes in the vertebroplasty technique. Serious complications reported in the literature are related to PMMA leakage in most cases; we think that the application of high-viscosity bone cement can reduce the complication rate, improving the safety of the PV technique, and consequently, even more referring physicians will propose this procedure to patients with vertebral collapses not responding to conservative therapy whose quality of life is poor.

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