Diagn Interv Radiol 2018; 24:158–165

INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

CT fluoroscopy-guided percutaneous osteoplasty with or without radiofrequency ablation in the treatment of painful extraspinal and spinal bone metastases: technical outcome and complications in 29 patients

Caroline A. Burgard
Julien Dinkel
Frederik Strobl
Philipp M. Paprottka
Nicolai Schramm
Maximilian Reiser
Christoph G. Trumm

PURPOSE
We aimed to assess the safety and technical outcome of computed tomography (CT) fluoroscopy-guided osteoplasty with or without prior percutaneous radiofrequency ablation (RFA) in patients with painful osteolyses.

METHODS
We performed a retrospective analysis of 29 patients with painful extraspinal and spinal osteolyses (16 women, 13 men; 63.1±14.4 years) who underwent CT fluoroscopy-guided osteoplasty (10-20 mAs tube current) with or without RFA (26 and 14 lesions, respectively), in 33 consecutive procedures from 2002 to 2016. Technical success was defined as at least one complete RFA cycle and subsequent polymethyl metacrylate (PMMA) bone cement injection covering ≥75% of longest diameter of extraspinal osteolysis on axial plane or of distance between vertebral endplates. Procedure-related complications within 30 days and dose-length-product (DLP) were also evaluated.

RESULTS
Osteolyses were located in the pelvis (acetabulum, n=10; iliac bone, n=4), spine (thoracic, n=6; lumbar, n=5; sacral, n=8), long bones (femur, n=3; tibia, n=1), sternum (n=2) and glenoid (n=1). Mean size of the treated osteolysis was 4.0±1.2 cm (range, 1.9–6.9 cm). Of 40 osteolyses, 31 (77.5%) abutted neighboring risk structures (spinal canal or neuroforamen, n=18; neighboring joint, n=11; other, n=8). Mean number of RFA electrode positions and complete ablation cycles was 1.5±0.9 and 2.1±1.7, respectively. Mean PMMA filling volume was 7.7±5.7 mL (range, 2–30 mL). Small asymptomatic PMMA leakages were observed in 15 lesions (37.5%). Mean total DLP was 850±653 mGy*cm. Six minor complications were observed, without any major complications.

CONCLUSION
CT fluoroscopy-guided percutaneous osteoplasty with or without concomitant RFA for the treatment of painful extraspinal and spinal osteolyses can be performed with a low complication rate and high technical success.

In advanced cancer, bone is a common site of metastases characterized by substantial skeletal morbidity, which itself is associated with a reduced overall survival (1). Up to 70% of patients with breast, lung, kidney, thyroid, and prostate cancer develop bone metastases, while only 20% of patients with gastrointestinal cancers are affected (2). About half of the patients with skeletal metastases suffer from complications such as excruciating pain, pathologic fractures or spinal cord compression requiring administration of opioids, surgical decompression or radiation therapy (2). Extensive surgery such as posterior vertebral stabilization or resection with implantation of a cage or tumor prosthesis is often associated with a comparatively long recovery period and is therefore reserved for patients with a longer life expectancy (3). Conversely, patients with a multifocal skeletal affection and limited life expectancy should preferentially undergo non- or minimally invasive therapy regimens.

Image-guided cementoplasty is a palliative interventional technique that can achieve a pain reduction in 80% to 97% of cases irrespective of the treated bone site (4–7). Moreover, a limited consolidation effect can be reached, especially in vertebral and pelvic metastases (8). A limited number of clinical studies evaluated the combination of cementoplasty

From the Institute for Clinical Radiology (C.A.B. ✉ *caroline.burgard@med.lmu.de*), University Hospitals Munich – Campus Großhadern, München, Germany.

Received 9 September 2017; revision requested 19 October 2017; last revision received 18 February 2018; accepted 19 February 2018.

DOI 10.5152/dir.2018.17265

You may cite this article as: Burgard CA, Dinkel J, Strobl F, et al. CT fluoroscopy-guided percutaneous osteoplasty with or without radiofrequency ablation in the treatment of painful extraspinal and spinal bone metastases: technical outcome and complications in 29 patients. Diagn Interv Radiol 2018; 24:158–165.

with thermal ablation procedures such as radiofrequency (9–18), microwave (19, 20) or cryoablation (17, 21–24), as well as with embolization (24, 25).

Mono- or biplane fluoroscopy is widely established for imaging guidance (15, 26, 27). Some interventional units employ a combination of a computed tomography (CT) scanner and a mobile C-arm, allowing for exact needle positioning using CT image to view the cross-sectional area of the osteolysis and adjacent soft tissues, and C-arm fluoroscopy to view needle inclination and cement extravasation (10, 21). Other authors stated successful needle placement, or the combination of needle placement for thermal ablation and consecutive cementoplasty under conventional sequential CT (12, 28), CT fluoroscopy (9, 29), or cone-beam CT guidance (25).

The purpose of this retrospective single-center study was to report the technical outcome and safety of CT fluoroscopy-guided osteoplasty with or without prior percutaneous radiofrequency ablation (RFA) in patients with painful extraspinal and spinal osteolyses.

Table 1. Population characteristics of 29 patients who underwent CT fluoroscopy-guided cementoplasty with or without prior radiofrequency ablation

Characteristics	
Age (years), mean±SD	63.1±14.4 (25–85)
Sex, n (%)	
Female	16 (55.2)
Male	13 (44.8)
Tumor entity, n (%)	
Multiple myeloma	7 (24.1)
Breast cancer	5 (17.4)
Renal cell carcinoma	5 (17.4)
Follicular thyroid cancer	4 (13.8)
Neuroendocrine cancer	2 (6.9)
Papillary thyroid cancer	1 (3.4)
Pancreatic cancer	1 (3.4)
Colorectal cancer	1 (3.4)
Sarcomatoid carcinoma	1 (3.4)
Cervical cancer	1 (3.4)
Carcinoma of unknown primary	1 (3.4)
Total	29 (100)
Localization of concomitant metastases*, n (%)	
Lung	11 (42.3)
Liver	5 (19.2)
Lymph node	5 (19.2)
Adrenal gland	2 (7.7)
Brain	2 (7.7)
Soft tissue	1 (3.8)
Total	26 (100)

*More than one affected organ region is possible in a patient.

Methods

This retrospective study involved 29 consecutive patients (16 women, 13 men; 63.1±14.4 years) who underwent osteoplasty with or without concomitant radiofrequency ablation (RFA) for the treatment of 40 painful extraspinal and spinal osteolyses due to metastatic disease (n=33) or multiple myeloma (n=7) (Table 1). All procedures performed in our study involving human participants were in accordance with the Helsinki declaration of 1964 and with the ethical standards of the institutional and/or national research committee and its later amendments or comparable ethical standards.

The interventional procedures were performed under low-milliampere (10–20 mA) CT fluoroscopy guidance in our institution from March 2002 to March 2016.

Our institutional ethics board did not require approval of this retrospective study regarding the review of patient charts. Data were collected and stored in compliance with local and national data protection laws and regulations. Informed consent by adult patients, or when applicable the patient's legal guardians, to undergo CT fluoroscopy-guided osteoplasty and RFA treatment had been obtained a minimum of 24 hours prior to the intervention after detailed explanation of the planned therapeutic intervention, the various available alternative therapeutic options (analgesic therapy, radiation therapy, surgery) and potential complications.

Study population

The patients were referred by the local oncology or tumor orthopedic departments. Clinical indication for osteoplasty with or without concomitant RFA was regularly confirmed by an interdisciplinary team of radiation oncologists, medical oncologists, interventional radiologists and spine surgeons prior to the intervention. Due to the long-standing history of metastatic disease or multiple myeloma in the majority of cases, biopsy of the treated osteolytic region was only performed in 3 of 40 lesions (7.5%).

Prior to the treatment all patients had been extensively evaluated within a multidisciplinary tumor board. Additionally, every patient underwent physical exam-

Main points

- In advanced cancer, bone is a common site of metastases characterized by substantial skeletal morbidity.
- About half of the patients with skeletal metastases suffer from complications such as excruciating pain, pathologic fractures or spinal cord compression requiring palliative therapy.
- The objective of this retrospective single-center study was to report the technical outcome and safety of CT fluoroscopy-guided osteoplasty with or without prior percutaneous radiofrequency ablation (RFA) in 29 patients with painful extraspinal and spinal osteolyses.
- CT fluoroscopy-guided percutaneous osteoplasty with or without concomitant RFA can be used for treatment of painful extraspinal and spinal osteolyses, with high technical success and low complication rates.

ination by the referring clinician in order to verify the painful extraspinal osteolytic lesion or vertebral level(s).

Clinical inclusion criteria for osteoplasty and vertebroplasty in accordance with the Quality Improvement Guidelines of the Cardiovascular and Interventional Society of Europe (CIRSE) (30, 31) and Society of Interventional Radiology (SIR) (32, 33) were: a typical history of severe pain due to malignant extraspinal and spinal osteolyses, with or without fracture, refractory to analgesic therapy alone, or the combination of analgesics and chemotherapy and/or radiation therapy. Technical inclusion criteria with respect to the osteoplasty and RFA procedure were: minimally invasive accessibility of the osteolysis via the RFA electrode and cement injection cannula, and the safety of thermal ablation respecting neighboring neurovascular and joint structures. Exclusion criteria were consistent with the general exclusion criteria for CT-guided interventions as well as the Quality Improvement Guidelines of the CIRSE and SIR (30–33).

The 29 patients included 22 subjects with osteolytic metastases (renal cell cancer [n=5], breast cancer, [n=5], follicular thyroid cancer [n=4], neuroendocrine cancer, [n=2], papillary thyroid cancer [n=1], pancreatic cancer, [n=1], cervical cancer [n=1], sarcomatoid carcinoma [n=1], colorectal cancer [n=1] and carcinoma of unknown primary [n=1]) and 7 subjects with multiple myeloma (n=7) (Table 1). Besides osteolytic bone involvement, metastatic disease to other organs at the time of the intervention was present in 13 of 29 patients (44.8%; pulmonary, n=11; hepatic, n=5; lymph nodes, n=5; cerebral, n=2; adrenal, n=2, soft tissue, n=1), with combination of synchronous metastases to several organs being possible.

Periprocedural imaging and image-guidance

Before the intervention, previous cross-sectional images such as CT, magnetic resonance imaging (MRI) or positron emission tomography-computed tomography (PET-CT) not older than 2 weeks, were analyzed in all patients to confirm the indication for the procedure. In addition, inhouse MRI (sagittal T1-, T2-weighted spin-echo and STIR sequences) was performed in all lesions in order to verify the level of malignant vertebral involvement with or without fracture, and to assess the tumoral bone marrow involvement and extraosseous tumor extension (34).

All procedures were performed using either 1-slice (Somatom Plus 4, Siemens), 4-slice (Somatom Sensation 4, Siemens), 16-slice (Somatom Sensation 16, Siemens), 64-slice (Somatom Sensation 64, Siemens) or 128-slice (Somatom Definition AS+; Somatom Definition Edge, Siemens) CT scanner with CT fluoroscopy (CARE Vision CT®, Siemens) capability.

Every patient underwent a pre- and postprocedure CT scan of the affected extraspinal bone region or the involved spine level (including at least 2 vertebral bodies above and below the treated vertebral level), respectively. The CT scan included 3 mm slices in axial reconstruction, as well as coronal and sagittal multiplanar reconstructions, to visualize the extent of bone destruction and presence of pathologic fracture, to detect osteolytic cortical / posterior wall involvement, and to plan the access path of the needle for osteoplasty. A postprocedure CT scan was performed to visualize polymethyl metacrylate (PMMA) distribution within the osteolysis and local extraosseous cement leaks.

The RFA and osteoplasty procedure including RFA electrode and cement injection cannula placement with subsequent PMMA injection were performed under intermittent quick-check CT fluoroscopic acquisitions, using low-milliampere CT fluoroscopy at a tube current-exposure time product of 10 to 20 mAs.

Precautions with respect to radiation protection of the operator during CT fluoroscopy included thyroid shields, aprons and eye-glasses of 0.5 mm lead equivalent. To reduce scattered radiation, an additional shield was put onto the lower half of the patient before sterile draping. With respect to radiation protection of the operator's hand, angular beam modulation (Hand Care®, Siemens) was activated during CT fluoroscopy, so that the radiation exposure is switched off between the ten and two o'clock positions of the x-ray tube (35).

Preprocedure local treatments

Local therapy prior to the osteoplasty and RFA procedure included radiotherapy in 6 cases, particle embolization in 3 cases, screw placement for stabilization in one case, and radiosurgery with Cyberknife® (Accuray) in 1 case.

Procedure

All procedures were performed by one of the board-certified authors under local anesthesia (9/33; 27.3%), conscious sedation (18/33; 54.5%) with piritramide (Dipidolor, Janssen Cilag) and midazolam (Dormicum, Roche Pharma) under continuous pulse oximetric monitoring, or general anesthesia (6/33; 18.2%). Shortly before the intervention, all patients received 2 g intravenous mezlocillin.

Patients were positioned on the CT table in prone (19/33), supine (11/33), left (2/33) or right (1/33) lateral decubitus positions depending on the localization of the osteolysis. Generally, the shortest access path through the bone was chosen to treat the osteolysis. In case this approach was regarded as not feasible or unsafe with respect to neighboring joint or neurovascular structures, an access path from the opposite cortical bone was preferred.

Local anesthesia with 10 to 20 mL of 2% Mepivacainhydrochloride (Scandicain®, AstraZeneca GmbH) was applied after sterile draping and disinfection of the skin overlying the planned needle entry point.

After performing a small skin incision, a vertebroplasty cannula (OptiMed Medical Devices) was inserted to create an access canal at the planned access site using a surgical hammer. The vertebroplasty needles (OptiMed Medical Devices) had diameters of 10, 13 and 15 Gauge with a length of 15 or 10 cm. In the minority of cases bone biopsy was primarily taken using a 14 or 13 Gauge bone biopsy cannula (Somatex Spi-Cut®). After successful drilling, the RFA electrode was inserted into the created access canal under CT fluoroscopy.

In 26 of 40 osteolyses (65%), RFA was performed prior to bone cement injection: 14 procedures (53.8%) were performed with a monopolar electrode with nine (RITA Starburst XL) deployable tines and a maximum diameter of 5 cm (Angiodynamics Inc.); 11 procedures (42.3%) were performed with a monopolar, multitined expandable electrode (LeVeen) with an umbrella diameter of 2 or 3 cm (Boston Scientific Corporation); and one procedure (3.9%) was performed with an internally cooled needle-shaped Cool Tip electrode (Tyco Healthcare). The RFA procedure was then carried out in a standardized manner according to the individual manufacturer's recommendations. In order to cover as much tissue of the osteolysis as possible, more than one RFA electrode position was necessary in 7 of 26 procedures (26.9%) (1 position, n=19; 2 positions, n=3; 3 positions, n=3; 4 positions, n=4).

Depending on the RFA system used, complete ablation was defined either by reaching a mean target temperature of 95ºC (average of five thermocouples within the array) maintained for at least 15 minutes, or by reaching a significant increase of impedance (so-called "roll-off") twice, corresponding to a complete coagulation necrosis. No thermocouple was used during RFA to monitor the temperature around vulnerable structures.

After completion of the RFA procedure, the electrode was withdrawn and the vertebroplasty cannula inserted with the surgical hammer. Consecutively, PMMA bone cement was prepared. Four types of PMMA were used during the study period: a) Osteopal V, b) Osteopal 40 and c) Biomet Bone Cement V (Biomet Deutschland GmbH) and d) CementoFixx-M (OptiMed Medical Devices). High viscosity bone cement was applied in procedures after 2011. In order to reduce the risk of extravertebral PMMA leakage (for PMMA types a, b, and c), cement injection with a 10 mL pressure syringe (Optimed Gangi Cemento-Re or Cemento-MP Gun; OptiMed Medical Devices) was started during the pasty phase of the cement. The bone cement was slowly injected under continuous CT fluoroscopy, sequential withdrawing of the needle and incremental table movement in order to assess the cement distribution within the extraspinal osteolysis or vertebra, respectively. If initial cement extravasation occurred, the injection was immediately stopped by depressurizing the application screw. In case of a persisting leakage, the needle tip was repositioned by turning the handle bar in 90° steps or sequentially withdrawing the needle.

Technical success in terms of completion of the intended cement injection was reached if the cement deposit covered at least 75% of the longest diameter of the extraspinal osteolysis in the axial plane or the distance between both endplates of the vertebra, respectively.

After the intervention, a CT scan of the treated osteolysis (including multiplanar reconstructions) and sterile wound draping were performed, and all patients were sent to the anesthetic recovery room or directly back to the ward for clinical monitoring for 24 hours.

Technical outcome

Two interventional radiologists (C.G.T. and JD, - each with more than 10 years of experience in CT-guided intervention) in consensus performed a retrospective analysis in PACS database of the pre- and post-procedure CT scans and the CT fluoroscopic datasets of all 33 consecutive osteoplasty procedures with or without concomitant RFA. The analysis comprised a) the underlying degree of osteolytic destruction (maximum diameter of osteolysis), b) the ratio of posterior wall involvement (0%, 1%–25%, 26%–50%, 51%–75%, 76%–100%), c) effect on neighboring risk structures (e.g., discontinuation of cortical bone affecting neurovascular, joint and other soft tissue structures), d) the involvement of extraosseous soft tissue, e) the degree of cement filling of the osteolysis (largest diameter of PMMA deposit compared with largest diameter of the osteolysis) and f) the presence and types of cement leakage. Complications of the cementoplasty and RFA procedures were classified according to SIR Standards of Practice Committee classification of complications by outcome.

Patient radiation dose

In analogy to Kloeckner et al. (36), CT dosimetry was performed for all procedures using the dose-length product (DLP [mGy*cm]), documented by the CT unit as primary dosimetric quantity data. We evaluated the DLP of the preprocedure planning CT scan, the DLP of the sum of all intraprocedure CT fluoroscopic acquisitions and the DLP of the postprocedure control CT scan if performed.

Statistical analysis

For data collection and statistical analysis, the software SPSS Version 24.0 (IBM Corp.) was used. Descriptive statistics are provided as counts and percentages for categorical variables, and mean, standard deviation (SD), median and range for numeric variables.

Results

Total number of treated osteolytic lesions was 40, located in the pelvis (acetabulum, n=10; iliac bone, n=4), spine (thoracic, n=6; lumbar, n=5; sacral, n=8), long bones (femur, n=3; tibia, n=1), sternum (n=2) (Fig. 1) and glenoid (n=1) (Table 2). More than one osteolysis was present in 23 of 29 treated patients (79.3%) at the time of the intervention.

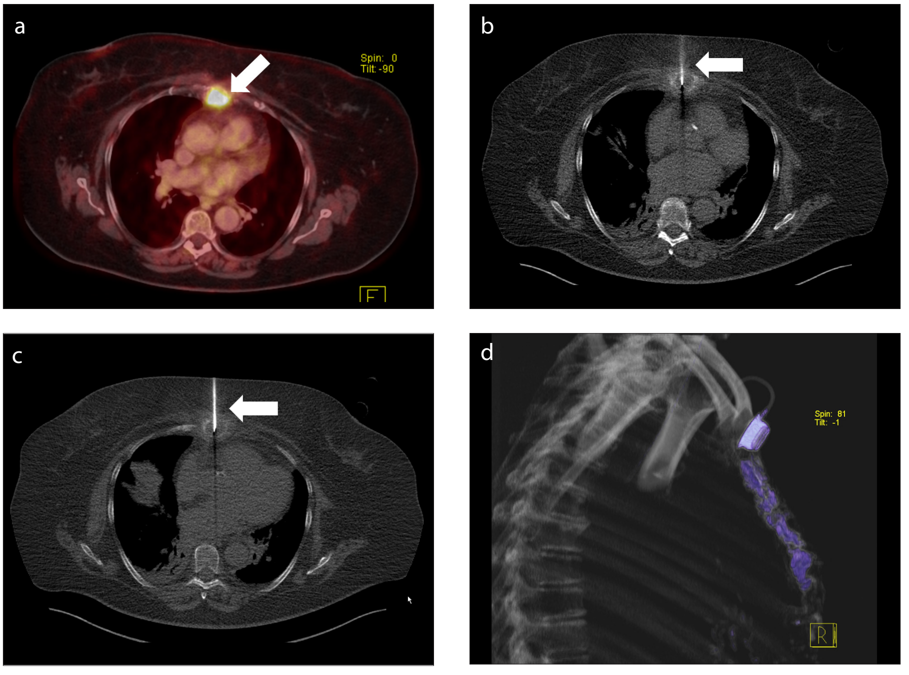

Figure 1. a–d. A 75-year-old female patient with a history of colorectal cancer who developed a painful, histologically proven isolated osteolytic metastasis of the sternum, refractory to the preceding stereotactic radiation therapy (5x5 Gy). Due to patient's obesity, resectability had been ruled out by the thoracic surgery unit before the intervention. The patient underwent two consecutive treatment sessions under general anesthesia with combined RFA (two needle positions per session) and cementoplasty (total high viscosity PMMA cement volume: 12 mL). Panel **(a)** shows FDG-PET/CT acquired before the intervention with a hypermetabolism (maximum standard uptake value: 16) of the osteolytic body of the sternum *(arrow)*. Intraprocedure CT fluoroscopic image **(b)** (20 mA, 120 kV) shows the radiofrequency probe (Le Veen; Boston Scientific; 2 cm umbrella diameter; *arrow)* within the osteolysis. Intraprocedure CT fluoroscopic image **(c)** shows vertebroplasty cannula (Optimed; 13 Gauge; *arrow*) before PMMA cement injection. CT scan volume rendering image **(d)** after second combined RFA/cementoplasty treatment session shows a continuous PMMA deposit covering the majority of the sternal body.

Table 2. Characteristics of osteolyses, cementoplasty and RFA procedures

	n (%)	n of affected patients*
Localization of osteolysis		
Acetabulum	10 (25)	8
Iliac bone	4 (10)	4
Thoracic spine	6 (15)	4
Lumbar spine	5 (12.5)	5
Sacral spine	8 (20)	7
Femur	3 (7.5)	3
Tibia	1 (2.5)	1
Sternum	2 (5)	1
Glenoid	1 (2.5)	1
Total	40 (100)	
Diameter of osteolysis (cm), mean±SD (range)	4.0±1.2 (1.9–6.9)	
Osteolyses abutting risk structures		
Neuroforamen	7 (22.5)	6
Spinal canal	5 (16.1)	5
Joint	11 (35.6)	10
Other soft tissues	8 (25.8)	6
Total	31 (100)	
Ratio of posterior vertebral wall involvement		
0%–25%	10 (52.6)	9
26%–50%	4 (21.1)	4
51%–75%	4 (21.1)	3
76%–100%	1 (5.2)	1
Total	19 (100)	
Osteolyses with extraosseous soft tissue component		
Yes	11 (27.5)	8
No	29 (72.5)	24
Total	40 (100)	
RFA electrode / system		
RITA Starburst XL / Angiodynamics	14 (53.8)	11
LeVeen / Boston Scientific	11 (42.3)	10
Cool-tip / Tyco	1 (3.9)	1
Total	26 (100)	
RFA electrode positions, mean±SD	1.5±0.9	
Minimum	1	
Maximum	4	
RFA ablation cycles, mean±SD	2.1±1.7	
Minimum	1	
Maximum	8	

RFA, radiofrequency ablation.
*More than one treated localization possible in one patient.

Mean size of the treated osteolyses (n=40) was 4.0±1.2 cm (range, 1.9–6.9 cm). This corresponds to a mean size of the osteolyses (n=26) treated with both RFA and consecutive cementoplasty of 4.2±1.1 cm (range, 2.2–6.9 cm), and a mean size of the osteolyses (n=14) treated with cementoplasty only of 3.6±1.2 cm (range, 1.9–6.4 cm).

Thirty-one osteolyses (77.5%) abutted neighboring risk structures (spinal canal or neuroforamen, n=18; neighboring joint, n=11; other, n=8) (Table 2). Five osteolyses (12.5%) were pretreated with radiotherapy, 3 (7.5%) with particle embolization, 1 (2.5%) with cyberknife therapy, 2 (5%) with radioiodine therapy and 1 (2.5%) with screw osteosynthesis.

Mean number of RFA electrode positions and complete ablation cycles was 1.5±0.9 and 2.1±1.7, respectively. Mean PMMA filling volume was 7.7±5.7 mL (range, 2–30 mL) (Table 3). This corresponds to a mean PMMA filling volume of the osteolyses treated with both RFA and consecutive cementoplasty of 7.9±4.4 mL (range, 2–16 mL) and to a mean PMMA filling volume of the osteolyses treated with cementoplasty only of 7.4±7.9 mL (range, 2–30 mL).

Mean degree of PMMA filling of osteolysis was 83.2%±18.4% (Table 3).

Small asymptomatic PMMA leakages were observed in 15 of 40 lesions (37.5%), comprising 13 cortical and 2 vascular leakages (1 segmental and 1 epidural vein). Ratio of intraspinal/foraminal and intraarticular PMMA leakages in osteolyses abutting the spinal canal/neuroforamen and neighboring joint can be found in Table 3.

Mean total DLP was 850±653 mGy*cm (range, 173–2918 mGy*cm). This comprised a mean pre-, intra- and postprocedure DLP of 401±280 mGy*cm, 399±292 mGy*cm, and 401±285 mGy*cm, respectively (Table 4).

No major and 6 minor (local hematoma, n=2; transient pain exacerbation, n=2; drop of oxygen saturation, n=1; temporary increase of the preexisting paresis of left leg, n=1) complications were observed.

One patient with hepatocellular cancer and painful osteolytic metastasis of the first lumbar vertebra developed a temporary increase of a preexisting paresis of the left leg after combined RFA and cementoplasty (Fig. 2). MRI of the lumbar spine showed a moderate contact of the L1 nerve root to the extravertebral tumor component, successfully managed conservatively.

Discussion

After lung and liver, osseous metastases, particularly osteolytic bone metastases, are among the most common types of metastases to occur in advanced cancer, and the

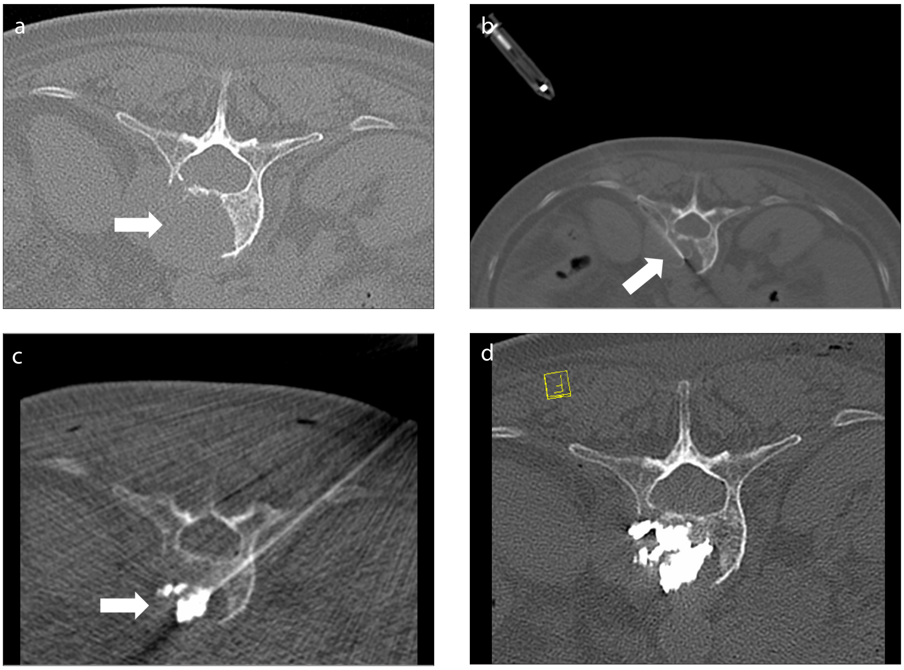

Figure 2. a–d. A 74-year-old woman with hepatocellular carcinoma and a painful osteolytic metastasis of the first lumbar vertebra, undergoing combined RFA (one needle position) and cementoplasty (total high viscosity PMMA cement volume: 4.5 mL) under general anesthesia. After the procedure the patient described a temporary increase of the preexisting paresis of the left leg. MRI of the lumbar spine revealed a moderate contact of the L1 nerve root to the extravertebral tumor component, successfully managed conservatively. Preprocedure CT scan **(a)** shows a 3.5 cm osteolysis of L1 *(arrow)* involving the left paravertebral psoas muscle and 2/3 of the posterior wall. Intraprocedure CT fluoroscopic image **(b)** (10 mA, 120 kV) shows the radiofrequency probe (Le Veen; Boston Scientific; 2 cm umbrella diameter; *arrow*) within the osteolysis. Intraprocedure CT fluoroscopic image **(c)** shows vertebroplasty cannula (Optimed; 13 Gauge; *arrow*) during PMMA cement injection. Postprocedure CT image **(d)** shows large PMMA deposit covering more than 80% of the osteolysis.

Table 3. Technical outcome parameters

PMMA filling volume (mL)	7.7±5.7 (2–30)
PMMA filling volume with prior RFA (mL)	7.9±4.4 (2–16)
PMMA filling volume without prior RFA (mL)	7.4±7.9 (2–30)
Diameter of PMMA deposit (cm)	3.3±1.3 (0–6.9)
Degree of PMMA filling of osteolysis	83.2%±18.4% (0–100)
Osteolyses with cement deposit covering ≥75% of the longest diameter	35 (87.5)
Osteolyses with PMMA leakage	
Yes	15 (37.5)
No	25 (62.5)
Type of PMMA leakage	
Cortical	13 (86.7)
Vascular	2 (13.3)
Presence of PMMA leakage in osteolyses abutting risk structures	
Neuroforamen	7 (22.6)
Spinal canal	5 (16.1)
Joint	11 (35.5)
Other soft tissues	8 (25.8)

Data are presented as n (%) or mean ± standard deviation (range).
PMMA, polymethyl metacrylate; RFA, radiofrequency ablation.

majority of the affected patients suffer from severe pain refractory to common treatment methods (2, 37). The majority (66%) of bone metastases are extraspinal, with the major proportion in the pelvis and sacrum (38, 39). After pain therapy, surgery, and chemotherapy, radiation is the treatment of choice in the palliation of bone malignancy; however, it has a late onset of therapeutic effects of up to 12–20 weeks (40). In addition, radiation therapy is not able to stabilize pathologic fractures or to ensure complete pain relief in some cases (41, 42). Thus, percutaneous osteoplasty may prove to be an effective treatment modality for reducing pain and stabilizing pathologic fractures, including vertebroplasty, which is the most established method in treatment of painful osteolyses in the spine. By internal trabecular stabilization, osteoplasty reduces activity of pain sensitive periosteal nerves and causes direct chemical toxicity and thermal necrosis of nerve endings (43, 44).

Especially for treatment of painful metastases in bones, osteoplasty is combined with radiofrequency ablation (RFA). Several studies have been published documenting up to 90%–100% pain relief in patients with painful osteolytic metastases in whom standard treatments had failed (45, 46). The analgesic effect of RFA is caused by local destruction of pain sensitive nerves, inducing tumor cell necrosis and therefore reducing the production of pain intensifying cytokines and growth factors like tumor necrosis factor alpha (47).

There exist only very few studies regarding the combination of osteoplasty and RFA in a single session in spinal osteolytic lesions, and there are even fewer reports about the combination of both therapies in extraspinal osteolytic bone metastases (10, 14–16, 18, 28, 40, 44, 47–51). To the best of our knowledge, our follow-up study of Hoffmann et al. (9) is one of the largest studies about treatment of spinal as well as extraspinal osteolytic metastases in the pelvic, sternal, and femoral bones by a combination of osteoplasty and RFA.

An additional benefit of combination of RFA and osteoplasty in treatment of painful bone metastases conducted in our study is the performance under local anesthesia, which means lower physical strain for palliative patients compared with surgical treatment under general anesthetic. Moreover, we used high viscosity PMMA, which is associated with a lower leakage rate, in our percutaneous osteoplasties.

Table 4. Patient radiation dose

	Preprocedure DLP (mGy cm)	Intraprocedure DLP (mGy cm)	Postprocedure DLP (mGy cm)	Total DLP (mGy cm)
Mean	401	399	401	850
Minimum	97	125	6	173
Maximum	1228	1128	1221	2918
Median	350	297.5	325	655
Standard deviation	280	292	285	653

DLP, dose length product; Gy, Gray.

Furthermore, the application of RFA before osteoplasty may have several advantages. Apart from reducing pain effectively, RFA may limit embolization events by thrombosis of intravertebral venous plexus (40, 51) and may reduce embolization of viable tumor cells by necrosing neoplastic cells within the bone marrow (47). Additionally, the combination of RFA and osteoplasty may cause a more homogeneous distribution of the cement because RFA is able to change the tumor's consistency by applying heat, which decreases the tumor's volume and destroys the cohesions between tumor cells (9).

In our study, which focused on the technical outcome, we could show that RFA in combination with osteoplasty is a minimally invasive and feasible method that is able to reduce pain in patients with spinal as well as extraspinal metastatic destruction. Despite the diverse localizations of the osseous metastases, only a few minor periprocedural complications occurred including minor PMMA leakages, local hematoma and transient pain exacerbation that had no further clinical consequences for the patient though some PMMA leakages occurred in osteolyses abutting risk structures like neuroforamina, spinal canal or joints.

This is consistent with various reports that quote the effectiveness and safety of RFA combined with osteoplasty for painful bone metastases (9, 10, 14–16, 47, 51, 52).

The interventional procedures in our study were performed using low-milliampere CT fluoroscopy in contrast to previous series (9, 10, 15, 47) which results in a low radiation exposure for the patient and for the performing interventional radiologist.

Clinical and technical results of the combination of RFA and osteoplasty for palliative treatment of painful spinal and extraspinal bone metastases have been previously reported, frequently in smaller or comparable numbers of patients. Tian et al. (15) reported on high technical success in combination of RFA and osteoplasty for treatment of painful extraspinal metastases in 38 patients, predominantly in osteolytic lesions of the pelvis. Clarencon et al. (14) evaluated 24 patients with spinal and extraspinal osteolytic metastases and Munk et al. (47) demonstrated effectiveness and safety of similar treatment in 19 patients in spine and pelvic bone. In our study, the technical results in 40 procedures in 29 patients were obtained with osteolytic metastases mainly in the spine and pelvic bone, as well as in rarer locations like the sternum.

Limitations of our study include the disadvantages of retrospective analysis of patient data. Second, no control group exists for comparing results of combination of percutaneous osteoplasty with radiofrequency ablation with each single therapy alone. Third, no pain scores were obtained from patients. Hence, we could not quantitatively monitor the therapeutic effect and were not able to guarantee for sure that patients had complete pain relief. Finally, the heterogeneous cohort of patient's diseases and therefore various tumor histopathologies, different locations of osteolyses and small sample size are additional limitations of our study.

In conclusion, our study underlined that CT fluoroscopy-guided percutaneous osteoplasty with or without radiofrequency ablation can be performed under local anesthesia with high technical success in treatment of painful extraspinal and spinal osteolytic bone metastases. Most frequently observed complications were small asymptomatic PMMA leakages, local hematoma or transient pain exacerbation, with the majority of them being self-limited. Despite the close localization of some osteolyses to risk structures like neuroforamina, spinal canal or joints, no clinical morbidities due to pulmonary cement embolism or cement leakages in surrounding tissue and no neurologic damages requiring surgical therapy were observed.

Conflict of interest disclosure

The authors declared no conflicts of interest.

References

1. Oster G, Lamerato L, Glass AG, et al. Natural history of skeletal-related events in patients with breast, lung, or prostate cancer and metastases to bone: a 15-year study in two large US health systems. Support Care Cancer 2013; 21:3279–3286. [CrossRef]
2. Jehn CF, Diel IJ, Overkamp F, et al. Management of metastatic bone disease algorithms for diagnostics and treatment. Anticancer Res 2016; 36:2631–2637.
3. Jacofsky DJ, Papagelopoulos PJ, Sim FH. Advances and challenges in the surgical treatment of metastatic bone disease. Clin Orthop Relat Res 2003 (415 Suppl):S14–8. [CrossRef]
4. Anselmetti GC. Osteoplasty: percutaneous bone cement injection beyond the spine. Semin Intervent Radiol 2010; 27:199–208. [CrossRef]
5. Cotten A, Dewatre F, Cortet B, et al. Percutaneous vertebroplasty for osteolytic metastases and myeloma: effects of the percentage of lesion filling and the leakage of methyl methacrylate at clinical follow-up. Radiology 1996; 200:525–530. [CrossRef]
6. Weill A, Chiras J, Simon JM, Rose M, Sola-Martinez T, Enkaoua E. Spinal metastases: indications for and results of percutaneous injection of acrylic surgical cement. Radiology 1996; 199:241–247. [CrossRef]
7. Alvarez L, Perez-Higueras A, Quinones D, Calvo E, Rossi RE. Vertebroplasty in the treatment of vertebral tumors: postprocedural outcome and quality of life. Eur Spine J 2003; 12:356–360. [CrossRef]
8. Deschamps F, de Baere T. Cementoplasty of bone metastases. Diagn Interv Imaging 2012; 93:685–689. [CrossRef]
9. Hoffmann RT, Jakobs TF, Trumm C, Weber C, Helmberger TK, Reiser MF. Radiofrequency ablation in combination with osteoplasty in the treatment of painful metastatic bone disease. J Vasc Interv Radiol 2008; 19:419–425. [CrossRef]
10. Toyota N, Naito A, Kakizawa H, et al. Radiofrequency ablation therapy combined with cementoplasty for painful bone metastases: initial experience. Cardiovasc Intervent Radiol 2005; 28:578–583. [CrossRef]
11. Santiago FR, Del Mar Castellano Garcia M, Montes JL, Garcia MR, Fernandez JM. Treatment of bone tumours by radiofrequency thermal ablation. Curr Rev Musculoskelet Med 2009; 2:43–50. [CrossRef]
12. Ruiz Santiago F, Castellano Garcia Mdel M, Guzman Alvarez L, Martinez Montes JL, Ruiz Garcia M, Tristan Fernandez JM. Percutaneous treatment of bone tumors by radiofrequency thermal ablation. Eur J Radiol 2011; 77:156–163. [CrossRef]
13. Jakanani GC, Jaiveer S, Ashford R, Rennie W. Computed tomography-guided coblation and cementoplasty of a painful acetabular metastasis: an effective palliative treatment. J Palliat Med 2010; 13:83–85. [CrossRef]

14. Clarencon F, Jean B, Pham HP, et al. Value of percutaneous radiofrequency ablation with or without percutaneous vertebroplasty for pain relief and functional recovery in painful bone metastases. Skeletal Radiol 2013; 42:25–36. [CrossRef]
15. Tian QH, Wu CG, Gu YF, He CJ, Li MH, Cheng YD. Combination radiofrequency ablation and percutaneous osteoplasty for palliative treatment of painful extraspinal bone metastasis: a single-center experience. J Vasc Interv Radiol 2014; 25:1094–1100. [CrossRef]
16. Lane MD, Le HB, Lee S, et al. Combination radiofrequency ablation and cementoplasty for palliative treatment of painful neoplastic bone metastasis: experience with 53 treated lesions in 36 patients. Skeletal Radiol 2011; 40:25–32. [CrossRef]
17. Masala S, Guglielmi G, Petrella MC, et al. Percutaneous ablative treatment of metastatic bone tumours: visual analogue scale scores in a short-term series. Singapore Med J 2011; 52:182–189.
18. Masala S, Manenti G, Roselli M, et al. Percutaneous combined therapy for painful sternal metastases: a radiofrequency thermal ablation (RFTA) and cementoplasty protocol. Anticancer Res 2007; 27:4259–4262.
19. Pusceddu C, Sotgia B, Fele RM, Ballicu N, Melis L. Combined microwave ablation and cementoplasty in patients with painful bone metastases at high risk of fracture. Cardiovasc Intervent Radiol 2016; 39:74–80. [CrossRef]
20. Wei Z, Zhang K, Ye X, et al. Computed tomography-guided percutaneous microwave ablation combined with osteoplasty for palliative treatment of painful extraspinal bone metastases from lung cancer. Skeletal Radiol 2015; 44:1485–1490. [CrossRef]
21. Uri IF, Garnon J, Tsoumakidou G, Gangi A. An ice block: a novel technique of successful prevention of cement leakage using an ice ball. Cardiovasc Intervent Radiol 2015; 38:470–474. [CrossRef]
22. Cazzato RL, Bonichon F, Buy X, et al. Over ten years of single-institution experience in percutaneous image-guided treatment of bone metastases from differentiated thyroid cancer. Eur J Surg Oncol 2015; 41:1247–1255. [CrossRef]
23. Kurup AN, Morris JM, Schmit GD, et al. Balloon-assisted osteoplasty of periacetabular tumors following percutaneous cryoablation. J Vasc Interv Radiol 2015; 26:588–594. [CrossRef]
24. Lee JH, Stein M, Roychowdhury S. Percutaneous treatment of a sacral metastasis with combined embolization, cryoablation, alcohol ablation and sacroplasty for local tumor and pain control. Interv Neuroradiol 2013; 19:250–253. [CrossRef]
25. Pellerin O, Medioni J, Vulser C, Dean C, Oudard S, Sapoval M. Management of painful pelvic bone metastasis of renal cell carcinoma using embolization, radio-frequency ablation, and cementoplasty: a prospective evaluation of efficacy and safety. Cardiovasc Intervent Radiol 2014; 37:730–736. [CrossRef]
26. Kelekis A, Lovblad KO, Mehdizade A, et al. Pelvic osteoplasty in osteolytic metastases: technical approach under fluoroscopic guidance and early clinical results. J Vasc Interv Radiol 2005; 16:81–88. [CrossRef]
27. Cotten A, Deprez X, Migaud H, Chabanne B, Duquesnoy B, Chastanet P. Malignant acetabular osteolyses: percutaneous injection of acrylic bone cement. Radiology 1995; 197:307–310. [CrossRef]
28. Wallace AN, Huang AJ, Vaswani D, Chang RO, Jennings JW. Combination acetabular radiofrequency ablation and cementoplasty using a navigational radiofrequency ablation device and ultrahigh viscosity cement: technical note. Skeletal Radiol 2016; 45:401–405. [CrossRef]
29. Wang Z, Zhen Y, Wu C, et al. CT fluoroscopy-guided percutaneous osteoplasty for the treatment of osteolytic lung cancer bone metastases to the spine and pelvis. J Vasc Interv Radiol 2012; 23:1135–1142. [CrossRef]
30. Gangi A, Sabharwal T, Irani FG, Buy X, Morales JP, Adam A. Quality assurance guidelines for percutaneous vertebroplasty. Cardiovasc Intervent Radiol 2006; 29:173–178. [CrossRef]
31. Gangi A, Tsoumakidou G, Buy X, Quoix E. Quality improvement guidelines for bone tumour management. Cardiovasc Intervent Radiol 2010; 33:706–713. [CrossRef]
32. Barr JD, Jensen ME, Hirsch JA, et al. Position statement on percutaneous vertebral augmentation: a consensus statement developed by the Society of Interventional Radiology (SIR), American Association of Neurological Surgeons (AANS) and the Congress of Neurological Surgeons (CNS), American College of Radiology (ACR), American Society of Neuroradiology (ASNR), American Society of Spine Radiology (ASSR), Canadian Interventional Radiology Association (CIRA), and the Society of NeuroInterventional Surgery (SNIS). J Vasc Interv Radiol 2014; 25:171–181. [CrossRef]
33. Baerlocher MO, Saad WE, Dariushnia S, Barr JD, McGraw JK, Nikolic B. Quality improvement guidelines for percutaneous vertebroplasty. J Vasc Interv Radiol 2014; 25:165–170. [CrossRef]
34. Baur A, Stabler A, Bruning R, et al. Diffusion-weighted MR imaging of bone marrow: differentiation of benign versus pathologic compression fractures. Radiology 1998; 207:349–356. [CrossRef]
35. Hohl C, Suess C, Wildberger JE, et al. Dose reduction during CT fluoroscopy: phantom study of angular beam modulation. Radiology 2008; 246:519–525. [CrossRef]
36. Kloeckner R, dos Santos DP, Schneider J, Kara L, Dueber C, Pitton MB. Radiation exposure in CT-guided interventions. Eur J Radiol 2013; 82:2253–2257. [CrossRef]
37. Antoni S, Soerjomataram I, Moller B, Bray F, Ferlay J. An assessment of GLOBOCAN methods for deriving national estimates of cancer incidence. Bull World Health Organ 2016; 94:174–184. [CrossRef]
38. Iannessi A, Amoretti N, Marcy PY, Sedat J. Percutaneous cementoplasty for the treatment of extraspinal painful bone lesion, a prospective study. Diagn Interv Imaging 2012; 93:859–870. [CrossRef]
39. Yin JJ, Pollock CB, Kelly K. Mechanisms of cancer metastasis to the bone. Cell Res 2005; 15:57–62. [CrossRef]
40. Halpin RJ, Bendok BR, Sato KT, Liu JC, Patel JD, Rosen ST. Combination treatment of vertebral metastases using image-guided percutaneous radiofrequency ablation and vertebroplasty: a case report. Surg Neurol 2005; 63:469–474. [CrossRef]
41. Agarawal JP, Swangsilpa T, van der Linden Y, Rades D, Jeremic B, Hoskin PJ. The role of external beam radiotherapy in the management of bone metastases. Clin Oncol (R Coll Radiol) 2006; 18:747–760. [CrossRef]
42. Blomlie V, Rofstad EK, Talle K, Sundfor K, Winderen M, Lien HH. Incidence of radiation-induced insufficiency fractures of the female pelvis: evaluation with MR imaging. AJR Am J Roentgenol 1996; 167:1205–1210. [CrossRef]
43. Heran MK, Legiehn GM, Munk PL. Current concepts and techniques in percutaneous vertebroplasty. Orthop Clin North Am 2006; 37:409–434. [CrossRef]
44. Nakatsuka A, Yamakado K, Maeda M, et al. Radiofrequency ablation combined with bone cement injection for the treatment of bone malignancies. J Vasc Interv Radiol 2004; 15:707–712. [CrossRef]
45. Callstrom MR, Charboneau JW, Goetz MP, et al. Painful metastases involving bone: feasibility of percutaneous CT- and US-guided radio-frequency ablation. Radiology 2002; 224:87–97. [CrossRef]
46. Thanos L, Mylona S, Galani P, et al. Radiofrequency ablation of osseous metastases for the palliation of pain. Skeletal Radiol 2008; 37:189–194. [CrossRef]
47. Munk PL, Rashid F, Heran MK, et al. Combined cementoplasty and radiofrequency ablation in the treatment of painful neoplastic lesions of bone. J Vasc Interv Radiol 2009; 20:903–911. [CrossRef]
48. Georgy BA, Wong W. Plasma-mediated radiofrequency ablation assisted percutaneous cement injection for treating advanced malignant vertebral compression fractures. AJNR Am J Neuroradiol 2007; 28:700–705.
49. Hoffmann RT, Jakobs TF, Trumm C, Weber C, Glaser C, Reiser MF. Vertebroplasty in the treatment of osteoporotic vertebral body fracture. Eur Radiol 2007; 17:2656–2662. [CrossRef]
50. Madaelil TP, Wallace AN, Jennings JW. Radiofrequency ablation alone or in combination with cementoplasty for local control and pain palliation of sacral metastases: preliminary results in 11 patients. Skeletal Radiol 2016; 45:1213–1219. [CrossRef]
51. Schaefer O, Lohrmann C, Markmiller M, Uhrmeister P, Langer M. Technical innovation. Combined treatment of a spinal metastasis with radiofrequency heat ablation and vertebroplasty. AJR Am J Roentgenol 2003; 180:1075–1077. [CrossRef]
52. Carrafiello G, Lagana D, Recaldini C, et al. Combined treatment of ablative therapy with percutaneous radiofrequency and cementoplasty of a symptomatic metastatic lesion of the acetabulum. Australas Radiol 2007; 51 (Suppl):B344–348. [CrossRef]