Respiratory Medicine Case Reports 25 (2018) 78–85

Contents lists available at ScienceDirect

Respiratory Medicine Case Reports

journal homepage: www.elsevier.com/locate/rmcr

Case report

Cement pulmonary embolism after percutaneous vertebroplasty in a patient with cushing's syndrome: A case report

Besharat Rahimi[a], Behdad Boroofeh[a], Roshan Dinparastisaleh[b,*], Hale Nazifi[b]

[a] Pulmonology Department, Imam Khomeini Hospital, Tehran University of Medical Sciences, Tehran, Iran
[b] Internal Medicine Department, Imam Khomeini Hospital, Urmia University of Medical Sciences, Urmia, Iran

ARTICLE INFO

Keywords:
Percutaneous vertebroplasty
Cement embolism
Complications
cushing's syndrome

ABSTRACT

Background: Vertebroplasty is a procedure most commonly used for vertebral compression fractures. Although it is a relatively safe procedure, complications have been reported. Cement embolism is seen in 2.1%–26% of patients after percutaneous vertebroplasty.

Case presentation: a 38-year-old male who was diagnosed with cushing's syndrome, underwent percutaneous vertebroplasty for his thoracic osteoporotic compression fractures. 24-hours following vertebroplasty, he presented to emergency department with acute-onset dyspnea and chest pain. Chest radiography showed an opaque linear lesion in left pulmonary artery which was suggestive of cement embolism. Pulmonary spiral CT-scan further confirmed the diagnosis. The patient's symptoms improved over time, and warfarin was started with close cardiopulmonary assessments for indicators of cement embolus removal.

Conclusion: in patients with pulmonary cement embolism, conservative treatment may be recommended rather than a surgical removal except when the obstruction is extensive enough to cause hemodynamic changes. Given that all the related studies have suggested that pulmonary thromboembolism can occur as a complication due to bone cement leakage, discovering new cement alternatives and/or injection devices, seems beneficial.

1. Background

Vertebroplasty is a minimally invasive procedure most commonly used for vertebral compression fractures which was first introduced by Galibert et al., in 1987 [1]. In this procedure, polymethylmethacrylate (PMMA) is injected directly into the vertebral body through its pedicle, to restore the height partially, stabilize bony trabeculae, and alleviate pain. Due to its minimal invasion and immediate pain relief, percutaneous vertebroplasty gained popularity for the treatment of painful tumor infiltration disease such as multiple myeloma [2], and metastatic carcinoma [3–5], and for patients who have refractory pain due to osteoporotic thoracolumbar compression fractures [6–8] Although it is a relatively safe procedure, complications have been reported [9,10]. Acrylic cement of polymethylmethacrylate injected into the vertebral body can leak into the paravertebral venous system and reach the pulmonary artery via the azygos vein leading to a cement pulmonary embolism [11–15]. Pulmonary embolism of cement is seen in 4.6% of patients after percutaneous vertebroplasty. It can be asymptomatic and is directly related to the frequency of paravertebral venous leak, but not to the number of vertebral bodies treated [16]. Here, we report a case of cement pulmonary embolism following vertebroplasty for thoracic compression fracture.

2. Case report

This is a 38-year-old smoker male who is a truck driver. He visited his family physician in July 2017, because of unintentional weight gain and a debilitating back pain. In physical examination he had a buffalo hump and central obesity, thus he was prescribed symptomatic treatment for his back pain and referred to an endocrinologist to evaluate for cushing's syndrome. His laboratory studies in following month showed a significantly high level of 24-h urinary free cortisol which was repeated 3 times and a plasma ACTH of 82pg/ml, which was suggestive of an ACTH-dependent cushing's syndrome. The urinary free cortisol after low and high-dose dexamethasone suppression test reported to be 546 and 764 mcg/24h respectively, which means resistance to dexamethasone and a negative test result. A magnetic resonance image (MRI) of pituitary following gadolinium administration was done which showed no abnormality. Because of the discordance between pituitary MRI, plasma ACTH level, and high-dose dexamethasone suppression

* Corresponding author.
E-mail addresses: besharatrahimi@yahoo.com (B. Rahimi), b.boroofeh@yahoo.com (B. Boroofeh), roshan.dinparast@gmail.com (R. Dinparastisaleh), h.nazifiii@gmail.com (H. Nazifi).

https://doi.org/10.1016/j.rmcr.2018.06.009
Received 30 March 2018; Received in revised form 16 June 2018; Accepted 17 June 2018

test results, inferior petrosal sinus sampling (IPSS) was done by interventional radiologist, which showed a petrosal/peripheral ACTH ratio of less than 2. An ectopic ACTH syndrome was suggested which could not be localized with chest and abdominal CT scan. Ketoconazole was administered to control the cortisol excess, while planning for a bilateral adrenalectomy. The patient was also evaluated for his refractoy back pain. MRI revealed diffuse osteopenic signal changes in lumbar vertebrae and multiple sites of compression fracture in all thoracolumbar vertebral bodies. Bone densitometry showed osteoporosis most severe at spine (mean Z-score and T-score < -2.9). As the patient was symptomatic, the decision has been made to proceed with vertebroplasty. High viscosity cement was injected into T7 to T12 vertebral bodies under fluoroscopic guidance in February 2018. The total volume of injected cement was 4 cc in each level. The patient tolerated the procedure and was discharged uneventfully. 24-hours following his vertebroplasty, he presented to our emergency department with a history of sudden-onset dyspnea and chest pain. Vital signs were within normal limits except tachycardia. He had no hypoxia, fever, chills, cough, and hemoptysis. The ECG was normal, except sinus tachycardia and cardiac troponins were negative. Echocardiography revealed no regional wall motion abnormalities with a 50% ejection fraction, a tricuspid valve regurgitation, and mildly increased systolic pulmonary artery pressure (35 mmHg). Chest radiography showed an opaque linear lesion in the left pulmonary artery (Fig. 1), which raised the suspicion of bone cement pulmonary embolism. Parenteral anticoagulation was started, and patient underwent pulmonary spiral CT-scan which revealed artifact-like hyperdense area in main pulmonary artery and left pulmonary artery suggestive of cement embolism (Figs. 2 and 3). During the hospitalization, patient's symptoms resolved, and warfarin was started. Cardiovascular surgery consultants recommended medical rather than surgical treatment with close cardiopulmonary monitoring for any signs and symptoms suggestive of worsening embolism. The patient was asymptomatic when he was discharged. Serial cardiac and pulmonary assessments will be carried out looking for increased pulmonary artery pressure as an indicator for the removal of the cement embolus.

3. Discussion

We present a case of 38-year-old man who underwent a T7 to T12 vertebroplasty because of osteoporotic compression fractures, and subsequently had a pulmonary cement embolization to his pulmonary arterial circulation, which was treated non-operatively with anticoagulation.

Operative treatment of vertebral compression fractures has included

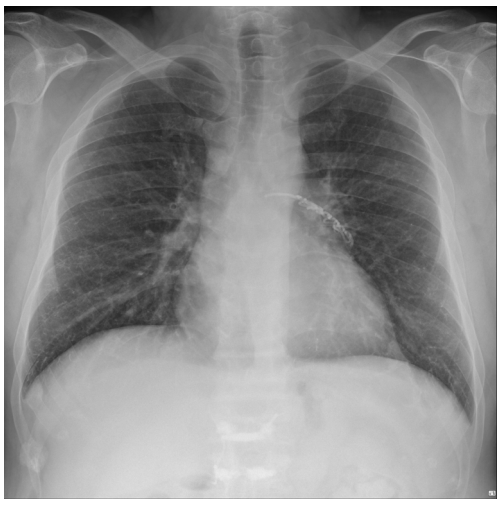

Fig. 1. Chest X-ray showing linear opaque lesion in left pulmonary artery.

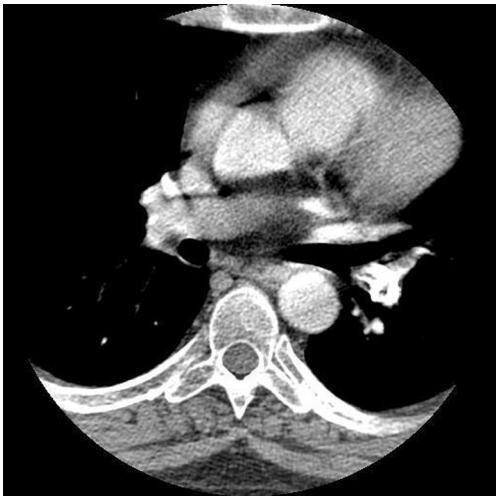

Fig. 2. Hyperdense lesion on left pulmonary artery.

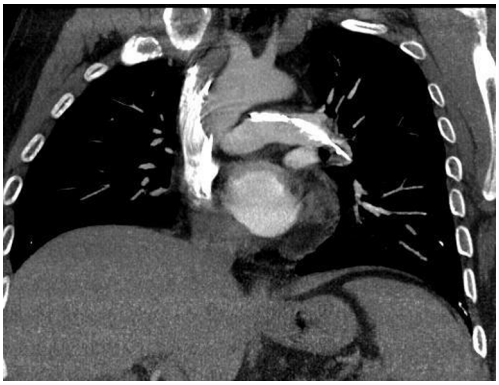

Fig. 3. Hyperdense lesion on main pulmonary artery and left pulmonary artery.

percutaneous vertebroplasty for the past 30 years. Introduced by Galibert et al. [1] in 1987, this procedure gained popularity steadily and is used as an immediate pain relief method, in osteoporotic compression fractures [6–8] and for treatment of tumor infiltration disease such as metastatic carcinoma [3–5], and multiple myeloma [2]. Efficacy of vertebroplasty in alleviating pain, is not without controversy according to Buchbinder et al. [17] and Kallmes et al. [18] studies, which showed no improvement in pain and pain-related disability in osteoporotic spinal fractures.

Bone cement leakage is of particular concern. Cement leakage into the spinal canal can lead to canal stenosis and cord compression [19,20], and cement leakage into the intervertebral foramina can cause nerve root compression [21]. Additionally, cement leakage into the perivertebral system and inferior vena cava (IVC) can drift toward the right heart and pulmonary arterial system with catastrophic results such as cardiopulmonary arrest [33,34], acute kidney injury [22], paradoxical embolism through a patent foramen ovale [23], and death [10,24,36]. Arterial embolization to the aorta and anterior spinal artery has also been described [25,26]. The risk of cement pulmonary embolism first reported by Padovani et al. [27] exists with both vertebroplasty and kyphoplasty, but the exact rate is uncertain because the patients are not routinely screened for cement embolism [28]. The incidences of pulmonary cement embolism after vertebroplasty ranges from 2.1% to 26%, with much of this variation resulting from which imaging technique is used and whether the study is prospective or retrospective [16,29–32]. Clinical features of cardiopulmonary side effects of cement leak in percutaneous vertebroplasty and kyphoplasty include precordial chest pain and tightness [33–36], dyspnea [35–38], cyanosis, palpitation [34], acute respiratory distress syndrome (ARDS)

Table 1
Published case reports of pulmonary/cardiac cement embolism (1999–2017).

Outcome	Treatment	Clinical manifestation	Indication	Gender	Age (years)	Author/Publication date
Uneventful recovery	Anticoagulant + Supportive oxygen	Chest patin Hemoptysis hypoxia	Chronic osteoporotic pain	F	41	Padovani et al. (1999) [27]
Uneventful recovery	Anticoagulant	Sudden onset dyspnea	Osteoporotic fracture			Perrin et al. (1999) [61]
Uneventful recovery	unclear	2 asymptomatic patients and 1 symptomatic patient	unclear	unclear	unclear	Amar et al. (2001) [62]
Recovered from respiratory and cardiac failure	Anticoagulant + Embolectomy	Respiratory distress, atrial fibrillation, hypoxia	Pathologic fracture (osteogenesis imperfecta)	M	55	Tozzi et al. (2002) [39]
Uneventful recovery	Supportive oxygen + Anticoagulant	Mild dyspnea and chest discomfort	Compression fracture	M	60	Jang et al. (2002) [50]
		dyspnea and chest discomfort	Compression fracture	M	57	
		Asymptomatic	Compression fracture	F	60	
Died	CPR for 60 minutes	Sudden onset bradycardia, shock,hypercapnia	Osteoporotic fracture			Chen et al. (2002) [24]
Uneventful recovery	Anticoagulant + Embolectomy (interventional catheter procedure + open heart operation)	Mild dyspnea Large mass on X-ray	Compression fracture	F	52	Franc¸ois et al. (2003) [38]
discharged	No treatment	No symptom Incidental finding on CXR	Multiple compression fractures	M	67	Bernhard et al. (2003) [44]
	Anticoagulation		Osteoporotic fracture			Torres Machi et al. (2003) [63]
Respiratory symptoms improved	Ventilation + 6 mg hydrochloride Ephedrine	Repiratory and cardiac distress	Osteoporotic fracture	F	62	Charvet et al. (2004) [64]
Died	Mask ventilation, positive pressure ventilation, repeated intravenous boluses of noradrenaline and adrenaline	Severe chest pain, Restless, tachypnea, tachycardia, hypertension, oxygen desaturation, loss of consciousness, pulseless electrical activity	Osteoporotic fracture			Stricker et al. (2004) [45]
Died	tracheal intubation and mechanical ventilation, intravenous anticoagulation, pulmonary embolectomy	Arthralgia, myalgia, fever, ARDS	Osteoporotic fracture	F	68	Yoo et al. (2004) [40]
Discharged	Anticuagulation	Asymptomatic	Osteoporotic fracture	F	80	Pleser et al. (2004)
Discharged	Open heart surgery for hemopericardium and cement removal Right atriotomy and inferior vena cavotomy	Chest pain, hemopericardium, cardiac perforation	Osteoporotic fracture	F	68	Kim et al. (2005) [33]
		Palpable mass on the subareolar of the left chest wall	Compression fracture	M	72	Seo et al. (2005) [65]
Respiratory symptoms improved	Anticoagulation	Sudden onset dyspnea	Osteoporotic fracture	F	78	Pott et al. (2005) [66]
died	ACLS	Shock, hypoxia, cardiac arrest	Pain	F	81	Monticelli et al. (2005) [12]
Discharged	Anticoagulation	Asymptomatic	Osteoporotic fracture	F	50	Baumann et al. (2006) [67]
Discharged	Anticoagulation	Hypotension Arrhythmia hypocapnia	Collapsed vertebra, pain	F	63	Freitag et al. (2006) [49]
Discharged	No treatment	asymptomatic	Osteoporotic fracture Due to multiple myeloma	F	65	MacTaggart et al. (2006) [42]
Died	Anticoagulant	Respiratory distress	Bone metastasis	F	68	Barragan-Campos et al. (2006) [10]
Uneventful recovery	Anticoagulant	Dyspnea, chest pain	Osteoporotic fracture	F	45	Abdul-Jalil et al. (2007)
Discharged	No treatment	asymptomatic	Osteoporotic fracture	F	64	[48]
Uneventful recovery	No treatment	asymptomatic	Lumbar hemangioma	M	61	Bonardel et al. (2007) [68]
Uneventful recovery	No treatment	Dyspnea Cough Chest pain	Osteoporotic fracture	F	85	Liliang et al. (2007) [51]
Uneventful recovery	Anticoagulant Open-heart surgery Atrial thrombectomy	Mild dyspnea	Osteoporotic fracture	F	55	Lim et al. (2007) [37]
Uneventful recovery	Pericardial collection aspiration Cement removal Right ventricular wall repair	Chest pain Dyspnea Pericardial effusion Cardiac perforation	Compression fracture	F	59	Lim et al. (2008) [35]
Uneventful recovery	Cement removal Right ventricular wall repair Tricuspid annuloplasty	Chest pain Chest tightness Hemopericardium Severe TR Cardiac tamponade	Compression fracture	F	65	Son et al. (2008) [56]
Discharged	Right cardiac catheterization Failed cement removal	Asymptomatic	Osteoporotic fracture	F	68	Cadeddu et al. (2009) [47]
Uneventful recovery	Endovascular cement removal	Chest pain palpitation	Bone metastasis (pain)	F	51	Braiteh et al. (2009) [34]
Uneventful recovery	Anticoagulant Surgical cement removal Pericardial drainage	Progressive dyspnea Tamponade	Osteoporotic fracture	F	64	Caynak et al. (2009) [36]
Uneventful recovery	Anticoagulant	Asymptomatic	Severe scoliosis and pain	M	76	Akinola et al. (2010) [69]

(*continued on next page*)

Table 1 (*continued*)

Outcome	Treatment	Clinical manifestation	Indication	Gender	Age (years)	Author/Publication date
Discharged	Conservative management	Dyspnea Cough	Osteoporotic fracture pain	F	79	Radcliff et al. (2010) [70]
Reported asymptomatic and clinically silent patients with PCE in 26% of patients treated with PVP						Venmans et al. (2010) [31]
Reported 23 cases of PCE after PVP in 244 patients whom 1 patient was symptomatic from PCE						Luetmer et al. (2011) [41]
discharged	Anticoagulant oxygen	Hypoxia	Osteoporotic fracture	F	78	Abd El-Rahman et al. (2012) [71]
Died	Percutaneous retrieval of large cement fragment Mechanical ventilation	Multiple pulmonary embolies seen in fluoroscopy ARDS Pneumonia	Fracture due to bone metastasis	M	74	Alcibar et al. (2012) [72]
Uneventful recovery	Anticoagulant	Pleuritic chest pain Dyspnea Generalized weakness	Compression fracture due to bone metastasis	F	37	Chick et al. (2012) [73]
Uneventful recovery	Lidocaine Amiodarone Magnesium sulfate Surgical cement removal	Non-sustained ventricular tachycardia Right ventricular failure Foreign body in right ventricle	Fracture due to bone metastasis	F	65	Cohen et al. (2012) [74]
Uneventful recovery	IVC filter Thrombectomy Urokinase Anticoagulant Balloon angioplasty	Leg swelling Thrombosis extending from IVC to right common iliac vein Subsegmental pulmonary embolism	Osteoporotic fracture	M	69	Kim et al. (2012) [75]
Uneventful recovery	Anticoagulant	Chest pain Tachypnea tachycardia	Osteoporotic fracture	F	63	Liu et al. (2012) [76]
Discharged	No treatment	Asymptomatic	Osteoporotic fracture	F	83	Matouk et al. (2012) [77]
Not clear	Not clear	Asymptomatic	Osteoporotic fracture	F	50	Mishriki et al. (2012) [78]
Uneventful recovery	No treatment	Dyspnea	Osteoporotic fracture	F	82	Bopparaju et al. (2013) [79]
Died	Anticoagulant Failure of complete cement removal	Sudden dyspnea Tricuspid regurgitation	Fracture due to multiple myeloma	F	62	Chou et al. (2013) [80]
Not clear	Not clear	Asymptomatic	compression fracture	M	69	Garcia-Fontan et al. (2013) [81]
Uneventful recovery	Anticoagulant Antibiotic Short-term corticosteroids	Asymptomatic	Osteoporotic fracture	M	70	Geraci et al. (2013) [82]
Discharged	Open-heart surgery Cement removal	Dyspnea Chest pain Right Ventricle perforation	Fracture due to multiple myeloma	F	58	Gosev et al. (2013) [83]
discharged	No treatment	Dizziness Generalized weakness	Compression fracture	M	58	Lee et al. (2013) [84]
Uneventful recovery	Cardiopulmonary bypass surgery Cement removal from left lower lobe artery	Dyspnea Chest pain	Osteoporotic fracture	F	68	Llanos et al. (2013) [85]
Uneventful recovery	Surgical removal	Pericardial effusion Fever leukocytosis Chest pain	Osteoporotic fracture	F	86	Moon et al. (2013) [86]
discharged	No treatment	asymptomatic	Osteoporotic fracture pain	M	74	Sifuentes et al. (2013) [87]
Not clear	Anticoagulant	Dry cough	Osteoporotic fracture	F	76	Yu et al. (2013) [88]
Uneventful recovery	Surgical removal of cement	Hypotension ARDS	Traumatic compression fracture	F	71	Arnaiz-Garcia et al. (2014) [89]
Uneventful recovery	Antiviral No treatment for PCE	Acute respiratory failure CMV pneumonia	Fracture due to bone metastasis	M	49	Chebib et al. (2014) [90]
discharged	No treatment	asymptomatic	fracture due to bone metastasis	F	39	Chen et al. (2014) [91]
Transferred to other hospital	Anticoagulant Inotrops	Intermittent dyspnea hypotension	Osteoporotic fracture	F	56	Huh et al. (2014) [92]
discharged	Open-heart surgery	Progressive dyspnea hemothorax	Chronic back pain	F	68	Kim et al. (2014) [93]
Uneventful recovery	No treatment	Syncope	Fracture due to multiple myeloma	F	52	Pannirselvam et al. (2014) [94]
Discharged	Cardiopulmonary bypass Embolectomy Pulmonary wedge resection	Chest pain	Traumatic fracture Pain	M	29	Rothermich et al. (2014) [95]
Discharged	No treatment	Dull chest pain	Pathologic compression fracture	M	60	Stevens et al. (2014) [96]
Uneventful recovery	Antibiotic Anticoagulant	Dyspnea	Compression fracture due to exogenous cushing	M	48	Toru et al. (2014) [97]
Uneventful recovery	Percutaneous retrieval of cement	Asymptomatic	Osteoporotic fracture	F	55	Zhao et al. (2014) [98]

(*continued on next page*)

Table 1 (*continued*)

Outcome	Treatment	Clinical manifestation	Indication	Gender	Age (years)	Author/Publication date
Discharged	No treatment	Asymptomatic	Painful fracture	M	72	Guirguis et al. (2015) [99]
Discharged	No treatment	Dyspnea responding to nitroglycerine	Compression fracture pain	F	70	Nooh et al. (2015) [100]
Discharged	Antiplatelet	Dyspnea Chest pain	Not clear	F	69	Polli et al. (2015) [101]
Discharged	Open-heart surgery Cement removal Right ventricular repair	Sudden onset chest pain	Chronic back pain	M	65	Schuerer et al. (2015) [102]
Uneventful recovery	Cardiopulmonary bypass Right atriotomy			F	63	Shen et al. (2015) [103]
Discharged	Anticoagulant	Dyspnea	Traumatic fracture	M	70	Shroff et al. (2015) [104]
Not clear	Not clear	Palpitation Chest pain Dyspnea	Osteoporotic fracture	F	54	Awwad et al. (2016) [105]
Discharged	Anticoagulant	Asymptomatic	Fracture due to bone metastasis	F	51	Chai et al. (2016) [106]
Uneventful recovery	Open-heart surgery	Dyspnea Hemopericardium	Osteoporotic fracture	M	28	Diab et al. (2016) [107]
Discharge	Open-heart surgery	Dyspnea	Traumatic fracture	M	64	Focardi et al. (2016) [108]
Discharge	No treatment	Asymptomatic	Osteoporotic fracture	F	58	Gabe et al. (2016) [109]
Discharge	No treatment	Asymptomatic	Fracture due to multiple myeloma	F	58	Gorospe et al. (2016) [110]
Discharge	No treatment	Asymptomatic	Not clear	M	32	Memarpour et al. (2016) [111]
Uneventful recovery	Endoscopic Robot-assisted open heart surgery	Chest pain Tachycardia Hypotension Pericarditis Atrial fibrillation	Osteoporotic fracture pain	F	72	Molloy et al. (2016) [112]
Uneventful recovery	Open-heart surgery	Chest pain Right ventricular penetration	Compression fracture	M	49	Park et al. (2016) [113]
Not clear	Not clear	Dyspnea	Osteoporotic fracture	F	77	Botia Gonzalez et al. (2017) [114]
discharged	Anticoagulant	Asymptomatic	Traumatic compression fracture	M	59	Chang et al. (2017) [115]
Not clear	Not clear	Palpitation	Traumatic compression fracture	M	65	Cianciulli et al. (2017) [116]
Uneventful recovery	Anticoagulant	Chest pain Pleural effusion	Osteoporotic fracture	F	57	Hatzantonis et al. (2017) [117]
Uneventful recovery	Steroids Anticoagulant	Fever Respiratory distress hemoptysis	Bone neuro-ectodermal tumor	F	15	Ramanathan et al. (2017) [15]
Uneventful recovery	Anticoagulant	Hypoxemia	Fracture of femur	F	96	Talec et al. (2017) [118]
Uneventful recovery	Anticoagulant Surgical removal	Dyspnea Chest pain	Not clear	M	57	Wu et al. (2017) [13]

M = male, F = female, PCE = pulmonary cement embolism, ARDS = acute respiratory distress syndrome, PVP = percutaneous vertebroplasty.

[39,40], and cardiac arrest [12], although some patients with pulmonary cement embolism are asymptomatic [41–44]. The symptoms of cement embolism occurs more commonly days to months after, rather than during the procedure [12,24,39,45]. The cement used in vertebroplasty is of such high density compared to lung field that the visualization of cement emboli on CXR is quite striking, but multiple dense opacities with a branching shape which are scattered randomly or diffusely throughout the lungs are more common [16,29,44]. In our patient, CXR showed an opaque linear lesion in the left pulmonary artery without significant scattered lesions in the lungs. Echocardiography is a safe and non-invasive modality to evaluate hemodynamic status and to reveal the probable echogenic material in the cardiac chambers [46,47]. Chest CT scan accurately shows the locations, the lengths, and the number of cement emboli [35].

Abdul-Jalil et al. proposed that PMMA has a prothrombotic property and can cause endothelial injury, which can result in additional thrombosis [48]. The formation of PMMA toxins can cause direct cellular injury by increasing membrane permeability through releasing inflammatory mediators, and superoxide production. Pulmonary cement embolism finally shares similar phathophysiological similarities with pulmonary embolisms [40].

The cornerstone of treatment of pulmonary cement embolism is close cardiopulmonary monitoring and anticoagulation [27,49–53] but there are some reports of cement embolism requiring surgical removal (including cardiopulmonary bypass and arteriotomy) [33,35–39,54–56]. Choe et al. proposed that asymptomatic pulmonary cement emboli should not alter medical treatment [16]. In Venman's study, all 11 patients with venous PMMA migration remained asymptomatic during 1-year follow up [31]. Krueger et al. proposed a management algorithm that includes conservative approach for peripheral asymptomatic cases, anticoagulation for the symptomatic peripheral and asymptomatic central emboli, and surgical treatment for symptomatic central embolism only [57]. We selected anticoagulation and close monitoring for our patient regarding the published case reports of cement embolism which is summarized in Table 1. Because of non-degradable and toxic properties of PMMA, attempts have been made to explore alternative materials that are more suitable for vertebroplasty and kyphoplasty [58–60].

4. Conclusion

In patients with pulmonary cement embolism, conservative treatment may be recommended rather than a surgical removal except when the obstruction is extensive enough to cause hemodynamic changes. Given that all the related studies have suggested that pulmonary thromboembolism can occur as a complication due to bone cement leakage, discovering new cement alternatives and/or injection devices, seems beneficial.

Funding

None.

Availability of data and materials

All data and materials described in the manuscript will be freely available to any scientist wishing to use them for non-commercial purposes.

Authors' contribution

Authors contributed equally to this paper.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Written informed consent was obtained from the patient for publication of this case report. A copy of the written consent is available for review by the Editor of this journal.

Ethics approval and consent to participate

Not applicable.

Aknowledgements

None.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.rmcr.2018.06.009.

References

[1] P. Galibert, H. Deramond, P. Rosat, D. Le Gars, [Preliminary note on the treatment of vertebral angioma by percutaneous acrylic vertebroplasty], Neuro chirurgie 33 (2) (1987) 166–168.
[2] P. Bosnjakovic, S. Ristic, M. Mrvic, A.E. Miljkovic, T. Vukicevic, G. Marjanovic, L. Macukanovic-Golubovic, Management of painful spinal lesions caused by multiple myeloma using percutaneous acrylic cement injection, Acta Chir. Iugosl. 56 (4) (2009) 153–158.
[3] S. Dalbayrak, M.R. Onen, M. Yilmaz, S. Naderi, Clinical and radiographic results of balloon kyphoplasty for treatment of vertebral body metastases and multiple myelomas, J. Clin. Neurosci. Offic. J. Neurosurg. Soc. Australasia 17 (2) (2010) 219–224.
[4] A. Mazumdar, L.A. Gilula, Relief of radicular pain in metastatic disease by vertebroplasty, Acta Radiologica (Stockholm, Sweden : 1987) 51 (2) (2010) 179–182.
[5] G. Saliou, M. Kocheida el, P. Lehmann, C. Depriester, G. Paradot, D. Le Gars, A. Balut, H. Deramond, Percutaneous vertebroplasty for pain management in malignant fractures of the spine with epidural involvement, Radiology 254 (3) (2010) 882–890.
[6] H. Yang, G. Wang, J. Liu, N.A. Ebraheim, G. Niu, L. Hiltner, A.H. Lee, T. Tang, Balloon kyphoplasty in the treatment of osteoporotic vertebral compression fracture nonunion, Orthopedics 33 (1) (2010) 24.
[7] B. Blondel, S. Fuentes, P. Metellus, T. Adetchessi, G. Pech-Gourg, H. Dufour, Severe thoracolumbar osteoporotic burst fractures: treatment combining open kyphoplasty and short-segment fixation, Orthop. Traumatol. Surg. Res. OTSR 95 (5) (2009) 359–364.
[8] F.M. Phillips, Minimally invasive treatments of osteoporotic vertebral compression fractures, Spine 28 (15 Suppl) (2003) S45–S53.
[9] M. Dohm, C.M. Black, A. Dacre, J.B. Tillman, G. Fueredi, A randomized trial comparing balloon kyphoplasty and vertebroplasty for vertebral compression fractures due to osteoporosis, AJNR Am. J. Neuroradiol. 35 (12) (2014) 2227–2236.
[10] H.M. Barragan-Campos, J.N. Vallee, D. Lo, E. Cormier, B. Jean, M. Rose, P. Astagneau, J. Chiras, Percutaneous vertebroplasty for spinal metastases: complications, Radiology 238 (1) (2006) 354–362.
[11] N. Milojkovic, S. Homsi, Polymethylmethacrylate pulmonary embolism as a complication of percutaneous vertebroplasty in cancer patients, J. Ark. Med. Soc. 111 (7) (2014) 140–142.
[12] F. Monticelli, H.J. Meyer, E. Tutsch-Bauer, Fatal pulmonary cement embolism following percutaneous vertebroplasty (PVP), Forensic Sci. Int. 149 (1) (2005) 35–38.
[13] Y.F. Wu, C.C. Lai, C.M. Chao, Severe pulmonary cement embolism, J. Emerg. Med. 53 (6) (2017) e139–e140.
[14] E. Unal, S. Balci, Z. Atceken, E. Akpinar, O.M. Ariyurek, Nonthrombotic pulmonary artery embolism: imaging findings and review of the literature, AJR Am. J. Roentgenol. 208 (3) (2017) 505–516.
[15] S. Ramanathan, T. Vora, A. Gulia, A. Mahajan, S. Desai, Pulmonary cement embolism in a child following total elbow replacement for primitive neuroectodermal tumour (PNET) of the humerus, Skeletal Radiol. 46 (5) (2017) 715–718.
[16] D.H. Choe, E.M. Marom, K. Ahrar, M.T. Truong, J.E. Madewell, Pulmonary embolism of polymethyl methacrylate during percutaneous vertebroplasty and kyphoplasty, AJR Am. J. Roentgenol. 183 (4) (2004) 1097–1102.
[17] R. Buchbinder, K. Golmohammadi, R.V. Johnston, R.J. Owen, J. Homik, A. Jones, S.S. Dhillon, D.F. Kallmes, R.G. Lambert, Percutaneous vertebroplasty for osteoporotic vertebral compression fracture, Cochrane Database Syst. Rev. (4) (2015) CD006349.
[18] D.F. Kallmes, B.A. Comstock, P.J. Heagerty, J.A. Turner, D.J. Wilson, T.H. Diamond, R. Edwards, L.A. Gray, L. Stout, S. Owen, et al., A randomized trial of vertebroplasty for osteoporotic spinal fractures, N. Engl. J. Med. 361 (6) (2009) 569–579.

[19] M.M. Teng, H. Cheng, D.M. Ho, C.Y. Chang, Intraspinal leakage of bone cement after vertebroplasty: a report of 3 cases, AJNR Am. J. Neuroradiol. 27 (1) (2006) 224–229.
[20] K.D. Harrington, Major neurological complications following percutaneous vertebroplasty with polymethylmethacrylate : a case report, J. Bone Joint Surg. Am. 83-A (7) (2001) 1070–1073.
[21] L. Alvarez, A. Perez-Higueras, D. Quinones, E. Calvo, R.E. Rossi, Vertebroplasty in the treatment of vertebral tumors: postprocedural outcome and quality of life, Eur. Spine J. Offic. Publ. Eur. Spine Soc. Eur. Spinal Deformity Soc. Eur. Section Cervical Spine Res. Soc. 12 (4) (2003) 356–360.
[22] S.E. Chung, S.H. Lee, T.H. Kim, K.H. Yoo, B.J. Jo, Renal cement embolism during percutaneous vertebroplasty, Eur. Spine J. Offic. Publ. Eur. Spine Soc. Eur. Spinal Deformity Soc. Eur. Section Cervical Spine Res. Soc. 15 (Suppl 5) (2006) 590–594.
[23] R. Scroop, J. Eskridge, G.W. Britz, Paradoxical cerebral arterial embolization of cement during intraoperative vertebroplasty: case report, AJNR Am. J. Neuroradiol. 23 (5) (2002) 868–870.
[24] H.L. Chen, C.S. Wong, S.T. Ho, F.L. Chang, C.H. Hsu, C.T. Wu, A lethal pulmonary embolism during percutaneous vertebroplasty, Anesth. Analg. 95 (4) (2002) 1060–1062 (table of contents).
[25] P.G. Yazbeck, R.B. Al Rouhban, S.G. Slaba, G.E. Kreichati, K.E. Kharrat, Anterior spinal artery syndrome after percutaneous vertebroplasty, Spine J. : offic. J.North Am. Spine Soc. 11 (8) (2011) e5–8.
[26] Y.D. Tsai, P.C. Liliang, H.J. Chen, K. Lu, C.L. Liang, K.W. Wang, Anterior spinal artery syndrome following vertebroplasty: a case report, Spine 35 (4) (2010) E134–E136.
[27] B. Padovani, O. Kasriel, P. Brunner, P. Peretti-Viton, Pulmonary embolism caused by acrylic cement: a rare complication of percutaneous vertebroplasty, AJNR Am. J. Neuroradiol. 20 (3) (1999) 375–377.
[28] L.J. Wang, H.L. Yang, Y.X. Shi, W.M. Jiang, L. Chen, Pulmonary cement embolism associated with percutaneous vertebroplasty or kyphoplasty: a systematic review, Orthopaedic surgery 4 (3) (2012) 182–189.
[29] C. Duran, M. Sirvanci, M. Aydogan, E. Ozturk, C. Ozturk, C. Akman, Pulmonary cement embolism: a complication of percutaneous vertebroplasty, Acta Radiologica (Stockholm, Sweden : 1987) 48 (8) (2007) 854–859.
[30] Y.J. Kim, J.W. Lee, K.W. Park, J.S. Yeom, H.S. Jeong, J.M. Park, H.S. Kang, Pulmonary cement embolism after percutaneous vertebroplasty in osteoporotic vertebral compression fractures: incidence, characteristics, and risk factors, Radiology 251 (1) (2009) 250–259.
[31] A. Venmans, C.A. Klazen, P.N. Lohle, W.J. van Rooij, H.J. Verhaar, J. de Vries, W.P. Mali, Percutaneous vertebroplasty and pulmonary cement embolism: results from VERTOS II, AJNR Am. J. Neuroradiol. 31 (8) (2010) 1451–1453.
[32] A. Venmans, P.N. Lohle, W.J. van Rooij, H.J. Verhaar, W.P. Mali, Frequency and outcome of pulmonary polymethylmethacrylate embolism during percutaneous vertebroplasty, AJNR Am. J. Neuroradiol. 29 (10) (2008) 1983–1985.
[33] S.Y. Kim, J.B. Seo, K.H. Do, J.S. Lee, K.S. Song, T.H. Lim, Cardiac perforation caused by acrylic cement: a rare complication of percutaneous vertebroplasty, AJR Am. J. Roentgenol. 185 (5) (2005) 1245–1247.
[34] F. Braiteh, M. Row, Right ventricular acrylic cement embolism: late complication of percutaneous vertebroplasty, Heart (British Cardiac Society) 95 (4) (2009) 275.
[35] S.H. Lim, H. Kim, H.K. Kim, M.J. Baek, Multiple cardiac perforations and pulmonary embolism caused by cement leakage after percutaneous vertebroplasty, Eur. J. Cardio. Thorac. Surg. Offic. J. Eur. Assoc. Cardio Thorac. Surg. 33 (3) (2008) 510–512.
[36] B. Caynak, B. Onan, E. Sagbas, C. Duran, B. Akpinar, Cardiac tamponade and pulmonary embolism as a complication of percutaneous vertebroplasty, Ann. Thorac. Surg. 87 (1) (2009) 299–301.
[37] K.J. Lim, S.Z. Yoon, Y.S. Jeon, J.H. Bahk, C.S. Kim, J.H. Lee, J.W. Ha, An intraatrial thrombus and pulmonary thromboembolism as a late complication of percutaneous vertebroplasty, Anesth. Analg. 104 (4) (2007) 924–926.
[38] K. Francois, Y. Taeymans, B. Poffyn, G. Van Nooten, Successful management of a large pulmonary cement embolus after percutaneous vertebroplasty: a case report, Spine 28 (20) (2003) E424–E425.
[39] P. Tozzi, Y. Abdelmoumene, A.F. Corno, P.A. Gersbach, H.M. Hoogewoud, L.K. von Segesser, Management of pulmonary embolism during acrylic vertebroplasty, Ann. Thorac. Surg. 74 (5) (2002) 1706–1708.
[40] K.Y. Yoo, S.W. Jeong, W. Yoon, J. Lee, Acute respiratory distress syndrome associated with pulmonary cement embolism following percutaneous vertebroplasty with polymethylmethacrylate, Spine 29 (14) (2004) E294–E297.
[41] M.T. Luetmer, B.J. Bartholmai, A.E. Rad, D.F. Kallmes, Asymptomatic and unrecognized cement pulmonary embolism commonly occurs with vertebroplasty, AJNR Am. J. Neuroradiol. 32 (4) (2011) 654–657.
[42] J.N. MacTaggart, I.I. Pipinos, J.M. Johanning, T.G. Lynch, Acrylic cement pulmonary embolus masquerading as an embolized central venous catheter fragment, J. Vasc. Surg. 43 (1) (2006) 180–183.
[43] H. Ren, Y. Shen, Y.Z. Zhang, W.Y. Ding, J.X. Xu, D.L. Yang, J.M. Cao, Correlative factor analysis on the complications resulting from cement leakage after percutaneous kyphoplasty in the treatment of osteoporotic vertebral compression fracture, J. Spinal Disord. Tech. 23 (7) (2010) e9–15.
[44] J. Bernhard, P.F. Heini, P.M. Villiger, Asymptomatic diffuse pulmonary embolism caused by acrylic cement: an unusual complication of percutaneous vertebroplasty, Ann. Rheum. Dis. 62 (1) (2003) 85–86.
[45] K. Stricker, R. Orler, K. Yen, J. Takala, M. Luginbuhl, Severe hypercapnia due to pulmonary embolism of polymethylmethacrylate during vertebroplasty, Anesth. Analg. 98 (4) (2004) 1184–1186 table of contents.
[46] J.S. Lee, Y.S. Jeong, S.G. Ahn, Intracardiac bone cement embolism, Heart (British Cardiac Society) 96 (5) (2010) 387.
[47] C. Cadeddu, S. Nocco, E. Secci, M. Deidda, R. Pirisi, G. Mercuro, Echocardiographic accidental finding of asymptomatic cardiac and pulmonary embolism caused by cement leakage after percutaneous vertebroplasty, Eur. J. Echocardiogr. J. Work. Group Echocardiogr. Eur. Soc. Cardiol. 10 (4) (2009) 590–592.
[48] Y. Abdul-Jalil, J. Bartels, O. Alberti, R. Becker, Delayed presentation of pulmonary polymethylmethacrylate emboli after percutaneous vertebroplasty, Spine 32 (20) (2007) E589–E593.
[49] M. Freitag, A. Gottschalk, M. Schuster, W. Wenk, L. Wiesner, T.G. Standl, Pulmonary embolism caused by polymethylmethacrylate during percutaneous vertebroplasty in orthopaedic surgery, Acta Anaesthesiol. Scand. 50 (2) (2006) 248–251.
[50] J.S. Jang, S.H. Lee, S.K. Jung, Pulmonary embolism of polymethylmethacrylate after percutaneous vertebroplasty: a report of three cases, Spine 27 (19) (2002) E416–E418.
[51] P.C. Liliang, K. Lu, C.L. Liang, Y.D. Tsai, C.H. Hsieh, H.J. Chen, Dyspnoea and chest pain associated with pulmonary polymethylmethacrylate embolism after percutaneous vertebroplasty, Injury 38 (2) (2007) 245–248.
[52] S. Moll, C. Kuzma, Images in vascular medicine: cement pulmonary embolism, Vasc. Med. 15 (4) (2010) 339–340.
[53] J.P. Tourtier, S. Cottez, Images in clinical medicine. Pulmonary cement embolism after vertebroplasty, N. Engl. J. Med. 366 (3) (2012) 258.
[54] A. Dash, D.R. Brinster, Open heart surgery for removal of polymethylmethacrylate after percutaneous vertebroplasty, Ann. Thorac. Surg. 91 (1) (2011) 276–278.
[55] B. Schoenes, D.H. Bremerich, P.S. Risteski, A. Thalhammer, D. Meininger, [Cardiac perforation after vertebroplasty], Anaesthesist 57 (2) (2008) 147–150.
[56] K.H. Son, J.H. Chung, K. Sun, H.S. Son, Cardiac perforation and tricuspid regurgitation as a complication of percutaneous vertebroplasty, Eur. J. Cardio. Thorac. Surg. Offic. J. Eur. Assoc. Cardio Thorac. Surg. 33 (3) (2008) 508–509.
[57] A. Krueger, C. Bliemel, R. Zettl, S. Ruchholtz, Management of pulmonary cement embolism after percutaneous vertebroplasty and kyphoplasty: a systematic review of the literature, Eur. Spine J. : Offic. Publ. Eur. Spine Soc. Eur. Spinal Deformity Soc. Eur. Section Cervical Spine Res. Soc. 18 (9) (2009) 1257–1265.
[58] G. Lewis, M.R. Towler, D. Boyd, M.J. German, A.W. Wren, O.M. Clarkin, A. Yates, Evaluation of two novel aluminum-free, zinc-based glass polyalkenoate cements as alternatives to PMMA bone cement for use in vertebroplasty and balloon kyphoplasty, J. Mater. Sci. Mater. Med. 21 (1) (2010) 59–66.
[59] C. Kim, A. Mahar, A. Perry, J. Massie, L. Lu, B. Currier, M.J. Yaszemski, Biomechanical evaluation of an injectable radiopaque polypropylene fumarate cement for kyphoplasty in a cadaveric osteoporotic vertebral compression fracture model, J. Spinal Disord. Tech. 20 (8) (2007) 604–609.
[60] T.R. Blattert, L. Jestaedt, A. Weckbach, Suitability of a calcium phosphate cement in osteoporotic vertebral body fracture augmentation: a controlled, randomized, clinical trial of balloon kyphoplasty comparing calcium phosphate versus polymethylmethacrylate, Spine 34 (2) (2009) 108–114.
[61] C. Perrin, V. Jullien, B. Padovani, B. Blaive, [Percutaneous vertebroplasty complicated by pulmonary embolus of acrylic cement], Rev. Mal. Respir. 16 (2) (1999) 215–217.
[62] A.P. Amar, D.W. Larsen, N. Esnaashari, F.C. Albuquerque, S.D. Lavine, G.P. Teitelbaum, Percutaneous transpedicular polymethylmethacrylate vertebroplasty for the treatment of spinal compression fractures, Neurosurgery 49 (5) (2001) 1105–1114 discussion 1114-1105.
[63] M.L. Torres Machi, V. Suarez Romero, C. Medina Ramirez, F. Gil Bedia, N. Ojeda Betancor, A. Rodriguez-Perez, [Pulmonary embolism caused by cement following vertebroplasty], Rev. Esp. Anestesiol. Reanim. 50 (9) (2003) 489–491.
[64] A. Charvet, P. Metellus, N. Bruder, D. Pellissier, F. Grisoli, F. Gouin, [Pulmonary embolism of cement during vertebroplasty], Ann. Fr. Anesth. Reanim. 23 (8) (2004) 827–830.
[65] J.S. Seo, Y.J. Kim, B.W. Choi, T.H. Kim, K.O. Choe, MDCT of pulmonary embolism after percutaneous vertebroplasty, AJR Am. J. Roentgenol. 184 (4) (2005) 1364–1365.
[66] L. Pott, B. Wippermann, S. Hussein, T. Gunther, U. Brusch, R. Fremerey, PMMA pulmonary embolism and post interventional associated fractures after percutaneous vertebroplasty, Orthopä 34 (7) (2005) 698–700 702.
[67] A. Baumann, J. Tauss, G. Baumann, M. Tomka, M. Hessinger, K. Tiesenhausen, Cement embolization into the vena cava and pulmonal arteries after vertebroplasty: interdisciplinary management, Eur. J. Vasc. Endovasc. Surg. Offic. J. Eur. Soc. Vasc. Surg. 31 (5) (2006) 558–561.
[68] G. Bonardel, B. Pouit, E. Gontier, G. Dutertre, M. Mantzarides, O. Goasguen, H. Foehrenbach, Pulmonary cement embolism after percutaneous vertebroplasty: a rare and nonthrombotic cause of pulmonary embolism, Clin. Nucl. Med. 32 (8) (2007) 603–606.
[69] B. Akinola, L. Lutchman, P. Barker, A. Rai, Pulmonary cement embolism during cement augmentation of pedicle screw fixation: a case report, J. Orthop. Surg. 18 (3) (2010) 364–366.
[70] K.E. Radcliff, C.A. Reitman, L.A. Delasotta, J. Hong, T. DiIorio, J. Zaslavsky, A.R. Vaccaro, J.A. Hipp, Pulmonary cement embolization after kyphoplasty: a case report and review of the literature, Spine J. : offic. J.North Am. Spine Soc. 10 (10) (2010) e1–5.
[71] A.M. Abd El-Rahman, A.G. Lazzarotti, M. Cosottini, M. Puglioli, Pulmonary embolism caused by cement leakage during percutaneous vertebroplasty. A case report of successful conservative management, NeuroRadiol. J. 25 (4) (2012) 481–485.
[72] J. Alcibar, R. Blanco, K. Garcia, N. Pena, L. Fernandez, J. Arriola, Multiple fatal pulmonary embolism during polymethyl-methacrylate vertebroplasty with successful percutaneous retrieval of a large cement fragment, Revista espanola de

cardiologia (English ed) 65 (6) (2012) 571–572.
[73] J.F. Chick, N.R. Chauhan, K.M. Mullen, R.J. Bair, B. Khurana, Pulmonary cement emboli after kyphoplasty, Intern. Emerg. Med. 7 (6) (2012) 569–571.
[74] J.B. Cohen, Bone cement embolism, Anesthesiology 117 (2) (2012) 407.
[75] S.M. Kim, S.K. Min, H.J. Jae, S.I. Min, J. Ha, S.J. Kim, Successful thrombolysis, angioplasty, and stenting of delayed thrombosis in the vena cava following percutaneous vertebroplasty with polymethylmethacrylate cement, J. Vasc. Surg. 56 (4) (2012) 1119–1123.
[76] F.J. Liu, H. Ren, Y. Shen, W.Y. Ding, L.F. Wang, Pulmonary embolism caused by cement leakage after percutaneous kyphoplasty: a case report, Orthop. Surg. 4 (4) (2012) 263–265.
[77] C.C. Matouk, T. Krings, K.G. Ter Brugge, R. Smith, Cement embolization of a segmental artery after percutaneous vertebroplasty: a potentially catastrophic vascular complication, Intervent Neuroradiol. J. Peritherapeutic Neuroradiol. Surg. Proced. Relat. Neurosci. 18 (3) (2012) 358–362.
[78] Y.Y. Mishriki, B. Hallinan, Puzzles in practice. Cement pulmonary embolism, Postgrad. Med. 124 (1) (2012) 174–176.
[79] S. Bopparaju, J. Varon, S. Surani, Pulmonary embolism with vertebral augmentation procedures, Case Rep. Pulmonol. 2013 (2013) 785307.
[80] C.W. Chou, C.L. Teng, W.L. Hwang, Bone cement-induced pulmonary embolism in a myeloma patient, Br. J. Haematol. 161 (4) (2013) 459.
[81] E. Garcia-Fontan, M. Blanco Ramos, G.A. Obeso Carillo, Cement embolism during a kyphoplasty, *Eur. J. Cardio. Thorac. Surg.* Offic. J. Eur. Assoc. Cardio Thorac. Surg. 44 (1) (2013) 183.
[82] G. Geraci, G. Lo Iacono, C. Lo Nigro, F. Cannizzaro, M. Cajozzo, G. Modica, Asymptomatic bone cement pulmonary embolism after vertebroplasty: case report and literature review, Case Rep. Surg. 2013 (2013) 591432.
[83] I. Gosev, L. Nascimben, P.H. Huang, L. Mauri, M. Steigner, A. Mizuguchi, A.M. Shah, S.F. Aranki, Right ventricular perforation and pulmonary embolism with polymethylmethacrylate cement after percutaneous kyphoplasty, Circulation 127 (11) (2013) 1251–1253.
[84] S.H. Lee, W.H. Kim, J.K. Ko, Multiple pulmonary cement embolism after percutaneous vertebroplasty, QJM Mon. J. Assoc. Phys. 106 (9) (2013) 877–878.
[85] R.A. Llanos, A. Viana-Tejedor, H.R. Abella, F. Fernandez-Aviles, Pulmonary and intracardiac cement embolism after a percutaneous vertebroplasty, Clin. Res. Cardiol. Offic. J. Ger. Card. Soc. 102 (5) (2013) 395–397.
[86] M.H. Moon, K.H. Jo, H.W. Kim, Cardiac perforation caused by bone cement embolism, Arch. Cardiovasc. Dis. 106 (6–7) (2013) 413–414.
[87] W.A. Sifuentes Giraldo, J.R. Lamua Riazuelo, J.I. Gallego Rivera, M. Vazquez Diaz, Cement pulmonary embolism after vertebroplasty, Reumatol. Clínica 9 (4) (2013) 239–242.
[88] C.H. Yu, S.C. Yang, W. Chen, Pulmonary cement embolism, QJM Mon. J. Assoc. Phys. 106 (10) (2013) 967–968.
[89] M.E. Arnaiz-Garcia, M.J. Dalmau-Sorli, J.M. Gonzalez-Santos, Massive cement pulmonary embolism during percutaneous vertebroplasty, Heart (British Cardiac Society) 100 (7) (2014) 600.
[90] N. Chebib, M. Cour, J. Ruiz Munther, L. Argaud, An unprecedented radiological presentation of a pulmonary cement embolism, BMJ Case Rep. 2014 (2014).
[91] C.Y. Chen, W.E. Cheng, C.H. Lin, S.C. Chen, C.M. Shih, Tadpoles in the lungs. Cement pulmonary embolism complicating vertebroplasty of spinal metastasis, Am. J. Respir. Crit. Care Med. 190 (3) (2014) 340–341.
[92] S. Huh, H. Lee, Pulmonary bone cement embolism: CT angiographic evaluation with material decomposition using gemstone spectral imaging, Korean J. Radiol. 15 (4) (2014) 443–447.
[93] S.P. Kim, B.S. Son, S.K. Lee, D.H. Kim, Cardiac perforation due to intracardiac bone cement after percutaneous vertebroplasty, J. Card. Surg. 29 (4) (2014) 499–500.
[94] V. Pannirselvam, H.T. Hee, Asymptomatic cement embolism in the right atrium after vertebroplasty using high-viscosity cement: a case report, J. Orthop. Surg. (Hong Kong) 22 (2) (2014) 244–247.
[95] M.A. Rothermich, J.M. Buchowski, D.B. Bumpass, G.A. Patterson, Pulmonary cement embolization after vertebroplasty requiring pulmonary wedge resection, Clin. Orthop. Relat. Res. 472 (5) (2014) 1652–1657.
[96] A.C. Stevens, Polymethylmethacrylate cement pulmonary embolism and infarct, Emerg. Med. J. Eng. Manag. J. 31 (3) (2014) 257.
[97] U. Toru, T. Coskun, M. Acat, H. Onaran, S. Gul, E. Cetinkaya, Pulmonary cement embolism following percutaneous vertebroplasty, Case Rep. Pulmonol. 2014 (2014) 851573.
[98] Y. Zhao, T. Liu, Y. Zheng, L. Wang, D. Hao, Successful percutaneous retrieval of a large pulmonary cement embolus caused by cement leakage during percutaneous vertebroplasty: case report and literature review, Spine 39 (26) (2014) E1616–E1621.
[99] M.S. Guirguis, G.S. Shroff, Cement pulmonary embolism, Am. J. Med. Sci. 349 (5) (2015) e5.
[100] A. Nooh, F.H. Abduljabbar, A.H. Abduljabbar, P. Jarzem, Pulmonary artery cement embolism after a vertebroplasty, Case Rep. Orthoped. 2015 (2015) 582769.
[101] F.M. Polli, A. Marongiu, M. Miscusi, F. De-Giorgio, A. Raco, Cardiopulmonary cement embolism after vertebroplasty, Spine J. : offic. J.North Am. Spine Soc. 15 (2) (2015) 376.
[102] S. Schuerer, M. Misfeld, G. Schuler, N. Mangner, Intracardiac cement embolization in a 65-year-old man four months after multilevel spine fusion, Eur. Heart J. 36 (13) (2015) 783.
[103] C. Shen, G. Liu, J.Z. Hu, X.H. Yang, Cardiac perforation and multiple emboli after percutaneous vertebroplasty, Orthopedics 38 (10) (2015) e947–950.
[104] G.S. Shroff, E. Okwandu, C. Viswanathan, M.T. Truong, Pulmonary cement embolism presenting with dyspnea, Semin. Roentgenol. 50 (3) (2015) 226–228.
[105] A. Awwad, I. Le Jeune, M. Kumaran, M.D. Sosin, A rock in a hard place: cement pulmonary emboli after percutaneous vertebroplasty, Int. J. Cardiol. 208 (2016) 162–163.
[106] T. Chai, G.S. Shroff, Cement pulmonary embolism after percutaneous vertebral augmentation in a patient with pathologic lumbar fracture from metastatic breast cancer, PM & R J. Inj. Funct. Rehabil. 8 (5) (2016) 488–490.
[107] M.S. Diab, A. Diab, W. Dihmis, S. Diab, Acute right atrial and pulmonary artery bone cement mass emboli following vertebroplasty, JRSM Open 7 (6) (2016) 2054270416643891.
[108] M. Focardi, A. Bonelli, V. Pinchi, F. De Luca, G.A. Norelli, Pulmonary cement embolism after kyphoplasty, J. Forensic Sci. 61 (Suppl 1) (2016) S252–S255.
[109] L.M. Gabe, I.B. Oliva, Pulmonary cement embolism, Am. J. Med. 129 (11) (2016) e279–e280.
[110] L. Gorospe, M.J. Blanchard-Rodriguez, A. Chinea-Rodriguez, Cement pulmonary embolism after percutaneous vertebroplasty in multiple myeloma, Asian Cardiovasc. Thorac. Ann. 24 (4) (2016) 400–401.
[111] R. Memarpour, B. Tashtoush, F. Nasim, D. Grobman, B.K. Upadhyay, F. Rahaghi, A deep-sea diver with cement pulmonary embolism, Undersea Hyperb. Med. J. Undersea Hyperb. Med. Soc. Inc. 43 (3) (2016) 249–255.
[112] T. Molloy, A. Kos, A. Piwowarski, Robotic-assisted removal of intracardiac cement after percutaneous vertebroplasty, Ann. Thorac. Surg. 101 (5) (2016) 1974–1976.
[113] J.S. Park, J.H. Shin, S.H. Lim, H.M. Yang, Lethal cement leakage embolization after kyphoplasty, Circ. J. Offic. J. Jpn. Circ. Soc. 81 (1) (2016) 119–120.
[114] C.M. Botia Gonzalez, L. Hernandez Sanchez, J.M. Plasencia Martinez, Cement pulmonary embolism, Am. J. Med. Sci. 353 (5) (2017) 507.
[115] C.Y. Chang, S.F. Huang, Asymptomatic pulmonary cement embolism, CMAJ Can. Med. Assoc. J.journal de l'Association medicale canadienne 189 (14) (2017) E543.
[116] T.F. Cianciulli, D.E. Mc Loughlin, L.A. Morita, M.C. Saccheri, J.A. Lax, Bone cement cardiac and pulmonary embolism, Echocardiography (Mount Kisco, NY) 34 (8) (2017) 1239–1241.
[117] C. Hatzantonis, M. Czyz, R. Pyzik, B.M. Boszczyk, Intracardiac bone cement embolism as a complication of vertebroplasty: management strategy, Eur. Spine J. Offic. Publ. Eur. Spine Soc. Eur. Spinal Deformity Soc. Eur. Section Cervical Spine Res. Soc. 26 (12) (2017) 3199–3205.
[118] P. Talec, M. Fromentin, C.M. Samama, Pulmonary embolism of cement after knee prosthesis replacement, Anaesth. Crit. Care Pain Med. 36 (1) (2017) 71–72.