ORIGINAL ARTICLE

# Cement extravasation as a complication for kyphoplasty and vertebroplasty procedure: a retrospective analysis of 171 cases

**Sultan Jarrar[1], Mohammed M. AL Barbarawi[1], Suleiman S. Daoud[1], Amer Jaradat[1], Rand Alkalbani[2], Layan Abu Qayyas[3], Nadeem B. Alabdallah[3], Basel W. Khurfan[4], Ala' M. Al Barbarawi[5], Ziad A. Audat[6]**

[1]Neurosurgery Department, Faculty of Medicine, Jordan University of Science & Technology, [2]Faculty of Medicine, Arab Medical Centre, Amman, [3]Faculty of Medicine, Ministry of Health, Amman, [4]Department of Diagnostic Radiology and Nuclear Medicine, Faculty of Medicine, Jordan University of Science and Technology, Irbid, [5]Faculty of Medicine, Jordan University of Science and Technology, Irbid, [6]Department of Special Surgery, Faculty of Medicine, Jordan University of Science & Technology, Irbid; Jordan

## ABSTRACT

**Aim** Kyphoplasty and vertebroplasty are minimally invasive procedures used in bone augmentation following vertebral fractures when conservative management has failed. Cement injection could leak into surrounding structures leading to post-operative sequelae, which could be symptomatic. This study compared the rate and site of cement extravasation in vertebroplasty, kyphoplasty, and a combined approach. The indications, aetiology, and factors influencing results and the effect of screws were considered.

**Methods** A retrospective descriptive study of 171 patients was conducted between 2009 and 2021. Only 89 patients had available imaging. The site of cement extravasation was evaluated postoperatively by CT-scan and X-ray.

**Results** There was a statistically significant difference in the prevalence of cement extravasation between kyphoplasty and vertebroplasty procedures (p=0.004). Age and gender had no significant influence on the rate of cement extravasation. Patients who underwent kyphoplasty had the lowest rate of cement extravasation (46.9%) compared to vertebroplasty (85.2%) and the combined approach (69.2%). The most common site of leakage was in perivertebral veins (37.9%). The use of screws did not indicate a greater risk of cement leak (p=0.652). Bone metastases were the aetiology with the highest cement leakage rate (27.5%).

**Conclusion** The use of kyphoplasty alone or in conjunction with vertebroplasty decreases the risk of cement extravasation and subsequent complications compared to vertebroplasty alone. The use of pedicle screws appears to be safe and was not found to increase the risk of cement extravasation.

**Key words**: bone metastases, minimally invasive surgical procedures, postoperative complications, spinal fractures

**Corresponding author:**
Sultan Jarrar
Neurosurgery Department,
Faculty of Medicine,
Jordan University of
Science & Technology
PO Box 3030, 22110 Irbid, Jordan
Phone: +962 790033567;
E-mail: dr_sultanmj@yahoo.com
ORCID ID: https://orcid.org/ 0000-0002-7892-7696

**Original submission**:
04 May 2023;
**Revised submission:**
30 June 2023;
**Accepted:**
22 August 2023
doi: 10.17392/1626-23

Med Glas (Zenica) 2024; 21(1):176-183

## INTRODUCTION

Spinal fractures are a major source of morbidity in patients suffering from osteoporosis and metastatic bone diseases. Despite the initial conservative management including bed rest, braces, and physiotherapy that aid in pain relief, vertebral height is unrestored giving a kyphotic appearance that decreases the quality of life and impairs mobility and respiratory function (1, 2) Minimally invasive procedures such as kyphoplasty and vertebroplasty are more beneficial in height restoration and early mobilization. Vertebroplasty emerged in 1987 and has gained popularity in stabilizing fractures without the need for open surgery (3). Due to the limited ability of vertebroplasty to restore height in acute fractures, kyphoplasty, a modification to vertebroplasty, was used to create an internal cavity that amplifies height restoration (4). The use of screws in combination with the above procedures was discussed in 2015, and had shown promising results in reducing the recurrence of vertebral compression fractures (5). Although the benefits of these operations have been thoroughly demonstrated, they are not without complications, the most prevalent of which is cement extravasation (6).

Radiological investigations play a pivotal role in the identification and assessment of cement leaks in patients who have undergone a combined approach. These investigations are essential for addressing pertinent clinical inquiries related to the clinical significance of cement leaks, including the comparative analysis of intervention-related cement leak rates, identification of contributing factors, determination of the most prevalent site for leaks, evaluation of the influence of screws on cement leak rates, and the need for subsequent follow-up and additional interventions (7). Based on our experience, employing radiological imaging techniques, such as CT scans and X-ray imaging, the occurrence and implications of cement leaks can be thoroughly examined, enabling informed decision-making and appropriate patient management strategies.

This investigation was conducted due to the increasing use of vertebroplasty and kyphoplasty in managing spinal fractures in Jordan, and the common complication of cement extravasation observed post-procedure. The literature lacks comprehensive analysis comparing cement leakage rates among these procedures, the factors influencing these rates, and the impact of screw use. Additionally, the role of radiological investigations in detecting and managing cement leaks requires further clarification.

The aim of this study was to compare the rate and site of cement extravasation in vertebroplasty, kyphoplasty, and a combined approach in order to complete these knowledge gaps and improve patient management strategies.

## PATIENTS AND METHODS

### Patients and study design

Retrospective descriptive analysis was done at King Abdullah University Hospital, Jordan University of Science and Technology, Irbid, Jordan, on patients treated between 2009 and 2021. Medical records were examined, and information on demographics, the cause of the fracture, the type of surgery, the use of screws, the existence of cement leaks, and the location were thoroughly scrutinized. The radiological evaluation of post-operative imaging, including CT and X-ray, was carried out to determine and compare the leak rates in kyphoplasty and vertebroplasty, the most frequent leak sites, and the potential role of screws in lowering leak rates. CT was termed the gold standard for detection, whereas X-ray requires inter-observer agreement (8–10). Therefore, two experienced radiologists utilized the X-rays when CT was unavailable, with the employment of both CT and X-ray for the majority of patients. In compliance with the rules of the Helsinki Declaration, patient confidentiality was preserved. This study was approved by the Ethics Committee of the King Abdullah University Hospital, Jordan University of Science and Technology, Irbid, Jordan (No 19 151 2022).

### Methods

Vertebroplasty is a procedure in which cement, such as polymethylmethacrylate (PMMA), is percutaneously injected into the cancellous bone of a vertebral body with the aim of reducing pain brought on by a vertebral compression fracture and halting further loss of vertebral body height or the development of a kyphotic deformity (11). Later, kyphoplasty was developed as a variant of vertebroplasty in which the cancellous bone is compre-

ssed and a chamber is created by inflating a balloon tamp inside the vertebral body (11,12). It is theoretically possible to inject cement into the cavity with less force, which reduces extravasation.

A combined approach was used in patients with a vertebral fracture that was managed by kyphoplasty, where adjacent vertebrae at high risk of fractures were managed prophylactically with vertebroplasty. First, patients were placed in a prone position under general or local anesthesia depending on their overall health status. Using fluoroscopic guidance, an entry point was marked on the skin of the patient's back, usually in the pedicle of the affected vertebra. For the kyphoplasty, a small incision was made at the marked entry point, and a narrow pathway was created into the fractured vertebra with the help of a surgical drill. A balloon was then inserted into the vertebra through this pathway. The balloon was carefully inflated to create a cavity and restore some of the lost vertebral height. The balloon was then deflated and removed, leaving the cavity behind. This cavity was filled with a specialized type of bone cement to stabilize the fracture. For vertebroplasty on adjacent vertebrae, a similar process was followed, but without the use of a balloon. A needle was inserted into the high-risk vertebra and bone cement was injected directly to prevent potential fractures. Throughout the procedure, real-time X-ray (fluoroscopy) was used to guide the instruments and to monitor the distribution of the bone cement. The combination of these two techniques aimed to provide immediate stability, reduce pain, restore vertebral height, and prevent further fractures in adjacent vertebrae.

### Statistical methods

Continuous variables were presented as means and standard deviation (SD), while categorical variables were presented as counts and percentages. Categorical data were compared and analysed using $\chi 2$ and Fisher's exact tests where appropriate. Means between groups were compared using T-tests and One Way ANOVA tests where appropriate. A $p< 0.05$ was considered to indicate a statistically significant difference.

## RESULTS

A retrospective analysis was done on 171 adult patients who underwent kyphoplasty, vertebroplasty, or a combination of both procedures for the management of vertebral fractures, of which 87 (50.9%) were males and 84 (49.1%) were females. The mean age was 63.4 (14) years of age, with the youngest patient being 22 and the oldest patient being 92 years old. The vertebral fractures were found to be caused by a traumatic injury (29.2%), bone metastasis (23.4%), multiple myeloma (19.9%), osteoporosis (18.1%), and hemangiomas (5.3%). Out of the 171 patients, 101 (59.1%) underwent kyphoplasty, 42 (24.5%) underwent vertebroplasty, and 28 (16.4%) underwent the combined approach. Patients' gender did not correlate significantly with the type of procedure performed (p=0.909). Patients undergoing the combined approach had a higher mean age compared to other two groups (p=0.044). Patients presenting with multiple myeloma were more likely to be managed using vertebroplasty (52.9%) than kyphoplasty (14.7%), while patients presenting with traumatic injury, bone metastasis, and osteoporotic vertebral fractures were more likely to be managed with kyphoplasty than vertebroplasty (Table 1).

The median number of vertebrae involved in each patient was two vertebrae, with a minimum of 1 and a maximum of 17. A significant association was observed between the number of treated vertebrae and cement leak rate. Specifically, patients experiencing cement leakage had a higher average number of involved vertebrae (6.65±5.75) compared to those without leaks (1.74±1.26). The number of vertebrae involved in each patient in the vertebroplasty group was significantly larger than in the kyphoplasty and the combined approach groups (p=0.000). Screws were used in 36.3% of the patients with no statistically significant difference between the groups (p=0.371). The patients with procedures where screws were used had a lower mean age than the procedures that did not use screws (p=0.000). The traumatic injury with vertebral fracture aetiology was most associated with the use of screws, accounting for 45.1% of cases requiring screws while being responsible for 29.2% of cases only (Table 2).

Cement leaks were evaluable only in 89 (52.0%) patients due to the absence of imaging records for the rest of patients. Cement leakage was noticed in 33.7%, 28.1% and 37.1% of patients according to CT, X-ray imaging, and a combination of CT scans and X-ray imaging, respectively. Overall

**Table 1. Comparison of surgical approaches**

| Variable | No (%) of patients in surgical procedure | | | | p |
|---|---|---|---|---|---|
| | Kyphoplasty (N=101) | Vertebroplasty (N=42) | Combined (N=28) | Total (N=171) | |
| **Age mean (SD)** (years) | 61.7 (14.5) | 63.5 (12.9) | 69.1 (12.7) | 63.4 (14.0) | 0.044 |
| **Gender** | | | | | |
| Female | 49.0 (48.5) | 22.0 (52.4) | 13.0 (46.4) | 84.0 (49.1) | 0.909 |
| Male | 52.0 (51.5) | 20.0 (47.6) | 15.0 (53.6) | 87.0 (50.9) | |
| **Aetiology** | | | | | |
| Trauma | 37.0 (36.6) | 8.0 (19.0) | 5.0 (17.9) | 50.0 (29.2) | 0.001 |
| Bone metastasis | 26.0 (25.7) | 8.0 (19.0) | 6.0 (21.4) | 40.0 (23.4) | |
| Osteoporosis | 23.0 (22.8) | 4.0 (9.5) | 5.0 (17.9) | 32.0 (18.7) | |
| Multiple myeloma | 5.0 (5.0) | 18.0 (42.9) | 11.0 (39.3) | 34.0 (19.9) | |
| Haemangioma | 5.0 (5.0) | 3.0 (7.1) | 1 (3.6) | 9.0 (5.3) | |
| Infection | 2.00 (2.0) | 0 | 0 | 2.0 (1.2) | |
| **Systemic lupus erythematosus fracture** | 1.00 (1.0) | 1.00 (2.5) | 0 | 1.0 (0.6) | |
| Spinal tumour | 1 (1.0) | 0 | 0 | 1.0 (0.6) | |
| Chordoma | 1 (1.0) | 0 | 0 | 1.0 (0.6) | |
| Spondyloarthropathy | 0 | 1 (2.4) | 0 | 1.0 (0.6) | |
| **Cement leak** | | | | | |
| Yes | 23.0 (22.8) | 23.0 (54.8) | 9.0 (32.1) | 55.0 (32.1) | 0.004 |
| No | 26.0 (25.7) | 4.0 (9.5) | 4.0 (14.3) | 34.0 (19.9) | |
| No image available | 52.0 (51.5) | 15.0 (35.7) | 15.0 (53.6) | 82.0 (48) | |
| **Use of screws** | | | | | |
| Yes | 40.0 (39.6) | 15.0 (35.7) | 7.0 (22.2) | 62.0 (36.3) | 0.371 |
| No | 61.0 (60.4) | 25.0 (59.5) | 21.0 (77.8) | 107 (62.6) | |
| Missing | 0 (0) | 2 (4.8) | 0 (0) | 2.0 (1.1) | |
| **Number of Vertebrae** | | | | | |
| Mean (SD) | 1.9 (2.7) | 7.90 (5.8) | 6.9 (4.8) | 4.2 (4.8) | 0.000 |
| Missing | 4.0 (4.0) | 2.0 (2.5) | 2.0 (7.4) | 8.0 (4.2) | |
| Number of leak sites | | | | | |
| Single | 16.0(15.8) | 6.0 (14.3) | 3.0 (10.7) | 25.0 (14.6) | 0.001 |
| Multiple | 7.0 (6.9) | 16.0 (38.1) | 6.0 (21.4) | 29.0 (17) | |
| None | 26.0 (25.7) | 4.0 (9.5) | 4.0 (14.3) | 34.0 (19.9) | |
| Missing | 52.0 (51.5) | 16.0 (38.1) | 15.0 (53.6) | 83.0 (48.5) | |
| **Leak sites** | | | | | |
| **Perivertebral veins** | 6.0 (5.9) | 20.0 (47.6) | 7.0 (25) | 33.0 (19.3) | 0.000 |
| Missing | 52.0 (51.5) | 17.0 (40.5) | 15.0 (53.6) | 83.0 (48.5) | |
| **Spinal canal** | 6.0 (5.9) | 12.0 (28.6) | 5.0 (17.9) | 23.0 (13.5) | 0.006 |
| Missing | 52.0 (51.5) | 17.0 (40.5) | 15.0 (53.6) | 83.0 (48.5) | |
| **Perivertebral soft tissue** | 7.0 (6.9) | 10.0 (23.8) | 4.0 (14.3) | 21.0 (12.3) | 0.075 |
| Missing | 52.0 (51.5) | 17.0 (40.5) | 15.0 (53.6) | 83.0 (48.5) | |
| **Intervertebral disc** | 11.0 (10) | 4.0 (9.5) | 4.0 (14.3) | 19.0 (11.1) | 0.426 |
| Missing | 52.0 (51.5) | 17.0 (40.5) | 15.0 (53.6) | 83.0 (48.5) | |
| **Injection tract** | 1.0 (1) | 2.0 (4.8) | 1.0 (3.6) | 4.0 (2.3) | 0.351 |
| Missing | 52.0 (51.5) | 17.0 (40.5) | 15.0 (53.6) | 83.0 (48.5) | |
| **Distal venous embolization** | 0 | 2.0 (4.8) | 2.0 (7.1) | 4.0 (2.3) | 0.059 |
| Missing | 52.0 (51.5) | 17.0 (40.5) | 15.0 (53.6) | 83.0 (48.5) | |

cement leak was noted in 55 (61.8%) patients. Across the three groups, the prevalence of cement leakage was highest in the vertebroplasty group (85.2%) and was significantly higher than in the kyphoplasty group (46.9%) and the combined approach group (69.2%). The type of procedure was found to be correlated significantly to the prevalence of a cement leak (p=0.004). The age and gender of the patients, as well as the use of screws during the procedure, were not found to correlate statistically with the prevalence of a cement leak. The correlation between the cement leak and the number of vertebrae involved was statistically significant (p=0.001). Multiple myeloma patients had a significantly higher prevalence of cement leaks compared to all other aetiologies (p=0.001) (Table 3).

Of the patients with documented cement leak, 46.3% had leakage to a single site, while 53.7% had leakage to multiple sites. The patients in the vertebroplasty group had a higher prevalence of cement leak to multiple sites rather than a single site compared to the kyphoplasty and the combined approach groups (p=0.001) (Table 4)**.** The most common site for cement leakage was the perivertebral veins (37.9%). Vertebroplasty was associated with a higher prevalence of cement leak to the perivertebral veins (p=0.000) and

**Table 2. Use of screws in different surgical approaches**

| Variable | No (%) of patients used screws | | | p |
|---|---|---|---|---|
| | Yes (N=62) | No (N=107) | Total (N=169) | |
| **Age (years)** | | | | |
| Mean (SD) | 57.7 (15.2) | 66.4 1(2.2) | 63.2 (14.0) | 0.000 |
| **Gender** | | | | |
| Female | 29.0 (46.8) | 54.0 (50.5) | 83.0 (49.1) | 0.643 |
| Male | 33.0 (53.2) | 53.0 (49.5) | 86.0 (50.9) | |
| **Etiology** | | | | |
| Trauma | 28.0 (45.2) | 21.0 (19.6) | 49.0 (29.0) | 0.000 |
| Bone Metastasis | 14.0 (22.6) | 26.0 (24.3) | 40.0 (23.7) | |
| Osteoporosis | 11.0 (17.7) | 20.0 (18.7) | 31.0 (18.3) | |
| Multiple Myeloma | 3.0 (4.8) | 31.0 (29.0) | 34.0 (20.1) | |
| Haemangioma | 5 (8.1) | 4 (3.7) | 9 (5.3) | |
| Infection | 0 (0) | 2 (1.9) | 2 (1.2) | |
| Chordoma | 0 (0) | 1 (0.9) | 1 (0.6) | |
| Spinal tumour | 1 (1.6) | 0 (0) | 1 (0.6) | |
| SLE fracture | 0 (0) | 1 (0.9) | 1 (0.6) | |
| Spondyloarthropathy | 0 (0) | 1 (0.9) | 1 (0.6) | |
| **Surgery** | | | | |
| Kyphoplasty | 40.0 (64.5) | 61.0 (57.0) | 101.0 (59.8) | 0.371 |
| Vertebroplasty | 15.0 (24.2) | 25.0 (23.4) | 40.0 (23.7) | |
| Combined | 7.0 (11.25) | 21.0 (19.6) | 28.0 (16.6) | |
| **Number of Vertebrae** | | | | |
| Mean (SD) | 2.3 (2.1) | 5.3 (5.6) | 4.2 (4.8) | 0.000 |
| Missing | 1.0 (1.6) | 5.0 (4.7) | 6.00 (3.6) | |
| **Number of leak sites** | | | | 0.426 |
| Single | 11.0 (17.7) | 14.0 (13.1) | 25.0 (14.8) | |
| Multiple | 7.0 (11.3) | 22.0 (20.6) | 29.0 (17.2) | |
| None | 14.0 (22.6) | 20.0 (18.7) | 34.0 (20.1) | |
| Missing | 30.0 (48.3) | 51.0 (47.7) | | |
| **Site of leak** | | | | |
| **Perivertebral veins** | 9.0 (14.5) | 24.0 (22.4) | 33.0 (19.5) | 0.391 |
| Missing | 30.0 (48.3) | 51.0 (47.7) | 81.0 (47.9) | |
| **Perivertebral soft tissue** | 4.0 (6.4) | 17.0 (15.9) | 21.0 (12.4) | 0.187 |
| Missing | 31.0 (50) | 51.0 (47.7) | 82.0 (48.5) | |
| **Intervertebral disc** | 6.0 (9.7) | 13.0 (13.1) | 19.0 (11.2) | 0.923 |
| Missing | 30.0 (48.3) | 51.0 (47.7) | 81.0 (47.9) | |
| **Spinal canal** | 7.0 (11.2) | 16.0 (15) | 23.0 (13.6) | 0.838 |
| Missing | 31.0 (50) | 51.0 (47.7) | 82.0 (48.5) | |
| **Distal venous embolization** | 0 (0) | 4.0 (3.7) | 4.0 (2.4) | 0.456 |
| Missing | 31.0 (50) | 51.0 (47.7) | 82.0 (48.5) | |
| **Injection tract** | 0 (0) | 4.0 (3.7) | 4.0 (2.4) | 0.456 |
| Missing | 31.0 (50) | 51.0 (47.7) | 82.0 (48.5) | |

**Table 3. Comparison of demographics and clinical features between patients with and without cement leakage**

| Variable | No (%) of patients with or without cement leak | | | p |
|---|---|---|---|---|
| | Yes (N=55) | No (N=34) | Overall (N=89) | |
| **Age (years)** | | | | |
| Mean (SD) | 62.1 (12.2) | 58.0 (14.0) | 60.3 (13.4) | 0.145 |
| **Gender** | | | | |
| Female | 29.0 (52.7) | 16.0 (47.1) | 45.0 (50.6) | 0.603 |
| Male | 26.0 (47.3) | 18.0 (52.9) | 44.0 (49.4) | |
| **Surgical Procedures** | | | | |
| Kyphoplasty | 23.0 (41.8) | 26.0 (76.4) | 49.0 (55.1) | 0.003 |
| Vertebroplasty | 23.0 (41.8) | 4.0 (11.8) | 27.0 (30.3) | |
| Combined | 9.0 (16.3) | 4.0 (11.8) | 13 (14.6) | |
| **Etiology** | | | | |
| Trauma | 8.0 (14.5) | 13.0 (38.2) | 21.0 (26.3) | 0.001 |
| Bone Metastasis | 11.0 (20.0) | 7.00 (20.6) | 22.0 (27.5) | |
| Osteoporosis | 10.00 (18.2) | 11.0 (32.4) | 21.0 (26.3) | |
| Multiple Myeloma | 21.00 (38.2) | 1.00 (2.9) | 22.0 (20.0) | |
| Spinal tumour | 0 (0) | 1.00 (2.9) | 1.00 (1.1) | |
| Chordoma | 0 (0) | 1.00 (2.9) | 1.00 (1.1) | |
| Haemangioma | 4 (7.3) | 0 (0) | 4 (4.5) | |
| SLE fracture | 1 (1.8) | 0 (0) | 1 (1.1) | |
| **Radiography type** | | | | |
| CT | 21.0 (38.2) | 9.00 (26.5) | 30.0 (33.7) | 0.061 |
| CT + X-ray | 23.0 (41.8) | 10.0 (29.4) | 33.0 (37.1) | |
| X-ray | 10.00 (18.2) | 15.0 (44.1) | 25.0 (28.1) | |
| Missing | 1.00 (1.8) | 0 (0) | 1.00 (1.1) | |
| **Number of vertebrae** | | | | |
| Mean (SD) | 6.65 (5.75) | 1.74 (1.26) | 4.75 (5.15) | 0.000 |
| Missing | 1.00 (2.1) | 0 (0) | 1.00 (1.3) | |
| **Screws** | | | | 0.652 |
| Yes | 19.0 (34.5) | 14.0 (41.2) | 33 (37.1) | |
| No | 36.0 (65.5) | 20.0 (58.8) | 56 (62.9) | |

**Table 4. Distribution of cement leak sites in 89 patients undergoing kyphoplasty and vertebroplasty**

| Leak site | No (%) of patients* |
|---|---|
| Perivertebral veins | 33.0 (37.9) |
| Spinal canal | 23.0 (26.4) |
| Perivertebral soft tissue | 21.0 (24.1) |
| Intervertebral disc | 19.0 (21.8) |
| Injection tract | 4.0 (4.5) |
| Distal venous embolization | 4.0 (4.5) |

*some patients having multiple sites of cement extravasation

spinal canal (p=0.0006) compared to the kyphoplasty and the combined approach groups. There was no statistical difference in cement leakage to other sites when comparing the three groups.

## DISCUSSION

Our study included 171 patients, 89 of whom had cement leakage confirmed. The patients in the vertebroplasty arm had significantly higher rates of cement leak (85.2%), followed by the combined approach (69.2%), and the kyphoplasty group (46.9%). These findings are consistent between multiple studies comparing kyphoplasty and vertebroplasty, although the cement leak rate was reported slightly less (41% for percutaneous vertebroplasty and 9% for kyphoplasty) (13,14). These findings indicate that surgeons operating on vertebral fractures should attempt to use kyphoplasty to manage these fractures whenever possible. To our knowledge, this is the largest cohort study looking at the prevalence of cement extravasation in Jordan, and it is the first study in the literature to compare patients who had undergone the combined approach with either procedure alone. Since the frequency of cement leakage shows up significantly, preoperative prediction of risk factors would be helpful to facilitate reduction in the event of leakage (15). In our study, age and gender were

not found to be correlated with leak rates. This is in accordance with multiple studies (16, 17). As for vertebral fracture aetiologies and indications for all three procedures, multiple myeloma had the highest cement leak rate 95.5%, and it was more prevalent in the vertebroplasty group (42.9%) with a mean number of vertebrae operated on being 15. In Tome et al. study, the incidence of leak in malignant-treated vertebrae was 90.0%, and earlier reports highlighted that pathological fractures pose a risk of leak in comparison with osteoporotic fractures (16, 18). This observation of the higher number of vertebrae and aetiology may have been factors that impacted the higher vertebroplasty cement leak rate; as the larger mean number of vertebrae involved in our study was higher in the cement leak group. It is unclear, however, if the higher leakage rate in vertebroplasty was related to the higher number of vertebrae involved or the aetiology of the fracture. Moreover, a meta-analysis showed that certain risk factors including the integrity of the vertebral wall, volume and viscosity of the injected cement, and the presence of the intravertebral cleft have an impact on cement leakage post vertebroplasty or kyphoplasty (19). These variables were difficult to assess in our study due to limitations in data. The perivertebral veins were the most common site of leak across all patient subgroups.

Delving deeper, patients who underwent vertebroplasty had a cement leak most commonly in perivertebral veins (47.6%), and kyphoplasty had a leak more frequently in the intervertebral disc (10.0%). Our results conflict with Lee et al. who found that the commonest site of the leak was the perivertebral soft tissue (38.1%) for vertebroplasty and perivertebral vein (24.1%) in kyphoplasty (20). The subset of our patients who underwent both procedures had leaks frequently in perivertebral veins (25.0%). To our knowledge, no study observed the common site of the leak for patients who underwent the combined approach. The use of pedicle screws with kyphoplasty and vertebroplasty has been described to improve the integrity of screws, the clinical outcome, and the fixation of all three columns of the spine using a single approach (21, 22). Dichao et al. was the first study to show that the use of screws with kyphoplasty can accomplish a longer fixation period and stronger support to the vertebrae compared to kyphoplasty in osteoporotic vertebral compression fractures (23). In our study, the hybrid technique of using screws with either procedure was employed in a number of patients (36.3%), a higher number of the kyphoplasty group had screws inserted than the vertebroplasty and the combined approach. The use of screws was evidently more in cases of trauma to further stabilize the vertebral column.

The hybrid technique did not show any increased risk for cement leak, whereas other studies showed that the use of kyphoplasty alone was associated with more complications such as cement leaks, fractured vertebral collapse, and reoperation due to new fractures than in patients who underwent the hybrid technique (23). This indicates that the use of pedicle screws is safe and associated with a reduced risk of complications when used in conjunction with kyphoplasty and vertebroplasty. Future studies with larger cohorts should attempt to identify if any specific patient populations based on aetiology, age, etc. would see a greater benefit to the use of pedicle screws and the combined approach rather than either procedure done individually.

In spite of the fact that cement extravasation is generally not a clinical symptom, in some cases it can lead to serious complications such as neurological deficits, new vertebral fractures, and even more serious fatal conditions such as pulmonary embolism (PE). Cement PE was found in 12.7% of the patients (18.9% had multiple myeloma), with 76.9% having malignant fractures; the majority of patients were asymptomatic, however, 38.5 % reported respiratory symptoms that led to the diagnosis (24). According to Hulme et al., the risk of PE increases with paravertebral vein cement leak (25). This is in accordance with our data where three of our patients had right pulmonary artery embolism discovered incidentally, with the common denominators being multiple myeloma and concomitant leak into the paravertebral veins. Luckily, these patients did not require any treatment and had no clinical signs and symptoms of respiratory distress. The finding of cement PE in asymptomatic patients should not prompt treatment, whereas symptomatic patients are typically treated with anticoagulation to decrease the risk of thrombus formation over the cement emboli (26, 27).

In our institution post-operative imaging is done immediately after the surgery to evaluate the spine and look for any signs of cement extravasation. Follow-up imaging was done two to three days after the surgery to evaluate any cement leaks that may have occurred. Long-term follow-up is not necessary for asymptomatic patients as the clinical benefit is low, and the financial cost and radiation exposure are considerable. If a patient becomes symptomatic, however, imaging is necessary to rule out complications secondary to cement extravasation after the procedure.

Our study is subjected to some limitations: the relatively small sample size due to data collection from a single health centre reduced the power of the study, renewal of the old electronic medical record system resulted in only 89 of the 171 patients having available imaging studies, viscosity and volume of cement were not attainable due to lack of specific guidelines regarding the amount of cement to be injected, and there were no specific follow-up imaging guidelines for asymptomatic patients in our medical centre. To gain a comprehensive understanding of the implications of cement extravasation, it would be valuable to explore the percentage of clinically manifested complications among patients with confirmed extravasation. Additionally, examining the rates of extravasation and clinically manifested complications in relation to specific patient groups, such as those with vertebral fractures, bone metastasis, multiple myeloma, osteoporosis, haemangiomas, and other conditions, would provide further insights into the outcomes and risks associated with these procedures. Future studies should aim to investigate the clinical impact of cement extravasation in different patient populations and assess the long-term outcomes and complications. By considering both the rates of extravasation and the corresponding clinical manifestation, a more comprehensive understanding of the risks and benefits of vertebroplasty, kyphoplasty, and the combined approach can be achieved.

In conclusion, our findings indicate that surgeons operating on vertebral fractures should attempt to use kyphoplasty to manage these fractures whenever possible. Even when kyphoplasty is not possible for all vertebral fractures in a patient, care should be taken to identify vertebrae that can be possibly managed with kyphoplasty in conjunction with vertebroplasty rather than opting for vertebroplasty for all fractured vertebrae. This practice may aid in minimizing the risk of cement extravasation and subsequent PE. The hybrid technique of using screws with either procedure was found to be safe with no indication of increased risk of cement leaks. Future studies with larger cohort should attempt to identify if any specific patient populations based on aetiology, age, etc. would see a greater benefit to the use of pedicle screws and the combined approach rather than either procedure done individually.

## FUNDING

No specific funding was received for this study.

## TRANSPARENCY DECLARATION

Competing interests: None to declare.

## REFERENCES

1. Armsen N, Boszczyk B. Vertebro-/kyphoplasty history, development, results. Eur J Trauma 2005; 31:433–41.
2. Schlaich C, Minne HW, Bruckner T, Wagner G, Gebest HJ, Grunze M, Ziegler R, Leidig-Bruckner G. Reduced pulmonary function in patients with spinal osteoporotic fractures. Osteoporos Int 1998; 8:261–7.
3. Galibert P, Deramond H. Preliminary note on the treatment of vertebral angioma by percutaneous acrylic vertebroplasty. Presse Med 1987; 16:399.
4. Coumans JVCE, Reinhardt MK, Lieberman IH. Kyphoplasty for vertebral compression fractures: 1-year clinical outcomes from a prospective study. J Neurosurg Spine 2003; 99:44–50.
5. Cui L, Jia P, Guo W, Zhang J, Zhang Z, Wang Y, Li D. Minimally invasive pedicle screw fixation combined with percutaneous vertebroplasty for the treatment of thoracolumbar burst fracture. Int J Surg 2016; 36(Pt A):255–60.
6. Nussbaum DA, Gailloud P, Murphy K. A review of complications associated with vertebroplasty and kyphoplasty as reported to the Food and Drug Administration medical device related web site. J Vasc Interv Radiol 2004; 15:1185–92.
7. Hiwatashi A, Ohgiya Y, Kakimoto N, Westesson PL. Cement leakage during vertebroplasty can be predicted on preoperative MRI. AJR Am J Roentgenol 2007; 188:1099–103.

8. Hulme PA, Krebs J, Ferguson SJ, Berlemann U. Vertebroplasty and kyphoplasty: a systematic review of 69 clinical studies. Spine (Phila Pa 1976) 2006; 31:1983–2001.
9. Gstöttner M, Angerer A, Rosiek R, Gäbler A, Eder T, Benditz A, Glaser C. Quantitative volumetry of cement leakage in viscosity-controlled vertebroplasty. J Spinal Disord Tech 2012; 25:E244–9.
10. Schmidt R, Cakir B, Mattes T, Wegener M, Puhl W, Richter M. Cement leakage during vertebroplasty: an underestimated problem? Eur Spine J 2005; 14:466–73.
11. McCall T, Cole C, Dailey A. Vertebroplasty and kyphoplasty: a comparative review of efficacy and adverse events. Curr Rev Musculoskelet Med 2008; 1:17–23.
12. Lieberman IH, Dudeney S, Reinhardt MK, Bell G. Initial outcome and efficacy of "kyphoplasty" in the treatment of painful osteoporotic vertebral compression fractures. Spine (Phila Pa 1976) 2001; 26:1631–8.
13. Hulme PA, Krebs J, Ferguson SJ, Berlemann U. Vertebroplasty and kyphoplasty: a systematic review of 69 clinical studies. Spine (Phila Pa 1976) 2006; 31:1983–2001.
14. Taylor RS, Taylor RJ, Fritzell P. Balloon kyphoplasty and vertebroplasty for vertebral compression fractures: a comparative systematic review of efficacy and safety. Spine (Phila Pa 1976) 2006; 31:2747–55.
15. Ding J, Zhang Q, Zhu J, Zhou Y, Dai M, Jiang J, Wang Y, Zheng Y. Risk factors for predicting cement leakage following percutaneous vertebroplasty for osteoporotic vertebral compression fractures. Eur Spine J 2016; 25:3411–7.
16. Tomé-Bermejo F, Piñera AR, Duran-Álvarez C, Román BL, Mahillo I, Alvarez L. Identification of risk factors for the occurrence of cement leakage during percutaneous vertebroplasty for painful osteoporotic or malignant vertebral fracture. Spine (Phila Pa 1976) 2014; 39:E693–700.
17. Ding J, Zhang Q, Zhu J, Zhou Y, Dai M, Jiang J, Wang Y, Zheng Y. Risk factors for predicting cement leakage following percutaneous vertebroplasty for osteoporotic vertebral compression fractures. Eur Spine J 2016; 25:3411–7.
18. Lee MJ, Dumonski M, Cahill P, Stanley T, Park D, Singh K. Percutaneous treatment of vertebral compression fractures: a meta-analysis of complications. Spine (Phila Pa 1976) 2009; 34:1228–1232.
19. Zhan Y, Jiang J, Liao H, Tan H, Yang K. Risk factors for cement leakage after vertebroplasty or kyphoplasty: a meta-analysis of published evidence. World Neurosurg 2017; 101:633–42.
20. Lee IJ, Choi AL, Yie MY, Byun JY, Park JH, Woo DC, Choi TY, Shinn KS. CT evaluation of local leakage of bone cement after percutaneous kyphoplasty and vertebroplasty. Acta Radiol 2010; 51:649–54.
21. Afzal S, Akbar S, Dhar SA. Short segment pedicle screw instrumentation and augmentation vertebroplasty in lumbar burst fractures: an experience. Eur Spine J 2008; 17:336–41.
22. Acosta FL, Aryan HE, Taylor WR, Ames CP. Kyphoplasty-augmented short-segment pedicle screw fixation of traumatic lumbar burst fractures: initial clinical experience and literature review. Neurosurg Focus 2005; 18:3–6.
23. Huang D, Ying J, Xu D, Zhang D, Lyu F, Li Z, Wang H. Comparison of percutaneous kyphoplasty with or without pedicle screw fixation in osteoporotic thoracolumbar vertebral fractures: a retrospective study. Dis Markers 2021; 2021:6669840.
24. Mansour A, Abdel-Razeq N, Abuali H, Saadeh SS, Abu Ali HA. Cement pulmonary embolism as a complication of percutaneous vertebroplasty in cancer patients. Cancer Imaging 2018; 18:7.
25. Hulme PA, Krebs J, Ferguson SJ, Berlemann U. Vertebroplasty and kyphoplasty: a systematic review of 69 clinical studies. Spine (Phila Pa 1976) 2006; 31:1983–2001.
26. Choe DH, Marom EM, Ahrar K, Truong MT, Madewell JE. Pulmonary embolism of polymethyl methacrylate during percutaneous vertebroplasty and kyphoplasty. AJR Am J Roentgenol 2004; 183:1097–102.
27. Wang LJ, Yang HL, Shi YX, Jiang WM, Chen L. Pulmonary cement embolism associated with percutaneous vertebroplasty or kyphoplasty: a systematic review. Orthop Surg 2012; 4:182–9.