Impact of the quantity of intradiscal cement leak on the progression of intervertebral disc degeneration

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ABSTRACT

INTRODUCTION We aim to assess the impact of the quantity of intradiscal cement leak during kyphoplasty on the rate of progression of degenerative changes in the affected disc.

METHODS Of 316 kyphoplasty procedures, we identified 32 episodes of intradiscal cement leak in 26 patients. The quantity of cement leaked was graded from I to IV. Disc degenerative changes were assessed at presentation and follow-up using radiographical scoring and magnetic resonance imaging (MRI) grading systems. Data for low-grade leaks (grade I) were compared with the medium- and high-grade leaks (grades II–IV) using a chi-squared test.

RESULTS Median follow-up radiographic and MRI assessments were made at 18 and 21 months, respectively. Medium- and high-grade leaks were associated with a significantly higher radiographic disc degeneration scores compared with low-grade leaks ($P = 0.04295$) but no difference was found in MRI disc degeneration grades and in adjacent vertebral fracture rates.

CONCLUSIONS Our findings indicate that the quantity of cement leaking into the disc space significantly influences the rate of progression of disc degeneration.

KEYWORDS

Percutaneous balloon kyphoplasty – Intradiscal cement leak – Disc degeneration – Osteoporosis – Vertebral fracture

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Introduction

Percutaneous kyphoplasty and vertebroplasty are widely recognised techniques used for the treatment of symptomatic osteoporotic vertebral compression fractures. The procedures are beneficial in stabilising the vertebral body and in alleviating pain.¹ Cement leaking outside the vertebral body is reported to occur in 13.5% to more than 70% of vertebroplasty procedures.² Commonly, cement leaks into the paraspinal soft tissue or the perivertebral venous system and it is of no clinical significance unless it compromises the neural structures or causes a pulmonary cement embolism.^{2–4} A cement leak into the adjacent disc space during vertebroplasty has been linked to an increased risk of new vertebral fractures by some authors.^{2,5,6} but not others.⁷ The impact of an intradiscal cement leak on the progression of degenerative changes in the affected disc space in general, and the influence of the amount of the cement leak on the long-term effect in particular, have not been examined adequately in the literature. The objectives of this study were to establish whether the quantity of intradiscal cement leaking during kyphoplasty has any influence on the rate of

progression of degenerative changes in the affected disc and on the incidence of the development of new adjacent vertebral fractures.

Methods

We reviewed images taken during all percutaneous balloon kyphoplasty procedures performed at the Royal Derby Hospital from 31 May 2014 to 1 October 2006. Of a total of 316 interventions, we identified and selected for this study 26 patients with had a total of 32 episodes of cement leaking into disc space. Using selected radiographic slices, the amount of intradiscal cement leaked was quantified by a grading system proposed by two of the authors (ZK and SP):

- > grade I: cement leak into the disc space was considered minimal/cloud (Figure 1a);
- > grade II: cement leak filled <20% of the disc space (Figure 1b);
- > grade III: cement leak filled 20–40% of the disc space (Figure 1c);
- > grade IV: cement leak filled >40% of the disc space (Figure 1d).

Figure 1 (a) Grade I: cement leakage into the disc space was considered minimal/cloud. (b) Grade II: cement leakage filled < 20% of the disc space. (c) Grade III: cement leak filled 20–40% of the disc space. (d) Grade IV: cement leakage filled > 40% of the disc space.

The progression of the degenerative changes in the affected disc space was assessed by comparing images obtained at presentation and follow-up. Radiographic evaluation of the anterior–posterior and lateral images was performed applying the Mimura et al. grading system (scores of 0–10; Table 1).⁸ Magnetic resonance image (MRI) evaluation of the T2-weighted images was done using the Puertas et al. grading system (grades I–V; Table 2).⁹ The occurrence of a new adjacent vertebral fracture was determined by comparing the radiographic images taken at presentation and follow-up.

The amount of intradiscal cement leaked in each of the 32 episodes and the radiographic and MRI assessments were independently graded by two consultants (ZK and SP) and disagreements were discussed. The outcome for disc degenerative changes was based on the change in scores between presentation and follow-up using both modalities

(radiographs and MRI). The outcome for vertebral fractures was based on occurrence of new adjacent fractures on radiographs at follow-up. Based on the quantity of intradiscal cement leaked, patients were divided into two groups for analysis: low-grade leaks (LGL, grade I) and medium- and high-grade leaks (MHGL; grades II–IV). The two groups were compared based on the duration from presentation to follow-up (≥ 18 months vs. < 18 months), affected disc level (T11–12 and above vs. T12–L1 and below), change in radiographic score (≤ 2 points vs. > 2 points), change in MRI grade (≥ 1 grade vs. < 1 grade) and occurrence of new adjacent vertebral fracture (yes vs. no). The data were analysed using a chi-squared test with significance obtained at $P < 0.05$. The Social Sciences Statistics site was used for statistical analysis.¹⁰

Results

Patient ages ranged from 45 years to 90 years (median 76 years). The instances of cement leaking into the 32 disc spaces were graded as follows: grade I: 18 (56.3%), grade II: 7 (21.9%), grade III: 5 (15.6%) and grade IV: 2 (6.3%). LGL was observed in 18 (56.3%) of the affected discs while MHGL was detected in 14 (43.8%). The levels of the affected disc spaces were: T7/8: 2 (6.3%), T8/9: 2 (6.3%), T9/10: 2 (6.3%), T10/11: 5 (15.6%), T11/12: 5 (15.6%), T12–L1: 10 (31.3%), L1/2: 2 (6.3%), L2/3: 1 (3.1%), L3/4: 2 (6.3%) and L5–S1: 1 (3.1%). Table 3 summarises the findings according to severity of the leak during the 32 procedures. There was no significant difference between duration of follow-up for LGL compared with MHGL (≥ 18 months vs. < 18 months; $P = 0.0765$) or the level of the affected disc (T11/12 and above versus T12–L1 and below; $P = 0.4760$).

At a follow-up radiographic assessment (6–50 months, median 18 months) of the degenerative changes in the 32 affected discs, changes ranging from 0 to 9 (median 1) points were scored. In 19 (59.4%) of the affected discs, the radiographic score had changed by 1 point or more and in 12 (37.5%) the score change was 2 points or more. Of the latter group, 4 (12.5%) had LGL and 8 (25%) had MHGL ($P = 0.04295$). A follow-up MRI assessment (6–48 months, median 2 months) for disc degenerative changes in the 18 patients who had a follow-up MRI examination revealed a grade change ranging from 0 to 2 (median 0) grades. Only

Table 1 Mimura et al. ⁸ system for scoring disc degeneration using anterior–posterior and lateral radiographs			
Score	Disc height changes (%)	Osteophyte formation ^a (points)	Endplate sclerosis
0	100	0	None
1	75	1–4	Either endplate
2	50	5–8	Both endplates
3	> 25	9–12	–
4	≤ 25	13–16	–
^a Sum of points on eight edges; ≤ 3 mm = 1 point, > 3 mm = 2 points			

Table 2 Puertas et al.⁹ classification for grading disc degeneration using magnetic resonance imaging

Grade	Structure	Nucleus	Signal intensity	Disc height
I	Homogenous	Light	Hyperintense	Normal
II	Heterogeneous with horizontal line	Light	Hyperintense	Normal
III	Heterogeneous, grey	Dark	Intermediate	Normal
IVa	Heterogeneous, grey	Dark	Intermediate	Reduced
IVb	Heterogeneous, black	Lost	Hypointense	Reduced
V	Heterogeneous, black	Lost	Hypointense	Collapsed

Table 3 Findings in 32 episodes of intradiscal cement leak according to severity of leak

Feature	Grade							
	I		II		III		IV	
	n	%	n	%	n	%	n	%
Follow-up								
≥ 18 months	6	18.8	5	15.6	4	12.5	1	3.1
< 18 months	12	37.5	2	6.3	1	3.1	1	3.1
Affected disc space level								
T11/12 and above	10	31.3	4	12.5	2	6.3	0	
T12–L1 and below	8	25	3	9.4	3	9.4	2	6.3
Radiography score change								
≤ 2 points	14	43.8	3	9.4	3	9.4	0	
> 2 points	4	12.5	4	12.5	2	6.3	1	3.1
New adjacent features								
Yes	2	6.3	0		1	3.1	1	3.1
No	16	50	7	21.9	4	12.5	1	3.1

four (22.2%) discs had an MRI grade change of 1 or more. Of these, 2 (6.3%) had LGL and 2 (6.3%) had MHGL ($P = 1.00$). A follow-up radiographic assessment for the development of new adjacent vertebral fractures (6–50 months, median 18 months) revealed an adjacent fracture in 4 of the 32 (12.5%) affected discs. Of these, 2 (6.3%) had LGL while 2 (6.3%) had MHGL ($P = 0.7876$).

Discussion

Augmentation of vertebral compression fractures with polymethylmethacrylate (PMMA) cement through vertebroplasty or kyphoplasty is a widely accepted treatment modality. In a recent meta-analysis, Zhao *et al.* demonstrated that both vertebroplasty and kyphoplasty had a similar effect on short-term pain relief, posterior body height and adjacent level fractures.¹¹ However, vertebroplasty can be associated with an increased risk of cement leak and pulmonary embolism, myelopathy or radiculopathy compared with kyphoplasty.¹¹

Cement leaking into the disc space was observed in 32 discs from 315 procedures (10.2%) in our series, which is lower than the 25% leak rate reported with vertebroplasty in the literature.^{7,12}

Intradiscal cement leakage occurs under two conditions: fracture endplates and vacuum clefts.¹⁵ The impact of vertebroplasty and kyphoplasty on the adjacent disc space has been a matter of concern. Qian *et al.* found that the incidence of disc degeneration above a fractured vertebra was 52.6% in patients treated with vertebroplasty and kyphoplasty compared with 29% in controls.¹⁴ The authors concluded that disc degeneration adjacent to a fractured vertebra was accelerated significantly by these procedures. However, they observed that the hastened degeneration had no significant effect on pain and functional disability outcomes.¹⁴

The risk of degenerative changes associated with intradiscal cement leakage has not been fully explored and currently the evidence in the literature remains limited to

animal studies. Haiqing *et al.* reported that intradiscal injection of PMMA particles induced significant disc degeneration in rabbits. Stimulation with PMMA particles significantly reduced disc height at 3 weeks and reduced the disc MRI signal intensity by 22% at 6 weeks.¹⁵ They also demonstrated cement-induced histological and quantitative immunohistochemical phenotypic changes from cartilaginous tissue into fibrotic tissue with apparent degeneration.¹⁵ Zhao *et al.* studied the effect of intradiscal cement injection using PMMA and calcium phosphate cement in dogs. They found that disc degenerative changes correlated with the cement type (PMMA caused more degeneration than calcium phosphate cement), the dose of the injected bone cement (0.3 ml to > 0.1 ml) and the time since the cement leak (24 weeks to > 12 weeks).¹⁵ Mao *et al.* investigated the effects of cement leakage on intervertebral disc degeneration in rabbits. They concluded that intradiscal injection of PMMA particles induced significant intervertebral disc degeneration in vivo.¹⁶

In our study, the majority of patients had LGL (56.3%). The number of patients who had grade II (21.9%), grade III (15.6%) or grade IV (6.3%) leaks were relatively smaller. As a result, it was considered appropriate during the analysis to gather the data from all patients who had grades II–IV leaks into a single group (MHGL). At a median follow-up of 18 months, and based on the radiographic assessment, we observed a significant difference between LGL and MHGL in the rate of progression of degenerative changes in the affected discs. This finding is not surprising, as an increase in the amount of the intradiscal cement leak is likely to result in a rise in the disc pressure and stress, which will alter the disc metabolism and cause severe disc degeneration.¹⁵

Disc degeneration was assessed using radiographic scores and MRI grading. Radiological evaluation was carried out using the Mimura *et al.* scoring system,⁸ which is based on three variables: disc space height, osteophytes and endplate sclerosis. Wilke *et al.*¹⁷ assessed the validity and inter-observer agreement of a radiographic grading system for disc degeneration similar to that of Mimura *et al.*⁸ and found it to be reliable in quantifying the degree of degeneration in lumbar discs. The authors did suggest that the degree of degeneration may be underestimated and slight differences between the ratings of observers with different levels of experience should be expected.¹⁷ In our study, to overcome any experience-related discrepancy, a spinal surgeon and a medical imaging consultant performed the radiological and MRI assessments independently and disagreements were discussed. MRI is recognised to be the more sensitive method for determining intervertebral disc degeneration compared with radiography.¹⁴ Surprisingly, in our study we observed no significant difference in the progression of degenerative changes in the affected discs between LGL and MHGL, based on MRI parameters. This contradictory result could be related to the limited number of patients who had MRI and the relatively short follow-up. Nevertheless, the same finding has been observed by others. Benneker *et al.* compared radiographic and MRI findings with morphological and biochemical assessment of disc degeneration.¹⁸ The

authors stated that, in their sample population, radiographic parameters were better able to distinguish different stages of degeneration whereas MRI could only detect advanced stages of disc degeneration. They concluded that radiographs may remain a cost effective non-invasive in vivo grading method to detect early disc degeneration.¹⁸

The causes of subsequent adjacent fractures, whether associated with the natural progression of osteoporosis or as a consequence of augmentation with bone cement, remains unclear. New vertebral compression fractures occur frequently in non-adjacent vertebrae after kyphoplasty and in patients with low bone mineral density.¹ In a meta-analysis, Zou *et al.* pooled the results of two randomised controlled trials and reported that there was no significant difference in the re-fracture ratio in treated fractures compared with conservatively managed fractures. The authors concluded that the mechanism for new fractures is most probably secondary to the underlying degree of osteoporosis.¹⁹

The influence of cement leakage into the disc space on the development of adjacent fracture has also been a matter of debate. Pitton *et al.* reported that the rates of secondary adjacent and non-adjacent fractures were quite similar and that there was no specific impact of intradiscal leakage on the occurrence of adjacent secondary fractures.¹² Lee *et al.* calculated an adjacent fracture rate of 10.3% at a mean follow-up of 38.5 months and stated that there was no significant difference between intradiscal cement leakage and new adjacent vertebral compression, except for fractures at a thoracolumbar location (T10–L2).⁷ On the other hand, Chen *et al.* estimated an adjacent fracture rate of 18.9% at a follow-up of at least 24 months and demonstrated a significant increase in new vertebral fractures following an intradiscal leak. They also indicated that the development of new adjacent fractures occurs earlier following cement leakage compared with no leakage (mean duration 8.54 weeks vs. 36 weeks).² In our study, at a median follow-up of 18 months, 12.5% of affected discs in our series developed an adjacent fracture. The occurrence of an adjacent fracture in our series was not influenced by the quantity of the intradiscal cement leaked.

The study has a number of limitations. The sample size is relatively small. This is not unusual as, there are practical difficulties in collating larger sample sizes when data are collected from a single centre. The proposed grading system for quantifying the amount of intradiscal cement leakage may not have been sufficiently validated. The grading results were reported by two consultants who examined the images independently; disagreements were discussed. However, statistical evaluation of inter-grader agreement and disagreement was not carried out. The study focused on the impact of the quantity of intradiscal cement leakage on the radiological and MRI evidence of progression of intervertebral disc degeneration. MRI images were not available to all patients and the validation of the Puertas classification used for the MRI assessment of disc degeneration may be arguably inadequate. The analysed cohort of patients was not compared with a control group that had kyphoplasty without a leak. In addition, the clinical implications of the intervertebral disc degeneration were not evaluated. This issue has

been examined in a recent study by Shen *et al.*,²⁰ who compared 20 patients who had an intradiscal leak with 104 patients who did not. They reported that at a mean follow-up of 20.56 months, intradiscal cement leakage was associated with a significant reduction in disc heights, without influencing clinical efficacy.²⁰ Our study also did not look at the risk factors for cement leakage during kyphoplasty. Ren *et al.* studied the correlative factors for complications resulting from cement leakage in 71 patients who had kyphoplasty.²¹ They reported that cement viscosity, injected cement volume, vertebral body wall incompetence and history of pulmonary disease were associated with an increased risk of complications resulting from cement leakage.²¹

Conclusions

The impact of intradiscal cement leakage on the progression of degenerative changes in the affected disc space and the influence of the quantity of the cement leaked on the long-term effects of this complication are matters that have not been examined adequately in the literature. This study highlights the influence of cement leakage into the disc during kyphoplasty. Our findings indicate that the quantity of cement leaked into the disc space significantly influences the rate of progression of disc degeneration. The proposed grading system for the quantity of intradiscal leak requires further validation.

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