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Original Article

Risk of post-vertebroplasty fracture in adjacent vertebral bodies appears correlated with the morphologic extent of bone cement

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Abstract

Background: New fractures in adjacent vertebral bodies were found after percutaneous vertebroplasty. We evaluated the correlation between extent of polymethylmethacrylate cement and occurrence of post-vertebroplasty fractures in patients with osteoporosis.
Methods: Totally 162 adjacent vertebral bodies with no fracture at the time of vertebroplasty and the distribution of cement in corresponding treated vertebral bodies of 98 patients were included for the evaluation. Length of follow-up after vertebroplasty was 734 ± 314 days (range, 366–1838 days). Based on proximity of bone cement to the adjacent vertebral body, cement extent was classified as disc level (the closest), endplate level, or trabecula level (the farthest).
Results: Forty-one adjacent vertebrae had post-vertebroplasty fracture occurring 2–1038 days after vertebroplasty. The percentages of adjacent vertebral bodies having post-vertebroplasty fracture about cement extent were: disc level, 44; endplate level, 29; and trabecula level, 7.
Conclusion: Our study revealed that the risk of subsequent fracture in the adjacent vertebral bodies was correlated with the extent of bone cement after vertebroplasty. Preventive measures can be taken from this observation to reduce the percentage of post-vertebroplasty fracture in adjacent vertebral bodies.

Keywords: Osteoporosis; Percutaneous vertebroplasty; Spine interventions; Vertebral fracture

1. Introduction

Percutaneous vertebroplasty has become an effective treatment of osteoporotic compression fracture.[1–3] This technique can relieve pain, restore vertebral height, and correct wedge deformity to some extent.[1–5] However, post-vertebroplasty new fractures remain a problem, especially in patients with osteoporosis.[2,6,7] Grados et al noted that 13 (52%) of 25 patients had at least one new vertebral fracture after percutaneous vertebroplasty during a follow-up period of 48 ± 21 months.[2] According to the report by Uppin et al,[6] 24 (67%) of 36 documented new fractures after vertebroplasty were adjacent to a vertebral body treated by vertebroplasty. Lin et al further reported that cement leakage into the disc increased the risk of new fracture of adjacent vertebrae.[8]

The purpose of this study was to further evaluate the relationship between the morphologic location of deposited bone cement and the occurrence of new fracture in adjacent vertebral bodies after vertebroplasty.

2. Methods

The study was approved by the Institutional Review Board of our hospital. We evaluated the correlation between the morphologic extent of polymethylmethacrylate bone cement

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("cement extent") implanted inside the vertebral body and development of post-vertebroplasty fracture in adjacent (immediately cranial or caudal) vertebral bodies. The post-vertebroplasty fracture in the adjacent vertebral body ("adjacent fracture") means that the adjacent vertebral body was normal at the time of vertebroplasty, and fracture occurred after vertebroplasty, regardless of the time it was detected.

Inclusion criteria of patients were: (1) Patients had severe back pain, plain film showed vertebral body fracture (i.e. reduced height of the vertebral body). The magnetic resonance imaging (MRI) showed the corresponding vertebral body edema, contrast enhancement or cavity inside. If MRI was contraindicated, the whole body bone scan showed increased uptake in the vertebral body with fracture. (2) Percutaneous vertebroplasty was performed only for the level of vertebral fracture with edema, enhancement or cavity inside on MRI, or increased uptake on whole body bone scan. (3) Imaging study including plain films and bone density study before the percutaneous vertebroplasty showed osteoporosis. Initial and follow-up imaging studies excluded tumor or metastasis as their cause of fracture. Inclusion criteria of adjacent vertebral bodies for evaluation were: (1) The adjacent vertebral body had no fracture at the time of vertebroplasty, i.e. they were normal in height and shape on pre-vertebroplasty plain film, with no evidence of fracture on other pre-vertebroplasty imaging studies, such as MRI or whole body bone scan. (2) The vertebral body was immediately adjacent to only one cemented vertebral body. Therefore, if both the immediate cranial and the immediate caudal adjacent vertebral bodies received vertebroplasty, the sandwiched vertebral body was excluded for evaluation.

Totally 162 adjacent vertebral bodies and the corresponding cement extent in 98 patients were included for evaluation. Mean age was 75.6 years (age range, 53–94 years). Twenty-nine patients were men and 69 were women. Length of follow-up after vertebroplasty for these adjacent vertebral bodies was 734 ± 314 days (range, 366–1838 days).

All patients who received vertebroplasty in our institution were asked to return for radiological evaluation within 2 weeks after the procedure and then return once a year thereafter for follow-up. They were also asked to return whenever they had persistent or recurrent back pain, to rule out occurrence of new fracture. All patients were suggested to wear brace for 3 months, although the compliance was not assessed in this study. Patients were advised to reduce the dose of nonsteroidal anti-inflammatory drug or acetaminophen after vertebroplasty according to the degree of residual back pain. They also received osteoporosis therapy tailored individually.

Sixty-four (65%) of these 98 patients received only one vertebroplasty, whereas 35% received two or three vertebroplasties because of new fractures and severe back pain. The extent of each cement cast was classified as disc level (in which the bone cement definitely protruded somewhere through the plane of the endplate and reached the disc level between the cemented vertebra and the adjacent vertebra), endplate level (the bone cement reached the endplate at some part of the treated vertebra), or trabecula level (the bone cement definitely remained inside the trabeculae and did not reach endplate anywhere) (Fig. 1). For each treated vertebra, the cranial extent and caudal extent of the cement cast were evaluated separately. For evaluation of the bone cement extension, we recorded the farthest extension of bone cement facing the adjacent vertebral body in the whole vertebral/disc column.

From a bone biomechanics point of view, the anterior third of the vertebral/disc column bears more pressure than the middle or posterior third does during flexing of the spine. To understand whether the bone cement in the anterior third of the vertebral/disc column associates with more risk of adjacent fracture than in the posterior two-thirds, we further reviewed the farthest extension of bone cement in the anterior third, and in the posterior two-thirds of the vertebral/disc column separately.

Digital images of anteroposterior and lateral plain radiographs taken after vertebroplasty on the same day and at first follow-up (within 2 weeks after the procedure) were reviewed by two neuroradiologists to decide the farthest extension of cement. These two neuroradiologists were blinded to the later condition of adjacent vertebrae and clinical and radiographic follow-ups. For cases with different initial classifications, they reviewed the images again together to reach a consensus.

3. Results

Forty-one (25%) of 162 adjacent vertebrae developed post-vertebroplasty fractures. The mean interval between the procedure of vertebroplasty and the first radiographic demonstration of adjacent fracture was 134 ± 225 days (median 24 days, range 2–1038 days). Approximately half (53%) of these adjacent fractures were found within 1 month after vertebroplasty. About 86% were found within 1 year, and 96% within 18 months after vertebroplasty (Fig. 2). Sixty-two (63%) of 98 patients had multiple vertebral fractures involving 2–7 vertebral bodies at their initial presentation. Post-vertebroplasty fractures were also found in 35 nonadjacent vertebral bodies in 22 (22%) of 98 patients.

Table 1 shows the relationship between cement extent and occurrence of adjacent fracture. When evaluation of cement extent was based on whole vertebral column, ratios of adjacent fracture in patient groups with cement extent at disc, endplate, and trabecula levels were 16/36 (44%), 21/72 (29%), and 4/54 (7%), respectively. When evaluation of cement level was based on only the anterior third of the vertebral column, ratios of adjacent fracture in patient groups with cement extent at disc, endplate, and trabecula levels were 12/24 (50%), 22/74 (30%), and 7/64 (11%), respectively (Table 1). Fisher's exact test showed significant difference in the cement extent distribution between patient groups with and without adjacent fracture when the cement extent was evaluated based on: (1) whole vertebral column ($p < 0.001$), or (2) only the anterior third of the vertebral column ($p < 0.001$). However, there was no significant difference when the evaluation was only based on cement extent in the posterior two-thirds of the vertebral column ($p = 0.087$).

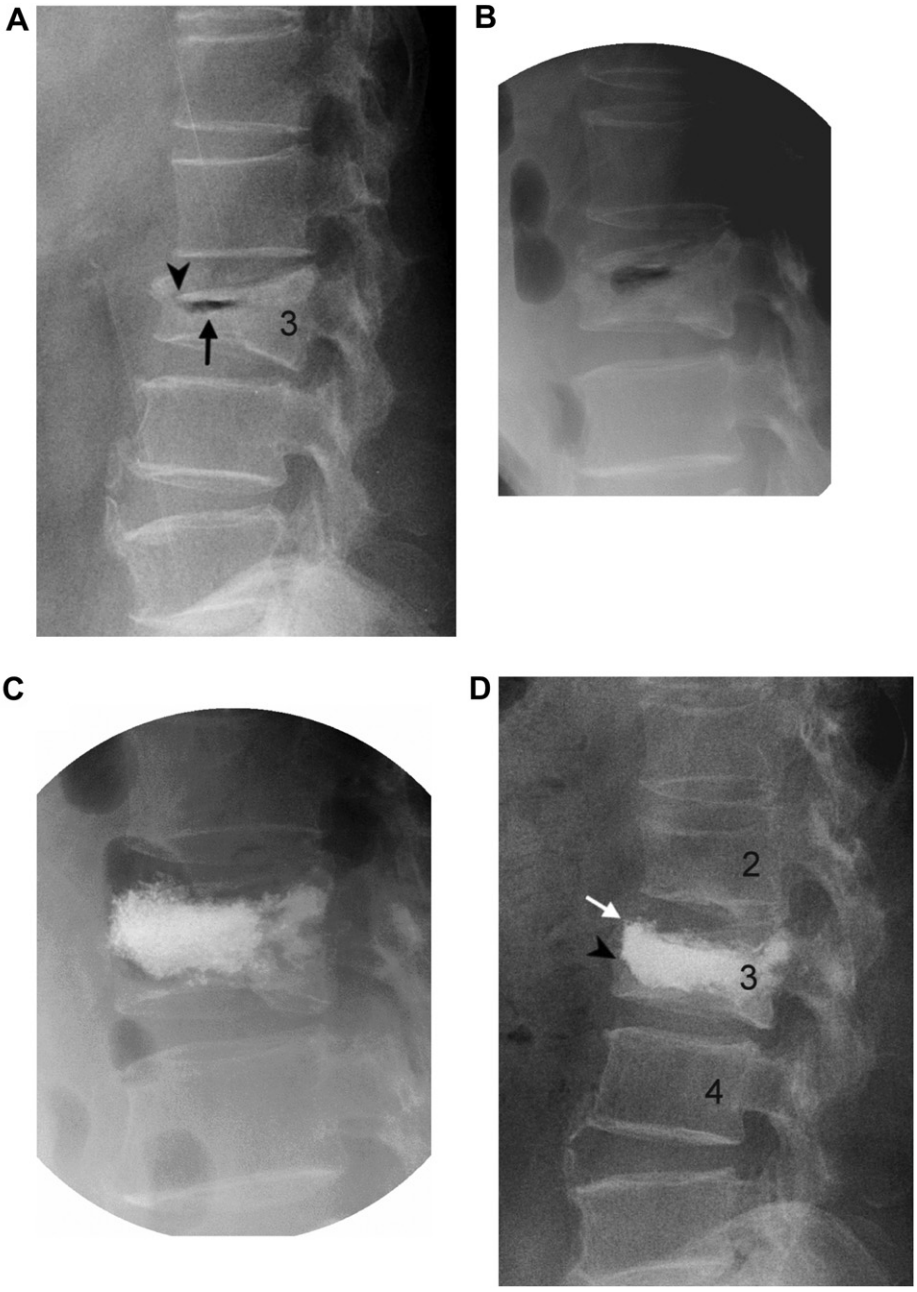

Fig. 1. Percutaneous vertebroplasty was performed on one vertebral body (L3) in this case. (A) Pre-vertebroplasty plain radiograph shows avascular necrosis with a cavity (arrow) filled with gas inside the L3 vertebral body, and a disruption (arrowhead) in the superior endplate of this vertebral body. (B) Stored lateral view image at the angiography suite before puncturing of needle for vertebroplasty. No fracture is noted in the cranial and caudal adjacent vertebral bodies. (C) Stored lateral view image at the angiography suite right after vertebroplasty. No fracture is noted in the cranial and caudal adjacent vertebral bodies. The farthest extension of cement in the cranial end is disc level in the whole vertebral/disc column, and in the anterior third of the column. The farthest extension of cement in the caudal end is trabecular level. (D) Plain radiograph taken 2 months post-vertebroplasty shows new fracture with reduced height in the cranial adjacent vertebral body (L2). The cranial end of the L3 cement (white arrow) is in the disc level.

When the classification of cement level was simplified as reaching disk level or not (Table 2), we found significant correlation between cement extent and adjacent fracture when the evaluation of cement extent was based on the whole vertebral column ($p = 0.005$), or based on the anterior one-third part alone ($p = 0.005$). There was no significant difference in adjacent fracture occurrence whether cement extension to disc or not when evaluation of cement extent was only based on the posterior two-thirds of the vertebral column ($p = 0.421$). We also classified cement level as reaching disk/endplate level or not; the statistic result is shown in Table 3.

We considered presence of adjacent vertebral body fracture as disease-positive, and evaluated two conditions: (1) the cement extension to disc level, and (2) cement extension to disc/endplate level as test positive to calculate the sensitivity, specificity, positive predictive values, and negative predictive

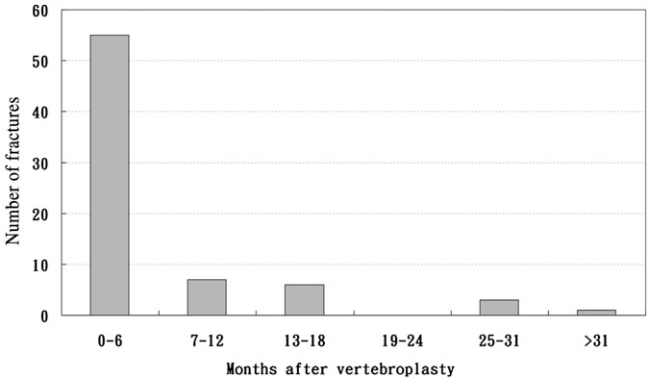

Fig. 2. The distribution of intervals from previous vertebroplasty to the first radiographic demonstration of new fracture at the adjacent vertebral body.

values. The sensitivity, specificity, positive predictive values, and negative predictive values using cement extension to predict post-vertebroplasty adjacent vertebrae fractures are shown in Table 4.

The specificity was better when the criterion was the cement reaching disc level (whole vertebral column 83%; anterior one-third vertebral column 90%). The sensitivity was better when the criterion was the cement reaching disc/endplate level (whole vertebral column 90%; anterior third of the vertebral column 83%). The positive predictive ratio was best when using cement extension to disc level in the anterior third of the vertebral column (50%).

4. Discussion

From our study, 25% of adjacent vertebral bodies had post-vertebroplasty fractures detected on X-ray taken one year or more after vertebroplasty. The percentages of adjacent vertebral bodies that had post-vertebroplasty fractures about extent of bone cement in our study were, in decreasing order: disc level cement (44%), endplate level cement (29%), and trabecula level cement (7%). Lin et al found 58% of vertebral bodies adjacent to a cement leakage into disc space developed new fractures post-vertebroplasty, and concluded that cement leakage into the disc increased the risk of new fracture in the adjacent vertebral body.[8] They proposed that the mechanism for post-vertebroplasty fractures was a combination of the underlying condition, mainly osteoporosis or neoplastic disease, and the hard cement in the discs. In our study, we confirmed the relative high percentage of adjacent vertebral bodies that had post-vertebroplasty fracture when the cement reached the contiguous disc.

The percentage of adjacent fracture was 44 when the cement extended to the disc level, and it was 50% when the cement extended to the disc level in the anterior third of the vertebra column. Furthermore, we analyzed cement ends at endplate level and trabecula level and found that the percentage of adjacent fracture was moderate when cement ends reached endplate level (29%), and the percentage was small (7%) when cement ends remained inside the trabecula level of the vertebral body. This study revealed that the cement extent was related to the occurrence of post-vertebroplasty fracture in the adjacent vertebral body. This was compatible with the previous report that states strengthening the treated level with cement infusion leads to an increase of mechanical force on the adjacent vertebrae, thereby predisposing to fracture.[9] The reason why the percentage of adjacent fracture was low (7%) when the cement remained in the trabecula level

Table 1
Relationship between cement extent and occurrence of adjacent fracture

Levels of cement end evaluated in different vertebral/disc columns	New fracture	No new fracture	Total
Total number of adjacent vertebrae evaluated	41 (25)	121	162
Whole vertebral column ($p < 0.001$*)			
Disc level	16 (44)	20	36
Endplate level	21 (29)	51	72
Trabecula level	4 (7)	50	54
Anterior third ($p < 0.001$*)			
Disc level	12 (50)	12	24
Endplate level	22 (30)	52	74
Trabecula level	7 (11)	57	64
Posterior two-thirds ($p = 0.087$)			
Disc level	7 (33)	14	21
Endplate level	19 (33)	39	58
Trabecula level	15 (18)	68	83

Data are presented as *n* (%).
*Fisher's exact test, 3 by 2, two-sided.

Table 2
Relationship between cement extent and the occurrence of adjacent fracture, using "cement reaching disc or not" as a criterion

The part of vertebral column for evaluating cement extent	Reaching disc level or not	New fracture	No new fracture	Total
Whole vertebral column ($p = 0.004$*)	Yes	16	20	36
	No	25	101	126
Anterior third ($p = 0.005$*)	Yes	12	12	24
	No	29	109	138
Posterior two-thirds ($p = 0.421$)	Yes	7	14	21
	No	34	107	141

*Fisher's exact test, 2 by 2, two-sided.

Table 3
Relationship between cement extent and the occurrence of adjacent fracture, using "cement reaching disc/endplate level or not" as a criterion

The part of vertebral column for evaluating cement extent	Extension to disc/endplate	New fracture	No new fracture	Total
Whole vertebral column ($p < 0.001$*)	Yes	37	71	108
	No	4	50	54
Anterior third ($p = 0.001$*)	Yes	34	64	98
	No	7	57	64
Posterior two-thirds ($p = 0.03$*)	Yes	26	53	79
	No	15	68	83

*Fisher's exact test, 2 by 2, two-sided.

Table 4
The sensitivity, specificity, positive predictive value, negative predictive value to predict new fractures in adjacent vertebral bodies according to cement extent

Cement extent and the part of vertebral column for evaluation	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
Reaching disc level or not				
Whole vertebral column	39 (16/41)	83 (101/121)	44 (16/36)	80 (101/126)
Anterior third	29 (12/41)	90 (109/121)	50 (12/24)	79 (109/138)
Posterior two-thirds	17 (7/41)	88 (107/121)	33 (7/21)	76 (107/141)
Reaching disc/endplate level or not				
Whole vertebral column	90 (37/41)	41 (50/121)	34 (37/108)	93 (50/54)
Anterior third	83 (34/41)	47 (57/121)	35 (34/98)	89 (57/64)
Posterior two-thirds	63 (26/41)	56 (68/121)	33 (26/79)	82 (68/83)

could be explained by the presence of buffer tissues: the normal disc space, endplate, and part of the trabecula of the treated vertebral body that were between the cement cast and the adjacent vertebral body. However, when the cement reached the disc level, the tissue cushion was diminished or entirely lost, thus resulting in a higher ratio of adjacent fracture. Therefore, the hardness (or stiffness) of bone cement and thinness of cushion between the cement and the adjacent vertebral body might be related to the risk of subsequent fracture.

We also evaluated cement extent in the anterior third and posterior two-thirds of the vertebral column separately. The percentage of adjacent fracture was higher when the cement extended to the disc level in the anterior third of the vertebral column (50%) than when cement extended to the disc level in the posterior two-thirds (33%) (Table 1). The positive predictive value to predict adjacent fracture by whether cement reached disc level or not was higher when the evaluation was based on the anterior third of the vertebral column (50%) than when based on the posterior two-thirds of the vertebral column (33%). We hypothesize that bone cement inside the anterior part of treated vertebral column impacted much more intensely on the adjacent vertebral body than did cement inside the posterior part during anterior flexion of the trunk. Therefore, limitation of anterior flexion of the trunk (e.g. using a brace) may reduce the occurrence of new fracture in the adjacent vertebral body before the osteoporosis was corrected.

However, post-vertebroplasty fractures in 35 nonadjacent vertebral bodies were also found in 22 (22%) of 98 patients in this series. The nonadjacent vertebral body was separated from the cemented vertebral body by at least one vertebral body and one disc acting as a buffer. Thus, the relative hardness of bone cement could not explain post-vertebroplasty fractures in nonadjacent vertebral bodies. According to a previous report, a single fracture at baseline examination increases the risk of new vertebral fractures by five-fold, and two or more fractures at baseline increase that risk by twelve-fold.[10] In this series, 62 (63%) of 98 patients had multiple vertebral fractures involving 2–7 vertebral bodies at their initial presentation. These data indicate that an osteoporotic patient tends to have multiple vertebral compression fractures either at one time or different times though the vertebroplasty was not performed. The patients' osteoporosis and increased activity (because of pain relief) could contribute to post-vertebroplasty fracture in both adjacent and nonadjacent vertebrae.[6,11]

Based on our findings, we propose the following measures to prevent post-vertebroplasty new fractures in adjacent vertebral bodies: (1) treat underlying disease, such as osteoporosis; (2) confine bone cement to the trabecula level or at least not protruding to disc level during vertebroplasty; (3) perform preventive vertebroplasty if necessary. It is difficult to restrict bone cement to the trabecula level when the fracture involves the endplate and disc. If the bone cement has reached the disc or endplate level, preventive vertebroplasty can be performed in the adjacent vertebra in which the bone cement deposition should be close to the vertebra that received vertebroplasty previously. The deposited bone cement during preventive vertebroplasty should not reach endplate level of the other end to prevent further propagation of post-vertebroplasty fracture at another adjacent vertebral body. Whether preventive vertebroplasty is necessary or not depends on the risk of adjacent fracture in different patient populations. Heini et al further recommended vertebroplasty involving at least four levels in one session to allow adjacent vertebrae to be prophylactically reinforced.[12] However, the issues of what situation and how "aggressive" a preventive vertebroplasty should be performed still need to be addressed with further study. In conclusion, in this study, we confirmed the high incidence of post-vertebroplasty fracture in the adjacent vertebral body when the cement reached disc level (44%). Furthermore, we found a moderate percentage of adjacent fracture when cement reached the endplate level (29%), and the percentage was small (7%) when cement remained inside the trabecula level. We also found that post-vertebroplasty fractures occurred more often when cement extended to the anterior third of the disc (50%) than when cement extended to the posterior two-thirds of the disc (33%). We proposed the preventative measures concerning post-vertebroplasty fractures in adjacent vertebral bodies based on the above findings.

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