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Clinical Article

The Proper Volume and Distribution of Cement Augmentation on Percutaneous Vertebroplasty

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Objective : The purpose of this study was to determine the optimal volume of injected cement and its distribution when used to treat vertebral compression fractures, and to identify factors related to subsequent vertebral fractures.

Methods : A retrospective analysis of newly developing vertebral fractures after percutaneous vertebroplasty was done. The inclusion criteria were that the fracture was a single first onset fracture with exclusion of pathologic fractures. Forty-three patients were included in the study with a minimum follow up period of six months. Patients were dichotomized for the analysis by volume of cement, initial vertebral height loss, bone marrow density, and endplate-to-endplate cement augmentation.

Results : None of the four study variables was found to be significantly associated with the occurrence of a subsequent vertebral compression fracture. In particular, and injected cement volume of more or less that 3.5 cc was not associated with occurrence (p = 0.2523). No relation was observed between initial vertebral height loss and bone marrow density (p = 0.1652, 0.2064). Furthermore, endplate-to-endplate cement augmentation was also not found to be significantly associated with a subsequent fracture (p = 0.2860) by Fisher's exact test.

Conclusion : Neither volume of cement, initial vertebral height loss, bone marrow density, or endplate-to-endplate cement augmentation was found to be significantly related to the occurrence of a subsequent vertebral compression fracture. Our findings suggest that as much cement as possible without causing leakage should be used.

KEY WORDS : Compression fracture · Volume · Subsequent fracture.

INTRODUCTION

Percutaneous vertebroplasty is a minimally invasive, effective means of managing painful compression fractures. However, sometimes, fractures occur after treatment and it is uncertain whether vertebroplasty is a cause of these subsequent fractures. Furthermore, there are controversies regarding the optimal volume and location of the injected cement. Adjacent fractures are related to strength differences associated with cement augmentation, and non-adjacent fractures are due to differences in segmental mobility[1]. Increased vertebral strength after vertebroplasty can cause a spontaneous vertebral compression fracture without any obvious traumatic event[6]. In osteoporotic patients, spontaneous vertebral fracture without trauma may be due to due to the greater strengths of augmented vertebrae[6]. Only 2-3.5 cc cement of cement is needed to restore a fractured vertebra[3,13], but more than 3.5 cc (4-8 cc) may be required to restore vertebral stiffness[3,13,15], although there has been a report that only 3.5 cc was required[10]. Furthermore, the restoration of motion segments and load-shearing require more cement than is required to restore normal stress distribution in fractured and adjacent vertebral bodies.

Injected cement volume and degree of pain relief have been reported not to be co-related[3,9]. Furthermore, the majority of secondary fractures occur within 1 year of percutaneous vertebroplasty,[2,19] and adjacent fractures occur around 3 months sooner than non-adjacent fractures[20].

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MATERIALS AND METHODS

Between January 2007 and December 2008, 180 patients were treated for a vertebral compression fracture by percutaneous vertebroplasty at our hospital. We used polymethyl-

Table 1. The rate of occurrences of subsequent vertebral fracture

	Volume of injected cement		Initial anterior vertebral height loss		Bone marrow density (Z-score)		Endplate-to-endplate cement augmentation	
Subdivided group	Less than 3.5 cc	More than 3.5 cc	Less than 25%	More than 25%	> -3.0	< -3.0	No	Yes
Rate of occurrence	2/18 (11.1%)	5/25 (20%)	3/22 (13.6%)	4/21 (19.0%)	1/14 (7.1%)	6/29 (20.7%)	4/21 (19.0%)	3/22 (13.6%)
p-value	0.2523		0.1652		0.2064		0.2860	

methacrylate (PMMA) in all patients. Among them, only 43 patients had a first onset compression fracture at a single level that was not pathologic. All of 43 patients were followed for more than 6 months. We reviewed patient's charts, cement volumes injected, cement distributions, decreases in anterior vertebral height, bone marrow densities, and subsequent fractures. We compared the risks of subsequent fracture according to; 1) injected volume (greater or less than 3.5 cc), 2) initial anterior vertebral height loss (greater or less than 25%), 3) bone marrow density Z-score (greater or less than -3.0), and 4) endplate-to-endplate cement augmentation (yes or no).

The occurrences of a subsequent vertebral fracture were analyzed according to; volume of cement injected, initial anterior vertebral height loss, Z-score, and endplate-to-endplate cement augmentation. Statistical analysis was performed using Fisher's exact test.

RESULTS

Subsequent fracture occurred in 7 of the 43 patients (16.3%). Four were adjacent fractures and three were non-adjacent fractures.

Volume of injected cement

Subsequent fractures occurred in 2 patients injected with greater than 3.5 cc (2/18, 11.1%), and in 5 patients injected with greater than 3.5 cc (5/25, 20%). Cement volume was not found to be related with the occurrence of a subsequent fracture (p = 0.2523).

Initial anterior vertebral height loss

Three of 22 patients with an initial anterior vertebral height loss of less than 25% experienced a subsequent fracture (3/22, 13.6%), and four patients with an initial anterior vertebral height loss of greater than 25% developed a fracture (4/21, 19.0%), which was not significantly different (p = 0.1652).

Bone marrow density (Z-score)

One patient with a bone marrow density of greater than -3.0 (1/14, 7.1%) developed a subsequent fracture, whereas six patients with a bone marrow density of less than -3.0 (6/29, 20.7%) developed a fracture, which again was not a significant difference (p = 0.2064).

Endplate-to-endplate cement augmentation

Three patients with cement well distributed developed a subsequent fracture (3/22, 13.6%), and four patients without endplate-to-endplate cement augmentation developed a subsequent fracture (4/21, 19.0%), which was also not a significant difference (p = 0.2860).

For all patients, the rate of vertebral compression fracture was slightly higher and anterior vertebral height was lower at last follow-up visits (mean 11.8 months postoperatively).

DISCUSSION

Percutaneous vertebroplasty is a relatively safe and non-invasive procedure, and can relieve pain and improve function. However, there is a possibility that it increases the risk of a new vertebral fracture. Although the cause of subsequent fractures is poorly understood, alterations of strength and stiffness are likely the causes. Moreover, the natural progression of osteoporosis provides another explanation. Adjacent fractures can reflect systemic weakening of bone in the osteoporotic spine, and thus, it may be difficult to prove a relation between vertebroplasty and subsequent fractures. Some authors have reported that patients treated by vertebroplasty/kyphoplasty have a greater risk of a new compression fracture than patients that did not undergo either procedure[16]. Han et al.[8] reported that bone marrow edema of an adjacent fracture appeared in the region of previous injected cement, which suggests that the biomechanical effect of the injected cement is a causative factors of adjacent vertebral fractures after percutaneous vertebroplasty.

Adjacent fractures occur more frequently and rapidly than non-adjacent fractures[12,20,21]. Refractures of cemented vertebrae after vertebroplasty have been reported to occur in 63% of osteoporotic patients[11]. Furthermore, in the present study, the majority of patients who underwent vertebroplasty showed a reduction in vertebral height during follow-up regardless of the presence of pain.

The optimal volume of cement injected is controversial. Belkoff et al.[3] reported that only 2 cc of cement is required

to restore strength, but that more cement is needed to restore stiffness. In one study, cement volume was not found to be correlated with pain relief,[2] and in another the magnitude of strength increase was found to be variable, and not to be correlated with the volume of cement injected[7]. Strength and stiffness of augmented vertebral body are weakly correlated with cement volume during vertebroplasty[15]. In one study, cement volume was found to influence adjacent fractures, but less than 5 cc had little effect[8]. However, in the present study, we dichotomized injected cement volume about 3.5 cc.

A unipedicular distribution of cement in a vertebral body can promote single-sided load transfer and toggle (medial-lateral bending motion), which represents a biomechanically suboptimal result[9,10]. Thus, the use of smaller cement volumes and associated symmetric displacement is better than the use of large fill volumes. It is known that greater filling can result in a substantial increase in stiffness of vertebral body.

The stiffness of PMMA cement is seven to ten times greater than osteoporotic vertebral bone,[4] and low-modulus cement is recommended rather than regular CMMA[4]. However, others have reported that the restoration of mechanical function following vertebroplasty is little influenced by cement type[14]. Even intradiscal cement leakage has been reported to be[1] or not to be[2] related to subsequent fracture. However, it is evident that an increase in the volume of cement used, increases the risk of leakage.

Vertebral fractures reduce segment stiffness in terms of bending and compression, and vertebroplasty partially reverse these effects. In general, a low body mass index and a low body weight are risk factors of recurrent fractures of the spine, and a low BMD is associated with increased fracture severity (height loss) and greater changes in stiffness and load-shearing following fracture. Low BMD and severe fractures are also associated with greater mechanical changes following vertebroplasty,[14] and significant anterior vertebral height restoration increases the risk of subsequent fracture in cemented vertebrae[11,14]. The relationship between initial vertebral height restoration and pain relief is controversial. Some authors concluded that degree of pain relief is increased in far advanced osteoporosis (lower the mean T-score)[17]. Accordingly, we studied pain relief with respect to BMD and degree of anterior vertebral height loss.

Vertebrae with injected cement connecting either the superior or inferior endplates were only up to 2 times stronger than non-augmented vertebrae, whereas vertebrae with cement connecting both endplates were 1 to 8 times stiffer and 1 to 12 times stronger. Cement augmentation bridging both endplates reduces stress transfer while providing sufficient strengthening[5].

It has been previously reported that the volume of injected cement and the degree of pain relief are not correlated,[2,9] and that larger cement volumes are probably associated with greater risks of complications related to cement leakage, such as, intradiscal leakage, epidural or neural foraminal compression, and pulmonary embolism. In addition, the magnitude of strength increase resulting from vertebroplasty is variable, and this was found not to be correlated with the volume of cement injected[7]. Furthermore, leakage tended to occur more frequently when a bipedicular approach was used[9].

Posttreatment strength has been reported to be significantly lower for partially augmented vertebrae than for endplate-to-endplate augmented vertebrae[18]. In cases with less than a 25% compression rate (anterior height loss), the strength of augmented vertebrae was similar to the nontreated vertebrae[18]. In the present study, we divided groups by compression rate and cement distribution.

Some authors have reported that the development of a new fracture is not associated with age, gender, BMD, number of vertebroplasties, volume of cement, or postoperative kyphotic angle[12]. Furthermore, degree of local kyphosis and vertebral level have been reported not to be significantly related to subsequent fracture[1].

The limitations of this study are its relatively short follow-up period and small population.

CONCLUSION

None of variables studied, namely, cement volume, initial anterior vertebral height loss, bone marrow density, and endplate-to-endplate distribution, were found to be significantly associated with the occurrence of subsequent fracture. Our findings suggest that as much cement as possible should be used without causing leakage.

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