Improvement in respiratory function after vertebroplasty and kyphoplasty

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Abstract Our objective was to study the changes in respiratory function of patients with osteoporotic vertebral compression fractures (OVCFs) after vertebroplasty and kyphoplasty. Thoracic kyphotic angle, local kyphotic angle, pain scores and pulmonary function parameters were measured in 38 older women with OVCFs before, three days after and three months after operation. Vital capacity, forced vital capacity and maximum voluntary ventilation significantly increased three days after operation ($P < 0.01$), but only maximum voluntary ventilation went on to improve three months later ($P < 0.01$); the thoracic kyphotic angle had a significantly negative correlation with vital capacity (vertebroplasty: $r = -0.832$; kyphoplasty: $r = -0.546$). In thoracic subgroups, the improvement of the local kyphotic angle and vital capacity had a remarkably positive correlation (vertebroplasty: $r = 0.778$; kyphoplasty: $r = 0.637$), and kyphoplasty could improve vital capacity more than vertebroplasty ($P < 0.01$). Vertebroplasty and kyphoplasty improve the lung function impaired by OVCFs, and kyphoplasty has a better effect in improving vital capacity for thoracic OVCFs.

Résumé Le but de cette étude est d'étudier les modifications des fonctions respiratoires chez les patients ostéoporotique présentant une fracture vertébrale en compression (OVCF) après vertébroplastie et kyphoplastie. Matériel et méthode : l'angle de cyphose thoracique, l'angle de cyphose au niveau du foyer de fracture, le score douleur, les fonctions pulmonaires ont été analysés chez 38 patientes

âgées présentant une fracture de type OVCF et ceci avant l'intervention, trois jours et enfin trois mois après l'intervention. Résultat : la capacité vitale, et la ventilation ont été améliorées de façon significative 3 jours après l'intervention ($p < 0,01$), la cyphose thoracique a également une corrélation significativement négative avec la capacité vitale (vertébroplastie $r = -0,832$, kyphoplastie $r = -0,546$). Dans le sous groupe des fractures dorsales l'amélioration de l'angle cyphotique fracturaire et la capacité vitale sont positivement corrélés (vertébroplastie $r = 0,778$ et kyphoplastie $r = 0,637$), la vertébroplastie et la kyphoplastie améliorent les fonctions pulmonaires de ce type de fracture. La kyphoplastie a un meilleur effet sur la capacité vitale pour les fractures localisées au niveau du rachis thoracique.

Introduction

Osteoporotic vertebral compression fractures (OVCFs) cause not only back pain, but also spinal misalignment, particularly kyphosis. Kyphosis of the thoracic spine in turn causes rib cage deformity. In this manner, OVCFs reduce the activities of daily living (ADL), cause respiratory dysfunction and increase the prevalence of lung diseases [13]. Mortality rates in osteoporotic women who have been clinically diagnosed with OVCFs are 15% higher than in those without compression fracture. Moreover, mortality rates are 23–24% higher in osteoporotic women with severe multiple compression fractures or kyphosis than in women without these conditions, and this is primarily related to compromised pulmonary function as a result of thoracic and lumbar vertebral fractures [13].

Vertebroplasty (VP) is a minimally invasive procedure to treat OVCFs, which was first reported in 1987 [7]. Since then, VP has been performed to alleviate pain caused by various types of vertebral compression fracture, and its

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dramatic effectiveness in this regard has led to frequent use [2, 6]. VP is also useful for back pain caused by OVCFs and has contributed greatly to improvements in ADL [6, 18].

As another effective minimally invasive procedure, kyphoplasty (KP) was developed from VP and uses an inflatable bone tamp to create a cavity in the fractured vertebral body and then bone cement is deposited into the cavity [10]. KP can improve back pain as does VP and has a better effect on reducing kyphosis and restoring the height of the vertebral body [8, 16].

Since VP and KP can improve back pain, reduce kyphosis and correct spinal misalignment to some extent, we postulated that respiratory function might also be improved. However, there are few studies that have appropriate data and follow-up to evaluate the effects of deformity correction on respiratory function after VP and KP or to compare the effects between the two procedures. This study investigated the changes of respiratory function and related factors in patients after VP and KP; it also compared the two procedures to see if KP had a better effect on respiratory function than VP since it has a better effect on reducing kyphosis and restoring the height of the vertebral body.

Materials and methods

Patients

Between July 2006 and March 2008, 38 older women (with no smoking history) with a total of 41 OVCFs were analysed. Of these patients, 18 (aged 63–81 years, mean: 70.2 years) with 19 OVCFs were subjected to VP; the involved levels of the spine included T9: 1, T11: 2, T12: 6, L1: 6, L2: 3 and L3: 1. KP was performed in the other 20 patients (aged 61–80 years, mean: 69.5 years) with 22 OVCFs, of which one T10, five T11, six T12, six L1, three L2 and one L3 were studied. All fractures involved gradual collapse of the vertebral body. Potential subjects were excluded from participation if they had had pulmonary diseases, infection of respiratory passages within three weeks, previous surgery or fracture of the spine, significant scoliosis, a neurological disorder or a cardiac pacemaker.

Procedures

The purpose and procedures involved in the study were explained fully to the patients and informed consent was obtained before data collection. Weight (kg) and height (cm) for each patient were measured. Arm span was measured with a tape measure as the distance between the tips of the middle fingers as subjects stood against a wall with their arms extended laterally at shoulder level. This measurement has been found to be equivalent and to be

more representative of the true height in subjects with spinal deformity [13]. All subjects were also interviewed to determine their health status and smoking history.

Lung function tests

A closed circuit spirometer (MasterScreen IOS, Jaeger, Inc., Höchberg, Germany) was used to measure pulmonary function of the patients. Vital capacity (VC), total lung capacity (TLC), forced vital capacity (FVC) and maximum voluntary ventilation (MVV) were selected as the parameters of pulmonary function. Subjects were seated throughout testing. All tests were conducted by the same pulmonary function laboratory technician. The parameters of each patient were measured three times during different periods—before, three days after and three months after operation.

Radiographic measures

Thirty-eight subjects were tested three times—pre-operatively and post-operatively after three days and three months after VP or KP—to obtain radiographs. All X-ray films were taken using standard radiographic techniques with the subject standing with her hands resting on a bar in front of the subject at shoulder level. The thoracic kyphotic angle (TKA) was measured from the upper vertebral end plate of T3 to the lower vertebral end plate of T12 [1] (Fig. 1). The local kyphotic angle (LKA) was measured by making a straight line from the superior end plate of the vertebra one level above the treated vertebra and a straight line from the inferior end plate of the vertebral body one level below the treated vertebra [15] (Fig. 2). Two lines were then drawn to perpendicularly intersect each of these lines. The angle that was formed by the intersection of the two perpendicular lines was then measured. Subjects who had a fracture at two levels (T12, L1) were measured from the superior end plate of T11 to the inferior end plate of L2 (one patient in the VP group and two patients in the KP group). Meanwhile, the anterior, middle and posterior heights of the fractured vertebral body were measured on each film. All radiographic measurements were performed by the same two physicians in a double-blind fashion to obtain a mean value.

Evaluation of pain

Patients rated their pain on a visual analogue scale (VAS) of 0=no pain to 10=severe pain. This test was done before, three days after and three months after operation.

Statistical analysis

All data were expressed as mean±standard deviation (SD). Paired *t* tests were used to compare parameters of patients

Fig. 1 The thoracic kyphotic angle (TKA) was measured from the upper vertebral end plate of T3 to the lower vertebral end plate of T12

before and after VP or KP. The comparison between the two groups was made by Student's *t* test. Pearson correlation coefficients were calculated to assess the relationship between the kyphotic angle and the parameters of pulmonary function. Meanwhile, the relationship between the decreased values of pain scores (VAS) and the improvement of respiratory function was analysed by the same methods. The results were considered significant when a *P* value was less than 0.05. All statistics were performed using SPSS 13.0 software.

Results

Characteristics of patients

Mean values of age, height, arm span and weight of the patients are presented in Table 1. The mean measured height of subjects in the VP group was 156.7 cm and the mean arm span was 158.7 cm, representing, on average, a 2.0-cm reduction of height in patients. In the KP group, the

Fig. 2 The local kyphotic angle (LKA) was measured from the superior end plate of the vertebra one level above the treated vertebra to the inferior end plate of the vertebral body one level below the treated vertebra

Table 1 Physical characteristics of patients ($n=38$)

	VP ($n=18$)			KP ($n=20$)		
	Mean	SD	Range	Mean	SD	Range
Age (years)	70.2	5.5	63–81	69.5	6.4	61–80
Height (cm)	156.7	4.6	147.5–167.3	156.9	4.7	148.0–168.0
Arm span (cm)	158.7	4.8	150.3–170.0	159.1	4.5	153.2–170.2
Weight (kg)	58.6	6.6	45.0–71.2	60.2	6.4	47.8–75.5

VP vertebroplasty, KP kyphoplasty

mean height, arm span and reduction of height was 156.9, 159.1 and 2.2 cm, respectively.

Changes of respiratory function

There was a statistically significant difference in the mean values of VC, FVC and MVV between before and three days after operation in both VP and KP groups. Additionally, there was a significant difference in the mean value of MVV between three days and three months after VP and KP, whereas there was no difference in VC or FVC. There was no statistically significant difference in the mean values of TLC between before and three days after operation in either the VP or KP group. The results of the respiratory function measures are presented in Table 2. Furthermore, in thoracic subgroups three days after the procedure, the percentage of improvement of VC in the KP group was greater than in the VP group ($P<0.01$), but there was no difference in lumbar subgroups. There were no significant differences of the remaining lung function parameters between VP and KP in either thoracic or lumbar subgroups.

Other changes after VP and KP

According to the measurements three days after operation, spinal sagittal alignment improved significantly in both VP and KP groups. Mean improvement in LKA was 2.33°

(range: -1 to 3.8°) and 8.19° (range: 2.1 – 14.4°) after VP and KP, respectively. The mean vertebral body height restorations of the anterior, middle and posterior portions of the vertebral body were 1.95, 2.12 and 0.48 mm, respectively, after VP and 4.20, 4.61 and 1.1 mm after KP. The differences of improvement of LKA and vertebral body height between VP and KP were statistically significant ($P<0.01$). Three months after the procedures, the height restored had not changed. All patients experienced pain relief after both operations. The pre-operative mean pain score was 8.26, whereas it decreased to 2.93 3 days after VP ($P<0.001$) and decreased from 8.27 to 2.77 after KP ($P<0.001$). In both groups, the mean pain score continued to improve three months later ($P<0.001$).

Correlation analysis of pulmonary function

There was a significant positive correlation between the decreased values of pain scores and the percent of improvement of FVC ($r=0.638$, $P=0.004$ in the VP group; $r=0.505$, $P=0.023$ in the KP group) and MVV ($r=0.526$, $P=0.025$ in the VP group; $r=0.473$, $P=0.035$ in the KP group) three days after the procedure even though pain scores did not significantly correlate to any parameters of pulmonary function. However, three months later, this was no longer significant except FVC in the KP group (Table 3). There was a significant negative correlation between TKA and

Table 2 Changes of pulmonary function ($n=38$)

Variable (L)		Pre-operation		3 days after operation		3 months after operation	
		Mean	SD	Mean	SD	Mean	SD
VP ($n=18$)	VC	2.41	0.23	2.42*	0.22	2.42	0.22
	TLC	4.08	0.44	4.07	0.42	4.07	0.42
	FVC	2.23	0.21	2.35*	0.22	2.35	0.16
	MVV	57.67	8.19	58.85*	7.49	60.71**	8.15
KP ($n=20$)	VC	2.44	0.17	2.47*	0.15	2.48	0.16
	TLC	4.03	0.38	4.03	0.40	4.03	0.39
	FVC	2.23	0.20	2.34*	0.20	2.35	0.20
	MVV	57.79	7.85	59.07*	7.71	61.10**	7.97

VP vertebroplasty, KP kyphoplasty

*Significant difference at $P<0.01$ compared with pre-operation; **significant difference at $P<0.01$ compared with 3 days after operation

Table 3 Correlation coefficient (*r*) between the decreased values of pain scores and the percentages of improvement of FVC and MVV (*n*=38)

		3 days after VP		3 months after VP		3 months after VP ^a	
		<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>
VP (<i>n</i> =18)	FVC (%)	0.638	0.004**	−0.046	0.885	−0.320	0.195
	MVV (%)	0.526	0.025*	0.262	0.294	−0.403	0.097
KP (<i>n</i> =20)	FVC (%)	0.505	0.023*	0.449	0.047*	0.192	0.417
	MVV (%)	0.473	0.035*	0.053	0.823	−0.064	0.787

VP vertebroplasty, KP kyphoplasty

*Significant correlation at $P<0.05$; **significant correlation at $P<0.01$

^a Compared with 3 days after operation

VC ($r=-0.832$, $P<0.001$ in the VP group; $r=-0.546$, $P<0.001$ in the KP group). The correlation coefficients between TKA and the remaining lung function parameters were not significant. Moreover, in thoracic subgroups three days after operation, the decreased values of LKA had a remarkably positive correlation with the percentage of improvement of VC ($r=0.778$, $P=0.023$ in the VP group; $r=0.637$, $P=0.048$ in the KP group), but no significant correlation in lumbar subgroups. The VAS values had no significant correlation with TKA or LKA.

Discussion

In our study, VP and KP were performed to improve spinal sagittal alignment, to restore the height of the vertebral body, to decrease LKA and to relieve the patients' pain though VP had a less efficient effect on the improvement of vertebral body height and LKA. The initial results were comparable with previous studies [9, 11, 14].

The respiratory pump is controlled by an automatic system involving complex anatomical, biochemical and physiological reflexes. The diaphragm, intercostals, scalene, sternocleidomastoid and other accessory muscles (e.g. the pectoralis major, latissimus dorsi, serratus anterior and abdominal muscles) form the muscular part of this pump. Although the deformity of the spine can cause pulmonary impairment, the relationship between deformity and impairment is complex [12]. Among the parameters, MVV values reflect the respiratory muscle endurance. The reduced respiratory muscle endurance of osteoporotic patients could be due to their inactivity [3]. Women with osteoporosis typically have impaired lung volumes, restricted rib mobility, reduced respiratory muscle endurance and isometric muscle strength [3, 13].

Consistent with previous studies [10, 20], our study has shown that both VP and KP could partially improve the impaired pulmonary function of older women with OVCFs. Three days after the procedures, VC, FVC and MVV were

significantly increased, and MVV went on to improve remarkably three months after the procedures. There was also a significant correlation between the decreased values of pain scores and the percentage of improvement of FVC and MVV three days after VP and KP. Back pain is a very significant complaint for older women with OVCFs who have to lie in bed to reduce their normal movement. Three days after VP and KP, back pain was relieved, which could have helped improve the strength and endurance of the respiratory pump. Three months later, although back pain improved little compared with three days after the procedures, patients increased their activity, which ultimately helped increase their MVV. The improvement of the parameters and relationship between the parameters mentioned above showed no significant difference between VP and KP. The results demonstrate, in summary, that VP and KP have similar potential ability to improve impaired lung function though KP has a better effect on the improvement of vertebral body height and kyphosis. It may be explained by the fact that VP and KP have similar effects on pain relief, and improvements in decreased lung function primarily resulted from reduction of pain [20]. In agreement with the finding of Yang et al. [10], LKA did not have a significant correlation with any parameters of pulmonary function in either the VP or KP group.

Some previous studies have verified that back pain is related to the severity of the hyperkyphosis in the osteoporotic [5, 17]. although some other studies disagreed [10, 19]. Our study supports the latter. In our study, there was a significant negative correlation between TKA and VC, which is also supported by Culham et al. and Yang et al. [4, 10].

Furthermore, in thoracic subgroups three days after operation, the percentage of improvement of VC after KP was greater than after VP, and the decreased values of LKA had a remarkably positive correlation with the percentage of improvement of VC. But in lumbar subgroups, there was no such finding. As described above, there was a significant negative correlation between TKA and VC. And it is

understandable that thoracic LKA has a great effect on TKA, but lumbar LKA has little effect on TKA. So it is reasonable that the decreased values of LKA have a remarkably positive correlation with the percentage of improvement of VC in thoracic subgroups. It also seems reasonable that the LKA does not have a significant correlation with any parameter of pulmonary function when the one group includes both thoracic and lumbar OVCFs. KP can reduce more LKA than VP, so KP has a better effect on improvement of VC for thoracic OVCFs.

In conclusion, although the most important goal of VP and KP is to alleviate pain, this study clarified that VP and KP also improve the impaired lung function. Such improvements could lower the incidence of pulmonary complications, thus increasing the clinical significance of VP and KP. Furthermore, KP has a greater effect on improvement of VC for thoracic OVCFs, and thus patients with thoracic OVCFs may obtain more benefit from KP than VP. However, further follow-up needs to be conducted to thoroughly examine this point.

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