Effectiveness of postural and instrumental reduction in the treatment of thoracolumbar vertebra fracture

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Abstract We compared the effectiveness of postural reduction and instrumental reduction in the treatment of thoracolumbar and lumbar vertebra fracture in 40 patients. Under general anaesthesia, postural reduction in a stretching prone position was first performed. Instrumental reduction and fixation were then conducted. Radiographs were made after each reduction. Comparisons between the two films and the fracture films were made based on the changes in prevertebral height of both the fractured vertebra and the adjacent superior and inferior intervertebral spaces. It was found that the recovery of the prevertebral height in postural and instrumental reductions was basically identical. The recovery of the prevertebral height in the intervertebral spaces was more significant in instrumental reduction. Both reductions were ineffective in patients whose compression of the diseased vertebra was more than

two-thirds of the normal. In cases of lower lumbar vertebra fractures, the effect of both reductions was unsatisfactory. Our findings indicated that the effectiveness of the reduction of vertebra fracture depends on the quantitative change of the spongy bone of the injured vertebra. Instrumental reduction only exerts an indirect tension. Postural reduction is effective in reducing thoracolumbar vertebral fracture, while instrumental reduction exerts only a relatively weak effect but it is particularly useful to maintain the result of postural reduction.

Résumé Nous avons comparé le bénéfice de la réduction orthopédique et d'une instrumentation dans le traitement des fractures dorso-lombaires et lombaires chez 40 patients. Sous anesthésie générale une réduction posturale a été réalisée puis une instrumentation a été mise en place avec réduction et fixation. Des radiographies ont été réalisées après chaque temps de réduction. Des comparaisons avec mesure ont été réalisées sur chaque cliché vertébral. Cette étude nous a permis de montrer que l'amélioration de la hauteur vertébrale après réduction orthopédique ou réduction chirurgicale était identique par contre l'espace inter vertébral a été amélioré de façon significative après réduction chirurgicale. Ces deux réductions sont efficaces chez les patients présentant une telle pathologie par contre, lorsque la fracture est lombaire, les réductions se sont révélées inefficaces. Nous pouvons conclure que la réduction orthopédique est efficace et que la réduction chirurgicale a pour rôle de maintenir celle-ci.

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Introduction

Thoracolumbar and lumbar fractures result from a compression failure of both the anterior and the middle columns

under axial loads [4, 5]. Some patients with fractures develop progressive instability characterised by progressive kyphosis, back pain and neurological sequelae [1, 6, 10]. To these patients, one of the goals of the operative treatment of spinal fractures is the restoration of the anatomy of the spinal column, including the spinal canal. In the dorsal approach, all fractures were treated by postural reduction, instrumental angular reduction and stabilisation with a transpedicular internal fixator [7, 8]. Both postural reduction and instrumental reductions perform important roles in the operative treatment [24, 25]. However, there has not yet been any report on the comparison of the two methods. The purpose of this study is to report the radiographic result of thoracolumbar and lumbar fractures treated by postural reduction and instrumental reduction and to evaluate and analyse the clinical effect of the treatment of vertebra fractures by postural reduction and instrumental reduction.

Materials and methods

Clinical data

In this study, 40 patients who had their thoracolumbar and lumbar fractures treated by operative treatment with a transpedicular internal fixator were selected. According to the classification of Denis et al. [5], all fractures were unstable burst fractures or unstable compression fractures where operations were needed for reduction and fixation. At the time of initial injury, none of the patients had any neurological deficit.

Of the 40 patients in this study, 28 were men and 12 women. The mean age at the time of injury was 38.3 years (ranging from 24–56). The injuries were caused by falling from height in 23 cases, motor vehicle accidents in 7 cases, bicycle accidents in 5 cases, and direct blows in 5 cases. Twenty-nine fractures (73%) were located at the thoracolumbar junction (T11–L1). The fractures were distributed as follows: two at T11, eight at T12, 19 at L1, five at L2, one at L4, and five at L5.

Methods

All patients were treated operatively and fixed with a transpedicular internal fixator. Under general anaesthesia, patients were laid in a prone position on the Hall–Relton brace that supported the body at the front of both shoulders and anterior superior iliac spines so that the spine was in a hyperextension position and postural reduction was performed (Fig. 1). Lateral radiographs taken at this time were called the intraoperative films. In these films, the instruments were not responsible for any reduction of the

fractured vertebra. Radiographs were taken by using Philips C-arm X-ray machines with a focal length of 100 cm. Transpedicular instrumental reduction and fixation were then performed. Radiographs taken at this time were called the postoperative films. At this time, both instrumental and postural reductions took effect on the vertebrae. All films of the same patient were collected. Measurement unit conversion and data analysis on the three lateral films, “the fracture (preoperative) film”, “the intraoperative film” and “the postoperative film” were performed (Fig. 2).

The methods of measurement of the lateral films are shown in Fig. 3. The letter h means the prevertebral height of the injured vertebra, while h_1 and h_2 represent the prevertebral height of the adjacent superior and inferior vertebrae respectively. L_1 and L_2 are the prevertebral height of the intervertebral spaces of the adjacent superior and inferior vertebrae. The theoretical normal value of the prevertebral height of the fractured vertebra is $(h_1+h_2)/2$. To exclude any error of condition, the letter M which is the result of $2h/(h_1+h_2)$ was employed. Similarly, N means the comparative value of the average height of the intervertebral spaces, which is the ratio of $(L_1+L_2)/2$ and $(h_1+h_2)/2$. Based on the prevertebral height (h) of the fractured vertebra, the patients were divided into two groups (group I: preoperative $h < 1/3$ of the normal value, and group II: preoperative $h > 1/3$ of the normal value).

Statistical analysis

Statistical analyses were performed using SPSS 10.0. Data are presented as the mean $\pm$ SEM. The difference between the means was determined by one-way ANOVA, followed by a Student–Newman–Keuls test for multiple comparisons. A probability value of $P < 0.05$ was taken to be statistically significant.

Fig. 1 The patients were laid prone on the Hall–Relton brace

Fig. 2 **a** L1 burst fracture before reduction. **b** L1 burst fracture just after postural reduction. **c** L1 burst fracture with instrumental fixation

Results

Table 1 presented the results of the M and N values obtained from “the intraoperative film” and “the postoperative film”. Statistical analysis demonstrated that there were no significant differences between the intraoperative and postoperative M values. However, it was found that the N value obtained from “the intraoperative film” differed significantly from that of “the postoperative film”.

Figure 4 shows the M values of the three lateral films (the fracture or preoperative film, the intraoperative film and the postoperative film) obtained from group I (preoperative $h < 1/3$ of the normal value) and group II (preoperative $h > 1/3$ of the normal value). Although the M values of both the intraoperative film and postoperative film were significantly higher than those of the preoperative film, no significant difference was found between the M values of the intraoperative film and the postoperative film in both groups I and II. The recovery of the M value did not reach 80% of the normal even after both reductions when the preoperative h value was less than $1/3$ of the normal

(group I). This implied that when the preoperative h value was less than $1/3$ of the normal, the reductions were not very effective.

However, the recovery of the M value in group II, where the preoperative h value was more than $1/3$ of the normal, reached 91% of the normal after both reductions. These findings showed that the effectiveness of the reduction treatment was associated with the preoperative prevertebral height of the injured vertebra.

Of the 40 patients in this study, the serious fractures of five of the patients (12.5%) were located at L5. Of these five patients, none had their prevertebral height restored to 75% of the normal even after treatment by reduction and fixation, though there was an obvious increase in their adjacent superior and inferior intervertebral spaces (data not shown). This showed that the effect of both reductions was unsatisfactory in cases of lower lumbar vertebra fractures.

Discussion

Most of the spinal fractures are burst and flexion compression fractures. Anatomically, the posterior bony structure in the spine is more stable than that of the anterior [9, 16, 17].

Fig. 3 The methods of measurement of the lateral films. The letter h (h_1/h_2) means the prevertebral height of vertebra. L_1 and L_2 are the prevertebral height of the intervertebral spaces

Table 1 Comparison of the M and N values between postural and instrumental reductions

	(Intraoperative)-(Postoperative)				
	$\sum d$	$\sum d^2$	Case	t	p
M	0.56	0.148	40	1.482	>0.05
N	1.00	0.110	40	1.863	<0.05

d =Comparing M/N values of the intraoperative and postoperative films

Fig. 4 Reduction results (group1: the prevertebral height of the diseased vertebra $<1/3$ of the normal; group 2: the prevertebral height of the diseased vertebra $>1/3$ of the normal). * $P<0.05$ vs. fracture (preoperative) film

The load distort centre is in the posterior part of the two fractures. As a result, it is easy to reflect the degree of vertebral injury according to the prevertebral height and the prevertebral height of the intervertebral spaces, which are often regarded as the measurement data from which we can assess the reduction effect [21, 24]. In this study, the prevertebral height and the intervertebral space were therefore used as the two major indexes or comparative parameters.

The vertebral body is made up of the spongy bone and cortical bone. Under a compression load, there is a deformity range of about 9.5% before the spongy bone of the vertebra is destroyed, while that of the cortical bone is less than 2% [3, 20]. Hence, cortical bone fractures often occur first under a compression load. If the load is increased continuously, the spongy bone will be destroyed. To resist the dynamic peak loadings, the spongy bone usually absorbs the energy of the pressure by decreasing the trabecular distance, which plays an important role when the vertebrae are compressed. The height of the spongy bone would decrease significantly and part of the trabeculae would have irreversible deformity needing reduction and fixation. The force necessary to recover the height depends on the reverse tension by the external force. And the prevertebral height will not reach its maximal recovery until the external force reaches the balance [8, 12, 18, 19, 24]. Our data showed no significant difference ($P>0.05$) between the two prevertebral heights (the intraoperative and the postoperative films) after both postural and instrumental reductions. It was found that the prevertebral height was almost recovered after the treatment of postural reduction. This suggested that the major reduction force was from the postural reduction. We also demonstrated that both of the reductions were unable to recover the normal prevertebral height of the diseased vertebra when the vertebral compression was more than $2/3$ of its real height.

This might illustrate that the more the spongy bone was compressed and the more seriously the vertebral structure was destroyed, the less the indirect tension effect of the reduction would be [12, 13]. In addition, the soft tissues of the vertebra, muscles and ligaments, as well as the posterior structure of the vertebra, all reached the maximum reduction when instruments were employed to act as the final distraction force. Contrarily, these same tissues would bring about resistance against greater reduction force [18, 19].

The intervertebral disc structure has a great ability to resist pressure. The nucleus pulposus would not protrude even if the disc is permanently deformed by an enormous compression load. Hence, the nucleus pulposus is not easily destroyed under the usual compression load. In general, the vertebral endplate fracture occurs first if the load continues to increase, and then the spongy bone may be compressed. During the course of reduction, the nucleus pulposus, which has the characteristics of changing slowly and lagging behind, will recover first when the compression deformity load returns to normal [9, 17, 20]. The annulus fibrosus is made up of multi-levelled crossing collagen fibres. The inner fibres are attached to the cartilage endplate, and outer fibres are contiguous with the bony structure of the vertebral body. These anatomical characteristics are important to reductions, which can transmit stress directly to the fractured vertebra when postural and instrumental reductions are being performed. When the adjacent intervertebral discs recover, the annulus fibrosus structure can exert an axial traction effect on the injured vertebra for reduction. According to our data, although the intervertebral disc height was greatly recovered during postural reduction and the height was increased additionally after instrumental reduction, the prevertebral height of the fractured vertebra changed little. The intervertebral disc can completely transform and absorb the distraction force from the instruments [12, 17, 19, 23]. But to the damaged vertebra, the instrumental reduction force is still an indirect tension and could hardly form a linear correlation to the increase of the prevertebral height. This indicates that the recovery of the prevertebral height does not depend on instrument reductions alone.

There are many ligamentous structures around the vertebra. In burst and compression fracture, although deformity occurs on the anterior and posterior longitudinal ligament, the ligament structures rarely break. As a result, in the process of fracture reduction, the ligaments not only transmit the axial distraction force, but also prevent hyperextension. In this study, the results of both postural and instrumental reductions were unsatisfactory in five patients with lower lumbar vertebra fractures (L5), but the adjacent intervertebral space still increased significantly. This finding was similar to that reported by Patrick et al. [2, 12, 18, 22]. The reason for this is associated not only with

the weaker elasticity of the intervertebral disc in the lower lumbar region, but also the ligaments themselves. Anatomically, the superficial part of the posterior longitudinal ligament starts from foramen magnum and terminates in the intervertebral disc of L3–4. Therefore, the fibres that reach the intervertebral disc of S1–2 become much more scarce and thin. In addition, the anterior longitudinal ligament located in L4–5 becomes wide and the tension falls [2, 11, 14, 15, 21]. All of these could bring about a reduction in the distraction force transmitted by the ligaments [11, 15]. Of course, the presence of more cancellous bone in the lower vertebral body is another reason for the ineffective reduction [11, 14].

In summary, our data demonstrated that there was no significant difference between the effectiveness of postural reduction and instrumental reduction in the treatment of thoracolumbar vertebra fracture. Findings also showed that it is beneficial to make use of postural reduction in clinical treatment. However, this does not mean that instrumental reduction could be replaced. On the contrary, with the help of a pedicle instrument called “power core fixation”, the reduction is well maintained, which not only fixes the height, but is also beneficial for the recovery of the bone structure.

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