Rollback Imaging as a Useful Tool in the Preoperative Evaluation of Osteoporotic Vertebral Fractures

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Abstract:

Introduction: When surgery is performed for osteoporotic vertebral fractures, the extent to which kyphosis can be corrected by the intraoperative position of the body is often determined by preoperative radiography in the extension position. However, patients have difficulty adopting an adequate extension position due to the pain associated with their vertebral fracture. We place a pillow beneath the fractured vertebral body before surgery and take radiographs in the supine position to evaluate the extent to which the kyphosis can be corrected. This study aimed to examine the usefulness of this imaging method by comparing postoperative radiographs with preoperative radiographs taken with a pillow placed beneath the fractured vertebral body.

Methods: Lateral preoperative radiographs were taken of the patients in seated flexion and extension positions and the supine position. Lateral radiographs (rollback) were also taken 5 min after placing a firm pillow 20 cm in diameter beneath the fractured vertebral body. The kyphotic angle was compared between preoperative lateral radiographs of patients in the flexion, extension, and supine positions, rollback, and postoperative lateral radiographs in the supine position.

Results: The mean kyphotic angle was 33.3° in the flexion position, 28.3° in the extension position, 14.8° in the supine position, and 5.6° in rollback preoperatively and 6.4° postoperatively. The preoperative kyphotic angle differed from the postoperative kyphotic angle by ≥11° in 91% and 83% of participants in the flexion and extension positions, respectively; the difference was ≤ 5° in 30% and 61% of participants in the supine position and rollback, respectively. Differences in the postoperative angle were small in the order of rollback, supine position, extension position, and flexion position.

Conclusions: Compared with radiographs taken in the flexion, extension, and supine positions, rollback showed little difference from postoperative radiographs, which showed almost the same angle as the intraoperative kyphotic angle.

Keywords:

Rollback imaging, Preoperative evaluation, Osteoporotic vertebral fractures, Anterior and posterior spinal fusion, Kyphotic angle, In situ fusion

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Introduction

Osteoporotic vertebral fractures are common in elderly people[1]. These fractures often heal with conservative treatment, but in some cases, they result in nonunion when the bone of the vertebral body does not fuse[2-4]. In such cases, low back pain persists, and sitting becomes difficult; paralysis of both lower limbs can even develop if it progresses[5-7]. Surgery is indicated in such an event, but patients exhibit kyphosis due to the vertebral fracture[8,9]. Generally, when surgery is performed, the extent to which kyphosis can be corrected by the intraoperative position of the body is often determined by preoperative radiography in the extension position. However, it is difficult for patients to adopt an adequate extension position due to the pain associated with their vertebral fracture. Kyphosis is corrected during surgery because it is performed under general anesthesia. Consequently, a divergence from the preoperative radiographs in the extension position arises, which can interfere with determining the size of the anterior cage and alignment when performing surgery. We place a pillow beneath the fractured vertebral body prior to surgery and take radiographs in the supine position to evaluate the extent to which the kyphosis can be corrected. Once the patient is in the supine position

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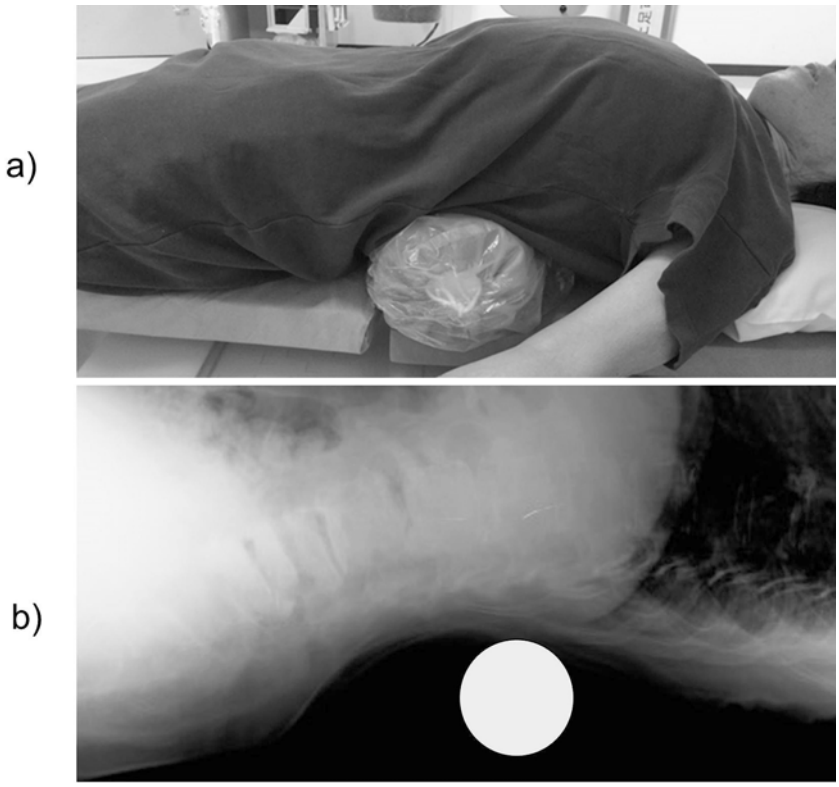

Figure 1. Rollback imaging.
a) A firm pillow measuring 20 cm in diameter is placed beneath the fractured vertebral body, and lateral radiographs are taken 5 min later.
b) Lateral radiograph using rollback imaging.

with a pillow beneath the fractured vertebral body, the lower back is initially placed under strain due to the pain, and correction of kyphosis is consequently inadequate. However, as time passes, the kyphosis is gradually corrected, resulting in opening of the nonunion in the vertebral body. This allows intraoperative correction of kyphosis, which was previously difficult to evaluate, to be predicted prior to surgery. If correction of kyphosis can be predicted, the size of the cage and kyphotic angle can be evaluated, which allows an accurate surgical approach to be determined preoperatively.

This study aimed to examine the usefulness of this imaging method by comparing postoperative radiographs with preoperative radiographs taken with a pillow placed beneath the fractured vertebral body.

Materials and Methods

Patients

A total of 54 patients who underwent surgery at our hospital for osteoporotic vertebral fractures were recruited from April 1, 2015 to January 31, 2019. The patients were aged 60 to 85 (mean: 77.5) years, with 14 men and 40 women. The fractured vertebral body was Th10 in 1 patient, Th11 in 1 patient, Th12 in 14 patients, L1 in 17 patients, L2 in 8 patients, L3 in 6 patients, and L4 in 1 patient; 4 patients had fractures of both Th12 and L1, and 2 patients had fractures of both L1 and L2.

Radiographic method

Lateral preoperative radiographs were taken of the patients in seated flexion and extension positions and the supine position. Lateral radiographs (rollback) were also taken 5 min after placing a firm pillow 20 cm in diameter beneath the fractured vertebral body (Fig. 1). When imaging was difficult for the patient due to pain, a diclofenac sodium suppository (25 mg, 50 mg) was administered prior to imaging. An additional pentazocine injection (15 mg, 30 mg) was given if the effect was weak. Lateral postoperative radiographs were taken of the patients in the supine position.

Radiographic measurement

The kyphotic angle was the angle formed on lateral radiographs by the superior margin of the vertebral body immediately cranial to the fractured vertebral body and the inferior margin of the vertebral body immediately caudal to the fractured vertebral body. The kyphotic angle was compared between preoperative lateral radiographs of patients in the flexion, extension, and supine positions and rollback, and postoperative lateral radiographs in the supine position.

Surgical approach

The surgery involved anterior and posterior spinal fusion in all cases. Autologous iliac bone was used for anterior fu-

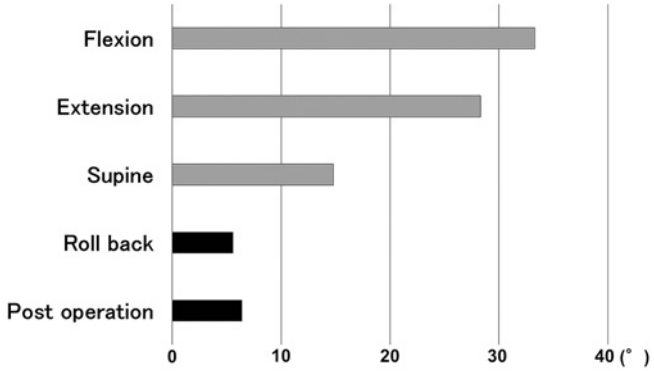

Figure 2. Mean kyphotic angle under each imaging condition.
The mean kyphotic angle is 33.3° in the flexion position, 28.3° in the extension position, 14.8° in the supine position, and 5.6° in rollback preoperatively and 6.4° postoperatively.

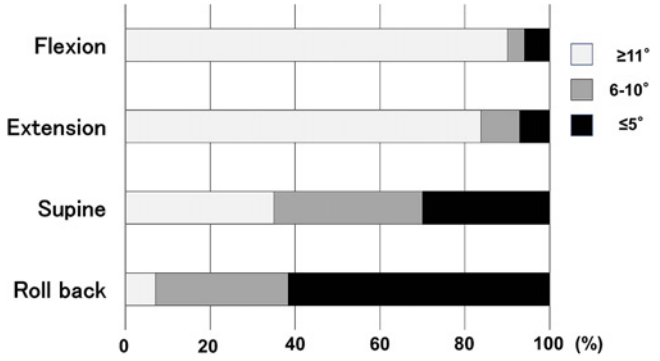

Figure 3. Difference between the kyphotic angle under each imaging condition and the postoperative kyphotic angle.
The preoperative kyphotic angle differs from the postoperative kyphotic angle by ≥11° in 91% and 83% of participants in the flexion and extension positions, respectively, whereas the difference is ≤5° in 30% and 61% of participants in the supine position and rollback, respectively. Differences with the postoperative angle are small in the order of rollback, supine position, extension position, and flexion position.

sion in 11 patients, and a fusion cage was used anteriorly in 43 patients. Posterolateral fusion with a pedicle screw was carried out after laminectomy in 11 patients with paralysis or severe instability. In the other 43 patients, posterior fusion was carried out using a percutaneous pedicle screw (PPS). A left-sided approach was used for anterior fusion in 49 cases, with a right-sided approach in 5. When autologous iliac bone was used for anterior fusion, the patient was first placed in the prone position, and posterior fusion was carried out in that position by *in situ* fusion. No instrumentation was used for correction. The patient was then placed in the lateral position, and subtotal resection of the fractured vertebral body was carried out via an extrapleural approach, with the intervertebral discs on the cranial and caudal sides also removed. A full-layer bone graft was harvested from the iliac bone, after which autologous iliac bone of the same length as the defect was grafted. In patients for whom a cage (X-CORE2: NuVasive®, https://www.nuvasive.com) was used, anterior fusion was first performed. This was because, when a cage is used, the procedure is performed under surgical imaging, and the intervertebral discs and vertebral body must be resected well into the opposite side. If posterior fusion is carried out first, the screw and rod interfere with the use of surgical imaging. The patient was placed in the intermediate lateral position (the same position as during surgery in the prone position), and subtotal resection of the fractured vertebral body was carried out under surgical imaging via an extrapleural approach, with the intervertebral discs on the cranial and caudal sides also removed. The cage was filled with rib bone (harvested during the approach) and local bone, and after the cage had been placed in the subtotally resected vertebral body, the cage was raised. The cage was raised to the point at which the cage was stable and would not become displaced. It was not raised any further beyond this point. The patient was then placed in the prone position, and posterior fusion was then carried out by *in situ* fusion with the patient in the same position as during surgery, without the use of instrumentation for correction.

Preoperative, intraoperative, and postoperative evaluations

Preoperative paralysis, operating time, intraoperative bleeding, and postoperative complications were investigated. Preoperative and postoperative lumbar pain was assessed using a Visual Analog Scale (VAS).

Analysis

Mann Whitney U tests were used to test for differences between groups. A P-value < 0.05 was considered to indicate a significant difference.

Results

The mean kyphotic angle was 33.3° in the flexion position, 28.3° in the extension position, 14.8° in the supine position, and 5.6° in rollback preoperatively and 6.4° postoperatively (Fig. 2). Significant differences were seen in the flexion, extension, and supine positions compared with the postoperative angle on statistical analysis; however, no significant difference was seen in rollback (P-value = 0.94). A difference of ≥11° between preoperative and postoperative kyphotic angles was seen in 49 patients (91%) in the flexion position, 45 patients (83%) in the extension position, 19 patients (35%) in the supine position, and 4 patients (7%) in rollback. A difference in the kyphotic angle of between ≥6° and ≤ 10° was seen in 2 patients (4%) in the flexion position, 5 patients (9%) in the extension position, 19 patients (35%) in the supine position, and 17 patients (31%) in rollback. A difference in the kyphotic angle of ≤ 5° was seen in 3 patients (6%) in the flexion position, 4 patients (7%) in the extension position, 16 patients (30%) in the supine position, and 33 patients (61%) in rollback (Fig. 3). Differences with the postoperative angle were small in the order of rollback, supine position, extension position, and flexion posi-

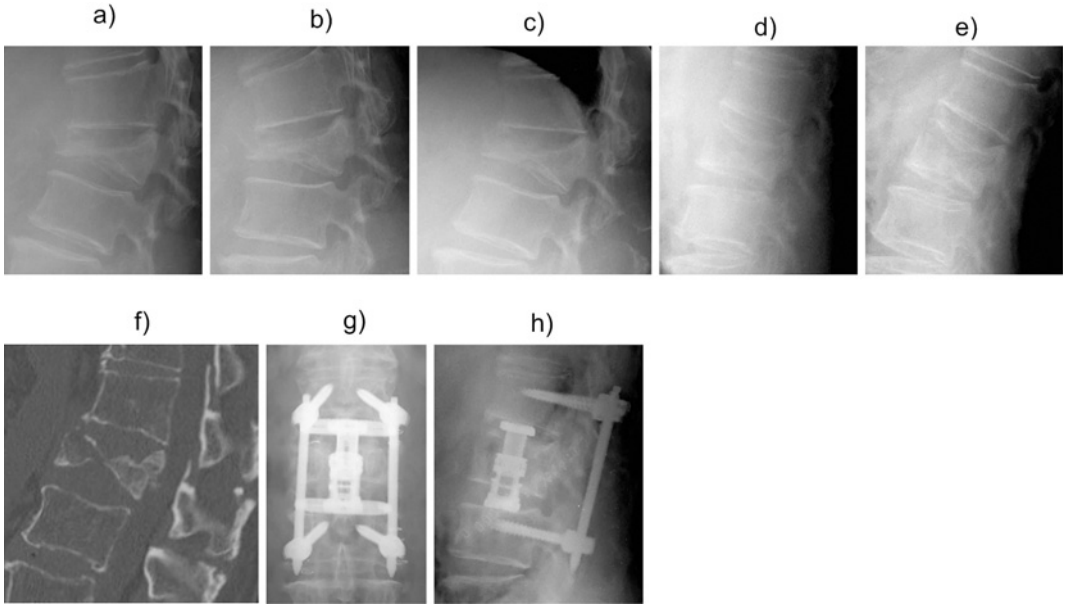

Figure 4. A 74-year-old man with a fracture of the 2nd lumbar vertebral body.
Preoperative lateral radiograph: Kyphotic angles of 35° in the flexion position (a), 32° in the intermediate position (b), 24° in the extension position (c), 0° in the supine position (d), −5° in rollback (e); preoperative sagittal computed tomography scan (f) and postoperative frontal (g) and lateral radiographs (h), kyphotic angle of 0°.

tion. There were no differences in the results between different vertebral levels.

Preoperative paralysis was evident in 5 cases, all of whom improved from having difficulty walking preoperatively to being able to walk postoperatively. Mean operating time was 2 h 24 min (1 h 17 min to 3 h 59 min) for anterior fusion and 1 h 2 min (21 min to 5 h) for posterior fusion. Mean intraoperative bleeding was 199 g (20-715 g), and postoperative complications comprised conversion to thoracotomy with the use of thoracic drainage in 5 cases, the appearance of postoperative paralysis (having been able to walk preoperatively but walking with a cane postoperatively) in 1 case, fracture at the bone harvest site in 4 cases, and reoperation in 4 cases (2 cases each of screw loosening and adjacent vertebral fracture). The mean preoperative VAS was 7.3 (3-10), and the mean postoperative VAS was 3.5 (0-7).

Case 1

A 74-year-old man presented with low back pain after engaging in bowling and farming 2 months earlier. His low back pain gradually worsened, and he sought consultation when even sitting became difficult. The man had no neurological abnormalities. He was diagnosed with low back pain associated with fracture of the 2nd lumbar vertebral body (Fig. 4a-f). Anterior and posterior fusion was performed using a cage anteriorly and a PPS posteriorly (Fig. 4g, h). The postoperative local kyphotic angle was 35° in the flexion position, 32° in the intermediate position, and 24° in the extension position (Fig. 4a-c). The kyphotic angle in the supine position was 0° and −5° in rollback (Fig. 4d, e). The postoperative kyphotic angle was 0° (Fig. 4h).

Case 2

A 62-year-old woman underwent anterior and posterior fusion using a cage anteriorly and a PPS posteriorly for fracture of the 12th thoracic vertebral body. The preoperative local kyphotic angle was 34° in the intermediate position, and the intervertebral height at the center of the vertebral bodies was 24 mm (Fig. 5a). The postoperative kyphotic angle was 17° (Fig. 5b). The end plate was damaged during insertion of the cage because the space between the Th11 and L1 vertebral bodies was narrow (Fig. 5a-c).

Discussion

Many reports state that the use of furculum backward bending is useful in the evaluation of preoperative radiographs of kyphosis correction for adult spinal deformity[10,11]. Preoperative low back pain is mild in the case of adult spinal deformity; therefore, adequate evaluation of kyphosis correction is possible by using tools such as manual manipulation or a pillow to correct the kyphosis and take radiographs. In adult spinal deformities, surgical techniques such as osteotomy are chosen with the aim of achieving further correction depending on the extent of preoperative kyphosis correction[12-15]. In the case of osteoporotic vertebral fractures, intraoperative correction using a screw can result in loosening of the screw because load is applied to the screw[16-18]. In situ fusion is therefore recommended without performing any unreasonable correction[19]. Consequently, when performing surgery to treat osteoporotic vertebral fractures, it is extremely important to determine in the preoperative plan to

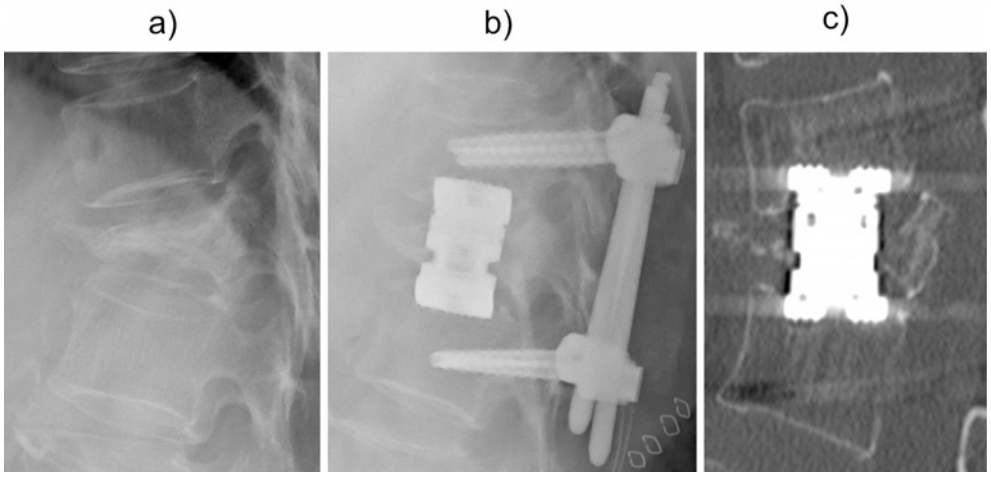

Figure 5. A 62-year-old woman with a fracture of the 12th thoracic vertebral body.
Preoperative lateral radiograph: Kyphotic angle was 34° in the intermediate position, and intervertebral height at the center of the vertebral bodies was 24 mm (a), postoperative lateral radiograph: kyphotic angle of 17° (b), postoperative sagittal computed tomography scan (c); the end plate was damaged during insertion of the cage because of the narrow space between Th11 and L1.

what extent kyphosis will be corrected by the intraoperative position of the body. Intraoperative kyphosis correction is often evaluated and determined using preoperative extension position radiographs. However, achieving an adequate extension position is difficult due to the pain associated with the vertebral fracture. Furthermore, an adequate extension position cannot be achieved due to pain even if imaging is done by furculum backward bending as in the case of adult spinal deformity. We, therefore, decided to perform imaging in the supine position with a pillow placed beneath the back after administering an analgesic immediately prior to imaging. Initially, correction of the kyphosis is inadequate due to the strain placed on the lower back by the pain. However, this strain gradually alleviates with time. Five minutes after assuming the supine position, the patients' low back pain had subsided, and an extension position could be achieved. The fracture is fused intraoperatively by in situ fusion while the patient remains in the same surgical position; the postoperative radiography position is therefore considered the same as the intraoperative position of the body. Postoperative and preoperative radiographs were then compared. In the present study, the mean kyphotic angle on preoperative extension position radiographs was 28.3°. This differed greatly from the 6.4° on postoperative lateral radiographs. Furthermore, a difference of ≥11° between preoperative and postoperative kyphotic angles was seen in 83% of patients in the extension position. Predicting the intraoperative kyphotic angle using preoperative extension position radiographs is therefore difficult. For rollback, meanwhile, the mean kyphotic angle was 5.6° on preoperative radiographs, but 6.4° on postoperative lateral radiographs, showing almost no difference (P-value = 0.94). Furthermore, only 7% of patients had a difference between preoperative and postoperative kyphotic angles of ≥11° in rollback. In addition, 61% of patients had a difference in the angle of ≤5°, which indicated almost the same angle as their postoperative corrected kyphotic angle. The kyphotic angle based on rollback, therefore, appears to be a useful method for predicting kyphosis correction preoperatively. It allows for accurate preoperative planning of the surgical approach by eliminating obstacles to determining the size of the anterior cage and alignment during surgery.

Recently, we have been performing surgery at our hospital using a cage anteriorly. A minimum height of about 25-28 mm is required for the size of the vertebral body replacement cage; any smaller cage is difficult to insert. If rigid kyphosis cannot be adequately corrected while the patient is in the intraoperative position, insertion of a cage is difficult because the end plate will be damaged during cage insertion (Fig. 5). In cases such as these, a surgical approach other than cage insertion (such as the use of autologous iliac bone) can be prepared in advance using preoperative rollback-based measurements.

A limitation of the approach described in this paper is that the placement of the pillow beneath the region where kyphosis is pronounced is not necessarily equivalent to the location of the fractured vertebral body. Further limitations include the fact that the fractured vertebral bodies were in the wide region of Th10 to L4; that the majority of cases were at the thoracolumbar junction level, meaning that the results may not apply to the thoracic or lumbar vertebrae; and that rollback imaging conditions are not standardized among individual patients because low back pain is not completely eliminated. This likely explains why the kyphotic angle still differed between rollback and postoperative lateral radiographs by ≥11° in 7% of patients and by ≥6° to ≤ 10° in 31% of patients. Meanwhile, the kyphotic angle differed between rollback and postoperative lateral radiographs by ≤ 5° in 61% of patients, which suggests that this percentage could be further increased if a condition with a high level of

accuracy were set.

Conclusion

Compared with radiographs taken in the flexion, extension, and supine positions, rollback showed little difference from postoperative radiographs, which showed almost the same angle as the intraoperative kyphotic angle. Rollback, therefore, made prediction of intraoperative kyphosis correction possible in preoperative planning for osteoporotic vertebral fractures. Determining the correct surgical approach prior to surgery becomes possible because the kyphotic angle and the size of the cage and alignment can all be evaluated based on rollback.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

Author Contributions: Hideo Baba wrote and prepared the manuscript, and all authors participated in the study design. All authors have read, reviewed, and approved the article.

Informed Consent: Informed consent was obtained from all participants in this study using opt out.

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