Prone position in balloon kyphoplasty leads to no secondary vertebral compression fractures in osteoporotic spine – a MRI study

Die Bauchlagerung während der Ballon-Kyphoplastie führt nicht zu sekundären Kompressionsfrakturen in osteoporotischen Wirbelsäulen – eine MRT-Studie

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Abstract

Purpose: Vertebral compression fractures are the most common fractures in the elderly.
Long lasting pain and deformity is responsible for consecutive impairment with markedly reduced life quality, increased morbidity and mortality. The beneficial effects of balloon kyphoplasty are verified in many studies. Subsequent fracture risk is not finally clarified, cement related risks and deformity related risks are discussed. There is less knowledge about the risk of bone marrow edema and new fractures during balloon kyphoplasty procedure. The goal of this study is to examine, if prone position during kyphoplasty is an independent risk factor for new fractures in the osteoporotic spine.
Methods: Consecutive MRI study of 20 patients with fresh, non-traumatic thoracolumbar vertebral compression fractures and balloon kyphoplasty treatment. MRI Scans of the thoracolumbar spine were obtained after surgery, before patients have been mobilized. Specific MRI changes like new bone marrow edema, signal intensity changes in adjacent and remote segments and new fractures were assessed by specialized neuro-radiologist.
Results: 20 MR images were examined within 48 hours after balloon kyphoplasty procedure.
85% did not show bone marrow edema extent changes after kyphoplasty. We found minor increase of bone marrow edema within the augmented vertebral body in 3 cases. We did not find any new bone marrow edema and no new fractures in adjacent and remote segments after balloon kyphoplasty treatment.
Conclusion: Prone position leads to no new bone marrow edema and no new fractures in the osteoporotic spine. Accordingly, prone position has no risk for adjacent level fractures in osteoporotic spines.

Keywords: osteoporotic vertebral compression fractures, adjacent level fractures, subsequent vertebral compression fractures, balloon kyphoplasty, prone positioning

Zusammenfassung

Einleitung: Wirbelkörperkompressionsfrakturen sind die häufigsten Frakturen in geriatrischen Patienten. Persistierende Schmerzen und sekundäre Deformitäten sind verantwortlich für eine zunehmende Beeinträchtigung mit reduzierter Lebensqualität, erhöhter Morbidität und Mortalität. Die positiven Effekte der Ballon-Kyphoplastie wurden in vielen Studien bestätigt. Das Risiko für Folgefrakturen ist noch nicht abschließend geklärt. Es werden zement- und deformitätenabhängige Risiken diskutiert. Es gibt wenig Erkenntnis über das Risiko von Knochenmarködemen und frischen Frakturen während des Ballon-Kyphoplastie-Verfahrens. Das Ziel dieser Studie ist es zu untersuchen, ob die Bauchlagerung während der Kyphoplastie einen unabhängigen Risikofaktor für frische Frakturen in osteoporotischen Wirbelsäulen darstellt.

Methoden: Es handelt sich um eine MRT-Studie an 20 Patienten, bei denen eine frische, nicht-traumatische thorakolumbale Wirbelkörperkompressionsfraktur mittels Ballon-Kyphoplastie behandelt wurde. Unmittelbar nach dem Eingriff wurden MRT-Untersuchungen der thorakolumbalen Wirbelsäule durchgeführt, noch bevor die Patienten mobilisiert wurden. Durch einen spezialisierten Neuroradiologen wurden postoperative MRT-Veränderungen wie Knochenmarködem, Signalintensitätsänderungen in den Anschlusssegmenten und frische Frakturen ausgewertet.

Ergebnis: Es wurden 20 MRT-Untersuchungen innerhalb von 48 Stunden nach Ballon-Kyphoplastie durchgeführt. 85% zeigten keine Änderungen des vorbestehenden Knochenmarködems nach der Kyphoplastie. In drei Fällen zeigte sich eine geringe Zunahme des vorbestehenden Knochenmarködems in den augmentierten Wirbeln. Es wurden kein neues Knochenmarködem und keine neuen Frakturen in den Anschluss- und Folgesegmenten nach der Ballon-Kyphoplastie nachgewiesen.

Schlussfolgerung: Die Bauchlagerung stellt kein Risiko für Anschlussfrakturen in osteoporotischen Wirbelsäulen dar.

Schlüsselwörter: Osteoporotische Wirbelkörperkompressionsfrakturen, Anschlussfrakturen, Folgefrakturen, Ballonkyphoplastie, Bauchlagerung

Introduction

One of the most important alteration in geriatric patients relates to the bone architecture. Typical changes start in cancellous bone, this explains why vertebral bodies are predestined for fractures and the thoracolumbar spine is the most affected area of osteoporotic fractures. Vertebral compression fractures (VCF) are the most common fractures in the elderly. The exact incidence is unknown. The worldwide prevalence is about 1.4 million (M) [1]. The economical importance is considerable. In the USA, VCF caused total costs of 1 M US$ in 2005 and will rise up to 1.6 M US$ in 2025 [2]. Treatment of VCF does not depend on morphological criteria, because most VCF are stable lesions. Long lasting pain is the most important factor that finally leads to surgery. Beneficial effects of vertebral body augmentation are demonstrated in various studies and pain reduction is the main effect [3], [4]. Advantageous therapeutic effects are confronted with cement related problems [5], [6], [7] and unclarified subsequent fracture risk [8], [9], [10], [11]. This study examines the importance of prone position during balloon kyphoplasty for the development of additional bone marrow edemas (BME) and thoracolumbar fractures. Earlier studies already reported the possibility of height restoration (reduction) and profile correction in prone position as a phenomenon in fresh VCF with dynamic mobility [12].This aspect was fundamental for our hypothesis that prone position and reduction stress could also lead to new fractures in osteoporotic conditions. Because anaesthetized patients lose the tonus of their autochthon trunk muscles, prone position and additional reduction stress by chest and pelvic pads might overstrain the load bearing capacity of the spine, which may lead to microfractures or bone bruises. Prone positioning seems to have an additional risk in the osteoporotic spine.

Patients and methods

Ethic votum

This study received an approval from competent ethic committee.

Patients

20 patients (6 men, 14 women) with fresh, non traumatic VCFs were included in this study. The average age was 78.4 years (64–94). Only patients older than 60 years were included in this study because of

1. rising incidence of osteoporosis and spontaneous fractures in the elderly and
2. we do not perform PMMA cement augmentation in patients under 60 years.

The following inclusion criteria were determined:

- age >60 years
- no trauma
- pain less than 8 weeks
- MRI not older than two weeks
- type A1.1, A1.2 and A1.3 fractures according to Magerl's classification [13]
- only single fresh fracture in MRI.

Exclusion criteria:

- previous spine surgery
- no consent.

Study period: February 2014 – May 2014.
Fracture classification: Fractures were classified according to Magerl's classification [13].

Methods

Standard balloon kyphoplasty

Patients were placed in prone position on a radiolucent op table with pads under the chest and pelvis and unstressed abdomen. Arms, knees and feet were padded to prevent nerve stretch and compression. Vertebral body height and alignment were tried to restore by varying pad position – increase/decrease of kyphosis or lordosis. Bilateral balloon kyphoplasty (Joimax SPASY) was performed in a standard manner, using 15 mm balloon in T5–T11 and 20 mm balloon in T12–L3 level. Balloons were inflated under fluoroscopy control up to a maximal volume of 2 ml (T5–T11), respectively 3 ml (T12–L3). The resulting cavity was filled with corresponding amounts of cement (each pedicle: 2 ml: T5–T11 and 3 ml: T12–L3). Consolidation time for PMMA cement (KyphX HV-R, Kyphon®) was 10 minutes.

MR imaging

MRI examination included sagittal and axial planes of the thoracolumbar spine using 3.0 tesla MRI system (Siemens TIM TRIO). Following sequences were performed:

Preoperative protocol:

- T1-weighted TSE sagittal (TR 526 ms, TE 10 ms, FOV 450 mm, SL 4 mm)
- T2-weighted TSE sagittal (TR 3900 ms, TE 94 ms, FOV 450 mm, SL 4 mm)
- T2-weighted TIRM sagittal (TR 5000 ms, TE 54 ms, FOV 450 mm, fatsupression, SL 4 mm)
- T2-weighted TSE transversal (TR 4250 ms, TE 118 ms, FOV 270 mm, SL 3 mm)

Postprocedural protocol:
Same protocol without T2-weighted TSE sagittal

Fresh fractures and bone marrow edema (bone bruise) were detected by decreased signal intensity on T1-weighted images, high signal intensity on T2-weighted and T2-weighted images with fat suppression (TIRM) [14]. Each MRI was analyzed by the same specialized neuroradiologist. The extent of bone marrow edema (BME) was assessed in sagittal TIRM images as percentage of volume of the fractured vertebral body. Three groups were classified: minor <25%, moderate 25–75% and severe >75%. Postoperative MRI control was performed within 48 h after surgery. Patients had absolute bed rest until postoperative MRI. BME extent between pre- and postoperative images was classified into less, the same, or more.

Results

Types of fractures

Figure 1 shows the different types of fractures.

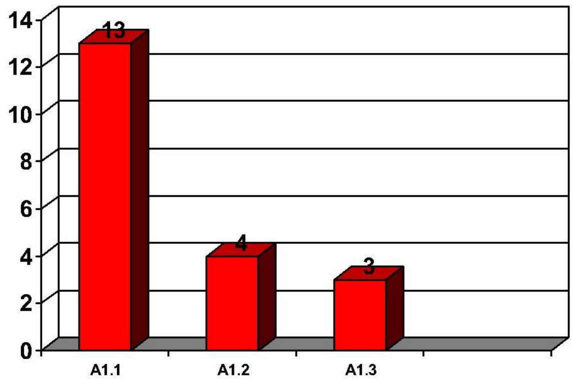


Figure1: Types of fractures

Fracture distribution

Most fractures were localized at T12 level (30%), followed by L1 (25%) and T10 (15%). 55% of the fractures were localized at the thoracolumbar junction (T12–L1).
Figure 2 shows the different fracture levels.

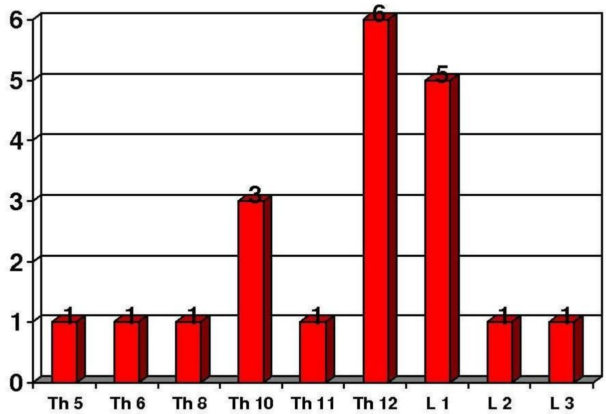


Figure 2: Distribution of fractures

MRI findings

Bone marrow edema

Preprocedural MRI evaluation revealed minor BME extent in one case. The majority revealed moderate and severe edemas (45% moderate, 50% severe). 85% did not show BME extent changes after kyphoplasty. Change of BME extent in postprocedural MRI was detected in 3 patients: one patient with preoperative minor edema showed moderate edema and 2 patients with moderate edemas showed severe edemas in postprocedural MRI. We did not find less extent of BME after kyphoplasty (Figure 3).

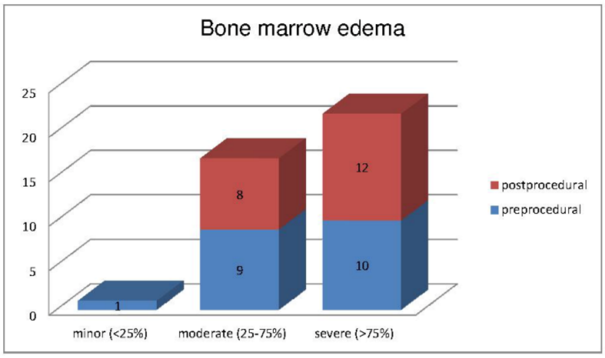


Figure 3: Bone marrow edema

Bright rim sign

Bright rim surrounding the cement on STIR weighted images (hypointense signal on T1-weighted images) represents a necrotic area as result of heat related local vertebral ischemia [15], [16], [17].
We did not recognize bright rim sign in any post-procedural MRI.

Adjacent segment/remote segments

Increased signal intensity in both adjacent discs (sagittal TIRM sequence) was seen in one case. In this case, we also found change of BME extent from moderate to severe. In one case we recognized cement extrusion into the cephaled disc space which led to hyperintense signal in TIRM sequence. There was no signal alteration in remote segments, neither in disc spaces, nor in any vertebral bodies. There was no new bone marrow edema and no new fracture, neither in adjacent nor in remote segments (Figure 4).

Intraoperative Complications

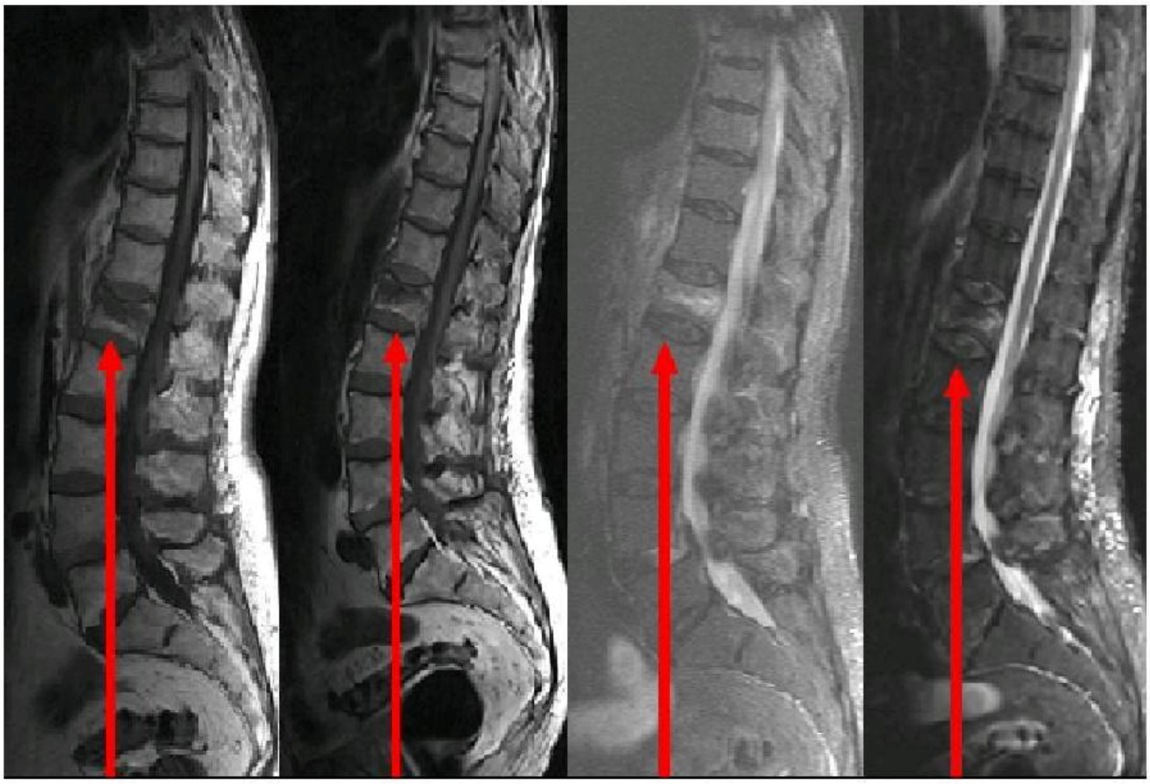
We identified two cement extrusions: one into the upper disc space and one anteriorly, protruding into the retroperitoneal space.

Discussion

Reduced bone mineral density is responsible for less mechanical stability with subsequent height loss and finally VCF in osteoporotic conditions. Interestingly, only 30% of all fractures become symptomatically [18]. Patients with long lasting pain, missing recovery and pain related immobilization, may benefit of minimally invasive vertebral cement augmentation [3], [4], [19]. Balloon kyphoplasty is one of the most common augmentation techniques and well investigated. Pain reduction is a crucial effect, which is well confirmed, even 2 years after kyphoplasty [4]. Additional to pain reducing effect, operative therapy is important for preservation of balanced spine profile. Especially in thoracic spine, vertebral compression fractures may lead to progressive kyphosis, deformity and restriction of pulmonary function [20]. In spite of its beneficial effects, risks of minimally invasive surgery related complications should not be underestimated: cement leakage up to 33% [21], pulmonary embolism up to 23% [22], neurologic deficits in 3.7%, spinal cord compression in 0.5% [21], [23]. Further, a not finally solved phenomenon is the presence of adjacent level and subsequent fractures after vertebral body augmentation. Reviewing the literature, three main hypotheses are discussed:

1. New fractures after cement augmentation may develop due to progress of disease – untreated osteoporosis [24].
2. New fractures after cement augmentation may develop due to too large cement volumes and increased stiffness [5].
3. New fractures after cement augmentation may result due to kyphotic deformity [8], [9].

The risk of subsequent fractures rises with the number of pre-existing deformities, independently of the bone quality. Three and more present fractures have a 35-fold increased subsequent fracture risk [8], [9]. Adjacent level fracture risk is also increased by increased vertebral body stiffness in case of too large cement volumes [5]. Finite element analysis demonstrated optimal volumes of 3.5 cm^3, to restore the original stiffness in vertebral bodies. Larger amounts increase the stiffness above original values [6]. Due to excessive augmentation, the cement acts like a pillar with reduction of the physiologically endplate concavity or even convex deformity. The intradiscal pressure is increased up to 19% [7], resulting in adjacent level fractures [10], [11]. Other authors assert that progressive kyphotic deformity is responsible for subsequent fractures. Wedge formation may lead to an anterior load shift with increased bending moments and additionally compression of the anterior column [8], [9].
These explanations demonstrate that the risk of subsequent and adjacent level fractures after cement augmentation is not finally clarified. Studies reported an incidence of subsequent fractures after balloon kyphoplasty between 7 and 26% [25], [26], [27], [28], [29]. Regarding onset of recurrent fractures, most authors report a peak within 12 months [4], [30], [31]. Trout et al. reported an early onset within 30 days, with high risk in case of cement extrusion into the disc space [32]. Fribourg et al. reported an increased incidence of subsequent vertebral fractures after kyphoplasty within 60 days after balloon kyphoplasty [27]. Finally, exact date is not clarified. It is not excluded, that early bony changes take already place during kyphoplasty procedure.
Reviewing the literature, the authors did not find any study that examines the role of prone position as an independent risk factor for new fractures in osteoporotic spine.
With respect to the biomechanical findings described above, peri-procedural conditions during kyphoplasty may



1 2 3 4

Figure 4: Scans
1 Pre-procedural sagittal T1-weighted Scan: hypointense signal in L1
2 Post-procedural sagittal T1-weighted Scan: hypointense signal in L1
3 Pre-procedural sagittal TIRM-weighted Scan: hyperintense signal in L1
4 Post-procedural sagittal TIRM-weighted Scan: hyperintense signal in L1 and discs

be decisive. General anaesthesia with full muscle relaxation prevents muscular trunk stabilization in prone position. Pads under chest and pelvis increase mechanical loads by eccentric forces. This might be enough to overstrain the weak bone consistency in osteoporotic spine and lead to microfractures. These microfractures are the beginning of continuing height loss and should be detected immediately after kyphoplasty. Magnetic resonance tomography is the method of choice. MR imaging is the gold standard to prove fresh lesions [33] with a reported sensitivity of 99% and specificity of 98.7% for fresh vertebral fractures [34]. It is the modality of choice to assess traumatic lesions [35]. MRI is able to detect fresh lesions, before vertebral body height loss is visible in X-ray and computed tomography. Acute vertebral fractures and BME are most sensitive detected in sagittal STIR images [14], [15], [36], [37], [38], [39]. Bone marrow pathologies are best evaluated in T1-weighted sequences on 3 Tesla MRI [40]. However, the crucial question is, when can first signal changes be detected in MRI. The authors did find no study that examined the time, when BME arises first. On the other hand, it is well known, how long these signal alterations are detectable. BME decreases gradual over time with complete vanishing after three months in 35%, at 6 months in 54% and 12 months in 71% [15], [39]. To the authors opinion, the best way to detect fresh lesions immediately after kyphoplasty procedure, is by 3 Tesla MRI.

In our study, evaluation of 20 post procedural 3 Tesla MRI by one spezialized neuro radiologist did show no new bone marrow edema and no new fracture in adjacent and remote segments. 85% did not show BME extent changes within the augmented vertebral body in post procedural MRI. We did not find less extent of BME after kyphoplasty. We did not recognize bright rim sign in any post-procedural MRI. In one case we found increased signal intensity in sagittal TIRM sequence in both adjacent discs. In this case, we also found change of BME extent from moderate to severe. In one case we recognized cement extrusion into the cephaled disc space and increased signal intensity in TIRM sequence.

The goal of this study was to evaluate the risk of prone position during balloon kyphoplasty and new vertebral compression fractures in generally anesthetized patients in osteoporotic spine. Benefit of this study was standardized operative protocol with determined volumes of balloon inflation and cement amounts in thoracic and lumbar levels to reduce the well-known cement related subsequent fracture risk. Further, we used identical MRI protocols and received each MRI within 48 hours after kyphoplasty. Because patients had bed rest till they received MRI, we minimized additional risks of signal alterations. Interobserver variability was reduced by MRI evaluation by only one specialized neuro-radiologist.

On the other hand, this study has some limitations. We did not measure bone mineral density (BMD) to proof osteoporosis. We defined osteoporotic vertebral compression fracture by average age older than 60 years, no recent trauma and typical findings in MRI, which was not older than two weeks. Postoperative MRI was not blinded to preoperative MRI. It was the aim to detect extent changes of BME, new bone marrow edema and new fractures. So we think it is important to compare these findings to the pre-procedural MRI. Further, we often recognized preexisting degenerative findings. It was important for us to look if these findings changed or increased post-procedural.

We performed post-procedural MRI within 48 hours. As mentioned above, the authors did not find studies that examined the beginning of MRI signal changes. It might be that these changes occur later and we could not have detected them. But if we had performed post-procedural MRI later, the risk of further factors influencing MRI signal intensity would also rise. The main limitation is the small number of patients (20 patients). This reveals only fractures if the prevalence is higher than 5%. If prevalence was close to 1%, 100 patients would be needed. On the other hand, there is a reported incidence of subsequent fractures after balloon kyphoplasty between 7 and 26% with a peak within 12 months. This means that these fractures could occur also within the first days after kyphoplasty. And than prone position could play a major role for secondary vertebral compression fractures in osteoporotic spine.

Conclusions

Kyphoplasty is well established in the treatment of osteoporotic VCF. The risk of adjacent level and subsequent fractures is not fully clarified. Various causes are discussed. The influence of prone position and external reduction stress is not investigated yet. This is the first consecutive MRI study, which examines the role of prone position in kyphoplasty treatment of osteoporotic vertebral compression fractures. The aim of this study was to examine, if prone position in anaesthetized patients is an independent risk factor for new fractures in osteoporotic conditions.

MRI evaluation of 20 thoracolumbar VCF, immediately after balloon kyphoplasty treatment, did not show bone marrow edema (bone bruise) and new vertebral compression fracture in adjacent and remote segments. Accordingly, prone position has no risk for adjacent level fractures in osteoporotic spines.

Notes

Competing interests

The authors declare that they have no competing interests.

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