Value of MRI imaging prior to a kyphoplasty for osteoporotic insufficiency fractures

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Abstract Previous studies have shown the safety and effectiveness of balloon kyphoplasty in the treatment of osteoporotic vertebral compression fractures (OVCFs). MRI and particularly the short tau inversion recovery (STIR) sequence are very sensitive for detecting vertebral edema as a result of fresh fractures or micro-fractures. Therefore, it has a great therapeutic relevance in differentiating vertebral deformities seen by conventional X-ray and CT scans. Although an MRI scan is expensive, to my knowledge no study has evaluated the benefits of preoperative MRI in evaluating a therapeutic plan for kyphoplasty. This is a prospective study evaluating the benefit of a preoperative MRI scan regarding changes of kyphoplasty therapy. Twenty-eight patients were included in this study. Twenty-four patients were treated by balloon kyphoplasty, in a total of 40 vertebral bodies. The mean age was 73 years. All patients suffered from OVCFs. As a first step, all patients got a CT scan. The individual therapeutic plan was then defined by the patients' history, complaints and the results of the CT scan. As far as all criteria for kyphoplasty were fulfilled, an MRI examination including the STIR sequences was performed preoperatively. The number of times a change was

made in therapy as a result from the additional information from the MRI was then evaluated. By performing a preoperatively MRI examination, the therapy plan was changed in 16 out of 28 (57%) patients. Eight patients underwent additional levels of kyphoplasty at the same procedure. In five patients, lesions were found to be old fractures and therefore were not treated operatively. Two of these patients received no kyphoplasty at all. Another patient only a part of the originally intended levels was treated. The other two cases received a kyphoplasty at different vertebral levels, as these vertebral bodies showed signs of an acute fracture in the MRI scan. Additionally, an incidental diagnosis of carcinoma of the kidney was made in two patients. Kyphoplasty was deferred and they were referred for further evaluation. One patient was found to have an aortic aneurysm. Kyphoplasty was performed and after that the patient was referred in order to treat the aneurysm. This study confirms the diagnostic benefits of an MRI scan before performing a kyphoplasty. For 16 out of 28 patients, the therapeutic plan was changed because of the information obtained by preoperative MRI. Preoperative MRI helped to generate the correct surgical strategy, by demonstrating the correct location of injury and by detecting concomitant diseases.

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Introduction

Osteoporosis is a systemic disease, which results in progressive bone mineral loss and concurrent changes in bony architecture. This is responsible for compression fractures of the vertebral bodies without significant trauma [19]. Approximately 500,000 vertebral fractures occur as a result

of osteoporosis every year in Europe [2]. 49% of all fractures occur in the region of vertebral bodies T11–L3. 11% occur in the middle part of the thoracic spine column and 5% occur at the cervical spine. The incidence of osteoporotic vertebral compression fractures (OVCFs) in women older than 50 years is more than 1 out of 100 per year, moreover there are three times higher after the age of 75 [2, 20]. Approximately 25% of women older than 70 years and more than the half of women older than 80 [8, 10] suffer from at least one OVCF. Primary osteoporosis is the main cause of vertebral fractures while secondary osteoporosis and neoplasm account for the remaining 15%. Vertebral fractures result in a structural deformation of the soma with an increased risk of fractures at the adjacent vertebral bodies [21]. OVCFs are the leading cause of disability and morbidity in the elderly [20]. Advances in minimally invasive spinal surgery have opened new methods for the treatment of these fractures [7]. Kyphoplasty is an evolution of percutaneous vertebroplasty. Kyphoplasty employs balloon catheters inflated with a contrast agent to restore the morphology of the collapsed vertebral body thus reducing kyphosis before the vertebral body is stabilized with bone cement [11, 22]. Evidence of edema by MRI, especially with the use of short tau inversion recovery (STIR) sequences, suggests “acute” structural deformity, which can then be corrected by kyphoplasty. This can best be managed when surgery is done within 9 months with the onset of symptoms [4]. This study evaluates the additional value of preoperative MRI.

Materials and methods

Patients

A prospective study was performed on all patients suffering from OVCFs at the Vertebral Spine Institute from January 2006 to August 2007. There were a total of 28 patients with persistent immobilizing pain caused by OVCFs. All patients had conventional radiographic imaging of the spine and CT scans of the spine. In 28 patients, 26 women and 2 men, kyphoplasty was indicated based up on the clinical and radiological findings. These included immobilizing back pain and maximal regional pain on pressure at the vertebral spine with correlating fresh vertebral fracture signs in the CT findings. The average age was 73 ± 9 years (between 55 and 89 years). All patients suffered from severe back pain. Ten patients had a recent known trauma. The others could not remember an instigating event. These patients had a history of slowly increasing back pain over a period of days to weeks. A CT scan of the thoraco-lumbar spinal column was performed in all patients. The fractures were

classified according to the AO classification [13]. The therapeutic plan was developed based upon the patient’s history, complaints, and the CT results. CT results, which are indicated for kyphoplasty are osteoporotic compression and sintering fractures. These are typically type A1.1 and 1.2 fractures with distinctive height loss or kyphotic deformity. Incomplete burst fractures with or without split component, type A3.1 and A3.2 fractures, can be indicated for kyphoplasty as long as the posterior alignment of the vertebral body is correct and a sufficient stability is warranted. In all 28 patients, a kyphoplasty was indicated for at least one vertebral body because of OVCF. An MRI, including STIR sequences, was done within 48 hours of admission in each patient. The decision to do kyphoplasty was then re-evaluated based on the results of the MRI and the clinical re-examination. The indication for performing kyphoplasty was the combination of adequate clinical signs of fracture and vertebral body edema in the STIR sequences plus one of the following: either retrospectively detected suspicion of a compression fracture in the region of interest noted on the CT scan, or vertebral edema which does not extend to the vertebral endplate of the same intervertebral disc as the adjacent vertebral body. In contrast to that, degenerative end plate changes are characterized by parallel signal alteration of the vertebral endplates associated with evidence of disc degeneration. The best diagnostic clue of disc degeneration is decreased signal of intervertebral disc on T2WI, loss of disc space height and vacuum phenomenon.

Contraindications were the lack of clinical fracture signs or coincident pathologies which had to be treated primarily. Patients who revealed only degenerative end plate changes and disc degeneration were also excluded.

Postoperative care

A postoperative CT scan was done the first postoperative day to evaluate the morphology of the treated vertebral bodies and the position of the bone cement. The patients were mobilized by a physical therapist, beginning the first postoperative day. All participated in our physiotherapy program to increase muscle strength, to improve coordination of the paravertebral muscles and were instructed in the proper body mechanics. Pain medication was adjusted to the individual need. All patients were followed up in the ambulatory clinic and standard radiographs were taken at 6 weeks, 6 and 12 months. A follow-up CT scan was performed at 3 months. Clinical symptoms were evaluated using the Odom score [16] for the clinical examination at discharge and at the 3-month follow-up examination. The postoperative pain relieve was analyzed using the visual analog scale (VAS) preoperative and at discharge.

Table 1 The initial CT findings, the additional information gained by MRI, and the final therapeutic strategy of all 28 patients are listed

Patients	CT: acute fracture levels	MRI: additional findings	Kyphoplastic procedures (levels)
1	T10	None	1 (T10)
2	T10	Vertebral body edema: T11/L4	3 (T10/11/L4)
3	T9/12	Vertebral body edema: T10	3 (T9/10/12)
4	L1	None	1 (L1)
5	L1	Kidney-CA, Meningeoma: L4	None
6	L1	Vertebral body edema: L2	2 (L1/L2)
7	L1	None	1 (L1)
8	T11/L4	No vertebral body edema: L4	1 (T11)
9	T11/L1	No vertebral body edema: L1	1 (T11)
10	T11/L4	Edema: T12, no edema: T11	2 (T12/L4)
11	L1	No vertebral body edema: L1	None
12	L4	Vertebral body edema: L3/5	3 (L3,4,5)
13	L2/3	Vertebral body edema: T12/L1	4 (T12/L1/2/3)
14	L4	Vertebral body edema: L3/5	3 (L3/4/5)
15	L1	None	1 (L1)
16	L1	None	1 (L1)
17	T11	None	1 (T11)
18	L2	None	1 (L2)
19	T8	None	1 (T8)
20	L4	None	1 (L4)
21	T7	None	1 (T7)
22	T11/12	None	2 (T11/12)
23	L1	None	1 (L1)
24	L2/3/4	No vertebral body edema: L2	2 (L3/4)
25	L1	Signs of vertebral metastasis: L1	None
26	T12/L2	Kidney-CA	None
27	T12	Vertebral body edema: L1/2	3 (T12/L1/2)
28	L1/3	Aortic Aneurysma	None

Results

Table 1 lists all patients, their acute fracture levels detected by CT with adequate clinical symptoms at the region of interest, the corresponding additional MRI findings, and their number of treated vertebral bodies. A total of 38 OVCFs (vertebral bodies Th7 to L4) were detected by the CT scans. Thirty-five fractures were classified as acute OVCFs by our radiologists, three as old fractures, which were excluded. Therefore, 19 patients were considered for a single level and nine patients for a two or higher level kyphoplastic procedure.

Five of these 35 fresh OVCFs showed no vertebral body edema in the STIR sequences of the following MRI. These were reclassified as old fractures. No kyphoplastic procedure was performed at these levels.

In contrast 14 additional vertebral bodies showed fresh fracture signs in the MRI scan. These vertebral bodies were located at the adjacent level(s) of the OVCFs classified by

the CT. Therefore, a total of 14 additional kyphoplastic procedures were performed (Fig. 1).

Additionally the MRI scan has shown coincidental pathological findings in four patients. A strong suspicion of a malignancy was present at three patients. All of them were immediately moved to a specialized hospital without performing a kyphoplasty. The MRI scan showed early stage malignant kidney carcinomas in two patients (Fig. 2). One patient's vertebral body showed manifestations of metastasis in the MRI scan. A metastasized mamma-Ca was diagnosed in the following screening. An aneurysm of the aorta was visible in the fourth patient. The aneurysm had a diameter of 5.5 cm presenting an urgent indication for surgery. This patient was transferred immediately.

In five patients no kyphoplastic procedure was done at that time. Additional kyphoplastic procedures were performed in seven patients. Three patients received a reduced number of kyphoplastic procedures (Table 2).

Fig. 1 A 62-year-old woman who suffered from severe back pain after a fall on her back. The STIR sequences of the MRI **a** showed a high signal intensity suggestive of edema L4 and Th 12, whereas L1 showed no edema. The CT scan **b** showed impression fractures L1 and L4. Therefore, kyphoplasty of Th 12 and L4 was performed

Fig. 2 A 69-year-old woman who complained of immobilizing pain in her lower back which started 2 days ago. The CT scan showed Th12 and L2 OVCFs. In the following MRI scan this suspicious area in her left kidney was detected turning out to be a renal cell carcinoma

In total of 16 patients (57%) the therapeutic plan was changed by the additional information we gained from the MRI.

All patients had a pain relief after kyphoplasty. The individual pain measured by VAS improved from preoperative $7.4 (\pm 0.9)$ to $3.7 (\pm 1.2)$ at discharge. At discharge

Table 2 Number and type of changes of the treatment strategy after MRI

Changed therapeutic strategy after MRI	Number of patients (%)
No change	12 (43)
Increased level kyphoplasty	7 (25)
Reduced level kyphoplasty	4 (11)
Same number but different levels	1 (4)
No kyphoplasty (no acute fracture)	1 (4)
No kyphoplasty (Coincident pathology)	4 (14)

on an average at the fifth postoperative day, all patients were mobile and had no leucocytosis or signs of inflammation. The Odom scores at discharge were good in 17 and fair in six cases. All wounds were healing appropriately. There have been no patients with signs of subsequent vertebral fractures at the clinical and radiological follow-up after 3 months. At the clinical control examination 3 months after kyphoplasty the Odom scores were very good in two patients, good in 17 patients and fair in four patients.

Discussion

Balloon kyphoplasty evolved from the technique of vertebroplasty, which represents the percutaneous injection of PMMA bone cement into a damaged vertebral body. Galibert et al. [5] first used this method to treat vertebral angioma. Soon as the pain relieving potential of this technique was detected it was applied to the treatment of OVCFs [6]. However, cement leakage is of some concern and therefore balloon kyphoplasty is a relatively new technique designed to overcome the risks and potential complications of cement leakage [7, 11]. Despite these technical differences of vertebroplasty and kyphoplasty, the indications for performing these procedures in cases of OVCFs without a burst and/or split components are the same. In this respect the benefits of preoperative MRI examinations for improving the indications of kyphoplasty, discussed later, can be equally applied to vertebroplasty.

Today the indications for performing kyphoplastic procedures are insufficiency fractures of the thoracolumbar vertebral in the elderly [1]. Studies have indicated that balloon kyphoplasty successfully improves pain in 95% of cases [7, 9, 17] and substantially restores quality of life [11, 14]. Primary osteoporosis is the main cause of vertebral fractures (85%). Kanis et al. [8] has shown that approximately 25% of women older than 70 years have at least one OVCF and more than 50% of women older than 80 suffer from these. Silverman et al. [21] demonstrated that the presence of one vertebral fracture increases the risk of

additional OVCFs in the following 5 years by 500%. This is caused by structural deformations of the affected vertebral body resulting in an increased risk of subsequent vertebral body fractures. A poor bone quality in combination with a history of vertebral fractures leads to a tremendous risk of developing multiple level lesions. Lindsay et al. [12] discovered that 74-year-old women had a cumulative incidence of additional vertebral fractures of 6,6% in the first year after suffering from an OVCF. After an incident vertebral fracture the incidence of a new vertebral fracture has been 19% in the subsequent year.

Fribourg et al. [3] reported of subsequent vertebral fractures in 21% of the patients within the first 2 months after performing a kyphoplasty. Vertebral fractures that occurred later were significantly less likely at adjacent vertebral levels. These findings may suggest that the adjacent level may remodel over time to support the additional stress from the kyphoplastic procedure. On the other hand these subsequent vertebral fractures may be the consequence of already existing micro-fractures in the adjacent vertebral bodies. These may become relevant after the kyphoplastic procedure is performed as a result of an increased pressure load on the subsequent vertebral bodies. These micro-fractures are primarily not visible in the CT scans.

In contrast MRI examinations especially when combined with STIR sequences are very sensitive in detecting vertebral edema due to fresh fractures or micro-fractures. By detecting additional OVCFs and performing multiple level kyphoplasty right in the first place in case of signs of clinical fracture at these levels, one may reduce the number of subsequent kyphoplastic procedures. On the one hand MRI might be oversensitive leading to over-treatment of vertebral bodies with edema due to bone bruise instead of vertebral body fractures. Interestingly, 8 of our 28 patients (29%) had vertebral body edema at additional levels leading to additional kyphoplastic procedures. But none of our patients had signs of subsequent fractures at the follow-up 3 months after performing kyphoplasty. These numbers correspond quite well to the 21% of subsequent vertebral fractures Fribourg has seen 2 months after kyphoplasty [3].

On the other hand vertebral edema can go along with degenerative diseases imitating OVCFs. The MRI findings of these degenerative diseases go along with adjacent vertebral body edema extending to the same intervertebral disc. Therefore, the morphology of edema at the MRI finding, the clinical suspicion of vertebral fractures, and the patient's history are of crucial significance to minimize an over-treatment.

Prior to a kyphoplasty, preoperative MRI examination is mainly postulated in literature. The correct patient selection can be improved by identifying vertebral body edema [12]. Basic requirements MRI revealed itself to be

equivalent to bone scan imaging in selecting patients to be treated by kyphoplasty. MRI was superior to bone scintigraphy in detecting vertebral collapses due to multiple myelosis [14].

In addition the percentage of coincidental pathologic findings has been exceptional high, affecting four patients (14%). Especially the prevalence of malignant diseases, three cases (11%), exceeds clearly the expected values. The highest prevalence of cancer is in North America with 1.5% of the population affected [18]. Kidney carcinomas are rare and make up 1–2% of all cancer diseases [15]. A 7% prevalence of kidney carcinoma in our study population exceeds the expected values even further. This can be incidentally. By looking at our study population more precisely this is caused partly by the patient selection. Patients suffering from OVCFs are mainly older women who have serious co morbidities, increasing their risk of additional malignant diseases. This comes especially true when the assumed OVCF is in effect caused by metastasis.

We performed this prospective study to determine the value of a preoperative MRI scan in addition to a CT scan concerning additional extra available information that changed our therapy plans. Thereby we have to keep in mind the high costs and the tremendous effort that goes along with such an examination. In this regard you have to keep in mind the percentage of changed therapeutic proceeding because of the information obtained by MRI. The therapeutic plan was changed in 57% of the patients. Even though the study group consists only of 28 patients, the results of the study point out that a MRI examination prior to kyphoplasty is absolutely necessary. The patient's benefits of this additional diagnostic technique outweigh the costs and efforts tremendously, by recognizing additional vertebral lesions, concomitant diseases and by avoiding unnecessary kyphoplastic procedures.

Conclusions

This study confirms the diagnostic benefits of an MRI scan before performing a kyphoplasty. For 16 out of 28 patients, the therapeutic plan was changed because of the information obtained by preoperative MRI. Preoperative MRI adds value to the diagnosis and can aid in diagnosis and identification of old or additional lesions.

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