Although new spinal compression fractures are believed to be mostly caused by the natural course of osteoporosis (15), PV itself may be the cause (16). In particular, involvement of PV is suspected in new compression fractures occurring in the vertebrae adjacent to treated vertebrae soon after therapy (17). To lower the risk of new compression fractures, we performed PV for painful fractured vertebrae and then prophylactically injected bone cement into adjacent vertebrae at risk for fracture. Although accurate prediction is difficult, new vertebral fractures often occur on the adjacent vertebra in nearly half of the cases (18,19). We hypothesize that the risk of recurrence might be lowered by performing prophylactic PV to the adjacent vertebra.

The objective of the present study was to confirm whether non-fractured adjacent vertebrae should be treated as a prophylactic measure during the first PV treatment for painful osteoporotic compression fractures.

MATERIALS AND METHODS

Subjects

The present study was approved by the institutional review board. A written informed consent was obtained from all patients after thorough explanation of the procedure, including prophylactic treatment on non-fractured vertebral body adjacent to the fractured vertebra. Patients in Group 1, who were treated between February 2002 and August 2004, consisted of 89 patients with osteoporotic spinal compression fractures (78 women, 11 men; mean age 70.2 years; range 38–98 years). During this period, conventional PV was performed to treat pain-causing vertebrae based on magnetic resonance imaging (MRI) and computed tomography (CT). These 89 patients underwent 89 sessions to treat 143 spinal compression fractures. Mean number of treated vertebrae per surgery was 1.6 (range 1–5).

Patients in Group 2, between September 2004 and October 2006, consisted of 155 patients who had treatment of the pain-causing vertebrae and also of the adjacent vertebrae at risk for secondary fractures. In Group 2, the majority of prophylactically treated vertebrae were located between Th10 and L2. These 155 patients underwent 155 sessions to treat 264 spinal compression fractures and to perform prophylactic cement injection into 198 non-fractured vertebrae. Mean number of treated fractured vertebrae per surgery was 1.7 (range 1–5), and mean number of treated vertebrae including prophylactic non-fractured vertebrae was 2.9 (range 2–6). All subjects in the present study had osteoporosis, including steroid-induced osteoporosis. The group without prophylactic therapy (Group 1) and the group with prophylactic therapy (Group 2) were compared to ascertain whether prophylactic therapy could reduce the risk of new fractures based on statistical analysis of recurrence rates.

PV Procedures

PV was performed under local anesthesia in all patients. As a general rule, 11-gauge Osteosite bone biopsy needles (Cook, Bloomington, IN) were used. When treating vertebrae with small pedicles or crushed and flattened vertebrae, 13-gauge needles were used in some cases. As to stylets (internal needles), diamond-cut stylets were predominantly used, and when minor adjustments were needed in the direction of puncture, bevel-cut stylets were used. As a general rule, PV was performed using two needles placed through the left and right pedicles to achieve adequate cement filling in the vertebra. As bone cement, a liquid monomer (17 mL) and 30 g of polymethylmethacrylate powder (Cranioplastic kit; Codman, Raynham, MA) were mixed. To ensure radiopacity, sterile powdered barium (9 g, Neobargin HD; Kyosei Pharmaceutical, Otaru, Japan) was included (30% weight/volume). The cement was manually injected with 1-mL syringes under biplane fluoroscopic observation. However, the Osteoject bone cement delivery system (Integra, Plainsboro, NJ) was also used in some patients.

Cement injection was performed under the guidance of biplane x-ray fluoroscopy, and blood pressure, electrocardiogram, and arterial oxygen saturation were monitored during surgery.

Analysis

Preoperative imaging assessment consisted of plain thoracolumbar imaging, MRI (T1-weighted, fat-suppressed, T2-weighted and gadolinium-enhanced imaging) and 16-slice CT (3-mm reconstructed axial, sagittal, and coronal scans). Immediately after surgery, plain radiography was performed to confirm cement distribution. Subsequent observations mostly comprised clinical symptom analysis and plain radiography during periodic outpatient visits.

When clinical symptoms suggested a new fracture, MRI and CT were performed in all cases. Follow-up visits were made at 1 day and at 1, 3, 6, and 12 months after surgery. Thereafter, patients were followed by telephone interviews. If recurrence was suspected, plain radi-

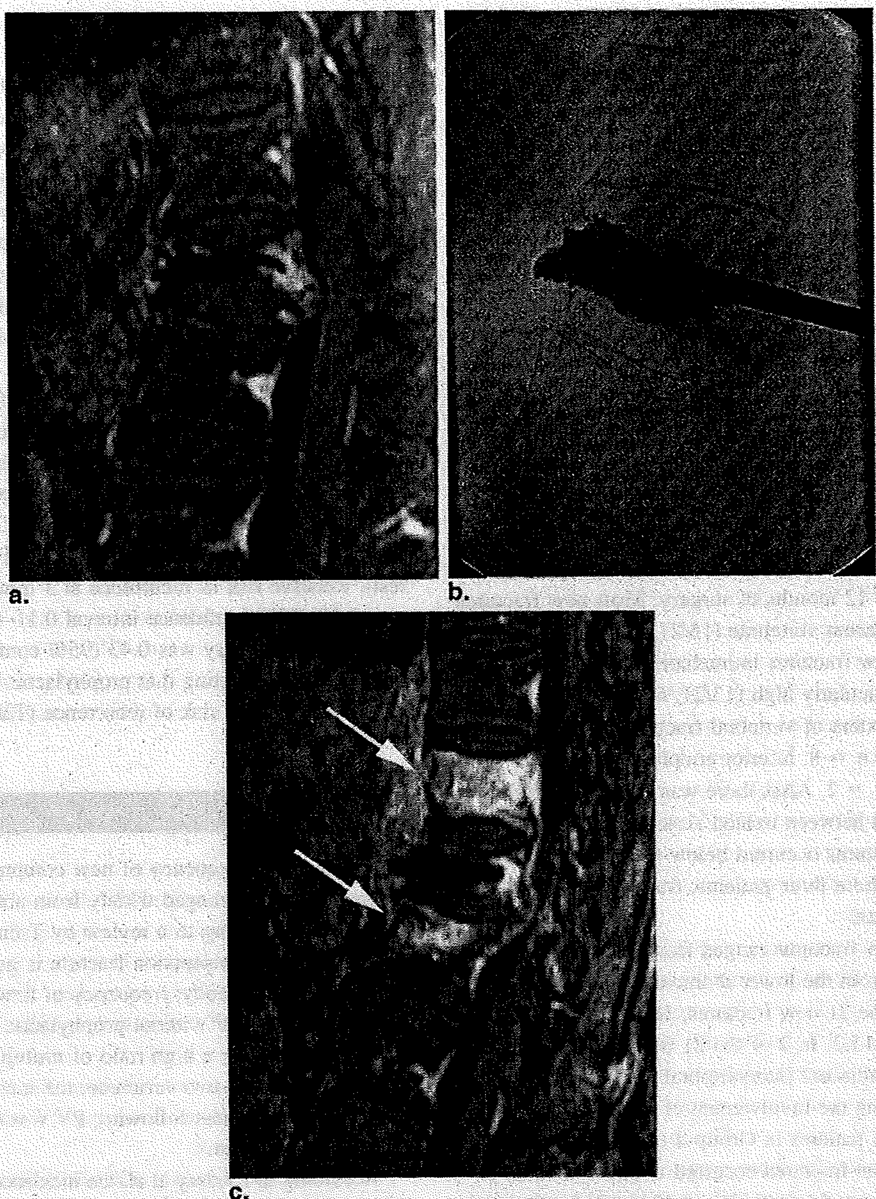

Figure 1. **(a)** Fat-suppressed contrast-enhanced T1-weighted sagittal image of a 78-year-old woman with osteoporotic compression fracture of the Th12 vertebra. **(b)** Cement was injected into the fractured vertebra. Fat-suppressed contrast-enhanced T1-weighted sagittal image. **(c)** Three weeks after percutaneous vertebroplasty, a new fracture developed in Th11 and L1 vertebrae. Bone marrow edema is seen throughout the entire vertebral body of Th11 and in the superior end-plate of L1 (*white arrows*).

ography, MRI, and CT were performed. When disagreement existed in imaging assessment between surgeons and radiologists interpreting scans, a conference was held to reevaluate the scans.

Between groups with and without prophylactic therapy, the frequency of new postoperative compression fracture was compared, and statistical analysis (Fisher's exact test) was performed by a third party. As for a primary end point, the presence or absence of new fracture was determined at 3 and 12 months after surgery. As for a secondary end point, the location of new fractures in relation to treated vertebrae, presence or absence of bone cement leakage into adjacent intervertebral disc spaces, and the frequency of compression fracture in adjacent vertebrae among patients with bone cement leakage into the intervertebral disc space were assessed.

RESULTS

In both Groups 1 and 2, no intraoperative complications were seen besides bone cement leakage into the intervertebral disc space in a limited number of patients.

Of the 89 patients in Group 1, new compression fractures occurred within 3 months of surgery in 15 patients (16.8%), and 21 new fractures occurred in 20 patients (22.4%) within 12 months of surgery. Most new fractures occurred in adjacent vertebrae (16/21, 76.1%) (Fig 1). The ratio of new fractures immediately above treated vertebrae was particularly high (13/21, 61.9%). For the 13 fractures, the extent of vertebral fracture was as follows: entire vertebra, $n = 8$; inferior endplate, $n = 3$; and superior endplate, $n = 2$. Also, there was one new vertebral fracture located between treated vertebrae. In three patients, new fractures occurred below treated vertebrae; and in two of these three patients, fracture occurred in the superior endplate.

Level of new fractures ranged from Th7 to L4, mostly concentrating from the lower thoracic to upper lumbar vertebrae. Of the 21 new fractures, 16 fractures were between Th11 and L2. In 2 of the 21 new fractures, cement leakage to the adjacent intervertebral disc space was noted, suggesting the involvement of cement leakage. Among the 155 patients in Group 2 (as seen in Fig 2), new compression fractures occurred within 3 months of surgery in seven patients (4.5%). Within 12 months of surgery, 17 new fractures occurred in 15 patients (9.7%). New fractures occurred between Th8 and L5.

Of the 17 fractures in the 15 patients, six fractures (35.3%) occurred immediately above treated vertebrae, and six more fractures occurred immediately below the treated vertebrae. Among the six vertebral fractures above the treated vertebrae, the extent of fracture was as follows: entire vertebra, $n = 2$; inferior endplate, $n = 2$; and superior endplate, $n = 2$. Among the six vertebral fractures below the treated vertebrae, the extent of fracture was as follows: entire vertebra, $n = 4$; and superior endplate, $n = 2$.

Including one vertebra sandwiched by treated vertebrae, 13 fractures occurred in adjacent vertebrae, but two fractures occurred in non-adjacent vertebrae (both Th8). Also, among non-fractured vertebrae treated by prophylactic cement injection, new painful fractures occurred in the superior endplate just above the injected cement within the same vertebra in two cases. In 2 of the 17 new fractures, cement leakage into the adjacent intervertebral disc space was seen, suggesting the involvement of cement leakage.

Statistical analysis showed that risk of recurrence was significantly lower for the group with prophylactic therapy than for the group without prophylactic therapy. A significant difference in rate of recurrence was seen at 3 months after surgery ($P = .0020$, Fisher's exact test) and at 12 months after surgery ($P = .0079$, Fisher's exact test). Relative risk of recurrence at 3 months after surgery was 0.27 (95% confidence interval 0.11–0.63) and at 12 months after surgery was 0.43 (95% confidence interval 0.23–0.80), suggesting that prophylactic therapy significantly lowered the risk of recurrence (Table 1).

DISCUSSION

The reported frequency of new compression fractures following PV has ranged widely from about 10% to 50% (7,12), but according to a review by Trout et al, the frequency of new compression fracture is generally 20% to 25% (16). In our study, frequency of new fracture within 12 months after PV without prophylactic therapy was 22.4%, and despite a high ratio of multiple fractures involving more than two vertebrae, the incidence of new compression fractures following PV was comparable to the previous studies.

According to Lindsay et al, the incidence of another new compression fracture within 12 months of the initial fracture was 19.2% among patients with a history of spinal compression fracture and 24% among patients with a history involving more than two vertebrae (15). Syed et al. deduced that new compression fracture following PV is part of the natural course of osteoporosis (12). In a review of 432 PV cases, Trout et al (17) reported that new compression fractures occurred in adjacent vertebrae after PV in 41.4% of cases. They suggested that a new compression fracture occurring soon after surgery in the vertebra adjacent to the treated one is likely due to PV itself (17).

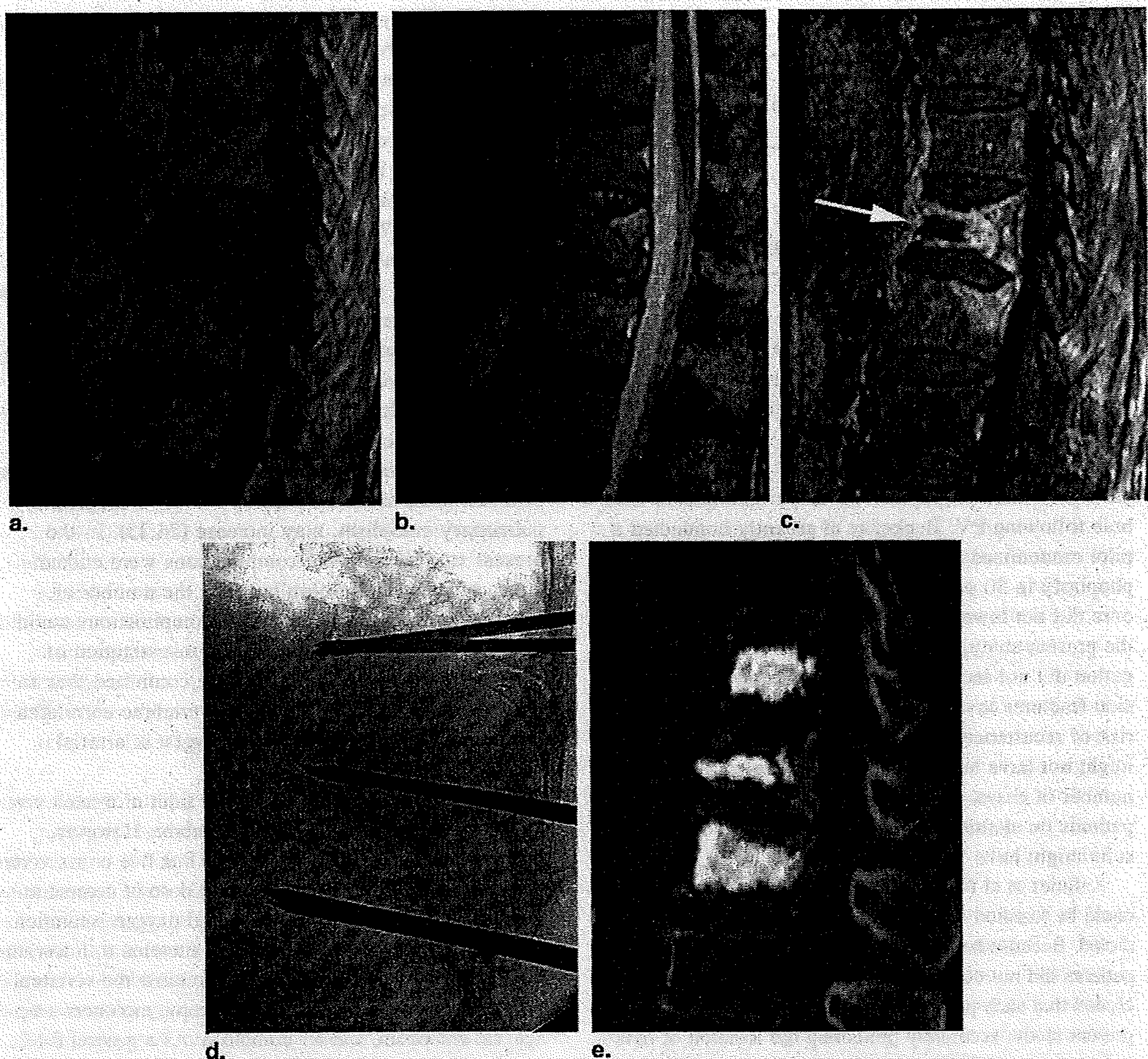

Figure 2. **(a)** T1-weighted, **(b)** fat-suppressed T2-weighted, and **(c)** fat-suppressed contrast-enhanced T1-weighted sagittal images of a 79-year-old man with osteoporotic compression fractures of L1 and L2 vertebrae. There is an unenhanced portion in L1 vertebral body indicating a cleft (*white arrow*). **(d)** Lateral fluoroscopic image showing 11-gauge needles inserted into the fractured vertebrae (L1, L2) and into a non-fractured vertebra (Th12) as prophylactic treatment. **(e)** Sagittal reconstructed computed tomography showing cement in the fractured vertebrae (L1, L2) and in the upper adjacent non-fractured vertebra (Th12).

In the present study, the group of patients without prophylactic treatment had new compression fractures occur in adjacent vertebrae in 16 of 21 (76.1%) fractures and 15 of the 20 patients (75.0%) with new fractures had the new fractures occur within three months of surgery. Because these fractures frequently occurred adjacent to the treated vertebrae, involvement of PV is suggested. Vertebral compression fractures tend to occur in the superior endplate. According to Baroud et al and other authors, analysis of new compression fractures often shows fractures above the treated vertebrae, and the incidence of fractures in the inferior endplate of the upper vertebrae is relatively high (18,19). In the present study, new compression fractures after PV often occurred in the upper adjacent vertebrae and, in such cases, fractures most often affected the entire vertebra or mostly the inferior end-

Table 1
Statistical Analysis (Fisher's exact test)

	New Fracture Within 3 Months (n = 244)	New Fracture Within a Year (n = 244)
Non-prophylactic group	15/89 (16.8%)	20/89 (22.4%)
Prophylactic group	7/155 (4.5%)	15/155 (9.7%)
P value	.0020	.0079
Relative risk	0.27 (0.11–0.63)	0.43 (0.23–0.80)

plate. Conversely, new fractures in the lower adjacent vertebrae often affected the superior endplate. This agrees with normal fracture patterns, and the effects of PV are unclear.

To the best of our knowledge, no previous authors have performed prophylactic therapy on adjacent vertebrae following PV. Becker et al recently conducted a pilot randomized controlled trial for prophylactic kyphoplasty in 50 patients and concluded that the procedure did not lower the risk of recurrence (20). Unlike the present study, because Becker et al's (20) investigation did not include patients with multiple compression fractures involving more than two vertebrae, the risk of recurrence was low and significant differences might not have been identified because of the low number of cases. If patients with multiple fractures or patients on steroid therapy had been included, the results might have been different.

Kallmes et al (4) mentioned that prophylactic therapy could be justified if the vertebrae at risk could be predicted. Because half of the secondary fractures in their patients did not occur in adjacent vertebrae, they concluded that such prediction was difficult (4). In the present study, accurately predicting the location of new fractures was difficult even when retrospectively analyzing preoperative MRI and CT. However, because the intervertebral disc adjacent to the superior endplate of a fractured vertebra is often degenerated from a decreased buffer action of the cartilaginous component, the risk of new fracture in an upper adjacent vertebra will be increased (21–23). For this reason, the prophylactic cement injection into the vertebra immediately above the fractured vertebra may be justified.

As shown in the Results section, the prophylactic therapy on the upper adjacent vertebrae of fractured vertebrae significantly lowered the frequency of subsequent compression fractures in our patients. The incidence of new fractures in lower adjacent vertebrae was relatively low; therefore, prophylactic therapy for these vertebrae may be unnecessary. However, prophylactic therapy for lower adjacent vertebra may be justified if the disc space immediately below the fractured vertebra is narrowed and the two vertebrae are closely related.

In Japan, PV is not covered by insurance and, as a general rule, patients pay 100% of the medical costs for the treatment. PV is thus an expensive treatment, and additional treatments incur substantial financial burdens for aged patients. If prophylactic therapy lowers the incidence of additional therapy, and if PV becomes covered by insurance in the future, the burden on the insurance system may also be lowered.

Adverse effects are the major concern when we perform multiple-level PV including prophylactic treatment. If the number of treated vertebrae increases, risk of latent complications, such as cement leakage and pulmonary embolism, may increase (24,25). In the present study, no severe complications were encountered, and the relationship between the number of treated vertebrae and the risk for complications could not be clarified; however, our past investigation of changes in alveolar partial pressure confirmed that an increase in the number of treated vertebrae correlated to decreased partial pressure of oxygen in arterial blood (26).

At present, we have set the upper limit of treated vertebrae per single session at four vertebrae. However, based on our experience, we believe that five or six vertebrae can be safely treated if the total dose of cement injection is less than 30 mL and arterial oxygen saturation is carefully monitored. We also pay attention to lowering such risks as minor cement leakage outside the vertebral body that cannot be seen by fluoroscopy, monomer seepage, fat embolism, and air embolism. As a general rule, we routinely use a two-needle technique even in prophylactic therapy for a non-fractured vertebra. While injecting cement from one side, the contralateral needle stylet is removed to lessen excessive increases in vertebral pressure during cement injection, thus preventing intravenous seepage of cement and vertebral fat tissue or cement leakage into the intervertebral disc space. We also try to reduce the risk of cement leakage by performing preoperative three-dimensional CT multiplanar reconstruction to thoroughly examine ruptured cortical bone and vertebral morphology.

In the event of bone cement leakage into the intervertebral disc space, the intervertebral disc may be in a pathologic state, and this may be one of the rationales for prophylactic therapy of adjacent vertebrae. Prophylactic therapy may also be justified if preoperative diagnostic imaging shows ruptured cortical bone, leading to a high risk of bone cement leakage into the intervertebral disc space (27). Because the number of patients with intervertebral disc leakage was low in our study, we could not investigate the relationships between intervertebral leakage and secondary fracture.

One study reported that PV using a small amount of cement did not induce secondary fracture (28,29), but in some of our patients, use of a small amount of cement caused painful fracture above the site of cement injection within the same vertebra or new fracture between uneven left and right cement masses. Therefore, as mentioned previously, we use two needles to treat a fractured vertebra and perform prophylactic therapy while paying attention to evenly distributing cement inside the vertebra.

As for study limitations, the present study was not a prospective randomized trial. The group without prophylactic therapy was studied first, followed by the group with prophylactic therapy. Given this historical cohort design, improved proficiency and skills could have influenced assessments. Also, the number of treated vertebrae ranged greatly from one to six vertebrae. Furthermore, because risk of recurrence is particularly high for patients on long-term steroid therapy (30–32), exclusion of such patients might have made the patient groups more homogeneous. In the future, randomized control trials investigating the usefulness of PV and the efficacy of prophylactic therapy are needed.

CONCLUSION

Prophylactic cement injection into non-fractured vertebrae adjacent to fractured vertebrae may prevent new compression fractures after vertebroplasty of osteoporotic patients.

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整形外科領域のIVR

■2. 椎体腫瘍に対する経皮的椎体形成術

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Abstract

Percutaneous Vertebroplasty for Painful Spinal Tumors

Percutaneous vertebroplasty is a minimally invasive, therapeutic procedure for painful spinal tumors. This technique involves percutaneous injection of bone cement, most commonly polymethylmethacrylate (PMMA), into affected vertebral bodies under radiological guidance from CT scanning or fluoroscopy and provides marked and rapid pain relief in a high percentage of patients with vertebral column neoplasms. While the overall risk is relatively low, potential complications include damage to nerve roots or the spinal cord, with radiculopathy or paralysis, leakage of material into the epidural or paravertebral spaces and passage of material into the venous system with embolization to the pulmonary vasculature. Appropriate patient selection for percutaneous vertebroplasty and continuous monitoring of blood pressure and oxygen saturation during this procedure are essential for effectiveness and safety. We described the practical aspects of percutaneous vertebroplasty for spinal tumors, such as its indications, techniques, especially under CT-fluoroscopic guidance, and effects.

はじめに

脊椎は転移性骨腫瘍の好発部位として知られている。これは骨を脆弱化し，しばしば病的骨折を引き起こす。特に荷重の影響を受けやすい胸腰椎では骨性疼痛が強く体動時の痛みは激烈である。こうした疼痛は麻薬性鎮痛薬を用いても十分な除痛が得られないことも多く，患者の日常生活を制限する原因となっている。したがって，このような腫瘍に起因する骨性疼痛を軽減することは，進行癌患者のQOLを向上する上で極めて重要な課題といえる。

経皮的椎体形成術 (percutaneous vertebroplasty：PVP) はこうした患者に対する非常に有効な治療オプションの一つといえるが，その施行にあたっては適応を十分に吟味し適切な治療対象を選択することも重要である。

本総説では，椎体腫瘍に対する経皮的椎体形成術の適応，手技，臨床成績などについて概説するとともに，椎体腫瘍の治療における本治療法の位置付けを明らかにするため，椎体腫瘍に対する外科的治療戦略についても簡単に述べる。

Key words
- Percutaneous vertebroplasty (PVP)
- Spinal tumor
- CT fluoroscopic guidance
- Pain relief

経皮的椎体形成術の歴史

経皮的椎体形成術は，1984年にフランスで最初に臨床応用された[1]。これは血管腫に対して施行されたものであるが，以後，転移性骨腫瘍をはじめとする有痛性悪性腫瘍にも応用されるようになり，1990年代になって欧米を中心に普及した。本邦でも1997年に馬場ら[2]により，肺癌の腰椎転移に対する治療が初めて報告された。金沢大学医学部附属病院でも1997年より本治療の臨床応用を開始し，CT透視を利用した方法を積極的に行い，その優れた除痛効果を確認している[3]。

椎体腫瘍に対する経皮的椎体形成術の除痛機序

本治療法の除痛機序については，骨セメントの注入により骨の安定性が増強することがあげられる[4]が，骨セメントの注入量と除痛効果には相関がないことも報告されており[4,5]，単一の機序によるものではないと考えられている。骨セメントの重合熱や化学毒性による抗腫瘍効果や発痛物質の抑制効果などの可能性も示唆されているが明らかではない[6]。

なお，椎体形成術は骨性疼痛には有効だが，腫瘍が神経根や馬尾を直接圧迫することによって生じる神経障害性疼痛には無効である[7]ことは認識しておく必要がある。

椎体腫瘍に対する外科的治療戦略と成績

以前の椎体腫瘍に対する掻爬などの手術は不完全切除や局所再発の頻度が高かったが，脊椎全摘術では局所再発が少なく良好な結果が報告されている。金沢大学医学部附属病院整形外科では腫瘍脊椎骨全摘術(total en bloc spondylectomy：TES)を行っており，これは当院整形外科で開発された腫瘍脊椎骨全体を一塊で切除する画期的な方法[8]で非常に良好な治療成績をおさめている。

転移性椎体腫瘍に対して当院整形外科では予後のスコア化に基づいた外科戦略を策定しており，臨床的にも非常にわかりやすいガイドラインとなっている(Fig.1)。ECOG performance status testで3以下もしくはKarnofsky performance scaleで30％以上の患者を対象とし，スコア法は予後に最も影響を与えると考えられる3つの因子，すなわち(1)原発腫瘍の悪性度，(2)他臓器転移，(3)骨転移より構成され，2〜10点の予後スコアを求める。このスコアと予後に基づいて患者の治療目標を設定し，それに沿って腫瘍の広がりなどから最も適切かつ実効可能な手術法を選択している[8]。

予後スコアが2〜4点と低いものに対して行ったTESでは，2年生存率66.6％，5年生存率46.6％という非常に良好な結果が得られているほか[8]，TESを施行したもののうち95％では局所再発がみられず，再発したものでも再発までには平均22.1ヵ月を要している。術後の神経障害はほぼ皆無であり，術前に麻痺がみられた32例中23例で症状の改善を認めている。また，手術治療では骨性疼痛のみならず神経障害性疼痛も改善させることができる点も重要である。

椎体腫瘍に対する経皮的椎体形成術の現時点での適応

経皮的椎体形成術による抗腫瘍効果については不明確，不確実であり，腫瘍増大に伴う将来的な圧迫骨折や脊髄神経障害の可能性が懸念される。前項で述べたように椎体腫瘍に対する外科手術の成績は良好であるため，特に長期の生命予後が期待される症例では，まず外科治療について検討する必要がある。当院では前述の治療戦略に基づき，6ヵ月以上の生命予後が期待できる症例に対しては手術を積極的に行い，経皮的椎体形成術は中長期の予後が期待できず手術適応がない

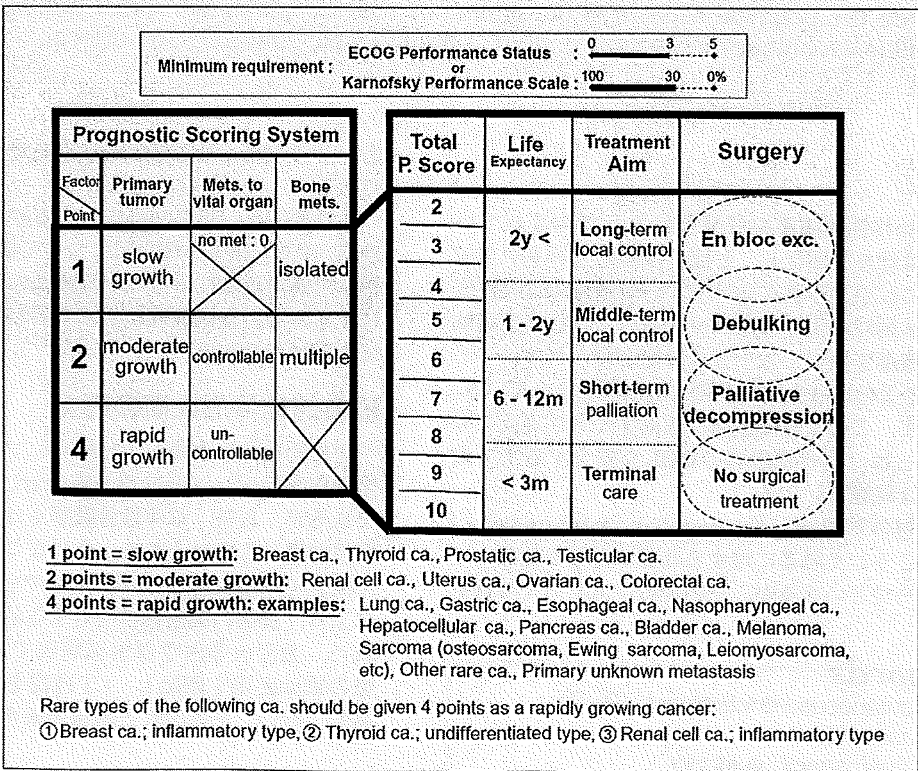


Fig.1 Surgical strategy for spinal metastases (used with permission from ref. 8.)

症例を対象とすることが多い[7]。ただし，予後のスコア化に基づく治療戦略はあくまでもガイドラインであり，最終的な治療法の決定には患者および家族の意志を尊重しているのはもちろんである。また，外科手術の適応については施設によって様々な方針があるので，当院の方針が全ての施設に当てはまるわけではない。

経皮的椎体形成術は，胸椎および腰椎の椎体腫瘍で腫瘍による骨脆弱性に起因する強い疼痛を有し，外科手術の適応がないものが対象となる（Table 1）。頚椎は技術的困難性・危険性などのため，一般的には対象としない。椎体腫瘍では骨性疼痛のほかに神経障害性疼痛を併発していることも多いが，こうした疼痛に対しては経皮的椎体形成術では効果が期待できない。したがって，術前にCT/MRIにより腫瘍と神経の関係を詳細に評価し，神経障害性疼痛を除外あるいは患者に説明しないと期待するような治療効果は得られない[9]。また，治療対象とするには，主要臓器の機能が保持されていること，ECOG performance status testで3以下，4週間以上の生存が見込めることも必要である。

Table 1　Indications for percutaneous vertebroplasty for vertebral tumor

適格条件

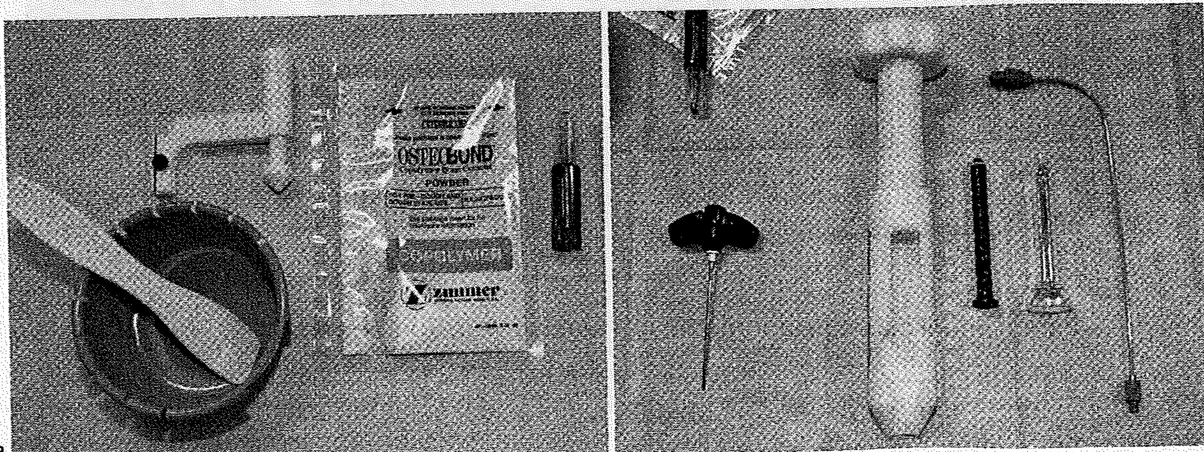
1 悪性腫瘍の転移や原発性腫瘍による胸椎，腰椎の病変である。
2 1による疼痛が強く，日常生活の行動に制限を生じている。
3 主要臓器（骨髄，心，肝，肺，腎など）の機能が保たれている。
4 Performance status (ECOG)：3以下。
5 4週間以上の生存が見込める。
6 年齢20歳以上である。

除外条件

1 補正しがたい出血傾向がある。
2 感染症を併発している。
3 薬物による維持療法が必要な心不全を伴っている。
4 骨病変に活動性炎症（結核性椎体炎，感染性椎体炎など）の疑いがある。
5 椎体後面の著しい破壊や脊髄の圧迫がみられる。（脊柱管の前後径が2/3以上に保たれ，脊髄と腫瘍の間に画像上脳脊髄液が介在する場合は可）
6 1回の治療で対象とする病変が4椎体以上存在する。
7 薬物あるいは理学的処置を施しても治療体位が保持できない。
8 高度な薬物アレルギー歴を有する。
9 妊娠もしくは妊娠している可能性がある。

補正しがたい出血傾向，感染症の併発，薬物による維持療法が必要な心不全を有する患者は，骨セメントの毒性や手技上の合併症予防の観点から適応外としている。骨病変に活動性炎症（結核性椎体炎，感染性椎体炎など）の疑いがある患者も適応外である。多椎体に腫瘍がある症例に遭遇することは多いが，1回の治療で対象とする病巣が4椎体以上ある場合も慎重を期す必要があり，我々の施設では1回に3椎体までとしている。椎体の扁平化が進んでいる場合には技術的に困難となるが，それのみでは適応外とはしていない。

腫瘍により椎体後面が破壊されている症例では脊柱管内へのセメント漏出による脊髄・馬尾神経障害の発生が危惧される。しかし，これまでの我々の経験では骨外へのセメント漏出は骨皮質破壊部からの直接漏出ではなく椎体静脈を介した漏出が多い[3]。椎体後面の軽度の破壊が直ちに脊柱管内へのセメント漏出に結びつくとは言えず，実際，多くの椎体後面破壊例で合併症なく経皮的椎体形成術が施行されてきた。脊柱管にセメントの漏れを許容できないような狭窄が存在するのかどうかという判断とセメントを漏出させない注入法および漏出時の早期検出が重要である。前者について今のところ確立した判断基準はないが，脊柱管の前後径が正常の2/3～3/4以上に保たれており，脊髄と腫瘍の間に画像上脳脊髄液の介在が確認できる場合は除外しなくてもよいだろうとされている。



a　b

Fig.2 Materials and devices for percutaneous vertebroplasty
a: Polymethylmethacrylate (PMMA) cement, bowl for preparation of bone cement, and I-I device for needle folder.
b: Needle for injection of bone cement, and OsteoJect bone cement delivery system.

手技とその注意点－CT透視を用いた方法

椎体腫瘍に対する経皮的椎体形成術の手技は，基本的には圧迫骨折に対するものと大きな相違はない。ここでは我々が実践してきたCT透視を用いた方法について簡単に述べる(Fig.2, 3)。

①輸液製剤で静脈路を確保し，心電図，自動血圧計，パルスオキシメータを装着する。罹患骨周囲の皮膚上にマーカーを貼付してCT撮影を行い，この画像をもとに穿刺部位と経路を決定する。穿刺経路は経椎弓根的アプローチを基本とする。CTの撮像断面は穿刺経路の断面と一致していることが望ましいので，事前に患者の体位やガントリー角度の調整（側面スカウト像などを参考に)を行うと良い。

②消毒，局所麻酔を行う。CT透視で針先を確認しながら穿刺部骨膜まで十分に麻酔する。穿刺時は，術者被曝軽減のため，I-IデバイスなどのCT透視用穿刺針保持器具を用いて針を保持し，CT透視はquick-

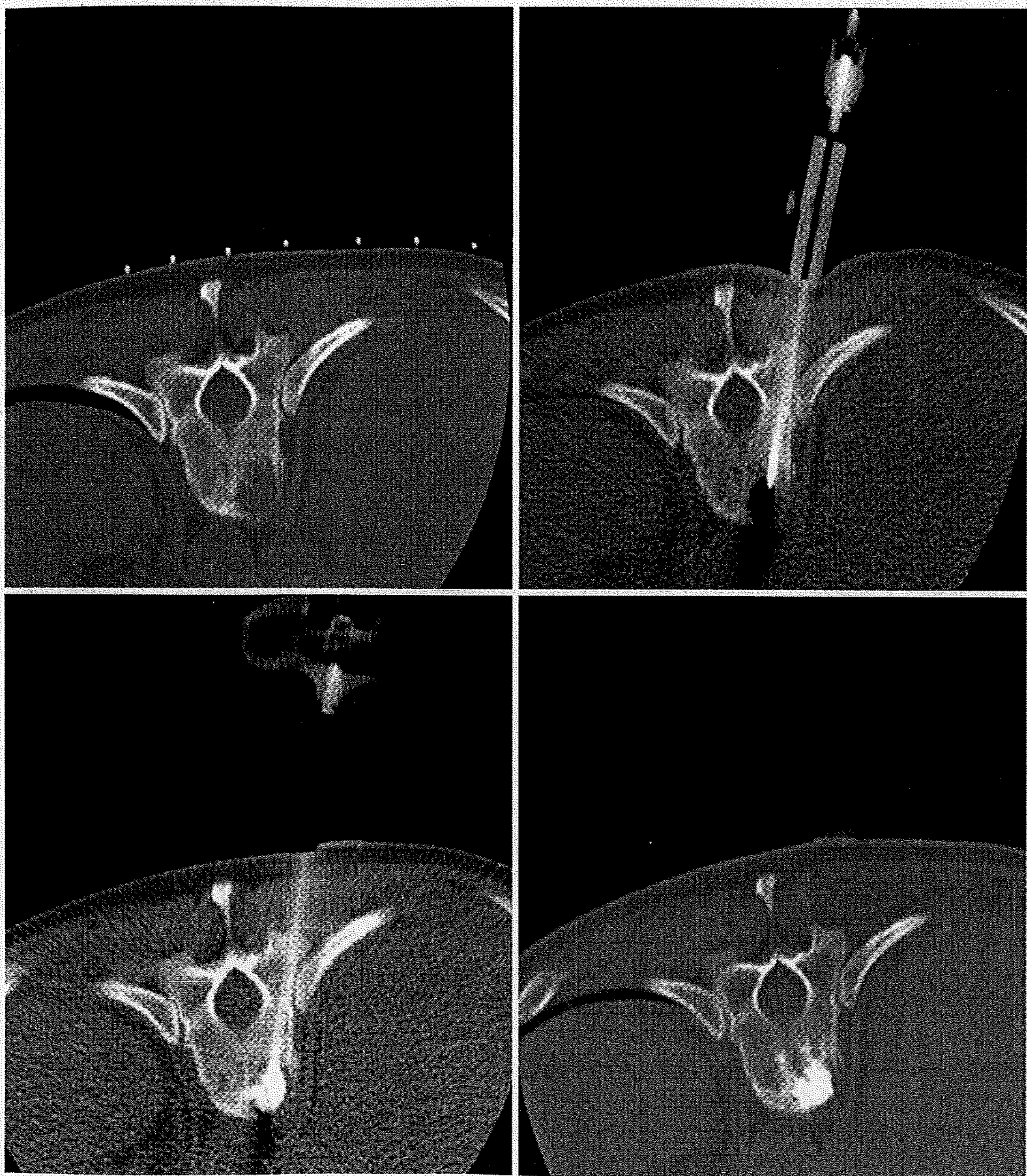


Fig.3 The technique of percutaneous vertebroplasty under CT-fluoroscopic guidance
a : The CT image of the affected vertebra putting CT marker on patient's skin.
b : The injection needle was placed in the vertebral body via its pedicle.
c : Bone cement was manually injected into the affected vertebral body under CT-fluoroscopic observation.
d : The CT image after bone cement injection.

a	b
c	d

check法を用いる。CT画像のみに頼らず，患者に違和感や電撃痛などがないか常に確認しながら行うことも大切である。穿刺部皮膚はメスで小切開し，小型ペアンで鈍的に剥離する。

③I-Iデバイスでセメント注入針を保持し，CT透視下(quick-check法)に経路に沿って進める。我々は13G OsteoSite針(Cook社製)を用い，用手的に刺入している。骨内に針が進んでからでは穿刺方向の変更は困難であるため，骨皮質に針先を十分に固定したところで経路を最終確認する。椎弓根に針を進めていくときは患者に電撃痛がないか常に確認しながら行い，電撃痛を訴える場合にはCT透視画面では問題なく見えても針が椎弓根をはずれている可能性が高いので，針を抜いて穿刺経路や断面を変更して手技を繰り返す。針が椎弓根を過ぎた後は，基本的には椎体の前方1/3～1/4の部位まで注入針を進める。腫瘍の部位や大きさによって針先の位置は変わってくるが，針先が椎体後方にあると骨セメントが脊柱管に漏出しやすいので注意する必要がある。我々の施設では椎体造影は原則として行っていない。

④骨セメントの調製を行う。我々はアクリル性骨セメント製剤であるOsteobond (Zimmer社製) を使用している。粉末のポリマーと液体のモノマーを混ぜ合わせると1～2分間程度で用手注入可能な硬度となり，数分間は注入可能な硬度を保つ。硬化時間は温度に影響されるため，氷水などで冷却しながら使用すれば注入可能時間を延ばすことができる。CT透視を用いる場合は，骨セメント製剤単独でも良好に視認できるため，バリウム製剤の添加は行っていない。骨セメントを骨セメント注入器OsteoJect (Integra社製) にセットし，注入針と接続すれば注入の準備が完了する。

⑤CT透視下に骨セメントを注入する。CT断面を頭尾方向に動かしながらreal-time法による透視を行い，ゆっくり注入する。この際，骨セメントの分布する領域を網羅するようにCT断面を移動させる必要がある。脊柱管内や骨外に骨セメントの漏出が確認された場合には直ちに注入を止める。静脈内への漏出を認めた場合にはいったん注入を停止し，20～30秒ほど待つことで硬化が進み，追加注入してもそれ以降の静脈内への漏出を防ぐことができる場合がある。骨セメントの漏出がない場合には十分に骨セメントが分布したと判断した時点で注入を止める。骨セメント注入中は加圧による疼痛を生じるので，患者には前もって説明しておく。また，注入中は患者の血圧と酸素分圧を常に監視し，患者に異変がないか十分に観察しながら行うことが大切である。

⑥セメント注入針を抜き，セメントの分布をCTで確認する。セメント注入直後に慌てて抜針すると，穿刺経路に沿ってセメントがリークするので，残った骨セメントが十分に硬化したのを確認してから抜針する。

⑦患者は背臥位で術後2時間の安静とする。

CT透視を用いて行う利点は，針と椎体の関係を瞬時に明確に確認できること，骨セメントの視認性が良いためセメント製剤にバリウム製剤を添加する必要がないこと，少量のセメント漏出を早期に検出できることがあげられる。我々は，CT透視により脊柱管内への骨セメントの漏れを最小限にとどめることができ，脊髄神経障害の発生を回避することができた症例も経験している[10]。

骨セメントの注入量は病変と椎体の大きさによって変化するものであるが，我々は胸腰椎での予定注入量を通常4～5mℓ程度以下に設定している。必要以上に圧を高めて注入すると脊柱管内漏出などの合併症をまねく危険性がある。注入セメントが少量でも効果はあらわれるので，入れすぎないように心がけた方がよい。

手技中は患者のモニタリングを欠かさず，緊急時にはすぐに適切な処置が行える体制を整えておく必要があり，我々は全例で麻酔科医による患者管理のもとに手技を行っている。本治療には麻酔科医および整形外科医との連携が必須であることを特に強調しておきたい。

椎体腫瘍に対する経皮的椎体形成術の臨床成績

経皮的椎体形成術の疼痛緩和効果について，文献的には60～70%の有効率との報告が多い[11,12]。骨粗鬆症による圧迫骨折と比較して効果は若干低下するとされている[12]が，その疼痛緩和効果は非常に高く，効果発現までの時間も多くは24時間以内，遅くとも3日以内と即効性もある。合併症については，同時に7，11椎体を全身麻酔下で治療した2例の死亡例[13]，骨セメントや骨髄脂肪による肺動脈塞栓[14]，脊柱管内の骨セメント漏出による脊髄神経障害などが報告されているが，このような重篤な合併症は稀である。合併症の頻度は骨粗鬆症の場合よりもやや高く，転移性骨腫瘍では約10%という報告がある[15]。

本療法の安全性と有効性についての前向きな臨床試験は世界的にも報告がなかったが，ようやく本邦で日本腫瘍IVRグループによる多施設共同第Ⅰ/Ⅱ相臨床試験(JIVROSG-0202)が椎体病巣をもつ33症例を対象に行われ，2007年6月に結果が発表された[16]。手技遂行率100%で治療に関連するGrade 3以上の有害事象はなく，術後1週間目のVAS値で評価された臨床的有効性は著効61%，有効12%，無効27%，治療効果出現までの期間が平均2.4日，中央値1日というものであった。この試験結果により，一定の安全性と有効性が示されたと考えられる。

椎体腫瘍の治療における経皮的椎体形成術の位置付け

椎体腫瘍の疼痛緩和治療において本治療法は一つの有効なオプションではあるが，現時点で中心的な位置を占めるものとは言えない。外科治療の適応がある病変についてはこれに取って代わって行うべき治療とは言えず，外科治療の適応がない症例，すなわち中長期

の予後が期待できない症例に対する疼痛緩和治療と位置付けられる。こうした症例に対しては，現在，放射線治療が最も一般的な治療法として認知されている。疼痛緩和の観点のみで議論すれば，椎体形成術は放射線治療と同等以上の効果が期待され，効果発現までの期間は短い。したがって，生命予後が短い患者，疼痛が極めて強い患者，早期の除痛が望まれる患者などでは，本治療法が特に有効であろうと思われる。また，放射線治療で効果が得られない症例や放射線治療後の疼痛再発例に対しても本治療は効果があることがわかっており，こうした患者も良い適応になる。

今後の展望

現在，本治療法は保険診療として認可されていないが，高い疼痛緩和効果と即効性は明らかであり，早期の認可が強く望まれている。近い将来，椎体腫瘍による疼痛緩和の有力な治療法として普及していくことが予想される。これまで行われてきた麻薬を中心とした薬物療法や放射線療法とは相補的に施行されていくものと思われ，本治療法単独の治療だけではなく放射線治療などと組み合わせた治療も考えられる。例えば，本治療を先行して疼痛を軽減させた上で抗腫瘍治療として放射線治療を追加するということも可能であり，我々の検討では本治療法単独よりも放射線治療を組み合わせた群で疼痛の再発率が低い傾向にあることを認めている。こうした他の治療法との併用療法の検討や本治療法の中長期的な成績を明らかにしていくことで，椎体腫瘍の治療における本治療法の適応が拡大していく可能性もある。

本治療法は我々がこれまでに習得してきたCT透視などの技術を駆使することにより，安全かつ効果的に施行できる治療であるが，その一方で不用意に行うと重篤な合併症を引き起こしかねない治療でもある。今後，より安全で有効な治療法の確立とともにその普及を図ることも必要であると思われる。

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ORIGINAL RESEARCH

Pedicle Involvement on MR Imaging Is Common in Osteoporotic Compression Fractures

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BACKGROUND AND PURPOSE: Pedicle involvement on MR imaging has been considered specific for malignancy. However, we also noted the findings in many patients with osteoporosis and hypothesized that it is not specific for malignant lesions. The aim of this study was to evaluate the prevalence of pedicle involvement in painful osteoporotic compression fractures and to determine whether the sign is specific for malignancy.

MATERIALS AND METHODS: We retrospectively reviewed MR images and CT scans of 152 patients who underwent PV for painful compression fractures. There were 140 patients (225 vertebrae) with osteoporotic fractures and 12 patients (19 vertebrae) with malignant fractures. Three radiologists evaluated the degree and extent of signal-intensity changes of the pedicle on MR imaging by consensus. The CT findings were also evaluated. The χ^2 test was used for statistical analyses.

RESULTS: Of the 225 vertebrae of osteoporotic fractures and 19 vertebrae of malignant fractures, pedicle involvement on MR imaging was seen in 144 (64%) and 16 (84.2%) vertebrae, respectively, and there was no statistically significant difference (P = .065). Positive pedicle involvement in osteoporotic fractures was seen in 84 (77%) of 109 vertebrae with early-phase fractures (≤3 months) and 60 (51.7%) of 116 vertebrae with chronic-phase fractures (>3 months), and this was statistically significant ($P < .001$). Among 144 osteoporotic vertebrae that showed positive pedicle involvement on MR imaging, 45 (31%) showed pedicle fractures and 55 (38.2%) showed sclerotic change on CT.

CONCLUSIONS: Pedicle involvement was seen frequently in patients with osteoporotic compression fractures and was not specific for malignancy in our study group.

ABBREVIATIONS: Gd-T1WI = gadolinium-enhanced T1WI; PV = percutaneous vertebroplasty; STIR = short-tau inversion recovery; T1WI = T1-weighted imaging; T2WI = T2-weighted imaging

Differentiation of benign osteoporotic compression fractures and malignant pathologic fractures is clinically important, particularly in the elderly, but is sometimes difficult. MR imaging and CT have been shown to be helpful in differentiating both conditions. Compression fractures due to malignant tumors have a convex posterior cortex of the vertebral bodies, epidural or paravertebral masses, or infiltration of the posterior elements.[1-5] Of these, pedicle involvement has been described as specific for malignant lesions.[3] Osteoporotic compression fractures usually show retropulsion of a posterior bone fragment or intravertebral fluid.[2,3,5,6]

In our experience of PV for painful compression fractures, abnormal signal-intensity change in the pedicle on MR imaging, which will be defined as "pedicle involvement," has commonly been noted not only in patients with malignant compression fractures but also in those with benign osteoporotic compression fractures, and differentiation by using only this sign is sometimes difficult.

The aim of this study was to evaluate the prevalence and features of pedicle-involvement change on MR imaging in painful osteoporotic compression fractures and to determine whether these findings are truly specific for malignancy.

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Materials and Methods

All protocols for this retrospective Health Insurance Portability and Accountability Act–compliant study were approved by the institutional review board. The need for informed consent was waived.

Subjects

We retrospectively reviewed medical records and MR imaging/CT data from 200 consecutive patients who had undergone PV for painful osteoporotic or malignant vertebral fractures. Patients who underwent full imaging studies (plain CT, T1WI, STIR imaging, and Gd-T1WI) were included. Exclusion criteria were the following: an insufficient imaging study, traumatic compression fracture without osteoporosis, PV for sacral fractures or Schmorl nodes, and repeat PV for vertebrae that had already undergone PV. The final study group comprised 140 patients with osteoporotic compression fractures (225 vertebrae; 35 women, 105 men; mean age, 77.8 years; range, 55–96 years) and 12 patients with malignant fractures (19 vertebrae; 7 women, 5 men; mean age, 61 years; range, 46–71 years). Diagnosis was primarily made on the basis of medical history, thorough physical examination, laboratory findings, and imaging studies, including plain radiography, CT, and MR imaging. When there were the characteristic findings indicating a benign process such as retropulsion of the posterior bone fragment or intravertebral cleft without bone destruction, the diagnosis was a benign compression fracture.

The final diagnosis of benign compression fracture was made by means of follow-up plain radiography and clinical history at 3 months and 1 year after PV. When the appearance of a follow-up radiographic study did not change significantly and no new malignancy was found, the fracture was considered to be caused by a benign process. Biopsy was performed to rule out malignant lesions for 3 patients with osteoporosis with a history of malignancy. When there was an intra- or

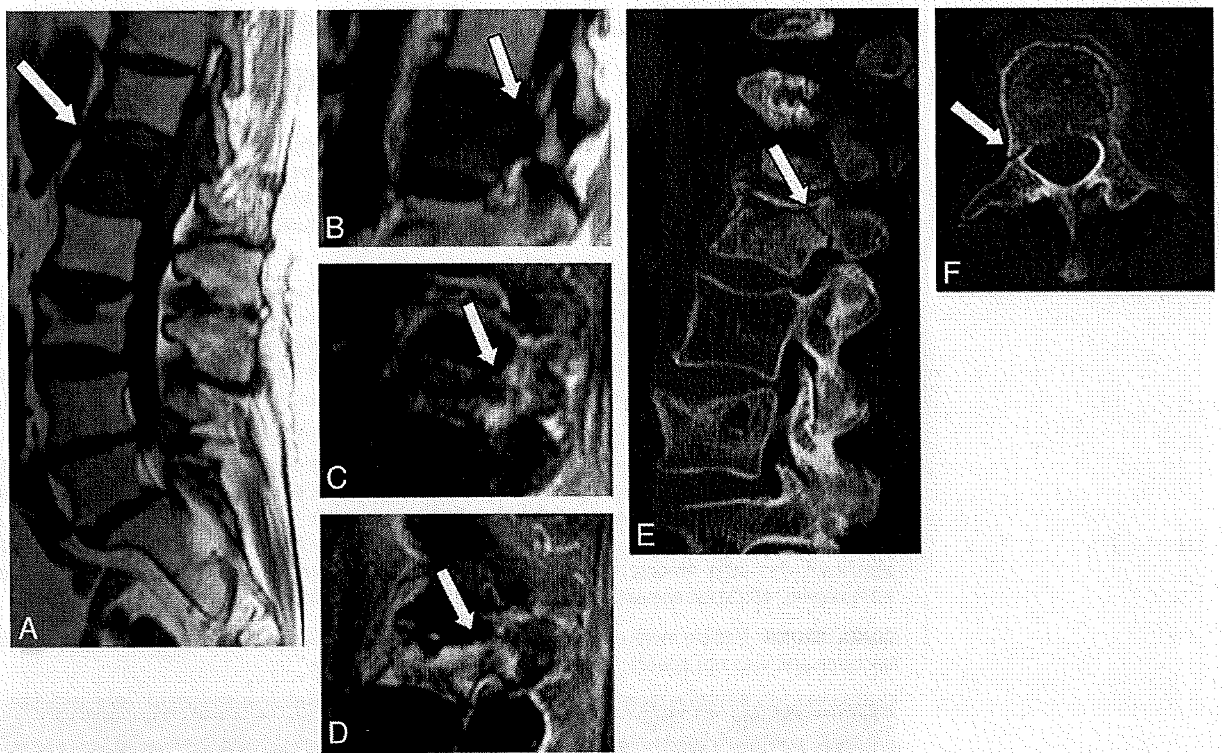

Fig 1. A 79-year-old woman with benign compression fracture which occurred one-and-a-half months earlier. *A* and *B,* T1WI shows diffuse hypointensity in the vertebral body and the right pedicle of L1 (*arrow*). *C,* STIR image shows heterogeneous hyperintensity in these areas (*arrow*). *D,* Contrast-enhanced T1WI shows marked enhancement (*arrow*). *E* and *F,* On sagittal (*E*) and axial (*F*) CT scans, fracture is seen in the right pedicle (*arrow*), which is a presumable reason for the abnormal signal intensity on MR imaging.

paravertebral mass or cortical bone destruction in the fractured vertebra, it was diagnosed as a malignant pathologic fracture. Among the 12 patients with malignancy, 11 patients had metastatic carcinoma (bronchogenic carcinoma, $n = 5$; prostate carcinoma, $n = 2$; breast carcinoma, $n = 1$; vaginal carcinoma, $n = 1$; pancreatic carcinoma, $n = 1$; and cervical carcinoma, $n = 1$), and 1 patient had multiple myeloma.

Imaging

MR imaging of the thoracolumbar spine was performed with 1 of two 1.5T scanners (Signa Excite, GE Healthcare, Milwaukee, Wisconsin; or Intera Achieva, Philips Medical Systems, Best, the Netherlands) by using a spine-array surface coil. The imaging protocol included sagittal spin-echo T1WI (TR/TE = 474–550/10.5–13 ms), STIR images (TR/TE/TI = 2500–6000/70–93/150 ms), and fat-saturated spin-echo Gd-T1WI (TR/TE = 460–600/6.2–12; flip angle = 80°–90°; 0.2 mmol/kg) with a 4-mm section thickness and 0.5-mm section spacing. The matrices were 512 × 306 and 512 × 384 with an FOV of 480 mm or 320 × 224 with an FOV of 280 mm (divided into 2 series). In some cases, axial images were obtained on Gd-T1WI, which were not evaluated in this study.

CT was also performed by using a 64-section scanner or a 16-section scanner. Reconstructed axial, transverse, and sagittal images were obtained with a 3-mm section thickness. The matrix was 512 × 512.

Image Analysis

Three radiologists evaluated the degree and extent of signal-intensity changes of the pedicle on MR imaging by consensus. Signal-intensity changes were classified as iso-, hyper-, or hypointense to the marrow of normal unaffected pedicles in the same patient on T1WI, iso- or hyperintense on STIR images and as showing mild or marked enhancement on Gd-T1WI. Pedicle involvement was defined as positive when at least 2 of 3 sequences showed abnormal signal-intensity change in the pedicle. The extent of the pedicle involvement was classified as partial or diffuse. CT findings of the pedicle were categorized into 3 groups: fracture (Fig 1), sclerosis (Fig 2), or no apparent abnormality (Fig 3).

Statistical Analysis

The χ^2 test was used for statistical analyses, with values of $P < .05$ considered significant.

Results

Pedicle involvement on MR imaging in benign osteoporotic compression fractures and malignant pathologic fractures is shown in Table 1. Of the 225 vertebrae of osteoporotic fractures and 19 vertebrae of malignant pathologic fractures, pedicle involvement was seen in 144 (64%) and 16 (84.2%) vertebrae, respectively. No significant difference ($P = .065$) was apparent. Sensitivity and specificity of pedicle involvement for malignant pathologic fractures were 84% and 36%, respectively. Among osteoporotic fractures ($n = 225$), 85 vertebrae (41.3%) showed signal-intensity changes in both T1WI and STIR images and diffuse contrast enhancement of the pedicle.

The relationship between pedicle involvement on MR imaging and the duration from the onset of pain in patients with osteoporotic compression fracture is given in Table 2. With osteoporotic fractures, pedicle involvement was seen in 84 (77%) of 109 vertebrae with early-phase fractures (≤3

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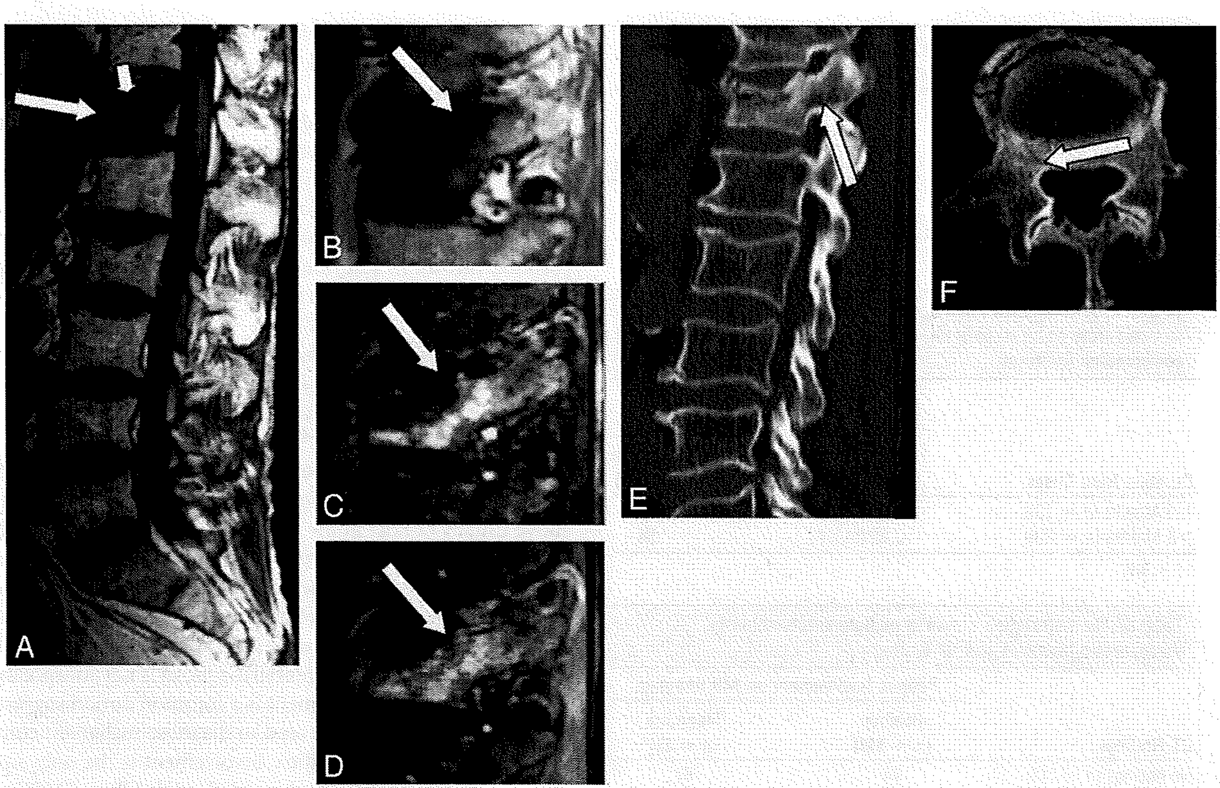

Fig 2. A 65-year-old man with benign compression fracture, which occurred 2 months earlier. *A* and *B*, T1WI shows diffuse hypointensity in the vertebral body and the right pedicle of T12 (*arrow*). There is a marked hypointensity band adjacent to the superior endplate, indicating a gas cleft (*small arrow*). *C*, STIR image shows heterogeneous hyperintensity in these areas (*arrow*). *D*, Contrast-enhanced T1WI shows moderate enhancement in the vertebral body and in the right pedicle (*arrow*). *E* and *F*, On sagittal (*E*) and axial (*F*) CT scans, sclerosis is seen around the gas cleft including the base of the right pedicle (*arrow*).

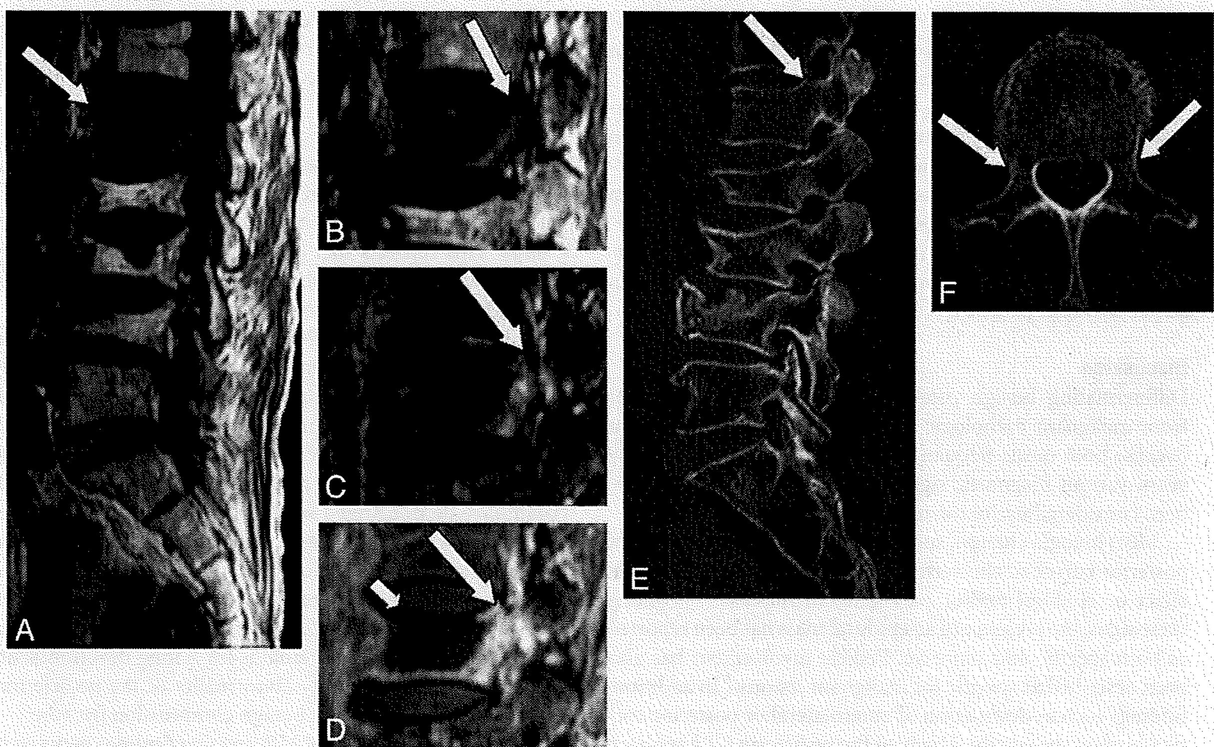

Fig 3. A 76-year-old woman with benign compression fracture, which occurred 1 month earlier. *A* and *B*, T1WI shows diffuse hypointensity in the vertebral body and in the left pedicle of L1 (*arrow*). *C*, STIR image shows heterogeneous hyperintensity in these areas (*arrow*). *D*, Contrast-enhanced T1WI shows marked enhancement (*arrow*). A large area of low signal intensity indicates necrosis or cleft (*small arrow*). *E* and F, On sagittal (*E*) and axial (*F*) CT scans, there is no apparent abnormality in the pedicle (*arrow*).

Table 1: Pedicle involvement in osteoporotic compression fractures (benign) and malignant pathologic fractures on MR imaging

Fracture	Pedicle Involvement on MR Imaging	
	Positive	Negative
Benign ($n = 225$)	144 (64%)[a]	81
Malignant ($n = 19$)	16 (84%)[a]	3

[a] $P = .065$.

Table 2: The relationship between pedicle involvement and duration from onset of pain in patients with osteoporotic compression fractures

Duration from Onset	Pedicle Involvement on MR Imaging	
	Positive ($n = 144$)	Negative ($n = 81$)
1–3 Months ($n = 109$)	84 (77%)[a]	25
>3 Months ($n = 116$)	60 (51%)[a]	56

[a] $P < .001$.

Table 3: The correlation between pedicle involvement in osteoporotic fractures and CT findings

CT Findings	Pedicle Involvement on MR Imaging	
	Positive ($n = 144$)	Negative ($n = 81$)
No findings ($n = 111$)	44	67
Sclerosis ($n = 69$)	55	14
Fracture ($n = 45$)	45	0

months) and 60 (51.3%) of 116 vertebrae with chronic-phase fractures (>3 months). Early-phase fractures showed a significantly larger number of patients with pedicle involvement than chronic-phase fractures did ($P < .001$).

The correlation between pedicle involvement on MR imaging for osteoporotic fractures and CT findings is given in Table 3. In 144 osteoporotic fractures with pedicle involvement on MR imaging, sclerosis and pedicle fractures were seen in 55 vertebrae (38.2%) and 45 vertebrae (31%) on CT, respectively. No abnormality in the pedicle was seen in 44 vertebrae (30.5%). MR imaging showed pedicle involvement in all patients with pedicle fracture on CT.

Discussion

Differentiating benign osteoporotic compression fractures from malignant pathologic fractures is clinically important because both occur frequently in elderly patients. For many years, various diagnostic signs on CT and MR imaging have been considered useful for such evaluation.[1-12]

Morphologic changes suggest malignancy when a convex posterior cortex of the vertebral body is seen due to a mass effect or epidural and/or paravertebral masses.[1-4,8] Among these signs, the presence of an epidural mass has been reported as both specific and sensitive. Pedicle involvement has also been described as specific for malignant lesions.[3] In addition, findings such as destruction of anterolateral or posterior cortical bone of the vertebral body or the pedicle on CT have been reported to suggest a malignant process.[2]

On the other hand, benign osteoporotic compression fractures show various signal-intensity patterns on MR imaging. Early-phase fractures typically show a bandlike low signal intensity on T1WI, which is localized adjacent to the collapsed endplate. In most cases, signal-intensity changes are focal, and normal marrow is preserved in at least 1 area of the vertebral body.[3] An intravertebral cleft including fluid or gas and a linear signal-intensity hyperintensity on STIR are significantly associated with osteoporotic fractures.[6] These are believed to reflect avascular necrosis or a nonunionized bony gap with pseudoarthrosis. In addition, retropulsion of a posterior bone fragment is considered both sensitive and specific for osteoporotic fractures.[2]

The usefulness of diffusion-weighted MR imaging or chemical shift MR imaging in differentiating benign and malignant vertebral lesions has been reported recently, but the results are controversial.[13,14]

Correct diagnosis can be made in most cases of osteoporotic compression fracture because the useful signs mentioned above usually coexist in the collapsed vertebrae. However, in our experience, imaging features mimic malignant compression fractures in acute osteoporotic compression fractures, when the height of the vertebral body is preserved and diffuse signal-intensity changes are seen on T1WI, STIR, and Gd-T1WI. In such cases, a differential diagnosis is not always easy.

Because pedicle involvement is a common notion suggesting a malignant nature, we tend to diagnose malignant compression fracture when pedicle involvement is the only sign (Fig 1). We always evaluate the pedicle with CT and MR imaging before PV, because fracture or abnormal signal-intensity changes of the pedicle may be the source of pain and instability. In such cases, pediculoplasty may be beneficial to relieve the pain.[15-18] From our experience, abnormal signals of the pedicle are frequently seen on MR imaging with osteoporotic compression fractures, particularly in the early phase, and fracture of the pedicle is seen in approximately one-third of our patients.

As described in the "Results" section, abnormal signal intensity and contrast enhancement were seen in the pedicle in 64% of benign compression fractures and 84.2% of malignant pathologic fractures, with no significant difference between groups. This suggests that pedicle involvement is also common in benign osteoporotic compression fractures. These results differ from those of previous articles.

Yuh et al[1] compared MR imaging findings between 84 benign fractures and 25 malignant fractures on T1WI and T2WI. They reported pedicle involvement in 22 of the 25 patients with malignant compression fractures but in none of 52 nontraumatic compression fractures, contrasting starkly with our observations. They did not perform STIR or Gd-T1WI, which could have demonstrated subtle pathologic abnormalities in the pedicle. The results might, thus, have differed if these sequences had been used. Moreover, onset of fracture and duration of pain were not described. The prevalence of pedicle involvement varies depending on the age of the fracture. Tumor involvement usually remains for a long duration if untreated, but signal intensity abnormality of the pedicle may disappear after healing of a benign compression fracture.

Cuenod et al[3] compared MR imaging findings between 63 osteoporotic fractures and 30 malignant compression fractures in the acute phase (<2 months). The MR imaging protocol included T1WI, T2WI, T2*WI, and Gd-T1WI without fat suppression. Pedicle involvement was seen in 24 malignant fractures and 4 benign fractures, and sensitivity and specificity for malignancy were 80% and 94%, respectively, suggesting pedicle involvement as a specific sign for malignancy. They did not use a fat-suppression technique, which might be the reason for the low detectability of pedicle involvement in their patients with osteoporosis. Generally, detection of pedicle involvement by tumor is not difficult due to the presence of homogeneous diffuse signal-intensity changes or a mass effect, but signal-intensity changes in osteoporotic fractures are sometimes difficult to recognize because they are often focal and inhomogeneous. Bone marrow is almost completely replaced with fatty tissue in elderly patients, so fat suppression is considered necessary for the evaluation of diseased vertebrae.

Shih et al[4] examined MR imaging findings for 37 patients with single-level vertebral compression fractures, including 21 patients with benign causes and 16 patients with malignancy. The imaging protocols included T1WI, T2WI with fat suppression, and Gd-T1WI with fat suppression, similar to those in the present study. They identified pedicle involvement in 6 vertebrae with benign fractures (28.6%) and 11 vertebrae with malignant fractures (68.8%), showing a clearly higher prevalence of pedicle involvement in benign compression fractures compared with those in the other studies mentioned above.[1,11] This higher rate of pedicle involvement in osteoporotic compression fractures compared with other studies is probably due to the use of fat-suppression techniques. However, a difference from our study is seen in patient selection. They selected patients with solitary vertebral collapse as the only inclusion criterion. Symptoms of patients were not mentioned in that investigation, while we analyzed patients with acute-to-chronic painful fractures. Signal-intensity changes are commonly seen in unhealed painful fractures and presumably contributed to the difference from our results.

To the best of our knowledge, no previous reports have identified correlations between the findings of pedicle involvement on MR imaging and CT. We investigated CT findings of the pedicle with or without pedicle involvement on MR imaging. Pedicle involvement in osteoporotic compression fractures exhibited 3 morphologic patterns on CT in this study: fracture, sclerotic change, and no abnormality. Fracture and sclerotic change of the pedicle were noted in 31% and 38.2% of vertebrae, respectively, in which MR imaging showed signal-intensity abnormality. Laredo et al[2] compared CT findings of 34 benign osteoporotic fractures with those of 32 malignant acute vertebral compression fractures. They found pedicle fracture in 3 vertebrae with osteoporotic fractures (8.8%). That prevalence was significantly lower than that found in the present study. The reason is unclear but may be attributable to differences in the CT imager and imaging protocol because they evaluated by using axial images alone. We analyzed images with reconstructed axial, sagittal, and coronal planes with 3-mm section thickness obtained by using 16- or 64-detector row CT, which seems likely to have contributed to the higher detectability of abnormal findings in the pedicle in our series compared with that of Laredo et al.[2]

Sclerosis of the pedicle appears to represent reactive change or the healing process of microfracture. Signal-intensity changes on MR imaging are considered to represent the inflammatory process, including exudation, inflammatory cell infiltration, granulation tissue, or fibrosis.

In our study, 30% of vertebrae in which abnormal signals were seen in the pedicle on MR imaging showed no obvious abnormality on CT. In those cases, the fractured vertebral body showed low signal intensity on T1WI and high signal intensity on STIR and Gd-T1WI, indicating edema and inflammatory changes. These changes presumably extended posterior to the pedicle. Our results show that abnormal signals can be seen more frequently in the pedicle with early-phase fractures than with chronic fractures. Such signal-intensity changes are likely to disappear when the healing process is completed, as with fractures in other locations; however, a long period may be required for complete healing.

The present study had some limitations. First, diagnosis of benign or malignant fracture was mainly made on the basis of patient history and clinical presentation, and biopsy was performed in only selected patients. Some patients diagnosed with benign fracture thus could possibly have had malignant compression fractures. However, we believe such cases were unlikely and would have had little influence on the study result because no new malignancies were found in any patients at 3-month and 1-year follow-ups after PV.

Second, our study had a selection bias. We included only patients who underwent PV. It is possible that patients included had a higher likelihood of pedicle involvement than the general population because we performed PV for patients who had some signal-intensity changes on MR imaging in fractured vertebrae. So, this result may not be applicable to the larger population.

Third, due to time constraints, the MR imaging protocol for PV at our institution included only sagittal images, and we could not assess axial images in any except a few patients. Axial imaging may thus yield some additional information.

Conclusions

Pedicle involvement, which is accepted as a common indicator of malignant processes, is also frequent in patients with osteoporotic compression fractures, particularly in the early phase, and was not specific for malignancy in our study group. Although differentiating benign osteoporotic compression fractures and malignant pathologic fractures is possible in most cases, a diagnosis of malignant pathologic fracture should not be assumed when pedicle involvement is the only sign.

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ORIGINAL ARTICLE

Preprocedural MR imaging for percutaneous vertebroplasty: special interest in contrast enhancement

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Abstract
Purpose. The success of percutaneous vertebroplasty (PVP) depends greatly on preprocedural evaluation of the patients. The purpose of this study was to evaluate the efficacy of preprocedural magnetic resonance imaging (MRI) for the indications of PVP.
Materials and methods. A retrospective review of 122 osteoporotic compression fractures in 63 patients who underwent preprocedural gadolinium-enhanced MRI and PVP was performed. Based on the extent of contrast enhancement on preprocedural MRI, each case was classified into one of two groups: group 1, which represented more than 50% of the vertebral body enhanced; and group 2, which represented less than 50% of the vertebral body enhanced. The most enhancing level was evaluated in multilevel PVP sessions. We evaluated the difference of pre- and postprocedural pain scales between groups 1 and 2 using Mann-Whitney's U-test.
Results. There was a trend toward higher preoperative pain score in group 1, but it was not statistically significant ($P = 0.0537$). In addition, the postoperative pain score in group 2 was significantly higher than that in group 1 ($P = 0.0007$). The difference between the pre- and postoperative pain scores was significantly higher in group 1 than in group 2 ($P = 0.0001$).
Conclusion. Contrast enhancement on MRI indicates a painful lesion and extensive contrast enhancement predicts better pain relief after PVP.

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Key words Percutaneous vertebroplasty · Contrast enhancement · MRI

Introduction

Percutaneous vertebroplasty (PVP) has been used to treat osteoporotic fractures and metastatic tumors of vertebral bodies. In addition to the technical aspect, the success of PVP depends much on the process of preprocedural evaluation of the patients. Magnetic resonance imaging (MRI) plays a pivotal role in the process, but its clinical application has not been established. Our hypothesis is that the extent of contrast enhancement (CE) of the vertebral bodies on fat-suppressed gadolinium-enhanced T1-weighted imaging may affect pain relief after PVP. Occasionally, in patients with multiple compression fractures, selecting the vertebral bodies to be treated is difficult. The purpose of this study was to evaluate the efficacy of preprocedural MRI for the indications of PVP in terms of pain relief.

Materials and methods

This study included 122 compression fractures in 63 patients (18 men, 45 women; mean age 76.9 years) between February 2002 and July 2004. Cases of malignancy-related compression fracture were excluded. All patients underwent preprocedural MRI within a month before the procedure. There were 23 single-level procedures and 40 multilevel procedures. The cases are summarized in Table 1. Regarding the duration of pain, it was less than 2 months in 26 patients and longer than 2 months in 37 patients. The preprocedural imaging