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ORIGINAL RESEARCH

Significance of preoperative MRI in establishing levels of augmentation for percutaneous vertebroplasty

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Objectives: To determine whether X-ray, computed tomography (CT), bone scan, and clinical impression accurately reflect the level of vertebral fracture in patients about to undergo vertebroplasty.

Design: Retrospective observational study, utilizing patient inpatient notes, referral correspondence, and clinicians' private notes.

Setting: Single center – all patients referred to one pain medicine physician for vertebroplasty who subsequently had the procedure.

Participants: All patients referred to a pain physician (PJG) over a 4-year period, who had a presumptive diagnosis of vertebral fracture(s) from the referring consultant physician, based on imaging other than magnetic resonance imaging (MRI) and clinical impression. Participants then had an MRI and subsequent vertebroplasty under the care of the pain physician. Participants were identified retrospectively from the vertebroplasty procedure list.

Intervention: Nil.

Main outcome measure: Number of cases in which the MRI identified a different level of pathology than X-ray, CT, bone scan, and clinical impression.

Results: In 50% (28/56) of patients MRI identified a fracture at a different level to that which was presumed to be the cause of patient pain on the basis of X-ray, CT, and clinical impression.

Conclusion: MRI is an essential investigation to determine accurately the level of fracture in osteoporotic patients. Studies on the effectiveness of treatment of vertebral fractures that do not utilize MRI in every case are unlikely to be accurate.

Keywords: vertebroplasty, back pain, osteoporosis, crush fracture

Introduction

Vertebroplasty is a technique used to treat vertebral fracture whereby methyl methacrylate is injected into the vertebral body, with the aim of alleviating pain. The National Institute for Health and Clinical Excellence (NICE) indications for vertebroplasty include vertebral fracture from osteoporosis, hemangioma or tumor invasion.[1] Where acute vertebral fractures occur due to these disease processes, patients who experience severe unremitting pain or pain continuing beyond 6 weeks duration of conservative treatment are considered appropriate candidates for vertebroplasty.[2–5] Several studies have highlighted the importance of the fracture being both acute and symptomatic in order for optimal outcomes to occur as a result of vertebroplasty, and have acknowledged that the vital step of correctly identifying and treating the symptomatic fracture is often done poorly.[3,6] In particular, the role of preprocedural magnetic resonance imaging (MRI) in establishing fracture position, age, extent and stability has been well

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documented as has the role of MRI in giving concurrent information about other spinal abnormalities.[3–10]

MRI can identify the acute nature of vertebral fractures based on certain features. In addition to anatomical vertebral collapse, these include signal changes such as hypo-intensity on T1-weighted images (edema), hypo-intensity or heterogeneous intensity on T2-weighted images, and hyper-intensity on fat-suppressed T2-weighted images or on short T1 inversion recovery (STIR) sequences where fluid represents marrow oedema.[3–5,11]

Other changes become characteristic once a fracture has been present for periods over one month, in fractures that are fully healed, and in situations where the fracture is related to malignant compression or a hemangioma.[4]

Two randomized controlled trials comparing vertebroplasty to a sham procedure aimed to draw conclusions on the effectiveness or otherwise of vertebroplasty.[12,13] The study by Kallmes et al[12] did not have a defined preprocedural imaging protocol that consistently included the use of MRI. Our study aims to re-focus the "vertebroplasty debate" on the preoperative patient/vertebral level selection for vertebroplasty, by comparing the information given by X-ray, computed tomography (CT), bone scan, and clinical examination in a series of patients thought to have vertebral fracture/s, with that gained from subsequent MRI assessment of the same patients.

Clearly, it is essential that any preoperative clinical diagnosis of the level of fracture is completely accurate if we are to make assumptions about the effectiveness of vertebroplasty as a procedure.

Study design

This was a retrospective observational study using hospital patient notes, clinician notes, and referral correspondence.

Methods

All patients treated with vertebroplasty by one pain physician (PG) at Hollywood Private Hospital Nedlands Western Australia over a 4-year period were identified by an independent researcher. Hospital notes, and clinician private notes, including referral correspondence and radiological reports were examined. Referrals where a definite clinical diagnosis had been made by a referring consultant physician on the basis of non-MRI imaging (X-ray, CT and/or bone scan) and clinical examination only were identified and included in this study (n = 68).

Patients who had an MRI prior to referral (n = 4), had an MRI as their only form of imaging (n = 5), or who could not have an MRI (n = 3) were excluded.

Plain films had been taken at various locations as had CT scans. However all patients had an MRI after referral, which was performed on a 1.5 tesla machine (Siemens Avanto, 2005, Erlangen, Germany) and comprised Sagittal T1- and T2-weighted sequences, STIR sequences, and axial T1 and T2 weighted images without contrast.

The difference in the diagnosis of the relevant level/s for vertebroplasty treatment before and after the MRI was noted. An analysis of the percentage of patients for whom the diagnosis before, and after, MRI was different was performed.

Results

During the period 2005–2009, 56 referrals among 51 patients (16 male, 35 female) were identified where the referring consultant physician had made a definite diagnosis based on X-ray, and/or-bone scan, and/or CT and clinical examination, but an MRI had not been performed. The average patient age at referral was 78.6 years. All patients after each referral underwent MRI immediately prior to any intervention which, in this group of patients, confirmed an acute fracture.

Due to the fact that we identified patients from a group who had gone on to have a vertebroplasty procedure, those who were referred over this period of time with a presumptive diagnosis of vertebral fracture but did not have a fracture on their preprocedural MRI were not identified or included in our cohort. This flaw in our study design is likely to have missed further cases of incorrect diagnosis at referral, and is expanded upon in our discussion section.

In 28/56 of the referrals (50%) the MRI resulted in a different level of treatment requirement than had previously been anticipated. Table 1 outlines patient details, the clinical and non-MRI imaging diagnosis, and the MRI diagnosis, along with the level which was subsequently selected for treatment with vertebroplasty in this series of patients.

In the majority of these cases (n = 24) the MRI revealed either (a) that there was an acute fracture at a different level to that of the referral (previously determined level shown to be an old fracture, or not fractured), or (b) that an additional level of acute fracture existed (as well as the originally determined level) which would require vertebroplasty treatment. Less commonly, the MRI revealed that an original fracture which on referral was thought to be old, was actually acute (n = 4).

Discussion

This retrospective observational study has confirmed that preprocedural MRI will often identify an acute fracture at a level not identified by clinical examination combined

Table 1 Summary of patient data, referral information and subsequent MRI findings

No	Age (years) sex	Referral details	XR/CT/bone scan location of #	MRI finding	VP performed on
1	90 Male	Fell 6/52 prior, increasing pain. Clinical level L4	XR # L4	Acute #s- L1, L2 Old #s- L4, L5	L1, L2
2	90 Male	Presented with back pain	XR #s L3 + L5	Acute #s L3 and L4	L3, L4
3	93 Female	Severe bilateral back pain radiating to left hip	Isotope scan # L2	Acute #s- L2 Old #- T10, T12, L3	L2
4	70 Female	Slipped and fell. Pain, +swelling lower thoracic area. Lumbar area non-tender	CT # T12 Isotope scan # T10 + T12 XR- # T10 + T12	Acute #- T10, T12	T10, T12
5	80 Female	Sudden onset LBP	XR old #s T12, L1, L2	Acute #- L4 Old # T12, L1	L4
6	86 Female	Inpatient referral-severe sacral pain	XR: no #s, SI joint intact CT: bilateral sacral #s	Acute bilateral sacral fractures	Bilateral sacroplasty
7	87 Female	Severe back pain mid lumbar	CT- L1 #	Acute L1 #	L1
8	81 Male	Fall, tender lumbosacral region	XR: old # L3 + L4	Acute #- L4	L4
9	76 Female	Multiple falls, increasing LBP; referred to anterior thigh	XR + CT: old # L4; acute # T12	Acute #- T11, L2 Old #- T4	T11, L2
10	87 Male	Back pain on walking, not increased by palpation/rotation	Bone scan # L4	Acute # L4	L4
11	61 Male	Fell from roof 6 months earlier	CT T12 #	Acute # T12	T12
12	86 Male	Thoracic pain after chest infection whilst inpatient	XR: #s of T3, 5,7,11,12, L1, L3,	Acute # T7	T7
13	86 Male	Vigorous lift, thoracic pain, also a fall	XR + Bone scan- no obvious acute #	Acute # T8	T8
14	87 Female	Sudden mid lumbar pain after lifting; spasms. Hx crush # of approx T8-10	XR: #s of T4, T6, T7, T8, T9, T11	Acute # T10 Old #s T8, T 11 with collapse at T11	T10, T11
15	87 Female	LBP increasing since fall, bilateral lower lumbosacral pain radiates down back of legs nil neurological signs	XR: old # T10 + T11, nil acute to explain pain	Acute # T11 Old # T9, T10	T11
16	84 Female	Severe back pain	XR # L1 + L2, old # T9	Acute # L1, L2 Old # T9	L1, L2
17	79 Male	Fell, LBP increases on walking, nil radiation, tender over lumbar spine	XR # T12	Acute # T12	T12
18	70 Female	Upper thoracic pain increased by inspiration and movement; Tender T7	XR # T7	Acute # T7	T7
19	85 Female	Significant back pain 2/52, Clinically T8 pain	Bone scan # T8	Acute # T8	T8
20	59 Female	Crush # on XR, LBP	XR # T12	Acute # T12	T12
21	60 Male	Fall, severe spasms of pain at thoracolumbar junction, nil radiation	XR- # L1	Acute L1 # and T12 #, both likely symptomatic	T12, L1
22	85 Female	Acute on chronic back pain, inc by sit/walk, no leg pain	XR # L1 + L2	Acute # L1 Old # L2	L1
23	87 Male	Central low back pain radiates to right Clinical impression # L4	XR- # L4 CT- central depression of L1, ?relates to past injury	Acute # L1 Old # L4	L1
24	82 Female	Sudden onset mid thoracic and upper lumbar pain. Limited movement, tender T6	XR and CT- # T6, T10, T12	Acute # T6, T10, T12 Old # L1, L2	T6
25	84 Female	Pain across back and down both legs, unable to cope, can't sit	XR # L3 + L4	Acute # L4	L4
26	85 Female	Severe pain difficult to localize left iliac crest area, ?# L iliac crest	XR 'nil evidence of fractures'	Acute # T11	T11

(*Continued*)

Table 1 (*Continued*)

	Age (years) sex	Referral details	XR/CT/bone scan location of #	MRI finding	VP performed on
27	86 Male	2/52 acute back pain radiation down R leg and some weakness R > L	Abdominal XR- # L2 Body scan technetium – acute # L2	Acute # L2	L2
28	35 Male	Approx 2 months of back pain unable to walk/straighten, interscapular pain, also upper and lower lumbar areas	XR # T8, L3, L5	Acute # T8, L2, L3, L5	T8, L1*, L2, L3, L5
29	65 Male	Fell, pain R upper lumbar area nil referred pain; non-tender to palpation	XR # L1 + T12 CT- extensive destruction to T12 vertebral body	Acute # T12	T12
30	76 Female	Pain in chest and abdomen, localized to thoracic spine	XR # T9	# T8	T8
31	80 Female	Increasing back pain over past year, refers to R groin + thigh	XR # L1	# L1 and lateral disc protrusion	L1
32	90 Male	Thoracolumbar back pain, sharp, nil radiation, previous vertebral #s years ago	XR # at T7, L1, L4	Acute # L2 Old #s at T7, L1, L4	L2
33	80 Female	Low back pain longstanding, worsening no reason over past 3/12, XR # L1, L2	XR # L1, L2	Acute #s L3 + L4, Old #s L1 + L2	L3, L4
34	85 Male	Had fall, R lumbosacral back pain, tender R side at L4/5 and L5/S1 Facet Joints and medial R iliac crest	XR # L1	# L1 acute	L1
35	72 Female	Fall, pain in back/right lower ribs, tender T12	XR # L2 + L3	Recent fracture L2, L3 no fracture	L2
36	89 Female	Some back pain post-fall, lumbosacral area	XR # L3	Acute L3 #	L3
37	57 Male	Right lateral chest pain radiating across scapula, non tender; mid thoracic gibbus deformity	XR and CT-T7 #	Acute T7 # Loss of anterior vertebral height T8, 9, 10, 11	T7
38	61 Female	8/52 back pain, flare up 10 days ago	XR # L3 appears old	Acute # L3	L3
39	80 Female	Acute onset mid back pain T12/L1, L1 point of max tenderness, ?fracture	XR # L1 + L2	T11 acute # L1 + L2 longstanding	T11
40	68 Female	Tender T11, pain coccyx and upper lumbar and thoracolumbar areas, pain on standing, nil radiation	XR # T11 + L1	# L1 (T11 appears normal)	L1
41	70 Female	Fell, immediate severe pain, mid thoracic spine, persisting, localized tender mid thoracic spine	XR # T8	T8 #	T8
42	67 Female	Referred with back pain	CT # T11	Acute # T11 Old # T7 + L1	T11
43	81 Male	Low back pain, trouble walking	CT # T12, L1, L3, L4	Acute # T12 + L1, minor line of edema seen L4, old wedging of L3	T12, L1, L4
44	88 Female	L4 fracture post-fall	XR didn't reveal #s Bone scan L4 #	Recent # L4	L4
45	88 Female	While inpatient had bone scan suggesting new L1 #	Bone scan showed recent L1 #`	Acute # L1	L1
46	76 Male	Thoracolumbar pain radiating variably to L groin, testes, loin, thigh, ?compression # L2 + radicular pain	Thoracic XR: # T10, T11, T12, L1; T12 worst; Lumbar XR: nil #; no change since 2003 CT- # L2 Bone scan- nil suggested fractures	Acute # L1 + L2; Old # T10, 11, 12	L1, L2
47	78 Female	Fall, central lumbar pain, tingling and discomfort R hip, nil tenderness	XR # L2	Acute # L2	L2

(*Continued*)

Table 1 (*Continued*)

	Age (years) sex	Referral details	XR/CT/bone scan location of #	MRI finding	VP performed on
48	82 Female	Low left back pain	XR and bone scan # L1	Acute # L1	L1
49	82 Female	Flare of severe LBP	XR- no recent fracture	Acute # T11 + T12 Old # L2	T11 + T12
50	82 Female	Pain at low thoracic spine, clinical impression T12	Bone scan # T12	Acute # L3, T12- benign compression #	L3
51	68 Female	Lifted, pain all over back, sometimes interscapular, lumbar or upper thoracic, non-tender normal ROM	XR # T6, 8, 10, T12 Bone scan # T8	Acute # T11 + T12 Old # T8	T11 + T12
52	86 Female	Recent exacerbation of spinal pain	XR # T8, L1, L2, L4, L5	Acute # T10 Old #s T8, L1, L2, L4, L5	T10
53	83 Female	Pain at T5, upper thoracic, nil radiation, increased by walking, tender T5-7	XR # T5	Acute # T5 + T6	T5 + T6
54	90 Female	Fell, couldn't sit, severe lower thoracic/upper lumbar pain	Bone scan – acute # R sacral ala, + Acute # L1 + L2	Acute # L2 Old # L1	L2
55	77 Female	Fell, persistent back pain increased on walking and standing, nil leg Sx, Tender upper lumbar some decreased movement Lumbar spine	Bone scan – # L1 + L3	# L1 + L3	L1 + L3
56	73 Female	Lower back pain past 1 month some bilateral radiation to buttocks	XR # T12 + L5	Acute # T10, T11, T12 Old # L5	T11 + T12

Note: *L1 noted at VP to have degenerated.

Abbreviations: CT, computed tomography; Hx, history of; LBP, lower back pain; Sx, symptoms; SI, Sacroiliac joint; R, right; L, left; VP, vertebroplasty; #, fracture; Acute, insufficiency fracture characterized by MRI findings of significant edema on STIR sequence at a vertebral level consistent with clinical level of pain; Old, old fracture characterized by MRI findings of collapsed vertebral body but with no edema on the STIR sequence; XR, X-ray; ROM, range of movement.

with X-ray and CT, and/or bone scan. This concurs with other studies which have also found that CT and/or X-ray alone misdiagnose a substantial number of vertebral fractures.[8–10,14–17] For example, Takahara et al studied osteoporotic fractures and using MRI, identified 47.3% of fractures not seen on plain X-ray.[8] Benz et al identified 14 new fractures in eleven patients by performing an MRI within 7 days of planned vertebroplasty in patients who had had an MRI 3 or more months previously.[10] By performing a preoperative MRI examination on patients previously diagnosed with osteoporotic fractures on the basis of CT and clinical assessment, the therapy plan was changed in 16 out of 28 (57%) patients in a study by Spiegl et al.[18] Thus, there already exists published evidence that without preprocedural MRI, misdiagnosis or under diagnosis of the affected level proposed for treatment by vertebroplasty is likely and our study further confirms this finding. The above mentioned studies either compared a previous MRI with an immediate preprocedural MRI, or a radiologist's reported X-ray with an MRI, or were looking at utilizing MRI in vertebral fracture diagnosis in the workup for potential kyphoplasty. To our knowledge, ours is the first study where, in the workup for vertebroplasty, the MRI is compared with a clinical diagnosis (combining clinical findings with non-MRI imaging) made by a consultant physician where the physician felt confident that the level identified was accurate.

In our study 50% of patients whose diagnosis was thought to be definite (based on X-ray, CT, and clinical impression by a consultant physician), were found to have a different pathological level after MRI suggesting that MRI preprocedure is necessary even if the clinical and radiological level seems certain without it (Figure 1).

There are some weaknesses in our study. As the data base used was patients who had undergone vertebroplasty, our study will have underestimated the number of patients in whom MRI changed the diagnosis, because it does not identify patients in whom the MRI demonstrated either no fracture or other pathology responsible for the patient's pain. In these patients vertebroplasty was not performed and therefore they were not identified and included in the database. Buchbinder et al found that 114 of 468 (24%) "eligible" patients (presumably thought clinically to have an osteoporotic fracture) did not have a fracture identified on MRI and a further 67 (14%) had "fracture greater than 12 months duration or did not meet MRI criteria".[13] Therefore it is possible that up to 38% more patients had the diagnosis

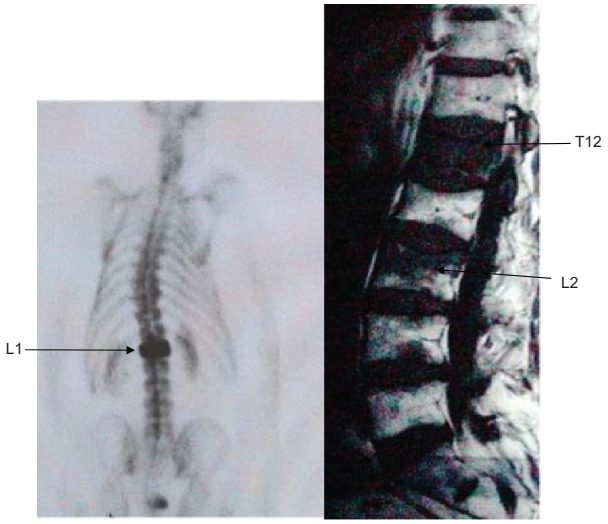

Figure 1 Example of bone scan and MRI in the same patient, showing conflicting location of acute fracture.
Notes: These images (technetium bone scan on the left and T1 weighted sagittal MRI lumbar spine on the right) are from the same patient and illustrate an example of misdiagnosis using non-MRI methods to diagnose level of vertebral fracture. The bone scan and X-rays suggested that the acute fracture was L1. However the MRI demonstrated that the fracture at L1 was old and the acute fractures were at T12 and L2.
Abbreviations: L, left; MRI, magnetic resonance imaging.

changed after MRI, resulting in no vertebroplasty being performed. In future, prospective studies to include these patients would give a more accurate indication of the effect of MRI preprocedure.

The finding of a fracture on MRI may not have resulted in vertebroplasty in other patients in whom the fracture level was distant to the level of pain. All the patients included in the study were elderly, and clearly these patients have many potential causes for acute back pain. For example, one patient under our care was referred and subsequently admitted to hospital with the diagnosis of a vertebral fracture on the basis of clinical and radiological analysis; however MRI identified an epidural hematoma as the main source of pain. Other patients both in our study and the wider population may have coincidental fractures at sites distant to their pain, and many patients have multiple fractures of varying ages, but not all clinically symptomatic.[19] Those patients in our practice with these clinical scenarios who did not undergo vertebroplasty were not included in our database.

Our study was not undertaken to assess the efficacy of vertebroplasty although an analysis of outcomes using standard criteria would have added to the many retrospective case series and uncontrolled studies already published. These suggest that vertebroplasty is effective.[17] Recent randomized studies by Kallmes et al and by Buchbinder et al have suggested that the procedure is no more effective than placebo.[12,13]

Without certainty over the diagnosis of the age and level of all fractures treated with vertebroplasty in one of the randomized trials, the results from this randomized study are difficult to interpret. Kallmes states in his methodology that "MRI was only performed when the age of the fracture was not clear".[12] MRI was otherwise not a requirement for inclusion in the study. No data identifying how many of his patients underwent MRI are supplied. In patients who had MRI, the date of MRI relative to the date of procedure is not supplied. On the basis of our study and the studies described above, up to 50% of his patients who did not have MRI are likely to have had an incorrect level treated or a fracture not treated. Thus the results of the study by Kallmes et al[12] are likely to have underestimated the effect of vertebroplasty. The degree of error depends on the proportion of patients who underwent MRI immediately prior to their procedure.

Staples et al published a meta-analysis of the Kallmes et al[12] study combined with the study by Buchbinder et al[13] (in collaboration with these two authors) in an attempt to increase numbers for evaluation.[20] Clearly, any underestimate in the Kallmes et al study will have been perpetuated by this analysis.

The study by Buchbinder et al[13] did use MRI preoperatively and therefore does cast some doubt on the effectiveness of vertebroplasty. There have been many criticisms of this study on other fronts though. These include small numbers, inexperienced proceduralists, inconsistent procedural technique, long duration of pain in some patients, questionable significance of the fractures found (linear fracture in patients with long standing pain), and high incidence of complications compared to other studies.[21,22] Furthermore, the "sham procedure" has been criticized as not being a true placebo.[22] Nevertheless, it does suggest that further studies are required, and the point of our paper is to highlight the necessity of preprocedure MRI in the selection process.

Conclusion

MRI is essential in accurately diagnosing vertebral fractures and any studies of the treatment of vertebral fractures in which MRI was not a requirement for inclusion are likely to have misrepresented the effect of the treatment under study.

Disclosure

The authors report no conflicts of interest in this work.

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