**NATIONAL INSTITUTE FOR CLINICAL EXCELLENCE**

# INTERVENTIONAL PROCEDURES PROGRAMME

## Interventional procedure overview of Percutaneous vertebroplasty (methyl methacrylate)

### Introduction

This overview has been prepared to assist members of IPAC advise on the safety and efficacy of an interventional procedure previously reviewed by SERNIP. It is based on a rapid survey of published literature, review of the procedure by one or more specialist advisor(s) and review of the content of the SERNIP file. It should not be regarded as a definitive assessment of the procedure.

### Procedure name

Percutaneous vertebroplasty (methyl methacrylate)
- also known as percutaneous vertebroplasty, percutaneous polymethymethacrylate vertebroplasty, vertebroplasty, transpedicular polymethylmethacrylate vertebroplasty or by the acronyms PV or PTPV, PPV.

### SERNIP procedure number

76

### Specialty society

British Orthopaedic Association
British Society of Skeletal Radiologists

### Executive summary

Percutaneous vertebroplasty using polymethylmethacrylate (PMMA) appears to be efficacious in the treatment of pain associated with vertebral compression fractures of osteoporotic, metastatic or myeloma aetiology. It appears safe, with a low complication rate, although when complications occur they can be major, for example, pulmonary embolism or extravasation of cement into the spinal canal and spinal cord compression. A higher complication rate is observed in patients with metastatic disease, as those patients are compromised because of their disease. There is also a high death rate for patients with metastatic disease, but this is unrelated to the percutaneous vertebroplasty procedure.

### Indication(s)

Vertebral compression fractures are a common cause of pain and disability, and each year over 270,000 painful vertebral fractures are clinically diagnosed in the USA, and numbers are increasing.[1] Osteopenia associated with aging or chronic steroid use and metastatic disease are the most common aetiologies of vertebral compression fractures. All patients experience pain, which can be of varied duration. Most patients are treated conservatively with analgesics, bedrest and bracing, but a small percentage is left with persistent pain and limited mobility[2]. Percutaneous vertebroplasty

may be used to provide pain relief for patients with severe painful osteoporosis with loss of height and/or with compression fractures of the vertebral body and also for patients with symptomatic vertebral haemangioma and painful vertebral body tumours (metastasis and myeloma).

**Summary of procedure**

Percutaneous vertebroplasty is the injection of acrylic bone cement (polymethylmethacrylate; PMMA) into the vertebral body in order to relieve pain and/or stabilise the fractured vertebrae.

Percutaneous vertebroplasty may be performed under general anaesthetic or more commonly, using conscious sedation (e.g. fentanyl and midazolam) and local anaesthesia affecting the skin, subcutaneous tissue and the periosteum of the vertebral body into which the needle will be introduced. Access to the vertebrae is percutaneous, although an open technique has been described by Wenger *et al.*, 1999.[3] The patient is placed prone, and local anaesthesia is administered. A small dermatotomy is made with a scalpel and an 11 or 12 gauge trocar or needle, under fluoroscopic guidance, is passed into the vertebral body. Access is usually transpedicular but the approach may change according to the vertebra under treatment, i.e. a single side transpedicular approach may be used at the thoracic level to avoid pleural tears, whereas a paravertebral approach may be used at lumbar levels. Unipediculate access may be sufficient, but contralateral access may be needed to obtain good vertebral filling. Venography may be performed to assess the risk of cement leakage outside the vertebral body. Computer tomography (CT) may also be used intraoperatively, which may be beneficial for cervical vertebra to allow visualisation of the carotid vessels. The polymethylmethacrylate (PMMA) is mixed with barium sulphate (or tantalum or tungsten) to enhance radio-opacity. The cement is allowed to thicken to the consistency of toothpaste, to lessen the risk of extravasation upon injection. Visualisation of the cement during injection, via fluoroscopy (biplane or single plane), is essential to ensure safety, as every attempt should be made to avoid extravasation of PMMA. Once the procedure is complete, the patient should remain recumbent to prevent weight bearing whilst the PMMA hardens. The procedure is commonly performed on an outpatient basis, but the patients should be observed for up to three hours post-operatively.

Standard interventions include; radiation therapy to treat the pain of bone lesions, but the pain relieving effect can be delayed for up to 2 weeks and the effect on bone reconstruction is partial and requires several weeks to develop,[4] plus conservative therapy such as analgesia, bedrest and casts. The use of percutaneous vertebroplasty does not modify the long-term outcome compared to conservative therapy, but it facilitates analgesia and early mobility that is important in older patients who may suffer major complications with long-term bed rest.[5]

**Literature review**

A systematic search of MEDLINE, PREMEDLINE, EMBASE, Current Contents, PubMed, Cochrane Library and Science Citation Index using Boolean search terms was conducted, from the inception of the databases

until October 2002. The York Centre for Reviews and Dissemination, Clinicaltrials.gov, National Research Register, SIGLE, Grey Literature Reports (2002), relevant online journals and the Internet were also searched in October 2002. Searches were conducted without language restriction.

Articles were obtained on the basis of the abstract containing safety and efficacy data on percutaneous vertebroplasty in the form of randomised controlled trials (RCTs), other controlled or comparative studies, case series and case reports. Conference abstracts and manufacturer's information were included if they contained relevant safety and efficacy data. Foreign language papers were included if they contained safety and efficacy data and were considered to add substantively to the English language evidence base.

Studies were rejected for reporting no clinical outcomes, being review articles, or involving techniques other than vertebroplasty using PMMA. In the case of duplicate publications, the latest, most complete study was included. Studies were selected for extraction of data firstly if they were comparative, then case series were rated as to number of patients, breadth of study population (therefore multicentre studies were rated most highly) and length of follow-up. Included studies are highlighted in bold in the reference list. Studies for which data were not tabulated are listed in the annex following the reference list.

**List of studies found**

Total number of studies: 41

- Randomised controlled trials 0
- Systematic reviews 1
- Non-randomised comparative studies 2
- Case series 32
- Case reports 6

**RCTs in progress**

- UK based – "A randomised controlled trial of vertebroplasty for treatment of osteoporotic vertebral crush factors", currently ongoing (Dr Simon Dolin, Pain Service, St Richards Hospital, Spitalfield Lane, Chichester, PO19 4SE, West Sussex)

- Australian based – "Prospective, single site, randomised, controlled study to assess the performance of Cortoss Synthetic Cortical Bone Void Filler in percutaneous vertebroplasty compared to an injection with a local anaesthetic". Cortoss overcomes a number of limitations of PMMA as Cortoss is ready as soon as mixed and is of appropriate consistency. It does not contain volatile monomers (which may be the cause of cardiovascular and respiratory effects, and hypersensitivity with PMMA use), is inherently opaque and does not need to be mixed with barium sulphate or other radio-opaque materials, and has a lower exotherm reducing the risk of thermal necrosis. Cortoss is also biomechanically stronger than PMMA. (Robert Fraser, Clinical Professor and Head of Spinal Unit, Royal Adelaide Hospital, The University of Adelaide, SA, 5005, Australia).

- A randomised trial comparing the use of Cortoss to conservative medical treatment is also underway in Europe.

**Summary of key efficacy and safety findings**
See following tables;

**Abbreviations:**

| | |
|---|---|
| CT | computer tomography |
| N/A | not applicable |
| PV | percutaneous vertebroplasty |
| PMMA | polymethylmethacrylate |
| VAS | visual analogue scale |

| Authors, date, location, number of patients, length of follow-up, selection criteria | Key efficacy findings | Key safety findings | Appraisal/Comments |
|---|---|---|---|
| ***Systematic review*** | | | |
| **Westesson[6] 2001, USA**<br>726 patients<br><br>*Follow-up*: not stated<br><br>*Selection criteria*: N/A | Complete pain relief: 26%<br>Marked improvement: 58%<br>No improvement: 14% | *Cement leakage into:*<br>neural foramen 38/726 (5%)<br>paraspinal region 27/726 (4%)<br>spinal canal 21/726 (3%)<br>adjacent discs 116/726 (16%)<br><br>9/726 (1% of total) [4.5% of those with leakage] required decompressive surgery | *Potential for bias:* reported only as a conference abstract. No details given about number or type of studies.<br><br>*Outcome measures and their validity:* N/A<br><br>*Other comments:* |

| Study details | Key efficacy findings | Key safety findings | Appraisal/Comments |
|---|---|---|---|
| ***Non-randomised comparative studies*** | | | |
| **Gaughen *et al.*[7] 2002, USA**<br><br>Group 1; 24 consecutive patients with osteoporotic fractures at 42 vertebral levels between Aug 2000 and June 2001; all levels treated with venography prior to cement injection. Group 2; 24 consecutive patients with osteoporotic fractures at 42 vertebral levels without venography.<br><br>*Follow-up:* 1 month<br><br>*Selection criteria:* Retrospective review of consecutive vertebroplasty in patients with and without antecedent venography | *Clinical improvement at 1 month follow-up*<br>With pain improvement; Group 1; 19/20 (95%), Group 2; 21/22 (95%)<br>Without pain; Group 1; 14/20 (70%), Group 2; 14/22 (64%)<br>With preoperative impaired mobility; Group 1; 11/20 (55%), Group 2; 12/22 (55%)<br>With mobility improvement; Group 1; 11/11 (100%), Group 2; 12/12 (100%)<br>(No significant difference detected between group 1 and 2)<br><br>*Cement extravasation*<br>Group 1; 22/42 levels (52%) and Group 2; 28/42 (67%) not statistically significant (p=0.266). | Perforation of thecal sac in 1/84 levels (1%), causing a cerebrospinal fluid leak and the patient had a postprocedural headache and left-sided pain<br><br>No evidence of spinal cord compression or pulmonary embolism<br><br>Cardiovascular and respiratory parameters remained within normal ranges | *Potential for bias*: 20/24 (83%) Group 1 patients complied with 1 month follow-up. 22/24 (92%) Group 2 patients complied with 1 month follow-up. Total loss to follow-up 6/48 (12.5%).<br><br>*Outcome measures and their validity:* Pain (0-10) and mobility (0-5) ordinal scales were not validated.<br><br>*Other comments*. |

| Study details | Key efficacy findings | Key safety findings | Appraisal/Comments |
|---|---|---|---|
| **Kim *et al.*[8] 2002, USA**<br><br>Group 1; 24 patients (29 vertebra) treated with a standard bipediculate approach.<br>Group 2; 41 patients (68 vertebra) treated with a modified unipediculate approach.<br><br>*Follow-up:* not stated<br><br>*Selection criteria:* Retrospective review of consecutive cases of vertebroplasty between Jan 1999 and Sep 2000. Some patients were excluded for reasons stated in the text. Patients that met the inclusion criteria were telephoned and asked to identify their pre- and post-op. pain and medication usage. | *Pain relief*<br>achieved in 16/17 (94%) of Group 1 and 28/32 (88%) of Group 2. No significant difference detected in pain level in patients treated with either the bipediculate or unipediculate approach (p=0.65)<br><br>*Medication usage*<br>decreased in 10/17 (59%) of Group 1 and 16/32 (50%) of Group 2. Neither the percentage of patients with a decrease in medication level nor the mean decrease in medication level was significantly different between bipediculate or unipediculate approaches.<br><br>*Cement deposition*<br>achieved in all vertebrae with both the bipediculate and unipediculate approaches. Mean filling of the width of the vertebral half was not significantly different (p=0.19) between the two approaches. | None stated. | *Potential for bias:* Large number of patients excluded from study (Group 1: 24 down to 17 patients, Group 2: 41 down to 32 patients) – 8 patients lost to follow-up and therefore excluded, 4 patients underwent multilevel vertebroplasty and both unipediculate and bipediculate approaches were used, these were excluded. Imbalance between patient and vertebra numbers between treatment groups. Recall bias, with some patients unable recall to the exact extent of the pain. Conversions from unipediculate to bipediculate not recorded, which would falsely elevate the result of the unipediculate filling.<br><br>*Outcome measures and their validity:* 0-10 pain and 0-4 pain medication scales not validated. Pain was assessed quantitatively and qualitatively.<br><br>*Other comments:* |

| Study details | Key efficacy findings | Key safety findings | Appraisal/Comments |
|---|---|---|---|
| ***Case series*** | | | |
| **Gangi *et al.*[9] 1999, FRANCE**<br><br>187 patients (289 vertebral bodies) osteoporosis 105/187 (56%), haemangiomas 11/187 (6%), metastasis and myeloma 69/187 (37%), postsurgical consolidation 2/187 (1%).<br><br>*Maximum follow-up* was 7 years for osteoporosis (average 2.7 years, 1.2 years, average 7 months for tumoural lesions (metastasis and myeloma).<br><br>*Selection criteria*: not stated. | *Osteoporosis*<br>Satisfactory results were obtained in 82/105 (78%) of cases based on the reduction of analgesic doses<br><br>*Tumoural lesions*<br>Satisfactory results in 57/69 (83%) of cases based on the reduction of opiate doses<br><br>*Haemangioma*<br>Satisfactory results in 8/11 (73%) of cases | *Epidural leak*<br>14/187 (7.5%) - caused neuralgia in 3 cases without spinal cord compression.<br>Cement leaks towards the disc were observed in 15/187 (8%) of cases, without clinical consequence.<br>*Asymptomatic pulmonary embolism*<br>2/187 (1%)<br>*Inability to reinsert needle*<br>In 1/187 (0.5%) hardening of the glue didn't allow reinsertion of the needle and a paravertebral cement leak was detected. The glue fragment was extracted percutaneously two days later. | *Potential for bias:* No enough detail given.<br><br>*Outcome measures and their validity:* Not stated.<br><br>*Other comments:* |
| **McGraw *et al.*[10] 2002, USA**<br><br>100 patients (156 vertebroplasties) 92/100 (92%) osteoporotic, 5/100 (5%) neoplastic, 2/100 (2%) compression fractures and spinal canal stenosis, 1/100 (1%) osteogenesis imperfecta).<br><br>*Follow-up:* 6-44 months follow-up (mean 21.5 months)<br><br>*Selection criteria:* Prospective study of 100 consecutive patients over a 35 month period. | *Pain relief* - 12-24 hours post op.<br>97/100 (97%) reported improvement<br>3/100 (3%) reported no change.<br>longer-term follow-up<br>92/99 (93%) improved<br>7/99 (7%) no change<br>0/99 (0%) worse<br>Mean VAS score was significantly different ($p<0.0001$) between preop. to 21.5 months follow-up.<br><br>*Mobility*<br>92/99 (93%) improved ambulatory ability<br><br>90/99 (91%) were able to decrease their oral pain medication<br><br>99/99 (100%) were satisfied with the procedure and would undertake it again. | 1/100 (1%) sustained a sternal fracture while transferring herself from the stretcher to the procedure table<br><br>1/100 (1%) experienced a 12-hour radiculopathy. | *Potential for bias:* 1/100 (1%) was lost to follow-up<br><br>*Outcome measures and their validity:* The validity of 0-10 VAS pain scale and the questionnaire of the author's design was not stated.<br><br>*Other comments:* |

## Specialist advisor's opinion / advisors' opinions

*Specialist advice was sought from the British Orthopaedic Association and British Society of Skeletal Radiologists*

Percutaneous vertebroplasty is an established practice in some countries and in six centres in the UK, although is a novel technique elsewhere in the UK. It is estimated that less than 10% orthopaedic specialists/radiologists are performing the procedure, and is likely to be performed in a minority of hospitals. The potential impact on the NHS is likely to be moderate, as although the indications (spinal metastases and osteoporotic vertebral fractures) are common, they do not always cause uncontrollable pain. Currently symptomatic patients are treated. The main potential adverse effects of the procedure are extravasation of cement and spinal cord compression. Pulmonary embolism is rare, nerve damage <0.5% and infection <0.5%. Overall complication rate per indication is osteoporosis 1.3%, haemangioma 2.5% and metastases 10%. The procedure appears to be low risk in experienced hands. There is no training available in the UK but there is overseas. Advisors recommend that all cases are registered, as at present there frequency data are not available. In observational studies, the procedure appears to be effective for spinal metastases and osteoporotic fractures in 70-85% of cases. No RCTs have been performed, and there are practical difficulties as the intervention is offered as a "last resort", when other methods have failed. The procedure is reasonable easy to teach, but as there is no commercial interest in the procedure (unlike kyphoplasty which is the use of an inflatable bone tamp, manufactured by Kyphon Inc. Sunnyvale, USA, to compact the cancellous bone and increase vertebral height before PMMA is injected) it is harder to set up training. Two Advisors are trying to set up a RCT for vertebroplasty, but there may be difficulties as the Kyphon Company has funded a trial in the USA which closed due to poor recruitment as patients were not prepared to accept the alternative treatment (observation). It is understood that a trial is being established in Europe by Kyphon.

Only six centres in the UK are using the procedure and there is a strong feeling from those doing it that the previous SERNIP decision to 'ban' the procedure was not justified. Kyphoplasty is seen as expensive, possibly safety and efficacy remains to be proved. The advisors also suggested; 1) approach the Kyphon Company who have registered all their (kyphoplasty) interventions, 2) encourage NHS funding of the vertebroplasty trial.

## Issues for consideration by IPAC

The studies included in this overview show possibly lower complication rates than those stated by the specialists. However this is based on a limited number of studies, and not a full systematic review. The numbers quoted by the specialist advisors appear to be from Chiras *et al*., 1997.[11]

## References


1. Cooper C, Atkinson EJ, O'Fallon WM, Melton LJ, III. Incidence of clinically diagnosed vertebral fractures: a population-based study in Rochester, Minnesota, 1985-1989. *Journal of Bone & Mineral Research* 1992;**7**(2):221-227.

2. Karjalainen M, Aho AJ, Katevuo K. Painful spine after stable fractures of the thoracic and lumbar spine. What benefit from the use of extension brace? *Annales Chirurgiae et Gynaecologiae* 1991;**80**(1):45-48.

3. Wenger M, Markwalder TM. Surgically controlled, transpedicular methyl methacrylate vertebroplasty with fluoroscopic guidance. *Acta Neurochirurgica* 1999;**141**(6):625-631.

4. Cortet B, Cotten A, Boutry N, Dewatre F, Flipo RM, Duquesnoy B, Chastanet P, Delcambre B. Percutaneous vertebroplasty in patients with osteolytic metastases or multiple myeloma. *Revue du Rhumatisme (English Edition)* 1997;**64**(3):177-183.

5. Cyteval C, Sarrabere MP, Roux JO, Thomas E, Jorgensen C, Blotman F, Sany J, Taourel P. Acute osteoporotic vertebral collapse: open study on percutaneous injection of acrylic surgical cement in 20 patients. *AJR American Journal of Roentgenology* 1999;**173**(6):1685-1690.

6. **Westesson PA. Vertebroplasty: a meta analysis of results and complications. *Radiology* 221[Suppl. S], 617. 2001.**

7. **Gaughen JR, Jensen ME, Schweickert PA, Kaufmann TJ, Marx WF, Kallmes DF. Relevance of antecedent venography in percutaneous vertebroplasty for the treatment of osteoporotic compression fractures. *American Journal of Neuroradiology* 2002;23(4):594-600.**

8. **Kim AK, Jensen ME, Dion JE, Schweickert PA, Kaufmann TJ, Kallmes DF. Unilateral transpedicular percutaneous vertebroplasty: initial experience. *Radiology* 2002;222(3):737-741.**

9. **Gangi A, Dietemann JL, Guth S, Steib JP, Roy C. Computed tomography (CT) and fluoroscopy-guided vertebroplasty: Results and complications in 187 patients. *Seminars in Interventional Radiology* 1999;16(2):137-142.**

10. **McGraw JK, Lippert JA, Minkus KD, Rami PM, Davis TM, Budzik RF. Prospective Evaluation of Pain Relief in 100 Patients Undergoing Percutaneous Vertebroplasty: Results and Follow-up. *Journal of Vascular & Interventional Radiology* 2002;13(9):883-886.**

11. Chiras J, Depriester C, Weill A, SolaMartinez MT, Deramond H. Percutaneous vertebroplasties - technique and indications [French]. *Journal of Neuroradiology* 1997; **24**(1):45-59

**ANNEX: Studies that met the inclusion criteria but which were not tabulated.**

Amar AP, Larsen DW, Esnaashari N, Albuquerque FC, Lavine SD, Teitelbaum GP. Percutaneous transpedicular polymethylmethacrylate vertebroplasty for the treatment of spinal compression fractures. *Neurosurgery* 2001;**49**(5):1105-1114.

Barr JD, Barr MS, Lemley TJ, McCann RM. Percutaneous vertebroplasty for pain relief and spinal stabilization. *Spine* 2000;**25**(8):923-928.

Bobra S, Maus TP, Thielen KR, Wald JT, Everson S. Early outcomes in osteoporotic patients with painful vertebral body fractures treated with percutaneous vertebroplasty. Radiology 221[Suppl. S], 136. 2001.

Chen HL, Wong CS, Ho ST, Chang FL, Hsu CH, Wu CT. A lethal pulmonary embolism during percutaneous vertebroplasty. *Anesthesia & Analgesia 95(4):1060-2,* 2002.

Cortet B, Cotten A, Boutry N, Dewatre F, Flipo RM, Duquesnoy B, Chastanet P, Delcambre B. Percutaneous vertebroplasty in patients with osteolytic metastases or multiple myeloma. *Revue du Rhumatisme (English Edition)* 1997;**64**(3):177-183.

Cortet B, Cotten A, Boutry N, Flipo RM, Duquesnoy B, Chastanet P, Delcambre B. Percutaneous vertebroplasty in the treatment of osteoporotic vertebral compression fractures: an open prospective study. *Journal of Rheumatology* 1999;**26**(10):2222-2228.

Cotten A, Dewatre F, Cortet B, Assaker R, Leblond D, Duquesnoy B, Chastanet P, Clarisse J. Percutaneous vertebroplasty for osteolytic metastases and myeloma: effects of the percentage of lesion filling and the leakage of methyl methacrylate at clinical follow-up. *Radiology* 1996;**200**(2):525-530.

Cyteval C, Sarrabere MP, Roux JO, Thomas E, Jorgensen C, Blotman F, Sany J, Taourel P. Acute osteoporotic vertebral collapse: open study on percutaneous injection of acrylic surgical cement in 20 patients. *AJR American Journal of Roentgenology* 1999;**173**(6):1685-1690.

Diamond TH, Clark WA. Percutaneous vertebroplasty: a novel treatment for acute vertebral fractures. *Medical Journal of Australia* 2001;**174**(8):398-400.

Finch L, Cheng SG, Steinberg KP, Stern EJ. Polymethylmethacrylate pulmonary emboli. *Clinical Pulmonary Medicine* 2002;**9**(2):133-134.

Gangi A, Dietemann JL, Guth S, Steib JP, Roy C. Computed tomography (CT) and fluoroscopy-guided vertebroplasty: Results and complications in 187 patients. *Seminars in Interventional Radiology* 1999;**16**(2):137-142.

Gaughen JR, Jensen ME, Schweickert PA, Kaufmann TJ, Marx WF, Kallmes DF. Relevance of antecedent venography in percutaneous vertebroplasty for the treatment of osteoporotic compression fractures. *American Journal of Neuroradiology* 2002;**23**(4):594-600.

Grados F, Depriester C, Cayrolle G, Hardy N, Deramond H, Fardellone P. Long-term observations of vertebral osteoporotic fractures treated by percutaneous vertebroplasty. *Rheumatology* 2000;**39**(12):1410-1414.

Harrington KD. Major neurological complications following percutaneous vertebroplasty with polymethylmethacrylate : a case report. *Journal of Bone & Joint Surgery* 2001;**83-A**(7):1070-1073.

Heini PF, Walchli B, Berlemann U. Percutaneous transpedicular vertebroplasty with PMMA: operative technique and early results. A prospective study for the treatment of osteoporotic compression fractures. *European Spine Journal* 2000;**9**(5):445-450.

Jensen ME, Evans AJ, Mathis JM, Kallmes DF, Cloft HJ, Dion JE. Percutaneous polymethylmethacrylate vertebroplasty in the treatment of osteoporotic vertebral body compression fractures: Technical aspects. *American Journal of Neuroradiology* 1997;**18**(10):1897-1904.

Kallmes DF, Schweickert PA, Marx WF, Jensen ME. Vertebroplasty in the mid- and upper thoracic spine. *Ajnr: American Journal of Neuroradiology* 2002;**23**(7):1117-1120.

Kaufmann TJ, Jensen ME, Schweickert PA, Marx WF, Kallmes DF. Age of fracture and clinical outcomes of percutaneous vertebroplasty. *Ajnr: American Journal of Neuroradiology* 2001;**22**(10):1860-1863.

Kim AK, Jensen ME, Dion JE, Schweickert PA, Kaufmann TJ, Kallmes DF. Unilateral transpedicular percutaneous vertebroplasty: initial experience. *Radiology* 2002;**222**(3):737-741.

Kyung SR, Chun KP, Moon CK, Joon KK. Dose-dependent epidural leakage of polymethylmethacrylate after percutaneous vertebroplasty in patients with osteoporotic vertebral compression fractures. *Journal of Neurosurgery* 2002;**96**(1 SUPPL.):56-61.

Lin CN, Wu YC, Wang NP. Transpedicular PMMA vertebroplasty for the treatment of osteoporotic vertebral compression fracture. *Formosan Journal of Surgery* 2002;**35** (2):74-79.

Martin JB, Jean B, Sugiu K, San Millan RD, Piotin M, Murphy K, Rufenacht B, Muster M, Rufenacht DA. Vertebroplasty: Clinical experience and follow-up results. *Bone* 1999;**25**(SUPPL. 1):11S-15S.

Maynard AS, Jensen ME, Schweickert PA, Marx WF, Short JG, Kallmes DF. Value of bone scan imaging in predicting pain relief from percutaneous vertebroplasty in osteoporotic vertebral fractures. *Ajnr: American Journal of Neuroradiology* 2000;**21**(10):1807-1812.

McGraw JK, Lippert JA, Minkus KD, Rami PM, Davis TM, Budzik RF. Prospective Evaluation of Pain Relief in 100 Patients Undergoing Percutaneous Vertebroplasty: Results and Follow-up. *Journal of Vascular & Interventional Radiology 13(9):883-6,* 2002.

Miranda C, Ceratto R, Ferrario A, Cohen J, Lyluk P. Percutaneous vertebroplasty with acrylic cement: indications and results in painful osteoporotic fractures. *Bone* 2002;**36**(6):943.

O'Brien JP, Sims JT, Evans AJ. Vertebroplasty in patients with severe vertebral compression fractures: a technical report. *Ajnr: American Journal of Neuroradiology* 2000;**21**(8):1555-1558.

Padovani B, Kasriel O, Brunner P, PerettiViton P. Pulmonary embolism caused by acrylic cement: a rare complication of percutaneous vertebroplasty. *Ajnr: American Journal of Neuroradiology* 1999;**20**(3):375-377.

Peh WC, Gilula LA, Peck DD. Percutaneous vertebroplasty for severe osteoporotic vertebral body compression fractures. *Radiology* 2002;**223**(1):121-126.

Peters KR, Guiot BH, Martin PA, Fessler RG. Vertebroplasty for osteoporotic compression fractures: current practice and evolving techniques. *Neurosurgery 51(5 Suppl):96-103,* 2002.

Ratliff J, Nguyen T, Heiss J. Root and spinal cord compression from methylmethacrylate vertebroplasty. *Spine* 2001;**26**(13):E300-E302.

Ruefenacht DA, Martin J, Jean B, Muster M, Murphy K, Piotin M. Vertebroplasty: Clinical results and follow-up. Radiology 213P[1357], 416. 1999.

Scroop R, Eskridge J, Britz GW. Paradoxical cerebral arterial embolization of cement during intraoperative vertebroplasty: case report. *Ajnr: American Journal of Neuroradiology* 2002;**23**(5):868-870.

Tsou IY, Goh PY, Peh WC, Goh LA, Chee TS. Percutaneous vertebroplasty in the management of osteoporotic vertebral compression fractures: initial experience. *Annals of the Academy of Medicine, Singapore* 2002;**31**(1):15-20.

Uppin AA, Hirsch JA, Cntenera LV, Pfeifer BA, Pazinos AG, Choi IS. Vertebral body re-fracture with percutaneous vertebroplasty: our experience with an under-reported phenomenon. *Radiology* 2001;221[Suppl. S], 616-617.

Vasconcelos C, Gailloud P, Beauchamp NJ, Heck DV, Murphy KJ. Is percutaneous vertebroplasty without pretreatment venography safe? Evaluation of 205 consecutives procedures. *Ajnr: American Journal of Neuroradiology* 2002;**23**(6):913-917.

Weill A, Chiras J, Simon JM, Rose M, SolaMartinez T, Enkaoua E. Spinal metastases: indications for and results of percutaneous injection of acrylic surgical cement. *Radiology* 1996;**199**(1):241-247.

Wenger M, Markwalder TM. Surgically controlled, transpedicular methyl methacrylate vertebroplasty with fluoroscopic guidance. *Acta Neurochirurgica* 1999;**141**(6):625-631.

Westesson PA. Vertebroplasty: a meta analysis of results and complications. *Radiology* 2001; 221[Suppl. S], 617.

Wong TY, Hsieh PC, Chan WB, Tzeng BC, Chen CH. Osteoporosis compression fracture of vertebral bodies with percutaneous vertebroplasty treatment. *Chinese Journal of Radiology* 2002;**27**(2):55-58.

Zoarski GH, Snow P, Olan WJ, Stallmeyer MJ, Dick BW, Hebel JR, De Deyne M. Percutaneous vertebroplasty for osteoporotic compression fractures: quantitative prospective evaluation of long-term outcomes. *Journal of Vascular & Interventional Radiology* 2002;**13**(2:Pt 1):t-48.