CIRSE Office Vienna, Neutorgasse 9/4a, 1010 Vienna, Austria
P +43 1 904 2003, F +43 1 904 2003 30, info@cirse.org, www.cirse.org

QUALITY ASSURANCE GUIDELINES FOR PERCUTANEOUS VERTEBROPLASTY

Afshin Gangi[1], Tarun Sabharwal[2], Farah G. Irani[2], Xavier Buy[1], Jose P. Morales[2], Andreas Adam[2]

1. Department of Radiology, University Louis Pasteur, Strasbourg, France.
2. Department of Radiology, Guy's and St Thomas' Foundation Hospital NHS Trust London, UK

INTRODUCTION

Vertebral compression fracture (VCF) is an important cause of severe debilitating back pain, adversely affecting quality of life, physical function, psychosocial performance, mental health and survival [1, 2]. Its diverse aetiology encompasses osteoporosis, neoplastic vertebral involvement (myeloma, metastasis, lymphoma, haemangioma) and osteonecrosis. There are more than 700,000 osteoporotic VCFs per year in the United States [3], but there is no published data available as to the incidence of VCFs in the European Union.

The lifetime risk of VCF is 16% for women and 5% for men and the incidence of osteoporotic fractures is anticipated to increase four fold worldwide in the next 50 years [3]. In addition, patients with VCFs have a 23% risk of mortality compared to age matched controls without VCFs. This is primarily related to compromised pulmonary function as a result of thoracic, as well as lumbar fractures [4, 5].

Irrespective of aetiology, treatment has largely been conservative, with bed rest, narcotic analgesics, biphosphonates and back bracing for several weeks. Percutaneous vertebroplasty (PVP) is a minimally invasive technique, in which a painful fractured vertebral body is internally splinted with image guided percutaneous injection of polymethylmethacrylate (PMMA) cement.

Originally described by Deramond et al in 1987, for the treatment of an aggressive vertebral haemangioma [6], the technique has evolved to become a standard of care for VCFs.

DEFINITION

VCF is the reduction in individual vertebral body height by 20% or 4mm [7].

Percutaneous vertebroplasty is a therapeutic, image guided procedure that involves injection of radio-opaque cement into a partially collapsed vertebral body, in an effort to relief pain and provides stability.

INDICATIONS (8-37)

- Painful osteoporotic VCF refractory to medical treatment. Failure of medical therapy is defined as minimal or no pain relief with the administration of physician prescribed analgesics for 3 weeks or achievement of adequate pain relief with only narcotic dosages that induce excessive intolerable sedation, confusion or constipation [24]
- Painful vertebrae due to aggressive primary bone tumours like hemangiomas and giant cell tumour [25, 26]. In hemangiomas treatment is aimed at pain relief, strengthening of bone and devascularization. It can be used alone or in combination with sclerotherapy, especially in cases of epidural extension causing spinal cord compression [27, 28]
- Painful vertebrae with extensive osteolysis due to malignant infiltration by multiple myeloma, lymphoma and metastasis [10, 12, 29-35]. Because PVP is only aimed at treating the pain and consolidating the weight bearing bone, other specific tumour treatment should be given in conjunction for tumour management
- Painful fracture associated with osteonecrosis (Kummel's Disease) [36]
- Conditions in which reinforcement of the vertebral body or pedicle is desired prior to a posterior surgical stabilisation procedure [37]
- Chronic traumatic fracture in normal bone with non-union of fracture fragments or internal cystic changes

CONTRA INDICATIONS

ABSOLUTE:

- Asymptomatic vertebral body compression fracture
- Patient improving on medical treatment
- Osteomyelitis, discitis or active systemic infection
- Uncorrectable coagulopathy
- Allergy to bone cement or opacification agents
- Prophylaxis in osteoporotic patients

RELATIVE:

- Radicular pain
- Tumour extension into the vertebral canal or cord compression
- Fracture of the posterior column – increased risk of cement leak
- Vertebral collapse >70% of body height – needle placement may be difficult
- Spinal canal stenosis - asymptomatic retropulsion of a fracture fragment causing significant spinal canal compromise
- Patients with more than five metastases or diffuse metastases
- Lack of surgical backup and monitoring facilities [38]

PATIENT SELECTION

A multidisciplinary team consisting of a radiologist, spine surgeon and referring physician (rheumatologist or oncologist) must come to a consensus on which patients should undergo this procedure and to ensure appropriate adjuvant therapy and follow-up [39]. A detailed clinical history and examination, with specific emphasis on the neurological signs and symptoms, should be performed to confirm the underlying VCF as the cause of debilitating back pain and rule out other causes like degenerative spondylosis, radiculopathy and neurological compromise. This should be correlated with the imaging findings [1, 9]. In osteoporosis and

metastatic disease, fractures may be present at multiple levels, not all of which require treatment with PVP. Manual examination under fluoroscopy localises and identifies the painful vertebral body [9].

TIME OF INTERVENTION

The ideal candidate for PVP is one who presents within four months of a fracture, has midline non-radiating back pain that increases with weight bearing and which is exacerbated by manual palpation of the spinous process of the involved vertebra [8].

Ideally patients should have at least 3 weeks of conservative treatment, failure of which should prompt one to consider PVP. Intervention within days of a painful VCF is considered in patients at high risk for decubitus complications like thrombophlebitis, deep vein thrombosis, pneumonia and decubitus ulcer [9, 40].

There is increasing clinical data now available on the usefulness of PVP in the treatment of chronic osteoporotic fractures more than a year old [41-43].

IMAGING

Preoperative planning requires radiographic studies to identify the fracture, estimate the duration of fracture, define fracture anatomy, assess posterior vertebral body wall deficiency [1] and exclude other causes of back pain like facet arthropathy, spinal canal stenosis or disc herniation [2] and determine the relevant level/s in cases of multiple fractures.

Radiographs of the spine give an overview of multilevel involvement of the vertebral column by the disease process, help assess the extent of vertebral collapse (grading of fracture) and guide further imaging investigation.

An MRI is a must in all patients considered for PVP as it provides both functional and anatomical information. T1, T2 and STIR sequences in axial and sagittal planes are required.

Acute, subacute, and non-healed fractures are hypo intense on T1W images and hyper intense on T2W and STIR sequences because of marrow oedema [2, 40]. Further MR helps differentiate benign from malignant infiltration and infection [1].

Bone scans are useful in determining the age of a fracture. An increased uptake of tracer “hot scan,” is highly predictive of a positive clinical response following PVP [2, 44].

If there is any doubt regarding the intactness of the posterior vertebral wall, a limited CT scan through the intended level/s should be performed [2]. It will also provide information regarding the location and extent of the lytic process, the visibility and degree of involvement of the pedicles, the presence of epidural or foraminal stenosis caused by tumour extension or retropulsed bone fragment which can increase the likelihood of complications.

In addition, if the MR is suggestive of healing of a compression fracture by sclerosis, a confirmatory CT scan should be performed, as needle placement and injection of PMMA in such cases will be difficult and yields suboptimal radiological and clinical results [2].

PRE-PROCEDURE

The treating radiologist should arrange for a pre-procedural consultation, with the patient and family (if so desired by the patient). The procedure, intended benefits, complications and success rates must be discussed in detail with the patient and informed consent obtained.

Anaesthesia consult should be arranged prior to the procedure date.

A complete blood count, coagulation screen and inflammatory markers (C Reactive Protein) should be performed.

TECHNIQUE

The procedure can be performed under local anaesthesia and sedo-analgesia [24, 45-47] or general anaesthesia [48,49]. Intra-procedural antibiotic cover (eg. Cefazolin 1 gram) is mandatory in immuno-compromised patients, however at present, in other patient groups there is no clear consensus. Pulse, oxygen saturation and blood pressure are monitored throughout the procedure. Strict asepsis is maintained.

A prone position is used for the thoracic and lumbar vertebrae and a supine position for the cervical region.

The classical transpedicular route is preferred in the thoracic and lumbar vertebrae as it is inherently safe. This can be performed either by a unipedicular or bipedicular approach. An intercostovertebral route is useful in the thoracic spine when the pedicle is too small or destroyed. It is associated with a higher risk of pneumothorax and paraspinal haematoma. The postero-lateral approach is an alternative in the lumbar vertebrae but is seldom use. In the cervical vertebrae antero-lateral approach is used. The needle path should avoid the carotid jugular complex.

Using dual guidance or bi-plane fluoroscopy, the needle is tapped into position using a hammer as it provides better control [37].

Bi-plane fluoroscopy guidance

The appropriate radiographic profile for pedicular approach is a straight antero-posterior view with 5-10 degree angulation, in which the pedicle appears oval. For an optimal approach the entry point and its

distance from the midline can be measured on the axial CT or MR images. Using AP and lateral screening the needle is advanced through the upper and lateral aspect of the pedicle because a breach in these locations is less significant than along the inferior or medial margin where there is greater risk of injury to the spinal cord and nerve roots. The tip is positioned in the anterior part of the vertebral body using lateral fluoroscopy, with the shaft of the needle maintained parallel to the superior and inferior endplates. With this technique, the tip is positioned in the ipsilateral half of the vertebral body resulting in a bipedicular approach for optimal filling of the vertebrae.

The use of a bevelled needle allows for precise placement. After penetration of the cortex within the pedicle, the bevel of the needle is rotated towards the midline allowing medial positioning. This allows bilateral filling of the vertebral body obviating the need for bi-pedicular approach.

Dual guidance

The combination of CT and fluoroscopy allows for precise needle placement (particularly in upper thoracic vertebrae, tumour cases and difficult cases), reduces complications, and increases the comfort of the operator, as it allows for visualization in three dimensions with exact differentiation of anatomic structures. Fluoroscopy is provided by placing a mobile C-arm in front of the CT gantry. Use of CT allows for precise medial positioning of the needle tip in the anterior third of the vertebral body, thus allowing complete vertebral fill and no need for a contralateral access. Once satisfactory positioning of the needle is obtained, the imaging mode is switched to fluoroscopy for real time visualization of cement injection.

Value of vertebral venography

Vertebral venography has been advocated for the identification of potential routes of cement extravasation. However, as the physical properties of the cement are different from those of iodinated contrast media, this objective is not always achieved. Therefore, for routine cases it is not generally performed and reserved for hyper vascular lesions with overflow of blood [50].

Cement Injection

The older generation cements were not sufficiently radio-opaque for good visualisation during PVP and hence barium sulphate, tungsten or tantalum was added to increase the radio-opacity. This addition was noted to interfere with the polymerisation of the cement and alter its chemical properties.

Radio-opacity is an important feature of cement because it allows for good visualisation of the cement during injection and hence early and easy detection of leaks. The new generation of cements are intrinsically radio-opaque.

Cement is prepared once the needle is in position [50]. A closed mixing system is advocated as it avoids cement contamination, excludes the inclusion of air bubbles in cement which can reduce its strength and provides homogenous mixing [47]. During the first 30 to 50 seconds the cement is very thin in consistency [50]. It then becomes pasty and thick. It is in this pasty polymerisation phase that the cement is injected as that reduces the risk of venous intravasation.

Injection should be performed either using a dedicated injection set (eg. from Optimed; Allegiance; Cook; Stryker) or a 2ml luer lock syringe. The injection sets allow aspiration and direct injection of cement in continuous flow and with minimal effort [50]. Although the use of the injection sets increases the expense of the procedure, it is safer than free hand injection.

Injection of cement is done under continuous lateral fluoroscopic control. The lateral projection is preferred as it allows for early detection of epidural leak. Intermittent AP screening should be done to rule out lateral leaks. If bi-plane fluoroscopy is available, the injection can be monitored in AP and lateral projection simultaneously.

The risk of cement leakage is particularly high at the beginning of cement injection. The operator should be very careful during the injection of the first drops of cement. If a leak is detected the injection is immediately stopped, and using the injection set the pressure can be reversed. Waiting for 30 to 60 seconds will allow the cement to harden and seal the leak. If on further injection, the leak persists the needle position and / or the bevel direction should be modified. If the leak still continues, the injection is terminated and the needle

removed. If incomplete fill of the vertebral body is obtained, the contra lateral pedicle is accessed and completion of fill achieved.

The cement injection is stopped when the anterior two-thirds of the vertebral body is filled and the cement is homogenously distributed on both sides and between both end plates. The mandarin of the needle is replaced under fluoroscopy control, before the cement begins to set and the needle is then carefully removed [50].

The effective working time with the cement is 8 to 10 minutes after mixing, (room temperature 20° C) following which it begins to set [50]. However, some new cements have longer setting times.

In patients with osteoporosis or hemangiomas, 2.5 to 4 ml of cement provide optimal filling of the vertebra, and achieves both consolidation and pain relief. In tumour disease, where the aim of vertebroplasty is relief of excruciating pain, smaller volumes (1.5-2.5ml) are usually sufficient [50].

POST-PROCEDURE CARE

Before removing the patient from the table, the operator should wait for cement hardening which is indicated by the setting of the rest of the cement in the mixing bowl.

The patient is maintained in recumbent position for two hours following the procedure and can then be mobilised. (Ninety percent of the cements ultimate strength is obtained in one hour.)

Vital signs and neurological evaluations (focussed on the extremities) are monitored every fifteen minutes for the first hour, then half hourly for the next two hours.

An immediate evaluation of the patient's condition must be undertaken if there is any increase in pain, change in vital signs or deterioration of the neurological condition. If neurological deterioration occurs, a detailed neurological examination carried out by a specialist is followed by a thin section CT scan of the level/s treated to look for spinal cord or nerve root compression by extravasated cement which may require urgent neurosurgical decompression.

Non steroidal or steroidal anti-inflammatory drugs can be used for two to four days after vertebroplasty to minimise the inflammatory reaction to the heat of polymerisation of acrylic bone cement.

COMPLICATIONS

Complications can be grouped into minor and serious adverse reactions.

Minor adverse reactions are defined as unexpected or undesirable clinical occurrences that require no immediate or delayed surgical intervention [9, 24].

Serious adverse reaction is the occurrence of an unexpected or undesirable clinical event, which requires surgical intervention or results in death or significant disability.

Published data has placed the complication rates in osteoporotic fractures treated with PVP at <1% and in malignant fractures at <10 % [36].

Centres planning on starting a PVP program should aim at keeping their complication rates below the published rates. A procedure threshold for all complications for PVP performed for osteoporotic indications is 2% and malignant indications are 10% [36].

Cement leakage

It is often asymptomatic [51]. Transient neurological deficit has an incidence of 1% in osteoporotic patients and 5% in patients with malignant aetiology, seldom persists beyond 30 days or requires surgery.

Permanent neurological deficit is defined as symptoms lasting >30 days and which requires surgery. It has not been reported in patients treated for osteoporosis but in neoplastic aetiology has an incidence of 2% [36].

Routes of cement leakage:

- Epidural space and neural foramina: It can produce radiculopathy and paraplegia as a result of nerve root and cord compression respectively. Radiculopathy is a minor adverse reaction. It occurs as a result of cement contact with the emergent nerve root and heating of the nerve tissue during polymerization of the cement. To avoid this complication, a spinal needle should be immediately positioned in the foramina and normal saline injected slowly to cool the nerve root. This radiculopathy may require a brief course of non-steroidal anti-inflammatory agents, oral steroids or local steroid injection in the affected area. Cord compression is a serious complication and requires urgent neurosurgical decompression to prevent neurological sequelae.

- Disc space and paravertebral tissue: it is usually of no clinical significance. However, in severe osteoporosis, large disc leaks could lead to collapse of the adjacent vertebral bodies.
- Perivertebral venous plexus: It can result in pulmonary embolism, which is usually peripheral and asymptomatic [45] and rarely central causing infarction [52, 53]. Paradoxical cerebral embolisation has been reported.

Infection

It occurs in less than 1%.

Fracture of ribs, posterior elements or pedicle

Incidence is <1%. It is considered a minor complication.

Risk of collapse of the adjacent vertebral body

It has a reported incidence of 12.4% [46] and an odds ratio of 2.27 [54].

Allergic reaction

It is to the cement and is characterised by hypotension and arrhythmias.

Bleeding from the puncture site

It is associated with localised pain and tenderness, which resolves in 72 hours. It is minimised by 5 minutes of compression once the needle is removed.

Complications reported have usually resulted from poor technique and patient selection, namely due to:

- Injection of cement in its liquid phase resulting in venous intravasation and bony extravasation
- Injection at multiple levels (It is advised not to treat more than three - four levels at one sitting [40, 45])
- Incorrect positioning of the needle tip (eg. in a basivertebral vein or close to the posterior wall)
- Treatment of highly vascular lesions like metastasis from thyroid and renal cancer

OUTCOME MEASURES

They determine the success rate of the procedure and are based on the following criteria.

CRITERIA	SUCCESS RATE
1. *Pain relief* • Acute osteoporotic fracture (within 72 hours) • Chronic osteoporotic fractures (onset is delayed) • Malignant fractures • Haemangiomas	90% [13, 14, 24, 55,56] 80% [42] 60-85% [12, 14, 30, 33, 34] 80% [14,57]
2. *Increased mobility* • Acute osteoporotic fracture • Chronic osteoporotic fracture	93% [24] 50% [42]
3. *Reduced requirement for analgesics*	91% [24]

QUALIFICATION AND RESPONSIBILITIES OF PERSONNEL

An experienced operator, who has been adequately trained in the procedure, should perform PVP. In addition, it is the responsibility of the operator to monitor the progress of patients, report adverse effects and conduct audit [38]. A PVP programme should be set up and run in an institute that has a spine surgery unit, to deal with any procedure related complications. A multidisciplinary team approach is the key to the success of the program resulting in good patient selection, post procedural care and follow up with fewer complications.

EQUIPMENT SPECIFICATIONS

The procedure is best performed in the interventional radiology suite rather than in the operative theatre, as the fixed fluoroscopic equipment is of better imaging quality than the mobile C-arm. High quality fluoroscopy should be available for adequate visualisation of the cement during injection, for early detection of leaks.

It is feasible and safe to use a single plane system as long as the operating physician recognises the necessity of visualisation in multiple planes PVP to ensure a safe procedure [47].

In addition, some radiological suites may have access to biplane fluoroscopy equipment, which permits rapid alternation between imaging planes without complex equipment moves and projection realignment [47].

REFERENCES

1. Phillips FM. (2003) Minimal invasive treatment of osteoporotic vertebral compression fractures. Spine 28(s):45-53.

2. Bernadette Stallemeyer MJ, Zoarski GH, Obuchowski AM. (2003) Optimising patient selection in percutaneous vertebroplasty. J Vasc Interv Radiol 14:683-696.
3. Riggs BL, Melton LJ. (1995) The worldwide problem of osteoporosis: insights afforded by epidemiology. Bone 17(suppl):505-511.
4. Uthoff HK, Jawaroski ZF. (1978) Bone loss in response to long term immobilisation. J. Bone Joint Surg [Br] 60:420-429.
5. Leech JA, Dulberg C, Kellie S, et al. (1990) Relationship of lung function to severity of osteoporosis in women. Am Rev Respir Dis 141:68-71.
6. Galibert P, Deramond H, Rosat P, et al. (1987) Preliminary note on the treatment of vertebral angioma by percutaneous acrylic vertebroplasty. Neurochirurgie 33:166-168.
7. Black DM, Palermo L, Nevitt MC, et al. (1999) Defining incident vertebral deformity: a prospective comparison of several approaches. The study of osteoporotic fractures research group. J Bone Miner Res 14:90-101.
8. Gangi A, Guth S, Imbert JP, et al. (2003) Percutaneous Vertebroplasty: Indications, Technique, and Results. Radiographics 23:10e; published online as 10.1148/rg.e10
9. Zoarski GH, Snow P, Olan WJ, et al. (2002) Percutaneous vertebroplasty for osteoporotic compression fractures: Quantitative Prospective Evaluation of Long-term Outcomes. J Vasc Interv Radiol 13:139-148.
10. Kaemmerlen P, Thiesse P, Bouvard H et al. (1989) Vertebroplastie percutanee dans le traitement des metastases: technique et resultants. J Radiol 70: 557-562.
11. Gangi A, Kastler BA, Dietman JL. (1994) Percutaneous vertebroplasty guided by a combination of CT and fluoroscopy. Am J Neuroradiology 15:83-86.

12. Weill A, Chiras J, Simon JM, et al. (1996) Spinal metastasis: indications for and results of percutaneous injection of acrylic surgical cement. Radiology 199:241-247.
13. Barr JD, Barr MS, Lemley TJ, et al. (2000) Percutaneous vertebroplasty for pain relief and spinal stabilization. Spine 25(8): 923-928.
14. Deramond H, Depriester C, Galibert P, et al. (1998) Percutaneous vertebroplasty with polymethylmethacrylate. Technique, indications and results. Radiol Clin North Am 36:533-546.
15. Cyteval C, Sarrabere MPB, Roux JO, et al. (1999) Acute osteoporotic vertebral collapse: open study on percutaneous injection of acrylic surgical cement in 20 patients.Am J Roentgenol 173: 1685-1690.
16. Gangi A, Dietemann JL, Schultz A, et al. (1996) Interventional radiologic procedures with CT guidance in cancer pain management. Radiographics 16:1289-1304.
17. Deramond H. (1991) La neuroradiologie interventionnelle. Bull Acad Natl Med 175:1103-1112.
18. Gangi A, Kastler B, Klinkert A, et al. (1995) Interventional radiology guided by a combination of CT and fluoroscopy: technique, indication and advantages. Semin Intervent Radiol 12:4-14.
19. Gangi A, Dietemann JL, Dondelinger RF. (1994) Tomodensitométrie interventionnelle Paris, France: Vigot 233-246.
20. Deramond H, Depriester C, Toussaint P, et al. (1997) Percutaneous vertebroplasty. Semin Musculoskelet Radiol 1:285-296.
21. Deramond H, Wright NT, Belkoff SM. (1999) Temperature elevation caused by bone cement polymerization during vertebroplasty. Bone 25(2 suppl):17S-21S.
22. Mathis JM, Petri M, Naff N. (1998) Percutaneous vertebroplasty treatment of steroid-induced osteoporotic compression fractures. Arthritis Rheum 41: 171-175.
23. Gangi A, Dietemann JL, Guth S, et al. (1999) Computed tomography and fluoroscopy-guided vertebroplasty: results and complications in 187 patients. Semin Intervent Radiol 16:137-141.
24. Kevin McGraw J, Lippert JA, Minkus KD, et al. (2002) Prospective evaluation of pain relief in 100 patients undergoing percutaneous vertebroplasty: Results and follow up. J Vasc Interv Radiol 13:883-886.

25. Cortet B, Cotton A, Deprez X, et al. (1994) Value of vertebroplasty combined with surgical decompression in the treatment of aggressive spinal angioma. Rev Rhum Ed Fr; 61: 16-22.
26. Ide C, Gangi A, Rimmelin A, et al. (1996) Vertebral haemangioams with spinal cord compression: the place of preoperative percutaneous vertebroplasty with methyl methacrylate. Neuroradiology; 38: 585-589.
27. Gangi A, Guth S, Imbert JP et al. (2002) Percutaneous bone tumour management. Seminars in Interventional Radiology 19(3):279-286.
28. Cotten A, Deramond H, Cortet B, et al. (1996) Preoperative Percutaneous injection of methyl methacrylate and N-butyl cyanoacrylate in vertebral haemangiomas. Am J Neuroradiol 17:137-142.
29. Murphy KJ, Deramond H. (2000) Percutaneous vertebroplasty in benign and malignant disease. Neuroimaging Clin N Am; 10: 535-545.
30. Shimony JS, Gilula LA, Zelle AJ, et al. (2004) Percutaneous vertebroplasty for malignant compression fractures with epidural involvement. Radiology 2004; 232: 846-853.
31. Jensen ME, Kallmes DE. (2002) Percutaneous vertebroplasty in the treatment of malignant spine disease. Cancer J; 8: 194-206.
32. Deramond H, Galibert P, Debussche C. (1991) Vertebroplasty. Neuroradiology 33(s): 177-178.
33. Cortet B, Cotten A, Boutry N, et al. (1997) Percutaneous vertebroplasty in patients with osteolytic metastases or multiple myeloma. Rev Rhum Engl Ed 64:177-183.
34. Cotten A, Dewatre F, Cortet B, et al. (1996) Percutaneous vertebroplasty for osteolytic metastasis and myeloma: effects of percentage of lesion filling and the leakage of methyl-methacrylate at clinical follow up. Radiology 200:525-530.
35. Dearmond H, Depriester C, Toussaint P. (1996) Vertebroplastie et radiologie interventionnelle percutanee dans les metastases osseuses. Technique, indications, and contre-indications. Bull Cancer 83:277-282.
36. Kevin McGraw J, Cardella J, Barr JD, et al. (2003) Society of Interventional Radiology Quality Improvement Guidelines for Percutaneous Vertebroplasty. J Vasc Interv Radiol 14:827-831.
37. Sabharwal T, Gangi A. (2004) Percutaneous Vertebroplasty. CME Radiology 4(2):71-75.

38. Peh WCG, Gilula LA. (2003) Percutaneous vertebroplasty: Indications, contraindications and technique. The British Journal of Radiology 76:69-75.

39. National Institute of Clinical Excellence (NICE). (2003) Percutaneous Vertebroplasty. Consultation document. http://www.nice.org.uk/cms/ip/ipcat.aspx?o=56770

40. Mathis JM, Barr JD, Belkoff SM, et al. (2001) Percutaneous vertebroplasty: A developing standard of care for vertebral compression fractures. AJNR Am J Neuroradiol 22:373-381.

41. Kaufmann TJ, Jensen ME, Schweickert PA, et al. (2001) Age of fracture and clinical outcome of percutaneous vertebroplasty. AJNR Am J Neuroradiol 22:1860-1863.

42. Brown DB, Gilula LA, Sehgal M, et al. (2004) Treatment of chronic symptomatic vertebral compression fractures with percutaneous vertebroplasty. AJR 182:319-322.

43. Garfin SR, Reilley MA. (2002) Minimally invasive treatment of osteoporotic vertebral body compression fractures. The Spine Journal 2:76-80.

44. Maynard AS, Jensen ME, Schweickert PA, et al. (2000) Value of bone scan imaging in predicting pain relief from percutaneous vertebroplasty in osteoporotic vertebral fractures. Am J Neuroradio 21:1807-1812.

45. Scroop R, Eskridge J, Britz GW. (2002) Paradoxical cerebral arterial embolization of cement during intra-operative vertebroplasty: Case report. AJNR Am J Neuroradiol 23:868-870.

46. Uppin AA, Hirsch JA, Centenera LV, et al. (2003) Occurrence of new vertebral body fracture after Percutaneous Vertebroplasty in patients with Osteoporosis. Radiology 226:119-124.

47. Mathis JM, Wong W. (2003). Percutaneous Vertebroplasty: Technical Considerations. J Vasc Interv Radiol 14:953-960.

48. White SM. (2002) Anaesthesia for Percutaneous Vertebroplasty. Anaesthesia 57(12): 1229-1230.

49. Martin JB, Jean B, Sugiu K et al. (1999) Vertebroplasty : clinical experience and follow up results. Bone 25 (2supppl) :11S-15S.

50. Gangi A, Wong LLS, Guth S, et al. (2002) Percutaneous Vertebroplasty: Indications, techniques and results. Seminars in Interventional Radiology 19:265-270.

51. Nussbaum DA, Gailloud P, Murphy K. (2004) A review of complications associated with vertebroplasty and kyphoplasty as reported to the food and drug administration medical device related web site. J Vasc Interv Radiol 15:1185-1192.

52. Padovani B, Kasriel O, Brunner P, et al. (1999) Pulmonary embolism caused by acrylic cement: A rare complication of percutaneous vertebroplasty. Am J Neuroradiol 20: 375-377.

53. Francois K, Taeymans Y, Poffyn B, et al. (2003) Successful management of a large pulmonary cement embolus following percutaneous vertebroplasty: A Case Report. Spine 28(20):E424-E425.

54. Gardos F, Depriester C, Cayrolle G, et al. (2000) Long term observations of vertebral osteoporotic fractures treated by percutaneous vertebroplasty. Rheumatology 39:1410-1414.

55. Jensen ME, Evans AJ, Mathis JM, et al. (1997) Percutaneous polymethylmethacrylate vertebroplasty in the treatment of osteoporotic vertebral body compression fractures: technical aspects. Am J Neuroradiology 18:1897-1904.

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

57. Cotten A, Bountry N, Cortet B, et al. (1998) Percutaneous vertebroplasty: state of the art. Radiographics 18:311-20.

The Cardiovascular and Interventional Radiological Society of Europe gratefully acknowledges the assistance of the Standards of Practice committee of the Society of Interventional Radiology in devising these guidelines, which are based, in part, on the article cited in reference 36.