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CIRSE Guidelines on Percutaneous Vertebral Augmentation

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Abstract 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. Different vertebral augmentation procedures (VAPs) are used in order to consolidate the VCFs, relief pain,and whenever posible achieve vertebral body height restoration. In the present review we give the indications, contraindications, safety profile and outcomes of the existing percutaneous VAPs.

Keywords Vertebral compression fracture · Osteoporosis · Vertebroplasty · Kyphoplasty · Percutaneous bone implant techniques

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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 aetiologies encompass osteoporosis, neoplasms (e.g. myeloma, metastasis, lymphoma and haemangioma), osteonecrosis and trauma. In 2010, 5.2 million non-traumatic fractures were expected in the 12 industrialised countries studied, of which 2.8 million were at the hip or spine. Women account for most of the total non-traumatic fracture burden (77%) [3]. Osteoporotic VCFs affect an estimated 1.4 million patients in the world annually [4]. The lifetime risk of VCF is 16% for women and 5% for men; the incidence of osteoporotic fractures is anticipated to increase fourfold worldwide in the next 50 years [5].

VCFs produce direct and indirect effects on patient quality of life and costs to the public health care systems. Patients with VCF present an increased mortality risk and lower survival rates compared to age-matched controls without VCF (survival rate at 5 years calculated at 31%) [6, 7]. This is primarily related to compromised pulmonary function as a result of thoracic as well as lumbar fractures [8, 9]. The quality of life of osteoporotic women showed significantly worse values for women with VCF compared to those without [10].

Irrespective of aetiology, treatment of VCFs has largely been conservative, with bed rest, narcotic analgesics, antiresorptive medications and back bracing for several weeks before taking into consideration of the vertebral augmentation techniques. The VERTOS III follow-up study evaluated the natural course of pain in a large cohort of symptomatic patients with VCFs and found that about half of the patients had insufficient pain relief at 12 months,

while in the other half, pain decreased progressively, particularly during the first 3 months. Analgesic medication was the most frequent treatment. The authors further found that physiotherapy did better than the other types of conservative treatments in the group of patients with insufficient pain relief at follow-up [11].

Definition

Vertebra compression fracture (VCF) is the reduction in the height of the individual vertebral by 20% or 4 mm [12].

Vertebra augmentation procedure (VAP) is a general term for several techniques used to treat VCFs. The VAPs aim to consolidate the fracture and, when possible, achieve height restoration.

- *Percutaneous vertebroplasty (PVP)* is a therapeutic, minimally invasive, image-guided procedure that involves injection of radio-opaque bone cement into a partially collapsed vertebral body, in an effort to provide pain relief and stability. Originally described by Deramond et al. in 1987 for the treatment of an aggressive vertebral haemangioma [13], the technique has evolved to become a standard of care for VCFs. The exact mechanism of pain relief remains unclear. Proposed theories include more favourable biomechanics after cement strengthening, chemical toxicity and exothermic effect of cement polymerisation on nerve endings [14].
- *Percutaneous kyphoplasty (PKP)* attempts to restore vertebral body height by inflating balloons prior to bone cement injection [15].
- *Percutaneous implant techniques (PIT)* include the placement of different types of expandable bone implant systems. The implants are inserted before the injection of the bone cement in order to impede the secondary loss of vertebral body height encountered with PKP after balloon deflation.

Percutaneous Vertebroplasty

Indications

- *Painful osteoporotic VCFs* 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 [16]. The 3-week delay depends on the patient status–risk of immobilisation, and in specific cases PVP can be performed with shorter delays.
- *Painful vertebrae due to benign bone tumours,* like *aggressive haemangioma*, giant cell tumour and aneurysmal bone cyst [17, 18]. In haemangioma, treatment is aimed at pain relief, bone strengthening and devascularisation. PVP can be used alone or in combination with sclerotherapy, especially in cases of epidural extension causing spinal cord compression [19, 20].
- Painful vertebrae with extensive *osteolysis* due to malignant infiltration by multiple myeloma, lymphoma and metastasis [20–28]. PVP is a palliative treatment aiming at treating pain and achieving bone consolidation. It has no anti-tumoural effect, and thus should be used in conjunction with existing systematic (chemo, hormone-therapy) and local specific tumour treatments (percutaneous thermal ablation, stereotactic external beam radiotherapy).
- Painful fractures associated with osteonecrosis (Kummell's disease) [28].
- Symptomatic vertebrae plana [29].
- Acute stable A1 and A3 traumatic fractures (Magerl's classification) [30].
- Chronic traumatic fracture in normal bone with non-union of fracture fragments or internal cystic changes.
- Need for vertebral body or pedicle reinforcement prior to posterior surgical stabilisation.

Contraindications

Absolute

- *Asymptomatic* VCFs or patient improving on medical treatment without worsening of the collapse.
- Unstable spinal fracture. Patients with diffuse idiopathic skeletal hyperostosis (DISH) and ankylosing spondylitis are highly susceptible to unstable 3-column spine fractures, even with minimal trauma [31].
- Osteomyelitis, discitis or active systemic infection.
- Severe uncorrectable coagulopathy.
- Allergy to bone cement or opacification agents.

The percutaneous augmentation techniques should not be used as prophylaxis treatment in severe osteoporotic patients.

Relative

- Radicular pain.
- Tumour extension into the vertebral canal or cord compression.
- Fracture of the posterior column, as there is increased risk of cement leakage and posterior displacement of loose fragment(s).

- Sclerotic metastasis, as the risk of cement leakage is high.
- Diffuse metastases (>5).

Patient Selection

A multidisciplinary team consisting of a radiologist, a neurologist, a spine surgeon and referring physician (rheumatologist, endocrinologist or oncologist) should come to a consensus which patients should undergo this procedure and they should ensure appropriate adjuvant therapy and the follow-up.

A detailed clinical history and examination with emphasis on neurological signs and symptoms should be performed to confirm that the VCF is the cause of debilitating back pain and to rule out other causes, like degenerative spondylosis, radiculopathy and neurological compromise. The typical patient suffering from VCF has midline non-radiating back pain that increases with weight bearing and manual palpation of the spinous process of the involved vertebra [21].

The clinical signs and symptoms should always be correlated with the imaging findings [1, 32]. In osteoporosis and metastatic disease, multiple fractures may be present; not all of the fractures necessarily require treatment.

Time of Intervention

Optimum timing for vertebroplasty is controversial. The recently published VAPOUR study found that PVP offers significant pain reduction (superior to placebo intervention) in patients with acute (<6 weeks) VCFs [33]. Ideally, the patient should present within four months of the fracture (onset of pain) and have at least 3 weeks of failure of conservative treatment. Intervention within days of a painful VCF can be considered in patients at high risk for decubitus complications like thrombophlebitis, deep vein thrombosis, pneumonia and decubitus ulcer [32, 34].

For patients undergoing conservative treatment, a weekly radiograph should be performed for VCF follow-up. In case of worsening of the compression fracture, PVP should be considered to arrest the height lost, particularly in thoracic spine and thoracolumbar junction, and avoid hyperkyphosis.

In cases of chronic (>4 months old) osteoporotic VCFs, PVP can be proposed if there is imaging evidence of osteonecrosis or incomplete healing (persistence of bone oedema on MR or bone scintigraphy) [35–40].

Imaging

Preoperative imaging is needed to identify the fracture (or fractures), estimate its age, define fracture anatomy, assess posterior vertebral body wall integrity [1] and exclude other causes of back pain (i.e. facet arthropathy, spinal canal stenosis and disc herniation) [2]. Radiographs of the spine give an overview of the number of levels involved by the disease process, help assess the extent of vertebral collapse (grading of fracture) and guide further imaging investigation.

MRI is a must in all patients considered for PVP as it provides information regarding the age and healing status of the fracture (acute vs chronic, incompletely healed vs consolidated). T1W, T2W and STIR sequences in axial and sagittal planes are required. Acute, subacute and non-healed fractures are hypointense on T1W images and hyperintense on T2W and STIR sequences because of the bone marrow oedema [2, 34]. Furthermore, MRI can help differentiate benign from malignant infiltration and infection [1].

Bone scintigraphy can be used to determine the age of a fracture in patients contraindicated for MRI (presence of metallic implants, pacemaker, claustrophobia). An increased uptake of the radionuclide tracer is highly predictive of a positive clinical response following PVP [2, 41].

If there is any doubt regarding the intactness of the posterior vertebral wall and the stability of the fracture (e.g. in patients with DISH or ankylosing spondylitis), a limited CT scan through the concerned level(s) should be performed [2]. It will also provide information regarding the location and extent of the lytic process, the involvement of the pedicles, the presence of epidural or foramina stenosis caused by tumour extension or retropulsed bone fragments which can increase the incidence of complications. In addition, if MRI suggests healing of a VCF, a confirmatory CT scan should be performed. If bone consolidation and sclerosis are already present, the needle placement and injection of bone cement will be difficult and may yield suboptimal imaging and clinical results [2]. If the VCF level responsible for pain cannot be identified, despite the applied clinical and imaging examinations, manual examination of the spine under fluoroscopy can be used to localise the culprit lesion [32].

Equipment and Personnel Requirements

An experienced operator, who has been adequately trained in the procedure, should perform VAPs. In addition, it is the responsibility of the operator to monitor the progress of

patients, report adverse effects and conduct audit [42]. A VAP programme should be set up and run in an institute that has a spine surgery unit ready to deal with any procedure-related complications. A multidisciplinary team approach is the key to the success of the programme, ensuring good patient selection, post-procedural care and follow-up while minimising complications.

The standard fixed fluoroscopic equipment used in interventional radiology suites should be preferred over the mobile C-arms, as image quality is higher and operator radiation exposure is less. *Single-plane* fluoroscopy is sufficient in most cases, but the multiple planes (anteroposterior, lateral and oblique views) should be used to ensure a safe procedure. *Bi-plane* fluoroscopic equipment permits the rapid alternation between the imaging planes without complex equipment movement and projection realignment [43]. Nowadays, modern fixed fluoroscopy equipment is also capable of *cone beam CT* which can be useful to evaluate the fracture and vacuum phenomena in the adjacent discs before vertebroplasty, and to identify any cement leakage after vertebroplasty [44]. Cone beam CT can also be used to plan computer-assisted needle guidance [45].

If available, combined multidetector CT (MDCT) and real-time fluoroscopy can be used (dual guidance). MDCT is particularly helpful for needle placement and cement injection when there is challenging anatomy (e.g. pedicle destruction by tumour, cervical/upper thoracic vertebrae and sacrum) [46, 47].

Pre-procedure Work-up

The treating radiologist should arrange a pre-procedural consultation with the patient. The procedure, intended benefits, complications and success rate must be discussed in detail, and informed consent should be obtained. Anaesthesia consultation 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 [48], local anaesthesia and conscious sedation [16, 43, 49, 50], epidural/spinal or general anaesthesia [51, 52]. Intraprocedural antibiotic cover (e.g. cefazolin 1 gr) is mandatory in immuno-compromised patients. There is no clear consensus on prophylactic antibiotic cover in other patient groups. Pulse rate, oxygen saturation and blood pressure monitoring is needed throughout the procedure. Strict asepsis is maintained.

Vertebroplasty Needles

Vertebroplasty needles are usually hollow, straight needles of the 10–14 G calibre. The needle stylet can be either diamond or bevel tipped. For bevelled needles, a bevel marking or notch is usually present indicating the bevel face. Needle bevel can be used to adjust the direction of the needle, as needle has a tendency to move far from the bevel face. Vertebroplasty needle is positioned using a sterile surgical hammer.

Sophisticated curved needles systems have been developed recently. The needles above bare an articulating tip that curls up to 90 degrees and allows access in osteolytic bone lesions in sites that are difficult to reach with conventional straight needles (sacral body, posterior acetabulum) [53].

Needle Trajectory

- *Cervical spine*

For cervical vertebroplasty, the combination of CT and fluoroscopy is recommended. For *C1* and *C2* a direct *transoral approach* should be used; this is the most direct route that avoids neural and vascular structures [54].

Below C2 level, both *anterolateral* and *posterior* transpedicular approaches can be used. For *anterolateral approach*, the patient is placed on supine position and needle trajectory is found between carotid sheath (that is pushed lateral by the operator's fingers), thyroid gland and oesophagus.

When using *posterior transpedicular approach*, the operating physician should always make sure the pedicles are large enough. Special attention should be paid not to puncture the vertebral artery.

- *Thoracic spine*

For *upper thoracic* level, dual CT and fluoroscopic guidance is preferable. Needle trajectory is through the horizontally orientated transverse process and using unilateral transpedicular approach.

For *lower thoracic* spine, unilateral *intercostovertebral approach* is proposed. It is associated with a lower risk of pneumothorax and paraspinal haematoma.

- *Lumbar spine*

The most common approach for the lumber spine is the unilateral, *transpedicular approach*. Needle trajectory is through the pedicle, and the needle tip is ideally placed on the middle line and anterior third of the vertebral body on AP and lateral view, respectively. If bipedicular approach is to be used, the needle trajectory is less oblique, and thus, the entry point on the skin is closer to the midline. The *postero-lateral* extrapedicular approach is an alternative in the lumbar

vertebrae but is seldom used and not recommended (higher risk of paraspinal haematoma and nerve traumatism).

- *Sacrum*

For stable non-displaced fractures of *sacral wings*, the needle is placed using *posterior* approach. If the fracture involves the *sacral body* (S1, S2 level), the *oblique* approach through the sacroiliac joint is needed.Due to a complex anatomy of the sacrum both needle placement and cement injection should be done under combined fluoroscopic and intermittent CT control.

Vertebral Venography

The use of vertebral venography has been favoured for the identification of potential routes of cement venous leakage. However, as physical properties of cement are different from those of the iodinated contrast media, this objective is not always achieved. Therefore, it is not performed in routine cases and only is reserved for hypervascular lesions (e.g. aggressive hemangiomas) which have a higher risk of cement leakage into the draining veins [55].

Cement Injection

Specially designed bone cements exist and can be safely used for VAPs. The viscosity, radio-opacity and polymerisation time defers between the existing cements. While a longer polymerisation time allows for a longer working time, and potentially multilevel injections, the cement takes longer to fix, and once a leakage is detected, the operator has to wait longer for the cement to set in order to seal the leakage point. The best cement is the one that operator is familiar with, that is radio-opaque enough and allows enough working time.

Cement is usually prepared once the needle is in position. Injection can be performed either using a dedicated injection set or 2-ml luer lock syringes. Cement injection sets allow aspiration and direct injection of cement in continuous flow and with minimal effort. Although the use of cement injection sets increases the expense of the procedure, it is safer than free hand injection and is associated with less radiation for the operator [56, 57].

Cement injection is done under continuous lateral fluoroscopic control in order to detect any epidural leakage at early stage, and intermittent AP screening to rule out lateral leaks and check the cement distribution.

The risk of cement leakage is particularly high at the beginning of the cement injection (when cement is at a more liquid phase), and this is when the operator should be very vigilant. If a leak is detected, injection should be immediately stopped. Waiting for 30–60 s will allow the cement to harden and seal the leak. If the leak persists, the needle position and/or the bevel direction should be modified; should the leaking continue, injection should be terminated. The cement injection is stopped when the anterior two-thirds of the vertebral body are filled and the cement is homogenously distributed in between lateral borders of the vertebral body and endplates. Stylet of the needle is reinserted under fluoroscopy to inject the remaining cement, from inside the needle lumen, and the needle is then removed under fluoroscopy to ensure there is no extra-osseous deposition of the cement. If the filling of the vertebral body is unsatisfactory at the end of the procedure, a contra-lateral pedicle can be accessed.

The volume of the cement injected depends on the size of the vertebrae and its consistency. In patients with hemangiomas, optimal filling is necessary to completely embolize the hemangioma and to avoid recurrences. In a tumour disease, where the aim of PVP is to relief excruciating pain, small cement volumes are usually sufficient [21]. If available, a CT scan or a cone beam CT should be performed at the end of the procedure to check the cement distribution and detect any cement leakage.

Post-Procedure Care

Before removing the patient from the table, the operator should wait for the cement to harden; hardened cement in the mixing bowl serves as a good indicator for this.

Vital signs and neurological evaluations (focused on the extremities) are monitored every fifteen minutes in the first hour, then every half an hour in the following two hours, looking for any increase in pain, change in vital signs or deterioration of neurological condition. Should any of the mentioned occur, a detailed neurological examination should be carried out, following a CT scan in order to look for spinal cord or nerve root compression from a possible cement leakage. Immediate post-procedure pain is usually mild and can be addressed with non-opioid drugs (paracetamol, NSAID's). In a rare case when pain is moderate to intense, administration of mild (codeine, tramadol etc.) to strong opioids (i.e. morphine) might be necessary.

No further post-procedural imaging is needed on a routine basis. An MRI control is proposed only in case of persisting or new pain appearing immediately or long after the procedure.

Outcomes

For osteoporotic fractures, the efficacy of PVP has been shown in several studies [33, 52, 58–61]. The recently published VAPOUR multicentre, randomised, double-blind trial found vertebroplasty to be superior to placebo

intervention for pain reduction in patients with acute osteoporotic fractures <6 weeks; the most benefit from the procedure was shown in the thoracolumbar spinal segment [33]. The VERTOS II trial compared PVP with conservative therapy for acute VCF (less than 6 weeks of symptoms) and found improvement in pain for the PVP group (significant difference in the Visual Analogue Scale (VAS) between baseline and 1 month being −5.2 (95% CI −5.88 to −4·72) after PVP, and −2.7 (−3.22 to −1.98) after conservative treatment). This effect was sustained for up to a year. Also, improvement has been shown in pain-related disability and reduced need for analgesia. A few years before the VERTOS II trial, two published double-blind randomised control trials (PVP versus sham procedure) [62, 63] had concluded that PVP was not superior to placebo and it led to an intense debate. A detailed evaluation of the controversy that ensued is out of the scope of this paper [64, 65], but of primary concern was the inclusion of patients with chronic fractures (up to 1 year of pain) and the lack of constant pre-procedural MR imaging. We believe that in case of carefully chosen patients with the proper indications, PVP provides good pain relief in majority of cases. At the time of this publication, VERTOS IV trial is still ongoing [66]. It aims at recruiting 180 patients with acute local back pain (less than 6 weeks) and MRI evidence of a fracture, in order to compare the outcomes of treating pain with PVP and sham intervention. The functional outcome of the vertebral augmentation procedures, and its positive effect on quality of life, shows a tendency for improved post-procedure outcomes in majority of studies and meta-analysis [33, 67–69].

PVP for malignant spinal disease has also shown to improve pain and disability [70, 71]. In their prospective study of PVP in myeloma and metastatic spinal disease, Chew et al. reported a decrease of 2.8 points in VAS [70], which is similar to other prospective studies involving patients with osteoporotic disease.

Table 1 shows response rates to PVP according to different parameters and serves as guidance for an individual operator.

Table 1 Table 1 reports response rates to PVP according to different parameters and in different pathologies

Criteria	Success Rate
1. Pain relief	
Acute osteoporotic fracture	90% [16, 72–77]
Chronic osteoporotic fractures	80–100% [36, 39]
Malignant fractures	60–85% [25, 27, 73, 78–80]
Hemangiomas	80–100% [73, 81–83]
2. Increased mobility	
Acute osteoporotic fracture	84–93% [16, 75]
Chronic osteoporotic fracture	50–88% [36, 39]
3. Reduced requirement for analgesics	91% [16, 75]

Complications

Published data have placed the symptomatic complication rates of PVP of osteoporotic at 2.2–3.9% [84, 85], and in malignant fractures at <11.5% [71]. Centres planning on starting a PVP programme should aim at keeping their complication rates below the published rates. We recommend a threshold of 2% for all symptomatic complications for PVP performed for osteoporotic indications, and 10% for malignant indications [86].

I. *Cement leakage*
Cement leakage is often asymptomatic [87]. CT scan or cone beam CT are undoubtedly superior to fluoroscopy or plain X-ray for leak detection [88].
Routes of cement leakage:

- *Epidural space* and *neural foramina*: this can lead to radiculopathy and paraplegia as a result of nerve root and cord compression, respectively. Radiculopathy can be a result acement contact with an emerging nerve root and its subsequent heating during polymerisation of the cement. To mitigate this complication, immediate nerve foramina infiltration with cool saline and steroids should be performed to reduce local inflammatory effects. After the procedure, patient can be given a brief course of non-steroidal anti-inflammatory agents and/or oral steroids. 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* and *pulmonary embolism*: it is usually asymptomatic. Leakage of cement into the perivertebral plexus can embolise distally into the lungs. There is a wide range of reported pulmonary embolism rates in the literature, ranging from 3.5–23% [89]. The embolus is usually lodged peripherally and asymptomatic [49] and requires no treatment. Rarely, there can be central pulmonary embolism leading to lung infarction [77, 90]. There is currently no consensus on management of cement pulmonary embolism, although Krueger et al. [89] recommend anti-coagulation for 6 months for the asymptomatic central or symptomatic peripheral embolism. Paradoxical cerebral embolisation has been reported [49].

II. *Infection*: Incidence < 1%.

III. *Fracture of ribs, posterior elements or pedicle:* Incidence < 1%.

IV. *Risk of collapse of the adjacent vertebral body.*

Risk of the adjacent vertebral body collapse still remains a controversial topic despite numerous conducted clinical and biomechanical in vitro studies.

Some biomechanical studies suggest fractured vertebra augmentation may rise stress level and cause new adjacent fractures, while others found no such correlation [91, 92]. Clinical studies show a similar correlation. While earlier single-arm studies found an increased risk of adjacent VCF after a PVP [93, 94], VERTOS II open-labelled randomised controlled clinical trial showed that there is no increase in the incidence of a new VCF after a PVP, nor increased risk of an adjacent vertebral body fracture [95], compared to a conservative treatment. In a review article on the same topic, Trout et al. also found no definite casual relation between PVP and incident VCF [96]. To further add to the controversy, recent retrospective studies have shown that prophylactic PVP of the non-fractured vertebra adjacent to the VCF reduces the incidence of new fractures after PVP [97, 98].

Taking existing evidence into account, we believe that the benefits provided by PVP outweigh the possible risk of adjacent VCF post-PVP, and this should be made clear to the patient during consent taking.

V. *Allergic reaction*

VI. *Bleeding from the puncture site*: It is associated with localised pain and tenderness, which resolves in 72 h.

We believe that complications can be minimised by:

- Not injecting cement in its liquid phase, as there is greater risk of venous intravasation and cement extravasation.
- Limiting the number of treated levels to not more than five [34, 49]. Studies have shown that oxygen saturation tends to drop during a PVP [99, 100], and Uemura et al. [100] reported a positive correlation between the number of vertebrae performed and drop in oxygen saturation. Aetiology may be multifactorial (e.g. sedation, prone position, fat embolism, long procedure time etc.). Although it has been shown that multilevel PVP is safe [101, 102] (in both studies, multilevel was defined as 3 or more levels), it is not advisable to treat more 5 levels within a single session. Procedure time should not exceed 2.5 h.
- Correct positioning of the needle tip (e.g. avoid positioning in a basivertebral vein or close to the posterior wall).
- Taking extra precaution when treating highly vascular lesions (e.g. metastasis from thyroid and renal cancer), as they are prone to cement leaks.

Percutaneous Kyphoplasty (PKP)

The aim of PKP is to restore height of the vertebral body and provide deformity correction, in order to achieve more favourable stress dynamics.

Indications

The best indication is traumatic acute (less than 7–10 days) VCFs (particularly Magerl A1) with local kyphotic angle >15°.

The rest of indications are similar to PVP (osteoporosis, metastatic disease and multiple myeloma).

Contraindications

- Burst fractures (though some Magerl A3.1 can be addressed with PKP).

In general, absolute and relative contraindications are similar to PVP.

Technique

Classically PKP is performed by bilateral transpedicular approach (needle trajectory is described above in the PVP session). Two access cannulas are placed bilaterally, and once in position (the external part of the cannula should be placed just in front of the posterior wall on the lateral view), a hand drill is advanced coaxially to cut clean through the cancellous bone and create a channel for balloon placement. The hand drills are removed, and two balloons are advanced and inflated simultaneously under fluoroscopic guidance and pressure control (up to 300 psi). During the balloon inflation, special care should be taken not to fracture the end plates or lateral walls. Once the vertebra kyphosis has been corrected, balloons are deflated and removed. Bone cement is finally injected through the access cannula and under fluoroscopic control [15].

PKP can be also performed using vertebroplasty needles, which should be then exchanged for the access cannulas over K wires, or with direct placement of K wires. The procedure is similar to the one described in the paragraph above.

Results

Chen et al., in a recent large retrospective review comparing conservative therapy, PVP and PKP using Medicare date, found that both PVP and PKP improved survival (the

adjusted hazard ratio for death was estimated to be 15.5 and 32.3% less for patients managed with PVP and PKP, respectively, compared to conservative therapy) [103]. The authors conclude that kyphoplasty is more costly and has a higher rate of subsequent vertebral compression fractures. Regarding the pain reduction, there is no difference between PKP and PVP [104–109].

There is clear evidence that cement extravasation is less frequent for PKP than for PVP [104, 108], probably due to lower cement injection pressure following balloon cavity creation. Most studies also favour PKP for height restoration and kyphotic angle correction.

Complications

Potential complications of PVP also exist in PKP. There is no significant difference in the incidence of adjacent vertebral body compression fractures compared to PVP [108].

Recommendation

We find that there is no strong evidence for recommending PKP over PVP in routine cases. PKP may be preferred in selected cases when restoration of height is of utmost importance, for example for acute kyphotic fracture in relatively young patients.

Percutaneous Implant Techniques (PIT)

PITs were introduced in order to impede the secondary loss of vertebral body height encountered with PKP after balloon deflation and till cementation.

The indications and contraindications are similar to those from PKP and PVP.

In all cases, VCF should be acute and less than one week. If older fractures are to be treated, trial balloons should be used before implant placement, to confirm intraoperative fracture mobility and restoration potential before any stent is inserted [110].

Most supplemental implants systems are intended for treatment of levels ranging for Th5–L5.

Technique

Technique should be chosen depending on the implant used [111]. For stent and other expandable scaffolding devices, the technique is similar to PKP (placement of cannulas, use of hand drills and bilateral approach). The scaffolding devices can be either balloon or self-expandable nitinol systems [110, 112].

Other existing supplemental augmentation systems are placed using a unilateral approach, while the implant is deployed over a nitinol coil guide wire [113].

Results

The PIT have been proven to reduce the mean local kyphotic angle and achieve height restoration in most of the cases [114]. Anselmetti et al. [112] report a statistically significant increase in vertebral body height and decrease in pain level immediately after the procedure that was preserved at one-year time point. Similarly, Diel P et al. report a reduction in the mean local kyphotic angle from 13.1° to 8.9° [110]. Lastly, Korovessis et al. [113] compared the placement of a supplemental implant system with PKP and found that residual local kyphosis more than 5° was more often in PKP group.

Complications

Cement leakage is reported to occur in 7–29% of the cases, while symptomatic cement leakage is reported in <1% of the cases [110, 112, 113].

Korovessis et al. report cement leakage rate per vertebra to be lower in the supplement implant than the PKP group. They also report no significant difference on post-procedure new fracture rate, when compared to the PKP group [113].

Recommendation

As for PKP, we believe that PITs should be reserved for young patients with acute (<7 days) traumatic fractures and a significant (>15°) local kyphotic angle, as in such cases correction of the deformity is desired. In the rest of the cases, a simple PVP may still be a better choice, as it may be equally effective in providing pain relief and is less invasive.

Conclusion

In the present review, we give the indications, contraindications, safety profile and outcomes of the percutaneous VAPs. Evidence about the use of PVP has been conflicting, although, lately, it seems clear that PVP offers significant pain reduction in patients with acute VCFs. Unilateral transpedicular PVP is sufficient in most cases. PKP and

PIT should be reserved for young patients with hyper acute traumatic fractures and only when improvement in local kyphosis is desired.

Compliance with Ethical Standards

Conflict of interest All authors declare that they have no conflict of interest.

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