Review article

Kyphopasty and vertebroplasty
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A B S T R A C T

Vertebroplasty and balloon kyphoplasty are percutaneous techniques performed under radioscopic control. They were initially developed for tumoral and osteoporotic lesions; indications were later extended to traumatology for the treatment of pure compression fracture. They are an interesting alternative to conventional procedures, which are often very demanding. The benefit of these minimally invasive techniques has been demonstrated in terms of alleviation of pain, functional improvement and reduction in both morbidity and costs for society. The principle of kyphoplasty is to restore vertebral body anatomy gently and progressively by inflating balloons and then reinforcing the anterior column of the vertebra with cement. In vertebroplasty, cement is introduced directly under pressure, without prior balloon inflation. Both techniques can be associated to minimally invasive osteosynthesis in certain indications.

In our own practice, we preferably use acrylic cement, for its biomechanical properties and resistance to compression stress. We use calcium phosphate cement in young patients, but only associated to percutaneous osteosynthesis due to the risk of secondary correction loss. The evolution of these techniques depends on improving personnel radioprotection and developing new systems of vertebral expansion.

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1. Introduction

Vertebroplasty and balloon kyphoplasty are increasingly important options for radiologists, orthopedic surgeons and neurosurgeons managing spinal lesions.

They are percutaneous techniques, performed under radioscopic control. The principle of kyphoplasty is to restore vertebral body anatomy gently and progressively by inflating balloons and then reinforcing the anterior column of the vertebra with cement. The balloons create a cavity within the vertebral body, compressing the cancellous bone and thus limiting the risk of cement leakage from the vertebral body. In vertebroplasty, cement is introduced directly under pressure, without prior balloon inflation.

Vertebroplasty was developed in France by Galibert and Dera mond in 1984 [1]. Its original indication was for aggressive vertebral angioma. Its proven efficacy led to an extension of indications to metastatic and myelomatous osteolytic lesions, and then to osteoporotic vertebral compression fractures.

Kyphoplasty was developed from the vertebroplasty concept, initially by Reiley in 1998, then taken up by Belkoff et al. in 2001 [2]. At first reserved to tumoral and osteoporotic lesions [3], it has gradually established its role in the treatment of fractures in young patients [4].

The benefit of these minimally invasive techniques compared to conventional attitudes (conservative treatment or open surgery) has been demonstrated in terms of pain and functional improvement. Cement injection into the vertebra may have an analgesic effect by consolidating microfractures and reducing the mechanical stress associated with weight and activity, and also by destroying bone nerve endings by cytotoxic and exothermal action in the course of cement polymerization.

Morbidity, moreover, is minimal, and the techniques bring cost savings over the medium term.

2. Technique

2.1. Instrumentation

Most cementoplasty instrumentation is basically similar (Fig. 1), differing in whether or not balloons or stents are used to expand the vertebra.

Instrumentation comprises beveled trocars (or Yamshidi needles) for the entry point and trajectory through the bone, blunt K-wires to guide the cannulae carrying the balloon or stent, a curette in case of dense cancellous bone, and devices for bone filling. The technique also requires an iodized contrast agent for fluoroscopic control of balloon inflation, and a dose of cement.
2.2. Patient positioning

Our attitude is to perform the procedure in theater under general anesthesia. The patient is positioned in ventral decubitus on the spine-surgery table in hyperlordosis, thus partially reducing the traumatic vertebral kyphosis (Fig. 2).

The procedure requires peroperative radioscopic control using one or two fluoroscopes to obtain AP and lateral views; we advise using two fluoroscopes, so as the limit the risk of infection associated with manipulating them during surgery. The frontal fluoroscope tank should be placed upwards. Having two surgeons, one on either side of the patient, reduces surgery time and irradiation time by operating on both sides simultaneously.

One technical variant is to operate under CT. This provides better visualization of the vertebra than radioscopy, especially in small tumoral lesions. However, it does not allow injection under fluoroscopy or monitoring the progress of the cement within the vertebral body.

In upper thorax procedures, superimposition of the two shoulders on lateral views hinders peroperative fluoroscopic control, and may even lead to abandoning cementoplasty. This is especially true in squat or muscular patients, for whom 3D fluoroscopy or peroperative CT seems indispensable. In other cases, it is usually possible to “eliminate” the shoulders, either by positioning the arms along the body and strapping them down or by holding them in antepulsion in the so-called “Superman posture” (although the latter incurs a risk of stretching the brachial plexus and generally requires a relatively narrow operating table such as the new carbon fiber models).

2.3. Surgery

2.3.1. Spinal approach

For dorsal and lumbar vertebrae, an extrapedicular posterolateral or a transpedicular approach is possible, the latter having the general advantage of avoiding dorsal pleural-parenchymal complications or lumbar psoas hematoma, with much less cement leakage from the vertebral body through the puncture hole; however, it is not feasible in case of pedicular lysis or presence of internal fixation material. The lesion level is determined before draping and the position of the vertebral pedicles is marked on the skin.

2.3.1.1. Transpedicular approach. As the objective is to inject cement into the center of the vertebral body, the incision should be shifted about 1 cm away from the pedicular skin landmark so that the cannulae converge horizontally. Vertically, the height of the incision depends on how steeply the cannula is to descend: for a very steeply descending orientation, the incision had to be shifted about 1 cm upward of the projection of the pedicle (Fig. 3).

The trocar entry point is determined manually, at the base of the superior articular process at the junction with the transverse process (Fig. 4A, B). The trocar advances to the inner edge of the pedicular ring seen on AP view; the ring is not to be crossed before the posterior wall of the vertebral body, seen on lateral view, has been; otherwise the trocar will penetrate the spinal canal (Fig. 5A, B). The trocar is introduced beyond the posterior wall of the vertebral body (Fig. 6). The major risks of this transpedicular approach are radicular lesion or dural breach through the medial pedicular cortical bone; this risk can easily be corrected by rigorous frontal fluoroscopic control of the pedicle or by adapting the caliber of the trocar to the size of the pedicle, especially in the superior dorsal region.

2.3.1.2. Extrapedicular posterolateral approach. We reserve the posterolateral approach to cases in which the transpedicular approach is contraindicated: pedicular lysis or internal fixation material. Some authors prefer a posterolateral approach at dorsal level where pedicle size is reduced. The entry point is about one hand-width from the spinous processes. At dorsal level, it is essential to make sure that the needle is always behind the line of pleural reflection: otherwise, the risk is a pleural wound and possible hemothorax. At lumbar level, the risks are the same as in vertebral body
biopsy: renal fossa puncture, psoas hematoma and above all leakage through the puncture hole.

2.3.1.3. Other approaches. Open kyphoplasty may be indicated in case of thoracolumbar fracture with neurologic deficit requiring laminectomy associated to stabilization: the fractured vertebral body can be reinforced, avoiding secondary anterior reconstruction or an extensive posterior assembly, especially in fragile patients [5,6].

Cervical kyphoplasty by short anterolateral cervicotomy has been described for tumoral pathology [7,8].
2.3.2. Continuation of the procedure

A guide wire is introduced in each trocar; the trocars are removed, leaving the guide wires. The cannulae are introduced into the vertebral body, guided by the wires. Bone biopsy may be associated at this point, especially in elderly patients, to screen for neoplastic lesions. A tunnel is created in the vertebral body, using a tap drill, to facilitate balloon insertion. The anterior wall of the vertebral body must not be damaged, as this could lead to large-vessel lesions or cement leakage.

If the cancellous bone is too dense, a curette can be used to create an initial cavity to facilitate and guide vertebral expansion (Fig. 6A, B). This should be performed under fluoroscopy, to avoid any cortical damage. The curette should always be oriented toward the interior of the vertebral body.

2.3.3. Vertebral expansion during kyphoplasty

The two balloons or stents are introduced into the cannulae and positioned under the fracture. They are deployed simultaneously. Frontal and lateral fluoroscopic controls are continued until reduction is satisfactory (Fig. 7A, B). Direct syringe reading of balloon volume enables an approximate assessment of the dose of cement required.

2.3.4. Fracture stabilization

The cannulae containing the cement are introduced into the anterior half of the vertebral body, to limit the risk of leakage into the canal. The cement is injected progressively, under fluoroscopic control. The resulting cavity is filled entirely, while avoiding over-filling the vertebral body and creating a hyper-rigid spinal segment. If any leakage is observed, the procedure must be stopped. The cannulae are removed immediately after injection (Fig. 8A, B).

2.3.5. Postoperative course

Analgesia and thromboprophylaxis are initiated immediately. The patient is seated in a chair and resumes walking the day after surgery. Discharge is possible as of day 2, after radiographic control.

At follow-up, residual pain is assessed on a VAS; spinal flexibility is assessed, and independence is estimated on the Oswestry
scale. Radiologic assessment focuses on fracture union, impact on adjacent levels (vertebral fracture, disc degeneration) and spinal parameters. Physical therapy may be initiated at an early stage, concentrating on flexibility. Return to work is authorized at month 2 or 3, but is often postponed to month 6 for patients with jobs involving heavy lifting.

2.3.6. Technical tips

Our kyphoplasty experience has taught us 2 main criteria guiding balloon positioning:

• the characteristics of the deformity;
• the density of the cancellous bone (related to patient age: osteoporotic or not).

2.3.6.1. Characteristics of the deformity. In the frontal plane, the vertebral body may be concave (Fig. 9). Cannula orientation should then be convergent, so as to create a central cement cavity. The skin incision is lateralized by about 1 or 2 cm with respect to the projection of the pedicles on AP views, enabling oblique introduction of the cannulae. The slope may be steepened when the guide wire is passed through the cannula after crossing the posterior wall of the vertebral body, controlled on lateral views; this ensures against crossing the vertebral canal. This is the “kissing balloon” as described by Maestretti (Fig. 10).

In the frontal plane, vertebral body compression may be lateralized, in which case the cannula on the affected side is oriented along the pedicle axis without convergence, so as to position the balloon at the site of maximal deformity. The skin incision is then made along the projection of the pedicle on AP view. In general, the other balloon is convergent, so as to create a single cement cavity.

In the sagittal plane, compression may be cuneiform, in which case the balloon is inflated in the anterior part of the vertebral

Fig. 9. Concave fracture, frontal plane.

Fig. 10. Kissing balloon.

Fig. 11. A. Cuneiform fracture, sagittal plane. B. Balloon inflation in anterior part of vertebral body.
body, while remaining remote from the cortical bone so as to avoid anterior leakage (Fig. 11A, B).

In the sagittal plane, the vertebral body may be concave, in which case the balloon is positioned in the center of the vertebra under the site of maximal deformity (Fig. 12A, B).

2.3.6.2. Cancellous bone density. Patient age and the related cancellous bone density are determining factors for balloon orientation. Fracture reduction differs depending on whether the bone is osteoporotic or not.

In young patients with dense cancellous bone, the balloon should be positioned close to the collapsed vertebral plateau: if it is too remote, expansion is limited by bone resistance and fracture reduction will be insufficient; if on the other hand it is too close, there is a risk of cortical damage and of cement leakage toward the disc. In that case, the cannulae should be oriented almost horizontally (Fig. 13A, B), and the skin incision should be at the level of the projection of the pedicle on AP view.

In osteoporotic patients, the balloons should be more remote from the collapsed plateau. Vertebral expansion is possible only if enough cancellous bone is compressed, in which case we tend to aim at the antero-inferior corner of the vertebra, with a descending orientation on lateral view (Fig. 14A, B). The skin incision is made about 1 cm above the projection of the pedicle on AP view.

3. Choice of cement

The cement fills the bone defect left by the fracture and by the inflation of the balloons in kyphoplasty. This enables lasting correction of the vertebral deformity, whether traumatic or not, and also exerts an analgesic effect, mainly by lesion stabilization. There are presently two types of cement available for kyphoplasty: calcium phosphate (TriCa++) and acrylic (PMMA).

3.1. Calcium phosphate cement

Calcium phosphate cement has been available for some 20 years. It is produced by hydrolysis or crystallization of an acid salt and an alkaline salt. The objective is to associate the mechanical properties of acrylic cement to the osteoconductive properties of calcium phosphate cement. It is resorbable. Although expensive, this kind of cement seemed to be the solution of choice when vertebral cementoplasty techniques were first developed, as there was at the time considerable doubt as to the long-term evolution of inert acrylic
cement injected into the vertebra. Several studies [9,10], including that of Maestretti in 2007 [4], converged with encouraging results. Experience, however, has shown that calcium phosphate cement is difficult to use by reason of its low radio-opacity and very rapid crystallization. Moreover, resorption is unpredictable and the biomechanical properties are far from optimal, leading to secondary correction loss [11–13]. These findings prompt us to advise against calcium phosphate cement as a stand-alone solution in vertebral expansion; association to percutaneous osteosynthesis [14], however, avoids secondary correction loss. We use calcium phosphate cement only in association to posterior percutaneous osteosynthesis in traumatic fracture in young patients.

3.2. Acrylic cement

Unlike calcium phosphate cement, acrylic cement is inert, providing immediate mechanical stability in cementoplasty and kyphoplasty. Long-term tolerance is excellent, as half a century’s experience in orthopedic surgery testifies. It is produced by mixing a powder of polymethacrylate plus initiator plus opacifier and liquid monomer methyl methacrylate. Polymerization induces a strong exothermal reaction (>70°C), causing necrosis in the tissue in contact with the cement. Acrylic cements show excellent mechanical resistance to compression stress, and good longevity when prepared under vacuum [15]. We prefer acrylic cement as a stand-alone solution in cementoplasty and kyphoplasty. Moreover, it is much less expensive than calcium phosphate cement.

4. Indications

4.1. Tumors

The first indications for vertebral cementoplasty were for symptomatic vertebral angioma [1]. They were then extended to benign (vertebral hemangioma) and malignant (metastases, myeloma) tumors.

Only 3% of vertebral fractures have a malignant origin. These are a source of considerable morbidity in case of solid metastatic vertebral tumor or malignant myeloma of poor prognosis. They are frequently associated with metastatic tumor, and are usually painful. Treatment is often palliative (analgesia, radiation therapy, corset) and sometimes etiological (chemotherapy, etc.).

Cementoplasty may be indicated in painful vertebral tumor without signs of compression. Contraindications are major osteolysis with cortical bone loss, entailing a risk of cement leakage, and osteocondensing lesions preventing vertebral expansion and cement injection. Vertebroplasty may also be indicated for cystic lesions.

The recent Cancer Patient Fracture Evaluation (CAFE) project included 134 patients with metastatic or myelomatous vertebral fracture [16] in a 22-center study spread over the US, Europe, Australia and Canada. It produced clinical proof of the superiority of balloon kyphoplasty over non-surgical management in terms of pain relief and improved quality of life.

4.2. Osteoporosis

Eighty-five percent of vertebral fractures are thought to be of osteoporotic origin. Annual incidence is estimated at more than 700,000 in the US and 450,000 in Europe, although only one-third are diagnosed. Incidence doubles in women with the menopause. Onset may be spontaneous or secondary to minimal trauma.

Conventional management of osteoporotic vertebral compressive fracture is based on analgesia, with or without corset. Bed-rest may be necessary during the acute phase, followed by early mobilization and physical therapy. Global management of the osteoporosis by a rheumatologist or family physician should be systematically associated (ostedensitometry, biphosphonates, etc.).

In osteoporotic pathology, cementoplasty is never an emergency attitude, although there is at present no consensus on this point. Our policy is to propose cementoplasty in case of failure of at least 1 month’s well-conducted medical treatment after correlating radiological and clinical data to bone-scans or MRI.

In a series of 254 patients with osteoporotic vertebral fracture managed by kyphoplasty, Majd reported immediate postoperative reduction in pain in 89% of cases [17], with ≥20% recovery of vertebral height in 63%.

4.3. Fractures in young subjects

Stand-alone kyphoplasty is an interesting alternative to traditional attitudes toward compression fracture (Magerl type A) of the thoracolumbar junction without neurological signs. Unlike corset immobilization [18], it provides significant reduction of the traumatic vertebral kyphosis [4,19,20]. Lasting restoration of vertebral body anatomy correlates directly with good functional results, according to the French Société d’Orthopédie de l’Ouest round-table of 2008 [21].

Many comparative studies between conservative management and kyphoplasty reported shorter bed-rest, hospital stay and time off work with the latter [22]. The rate of complications is low [23,24], and the difficulties inherent to wearing a corset for 3 months are avoided.

After suitable information, we propose kyphoplasty to young patients, as it corrects the traumatic vertebral deformity while avoiding the complications associated with corset immobilization or open surgery.
4.3.1. Fracture classification

Thoracolumbar junction fracture classification seeks to assess instability and guide treatment strategy. Classification systems are basically founded on imaging: plain AP and lateral X-ray and CT. In case of associated distraction or translation, MRI assesses the intervertebral disc and posterior ligamentous complex; it is, however, not readily available in emergency.

We use the Magerl classification [25]. Based on purely morphological criteria, it is the most widely used system (Fig. 15). It distinguishes 3 types of fracture (A = pure compression, B = distraction, C = translation or rotation), 3 groups and 3 subgroups, using the AO codes. Its interest lies in its good predictive value, with vertebral instability increasing from type A to type C. On the other hand, it distinguishes 27 types of fracture and requires rigorous interpretation of imaging to limit inter-observer variation.

In comminutive type A33 fracture, we associate McCormack’s Load Sharing classification [26] (Table 1), originally intended to assess risk of failure of conservative treatment of burst fracture, but also useful to guide indications between stand-alone kyphoplasty and associated percutaneous osteosynthesis. Scores are from 3 to 9, according to percentage vertebral height loss in the sagittal plane, comminution and vertebral kyphosis reducibility in hyperextension on the operative table.

4.3.2. Indications

Kyphoplasty reinforces the vertebral body and restores its anatomy. Indications for stand-alone kyphoplasty are therefore limited to fractures in which the posterior vertebral arc is conserved: Magerl type A.

4.3.2.1. Type A1 fracture (compression fracture). In type A11 fracture, in which body lesions are minimal and there is no vertebral kyphosis, functional treatment is indicated. In types A12 and A13, kyphoplasty can be considered as an alternative to corset immobilization, on a case-by-case basis.

4.3.2.2. Type A2 fracture (separation fracture). It is generally agreed that type A22 (or “diabolo”) fracture requires anterior reconstruction due to the risk of discal incarceration. Kyphoplasty offers an attractive alternative if the inter-fragment gap is moderate (< 2 mm). In case of failure of kyphoplasty (non-union or insufficient cement injection), anterior revision by corporectomy with removal of cement and reconstruction remains possible.

4.3.2.3. Type A3 fracture (burst fracture). In our experience, type A31 fracture is the best indication for kyphoplasty as an alternative to corset immobilization and especially to conventional surgery. Canal stenosis due to posterior displacement of the posterior wall is not an absolute contraindication, if the balloons are correctly positioned away from the vertebral plateau.

Type A33 burst fracture is also a good indication for kyphoplasty if properly analyzed on pre-operative CT. A load sharing score ≥ 6, on the other hand, is a contraindication: the risk of cement leakage out of the vertebral body and the likely failure of body reinforcement indicate corporectomy and implantation of an expandable cage [27,28] (Fig. 16).

4.3.3. Indications for associated posterior percutaneous osteosynthesis

Posterior percutaneous osteosynthesis was originally developed for degenerative pathologies [29], but authors such as Pelegri [30] and Rampersaud [31] have demonstrated its application in traumatology. As the multiaxial screws do not allow effective reduction maneuvers, the aim is to stabilize the fracture with an internal

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**Table 1**
McCormack classification.

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<th>2 points</th>
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Fig. 15. Magerl classification.

Fig. 16. Corporectomy with intersomatic cage reconstruction.
corset effect. Instrumentation is available with pre-curved rods (e.g., Sextant™, Medtronic) or with curvable rods (e.g., Viper™, Depuy); the latter allow indications to be extended to the lower and middle thoracic spine. These various means of posterior percutaneous osteosynthesis are the perfect complement to kyphoplasty in certain indications:

- use of calcium phosphate cement (Fig. 17); the aim is to prevent the secondary correction loss found with this kind of cement, by providing a supplementary posterior fixation [14];
- insufficient injection of acrylic cement (e.g., when injection is stopped because of leakage); the aim is as in the previous case;
- posterior bone lesion: whether in compression (isolated sagittal fracture line on the posterior lamina) or distraction fracture (Chance fracture), percutaneous osteosynthesis provides stabilization awaiting bone fusion;
- disc protection following vertebral plateau impaction: although several studies demonstrated that kyphoplasty, by restoring vertebral body anatomy, partly conserves adjacent discs [32,33], in case of severe damage to the plateaux (in practice, type A22 or A33 fracture) temporary supplementary posterior fixation may facilitate fusion;
- posterior ligamentous complex (PLC) protection: according to Vaccaro and the Spine Trauma Study Group, PLC lesions are central to the therapeutic algorithm for thoracolumbar junction fractures [34,35]. The TLICS classification [36] includes an “undetermined” PLC status: distraction fracture without posterior arc bone involvement (Magerl type B1) and/or without radiologic criteria of PLC tear. In such fractures, posterior percutaneous osteosynthesis associated to kyphoplasty promotes PLC healing by the protection afforded by the osteosynthesis after vertebral body anatomy has been restored. The internal fixation material can be ablated via short incisions centered on the screws, as described by De Peretti’s team [37].

The advent of new percutaneous pedicul ostéosynthèse instrumentation, with uniaxial screws, allows reduction maneuvers by distraction between the screw-holders ahead of kyphoplasty. In theory, this should provide supplementary correction by ligamentotaxis, although the recent report by Blondel [38] failed to demonstrate this.

5. Contraindications

5.1. Absolute contraindications

The first absolute contraindication to these vertebral cementoplasty procedures is, obviously, the lack of a spinal surgeon on site. The others are:

- anesthesiological;
- infection (sepsis);
- > 30% posterior displacement or lytic lesion of the posterior vertebral wall (risk of neurologic compression);
- complete vertebral collapse or A33 fracture with load sharing score ≥ 6 (see Indications section).

5.2. Relative contraindications

Relative contraindications and precautions concern:

- iodine allergy (in case of balloon rupture), although non-iodized radioopaque solutions exist;
- coagulation disorder;
- osteocondensing tumor (risk of failure of balloon deployment and cement injection).

Finally, as described in the Approaches sections, fracture with associated neurologic deficit is not a contraindication if cementoplasty is associated to open decompression and stabilization.

6. Complications

The international literature is unanimous as to the low rate of complications associated with vertebral cementoplasty. Recent meta-analyses found fewer complications in kyphoplasty than in vertebroplasty [39-41]. This is partly due to low-pressure cement injection into a preformed cavity in kyphoplasty, reducing leakage risk. Balloon correction of part of the traumatic vertebral deformity also helps avoid mechanical complications.

6.1. Complications related to cement leakage

Taylor [42] demonstrated that, despite high rates of cement leakage, the incidence of associated complications is low (2%).

The most severe leakage-related complication is pulmonary embolism. It is, however, exceptional: Krueger et al. [43], in a literature review, found 86 cases in 20,000 procedures, only half of which were symptomatic.

Disc degeneration due to cement leaking into the nucleus pulposus is also reported to be exceptional [14], although this is probably biased by the small number of reports on disc behavior after cementoplasty [32].

Finally, the risk of neurologic compression by foraminal or intracanal leakage is also low [42,44]. In case of heavy periprostatic leakage, we recommend immediate decompression, with associated fixation if neurolysis induces instability.

To reduce the rate of complications related to cement leakage, Greene et al. [45] described the “eggshell” trick: beginning by injecting a small amount of acrylic cement into the kyphoplasty cavity and compacting it by redeploying the balloons before completing injection.

6.2. Other complications

The most frequently reported mechanical complication is fracture in adjacent levels, found in osteoporotic patients. It is caused
by the production of a hyper-rigid segment within the spine [46]. The risk is 1.5-fold higher than in medical treatment, and predominates at the thoracolumbar junction [47]. There is, however, a bias introduced by the significantly earlier resumption of activity by kyphoplasty patients [48].

The other mechanical complication, and a matter of controversy in vertebral expansion, is loss of correction over time. As mentioned above in the Cements section, this mainly concerns calcium phosphate substitutes [49].

Infection (spondylodiscitis, subcutaneous abscess) is exceptional [50], arguing in favor of this percutaneous attitude.

7. Alternatives and perspectives

Our experience with kyphoplasty suggests certain improvements and perspectives for evolution.

7.1. Reducing radiation dose

Fluoronavigation enables reliable kyphoplasty [51] while considerably reducing the radiation dose received by the surgeon and theater team during repeated percutaneous procedures [52].

Simple measures, easy to implement, such as simultaneous use of two fluoroscopes, use of an obturator and moving the team back during surgery also serve to reduce exposure.

7.2. Other vertebral expansion devices

Various vertebral expansion systems have recently been described. The VBS™ system (Synthes) is one of the most widely used vertebral expansion systems in the world. It associates a kyphoplasty balloon and a stent similar to those used in vascular surgery. The principle is that the stent remains in the cavity, preventing the correction loss classically observed after balloon withdrawal [44].

OssoFix™ (Sientx-Alphatec) and Spine Jack™ (Vexim) use stents (or jacks) alone. The declared objective is to reduce the dose of cement. However, they show poorer correction of the vertebral deformity than with balloons, which raise the plateau more gradually and physiologically.

The AscendX™ system (AscendX Spine) introduces the balloon via a unipedicular route, theoretically reducing operative time and radiation. It also enables cement injection to be initiated with the balloon still in place. It is, however, technically difficult to center the balloon, which is deployed asymmetrically.

The Kiva™ system (Zimmer) deploys a spiral PEEK cage via a unipedicular route. The drawbacks are the same as above: poor correction and difficult technique. This system does, however, reduce the risk of cement leakage, and could be a good solution for lytic vertebral lesions.

8. Conclusion

Vertebral balloon kyphoplasty is a reliable technique, the clinical benefit of which has been well established. Initially developed for tumoral lesions and osteoporotic compression, it has proved its usefulness in traumatic fracture in young patients, where it is a legitimate alternative to very demanding conventional treatments.

The possibility of associating posterior percutaneous osteosynthesis extends indications to fractures with an element of distraction. Benefit in terms of quality of life is a major argument in favor of developing this technique, especially in young patients.

The main issue concerns the cement. As well as the theoretic risk of shock associated with injection, the long-term evolution of acrylic cement within the vertebral body remains to be seen. Developing novel “physiological” cements with the same biomechanical properties as acrylic cements is a hopeful prospect.

Irradiation of patient and theater team by the indispensable peroperative fluoroscopy is a drawback. Experience and rigorous training allow the team to reduce exposure significantly.

These percutaneous techniques require surgeons well experienced in standard open surgery and able to deal with possible peroperative complications. Ideally, they should be performed in specialized spine-surgery centers.

Finally, costs remain high (around €4000), while reimbursement by the French national health insurance scheme is still under negotiation.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References

Assessment

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