Kyphoplasty

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ABSTRACT

The advent of the use of kyphoplasty in 1998 was the result of the expected evolution of materials and methods related to the successful introduction of vertebroplasty as a valid treatment of painful vertebral compression fractures. Kyphoplasty introduced a method of creating bilateral bone voids and in many cases elevation (reduction) of depressed end plates with variable degrees of height restoration. This was achieved by using bilateral balloon bone tamps capable of pressures significantly higher than conventional angioplasty balloons. This allows creation of bilateral bone voids, resulting in the ability to apply a much thicker cement mixture. This is felt to be the reason for fewer cement-related complications compared with vertebroplasty including extravasation and embolization. Although the procedural cost presently is higher for kyphoplasty, this is expected to decrease as patents expire and industry competition increases. Kyphoplasty indications include all those of vertebroplasty plus additional ones either contraindicated or not recommended for treatment with vertebroplasty. Kyphoplasty achieves the same degree of pain relief as vertebroplasty but may offer additional benefits of fewer complications, more indications, better biopsy specimens, and potential for height restoration of compression fractures of the spine. Further studies regarding potential benefits are warranted to assess any added value of kyphoplasty compared with vertebroplasty.

KEYWORDS: Kyphoplasty, vertebral compression fractures, vertebroplasty, pathological fractures, osteoporosis, vertebral augmentation

Objectives: Upon completion of this article, the reader should be able to list the indications, methods, and outcomes of kyphoplasty and explain the differences compared to vertebroplasty.

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The interventional treatment of vertebral compression fractures (VCFs) has undergone tremendous and anticipated evolution since its introduction by Herve Deramond and colleagues^{1,2} in the 1980s. Vertebroplasty was the first type of intervention that demonstrated tremendous success in controlling, and many times completely relieving, the pain associated with

VCFs.³⁻⁷ Prior to this, medical therapy with narcotic analgesia as the core component was the mainstay of treatment.

Developed in 1998 by an Orthopedic Surgeon in the United States and then refined and marketed by the Kyphon Corporation (Sunnyvale, CA) for use in 2001, kyphoplasty offered an additional type of intervention

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Musculoskeletal Interventions; Guest Editors, Tarun Sabharwal,

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Semin Intervent Radiol 2010;27:172-184. Copyright © 2010 by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA. Tel: +1(212) 584-4662.

DOI: <http://dx.doi.org/10.1055/s-0030-1253515>.

ISSN 0739-9529.

for VCFs. Kyphon Corporation was since acquired by Medtronic Corporation (Minneapolis, MN, USA) 2009. The primary difference compared with vertebroplasty was the use of bilateral balloon bone tamps that allowed creation of bilateral bone voids (Fig. 1A, B) and in many cases reduction (elevation) of fracture fragments, which restored some lost height of the bodies prior to the application of polymethyl methacrylate (PMMA) cement (Fig. 1C). The advent of this procedure has stimulated development of many other vertebral augmentation techniques including skyphoplasty (Disc Orthopedic Technology, Monroe Township, NJ)⁸ and soon to be introduced vertebral body stenting (Synthes, Oberdorf, Switzerland). Initially, the introducer cannula for the balloon bone tamps was 8-gauge in size, which was larger than the usual 11-gauge vertebroplasty cannula. Recently the “Express” system (Medtronic, Minneapolis, MN, USA) has been introduced, which is a tapered cannula

with the portion entering the body being only 10-gauge (Fig. 2), and the external portion, 8-gauge.

With the creation of bilateral bone voids in vertebral bodies, the application of the PMMA cement is significantly different compared with vertebroplasty.^{9,10} It is more similar to drilling out a dental cavity and then packing in the filling material with a cement of puttylike consistency. It is applied under no or minimal pressure through each of the cannulas after deflation and removal of the bone tamps. This significantly reduces the risk of any leak or embolization of the cement material from the confines of the vertebral body, resulting in statistically fewer complications compared with vertebroplasty.^{11–13} As the majority of complications are related to cement embolization/extravasation, this is a key feature of kyphoplasty.

With time, this procedure has evolved from inpatient-based requiring general anesthesia and computed

Figure 1 (A) Typical vertebral body compression fracture. (B) Placement and inflation of balloon bone tamps for creation of bone voids and potential reduction of depressed bone fragments. (C) Deflation and removal of bone tamps and then filling of created voids with polymethyl methacrylate cement.

Figure 2 Kyphon Express Access system. Left to right: bone access trocar with diamond tip; hand bone drill to create tract for balloon bone tamps; interchangeable bevel bone trocar tip; cement delivery cannula with pusher; bone biopsy cutting cannula. Bottom: balloon bone tamp with insufflator attached.

tomography (CT) guidance to an outpatient procedure performed under conscious sedation using biplane or C-arm fluoroscopy similar to vertebroplasty.

PATIENT SELECTION AND CLINICAL CONSIDERATIONS

The indications for kyphoplasty are the same as for vertebroplasty.¹³ Kyphoplasty has been used additionally in certain patients where vertebroplasty historically has been contraindicated or at least not recommended.^{14–18} This includes patients with loose, retropulsed fragments (Fig. 3A, B) as well as pathological fractures, particularly

multiple myeloma^{19,20} where the integrities of bony cortex is uncertain (Fig. 4A–F).

In retropulsed fragments, it has been demonstrated that kyphoplasty can actually result in anterior reduction of retropulsed fragment(s) after elevating the depressed anterior end plates.^{21,22} Never have the retropulsed fragments moved any more posteriorly with kyphoplasty. Whenever the integrity of bone is suspect either on the basis of trauma or pathological fracture or destruction, kyphoplasty is preferred over vertebroplasty as the risk of cement leakage or embolization is less.^{11,13,23}

The original indications for intervention of VCFs dealt primarily with refractory pain after a period of

Figure 3 (A) Radiograph of L1 compression fracture with question of retropulsed fragment of the posterosuperior corner of the body. (B) Computed tomography sagittal reconstruction at same level showing retropulsed fragment.

Figure 4 (A) Magnetic resonance imaging Shortened T1 Inversion Recovery (STIR) sequence showing extensive involvement of spine with multiple myeloma (areas of increased signal) with pathological compression fracture of T7. (B) Lateral radiograph of pathological fracture of T7. (C) Advancement of guiding cannula to posterior portion of body, and then coaxial hand drill is used to create bony tract for balloon tamps. (D) Advancement of balloon bone tamps with creation of bilateral bone voids and potential reduction of depressed endplates. (E) Simultaneous inflation of both balloon bone tamps with creation of bilateral bone voids and potential reduction of depressed endplates. (F) Application of polymethyl methacrylate cement to each created void. Note that cement distribution approximates the shape of inflated bone tamps.

optimized medical therapy.^{15,24,25} With the advent of kyphoplasty and the potential to augment lost body height, the ideal time to achieve this is earlier rather than later. After 6 to 8 weeks, most patients have undergone some degree of healing with deposition of callus along fracture lines. The bone will probably still be somewhat “plastic,” allowing successful kyphoplasty-produced restoration of height. Beyond 6 months, the chance of significant restoration of height drops dramatically.^{26,27} This begs the question as to when we should be performing these procedures. Although some parts of the world are mandated by arbitrary time periods before performing VCF intervention, I would suggest the following categories of VCF patients be considered earlier rather than later for intervention with either vertebroplasty or kyphoplasty:

1. Osteoporotic fractures still requiring narcotic analgesia after 2 to 6 weeks of optimal medical treatment.
2. Demonstration of continued vertebral body collapse on subsequent imaging particularly if associated with increased pain (additional or refractures).
3. Painful pathological fractures requiring moderate- to high-dose narcotics for management, particularly if the narcotics are poorly tolerated.
4. Any person requiring hospitalization for pain control of vertebral fractures.
5. Chronic (>6 months old) fractures still requiring pain management therapy that show persistent bone edema on Shortened TI Inversion Recovery (STIR) magnetic resonance imaging (MRI) sequences correlating to area of pain on physical exam.
6. Immobilization due to the pain of the fracture and/or narcotics required for management; earlier than usual intervention recommended in particular for bedridden elderly patients at risk for decubitus ulcers, deep

vein thrombosis, or pneumonia with the goal being early ambulation to reduce these risks.^{28,29}

7. Acute fractures in people with significant vertebral height loss that may benefit from height restoration and corrected axial alignment over the long term (i.e., multiple wedge compression fractures causing focal kyphosis in young or middle-aged individual).

These suggested categories expand the initial recommendations of conditions that may benefit from percutaneous intervention, with some being more specific to kyphoplasty, particularly those in groups 2, 3, and 7.

All potential candidates for this procedure should be fully evaluated including detailed history, review of laboratory and imaging studies, check of coagulation parameters, and last but not most importantly, a physical exam. This should be a complete examination and not just focused on the spine. To provide adequate anesthesia, the patient's cardiopulmonary status needs to be fully evaluated. Additional laboratory and imaging tests may be needed after the assessment. The gold standard imaging for VCFs is an MRI of the affected spine with STIR sequences (Fig. 5A, B), which show edema at fractures that are acute or subacute. Increased signal in the affected vertebra has the highest degree of correlation to being the source generator of pain. If MRI cannot be performed due to contraindication or lack of available scanner, then nuclear medicine bone scintigraphy is a valuable alternate tool that will show increased activity at areas of active bone metabolism including healing.³⁰

Finally, all patients should be seen postprocedure, preferably at least a week later. This allows follow-up of the wound as well as evaluation as to the effectiveness of the procedure. All patients suspected of having osteoporosis as the cause of their fractures should be evaluated

Figure 5 (A) Increased signal in subacute vertebral body fracture on Shortened TI Inversion Recovery (STIR) sequence magnetic resonance imaging (MRI). Note previous kyphoplasty two levels below where polymethyl methacrylate cement corresponds to decreased signal in center of body. (B) Increased signal on STIR sequence MRI of recent fracture of T12 indicating bone edema due to fracture.

and placed in long-term treatment programs by either their referring physician or specialists in bone mineral metabolism, such as an endocrinologist. If the pain is not significantly relieved, patients need to be reevaluated as to the cause, which could include undetected fracture at another level or a myriad of other conditions that cause back pain and referral to a neurosurgeon or orthopedic surgeon or physical medicine specialist may be necessary.

PROCEDURAL AND TECHNICAL CONSIDERATIONS

As stated before, after full evaluation of the patient and assessment as to the safety of the performance of the procedure, the majority of patients do very well with monitored conscious sedation.^{31,32} Typically a combination of intravenous Midazolam, (Baxter Healthcare, Deerfield, IL, USA) and fentanyl (synthetic opioid) is given in titrated amounts to produce adequate anesthesia while under constant monitoring of respiratory and cardiac function. A few patients will require the assistance of the anesthesia service to either provide deep sedation with propofol infusion or general anesthetic with intubation. These are generally patients who have significant comorbidities such as diffuse, painful metastatic disease or severe cardiopulmonary compromise. The use of prophylactic antibiotics has been advocated for patients who are severely immunocompromised and the usual antibiotic given is cephazolin (Ancef, Glaxo SmithKline, Brentford, Middlesex, UK) 1 g intravenously prior to the procedure. In the past, some operators added powdered tobramycin to the cement/barium combination. No proven advantage to this was demonstrated, and once the high cost of it was realized, this ritual was abandoned. The ideal platform for performance of the procedure is a high-resolution dedicated biplane fluoroscopy procedure room with monitoring equipment and medical gases support suited for general anesthesia if needed. The minimum equipment necessary is a room with adequate cardiopulmonary monitoring equipment, medical gases readily available, high-resolution rotating C-arm fluoroscopy, and trained medical and nursing staff capable of performing the procedure while providing monitored conscious sedation (and reversing it if needed). The American College of Radiology classifies this as an embolization procedure with all the inherent recognized standards of care and expected outcomes as to success and complication rates.³³⁻³⁵ Some authors have advocated use of CT guidance^{36,37} because even the smallest amounts of extravasated cement can be detected, but this can be quite cumbersome and typically results in longer procedural times as well as increased radiation doses.^{38,39} CT guidance has been used more frequently for other spinal interventions, such as selective nerve root blocks and focused body or pedicle biopsies. The best of both worlds may soon be available as vendors now

provide combined biplane fluoroscopy with dynamic CT in the same interventional suite.

The usual positioning of the patient for the procedure is prone with creation of slight obliquity using foam wedges for better patient comfort, as well as to allow the lateral arm of the fluoroscopy unit to actually go slightly past true lateral, which is very helpful in rotoscoliotic patients. As bipedicle approach is the standard for kyphoplasty, both A and B planes are oriented in true anteroposterior and lateral positions. If using a single rotating C-arm, many of these machines have memory software that can be utilized for rapid changes between the two planes. The key to success with any vertebral intervention is optimizing the initial imaging geometry to plan the safest and most accurate route of the bone trocars. A little extra time planning can save a tremendous amount of procedural time as well as operator stress later. Local anesthesia of the skin is accomplished with 1% lidocaine buffered with bicarbonate (to reduce the burning sensation) along the expected tract. Deeper local anesthetic including that of the periosteum and bone of the pedicle is then performed with 2% bupivacaine, as this has better efficacy and is longer lasting than that of lidocaine, particularly in the periosteum. A blade is then used to create a tract from the skin to the superolateral corner of the pedicle. As the surface of the pedicle is not a flat surface to the path, the blade is used to "notch" the periosteum to allow the access trocar to be seated in it and not slide off. The kyphoplasty access trocar has interchangeable stylets including a diamond tip, a bevel tip, and a seating-type screw tip (Fig. 6). Generally, the diamond or screw tip is used for initial access and seating of the cannula, and the bevel tip is used after the initial seating for small redirections as it is advanced. As with any vertebral intervention, particular care is taken to pass the trocar through the pedicle, angling from lateral to medial aspect but absolutely ensuring that the medial wall of

Figure 6 Top to bottom: bevel tip, bone trocar of coaxial access system; outer cannula; diamond tip bone trocar.

the pedicle is respected, as any breach may result in entry into the spinal canal. The trocar needs to be advanced only 3 to 5 mm into the posterior aspect of the vertebral body. Gradual advancement of the trocar is accomplished using a small mallet, with each tap giving small controlled forward advancement of the trocar. The procedure is performed bilaterally, and at this point, biopsy would be performed if indicated. We do not routinely biopsy all patients, particularly ones that already have pathologically proven disease. Some authors advocate biopsying all patients, but this is not cost-effective when the results may not always dictate clinical management. Unfortunately, in some areas of the world, the additional remuneration for biopsy may dictate clinical decision making. An advantage of kyphoplasty as far as biopsy is concerned is the dedicated coring cannula that is paired to the outer-access cannula, which produces long, continuous cores bilaterally, which will place you back on the Christmas card list of your pathology department.

Following biopsy, a small hand drill (Fig. 7A) is advanced through the access cannula and is used to create a bony tract to the anterior portion of the vertebral body to allow advancement of the balloon bone tamp. The outer cannula can be used for minor changes in the path of the drill by applying gentle angulation of it during the drilling process. The advancement of the drill tip is constantly monitored under fluoroscopy to ensure the anterior wall of the vertebral body is not breached. If a cleft fracture line is present, it is necessary to pass either into or through it to allow the cement to fuse the fragments. The created bony tract may have small sharp fragments that are capable of rupturing the balloon even at lower pressures. A blunt-end pusher is utilized to clear and compact these fragments prior to advancing the balloon bone tamp down the tract into position. Depending on the size of the vertebral body, either a 10- or 15-mm balloon bone tamp is chosen, with the former usually tailored to the thoracic vertebrae and the latter to the lumbar vertebrae. The balloon is mounted on a stiffened catheter (Fig. 7B) and advanced through the access cannula till the markers of each balloon are centered in their respective hemivertebra. A nominal amount of a 50/50 mixture of myelographic contrast and saline is used to inflate each balloon just enough to hold each in position. Under constant fluoroscopic monitoring, the balloons are simultaneously inflated in increments of about 0.5 mL at a time. Attention is also paid to the pressure monitors of each inflation device so as to not exceed the recommended maximum of 300 psi. Ideally, as the balloons expand and the cavities are created, there will be gradual degradation of the pressures, allowing addition of more volume to each balloon and potentially fracture reduction with elevation of the depressed end plates. End points of inflation include flattening of the balloon along a lateral

Figure 7 (A) Cutaway vertebral body showing transpedicle approach. Hand drill entering through pedicle on left (above) and outer guiding cannula (Express) entering through right (below) pedicle. (B) Inflated 10-mm balloon bone tamp.

wall, herniation of balloon through a defect in end plate, or rupture of balloon. Posteriorly, care must be taken to ensure the posterior margin of the balloon does not pass beyond the margin of the posterior quarter of the vertebral body. As the main goal of this procedure is to relieve the pain of the fracture in the safest fashion possible, the reduction of the fractured (depressed) end plates is a secondary ancillary benefit if it occurs and not a procedural goal. The majority of cases do demonstrate some reduction in the degree of compression having stated this.

During the process of gradual inflation of the bone tamps, an assistant can be mixing the cement/barium particle mixture as it typically takes ~10 to 14 minutes for it to thicken to a puttylike consistency after mixing. The time depends on the ambient temperature of the room. Typically, it is ~12 minutes at 68°F (20°C) when the cement is ready for application to the created

Figure 8 Balloon bone tamp attached to insufflator device. Black plunger position corresponds to volume in milliliters within inflated balloon.

voids. The recommended cement for kyphoplasty is Kyph-X HV-R (Medtronic, Minneapolis, MN, USA), which is specifically formulated to allow extended working times, making it easier to handle while in a thickened state. Prior to deflating and removing either of the balloon bone tamps, the amount in each balloon can be determined by looking at the transparent fluid-filled measurement chamber (Fig. 8) of the inflation device. The volume is measured from the 0 marker, with the plunger position being the applied volume to the balloon. This aids in determining the ideal amount of cement to be applied to the void once the balloon tamp is deflated and removed. The latest Kyphon Express system cement cannulas each hold 1.2 mL of cement, with a total of 16 cannulas (Fig. 9) supplied in each kit with accompanying pushers. The cement is tested by injection from a syringe directed downward. If the column of extruded cement lengthens and breaks

off, it is still too thin. If the column does not stretch and break off, it is ready for application. One of the bone tamps is deflated and removed after determining the volume of the inflation. The preloaded cement cannula is advanced through the access cannula under fluoroscopic monitoring until the tip reaches the anterior margin of the created bone void. The cement is gradually applied to this space under little or no pressure with the pusher. The cement remains in a continuous rounded globular shape and is easily pressed up against the anterior wall of the void. This portion of the procedure requires the undivided attention of the operator to ensure no cement leaks from the confines of the created bone void. The cement fortunately has a uniform radiopaque consistency, making visualization of it quite easy compared with the “speckled” appearance of the typical vertebroplasty cement. Additional cannulas are then substituted till the volume approximates that of the created void. The cannula and pusher are left in to hold the posterior margin of the cement in position as the opposite-side balloon tamp is deflated and removed. The same procedure is then performed on that side. If at any point during the application of cement to either cavity the cement goes through a defect in an end plate or sidewall or fills a draining vein, the application is stopped. Further application can be attempted only after waiting for the nontarget cement to seal the leak or by repositioning the application cannula tip to redirect the cement elsewhere.

The filling of these created voids with the cement material is equivalent to a dentist drilling out a dental caries and then filling the cavity with dental cement. The chance of nontarget embolization of cement is dramatically decreased with this low-pressure, known-volume

Figure 9 Typical table setup for kyphoplasty (left to right). Cement pushers; cement delivery cannulas; access cannulas with interchangeable trocar tips; hand drills and insufflators with attached balloon bone tamps. Note closed cement-mixing system on far left, upper portion of table.

system. Both cannulas and their respective pushers are brought back to the posterior margins of the cement and held there to allow the cement to harden sufficiently for safe removal of the cannulas. Once a firm surface is felt when struck with the pusher, this indicates the cement has hardened sufficiently and the cannula can be removed without any cement leakage along the access tract. After removal of the cannulas, direct pressure is applied to each tract for a minimum of 5 minutes to provide hemostasis of the tract and prevent soft tissue hematoma, which can be quite painful in the postprocedural period. The wounds are cleaned and dressed, and then the patient is transferred to a monitoring area for generally a 2-hour postprocedural observation period. Patient is placed in a supine position for the first hour of bed rest primarily to tamponade the access wounds. After the first 30 minutes, the patient is allowed to progress to usual diet. Near the end of the observation period, the patient is gradually ambulated prior to discharge. Inpatients are taken back to their hospital rooms

for postprocedural monitoring. Prior to discharge, patients are instructed to begin gradually increasing levels of ambulation with hopes of increasing their mobility and at the same time reducing their needs for any narcotic analgesics. Follow-up in a week to 10 days is recommended as described earlier in this article.

CLINICAL OUTCOMES AND COMPLICATIONS

The achievement of relief of pain from VCFs is the penultimate goal in vertebral interventions. The literature states this is achieved 92% of the time in kyphoplasty and a comparable 87% in vertebroplasty. The rate of cement leakage and/or embolization is reported to be 20 to 40% in vertebroplasty and 9% in kyphoplasty.⁴⁰⁻⁴² Symptomatic complication rates are reported as 1.6 to 3.0% for vertebroplasty and 0 to 0.3% for kyphoplasty.^{43,44} These symptomatic complications include radicular neuropathies, pulmonary emboli (Fig. 10A-C), renal emboli,

Figure 10 (A) T8 vertebroplasty with cement filling draining veins on patient's right side (prone position). (B) Same patient showing cement emboli in right pulmonary arterial system. (C) Same patient chest posteroanterior radiograph demonstrating cement-cast paravertebral veins and pulmonary artery branches on right side.

Figure 11 (A) Axial computed tomography (CT) image postkyphoplasty demonstrating ideal cement distribution resulting in bridging of the multiple complex fracture fragments. (B) Axial CT image postvertebroplasty showing casting with cement of epidural veins causing impression upon thecal sac and extension toward neural foramina.

femoral neuralgia with sciatica, neurological deficit, and posterior column deficit with proprioception loss.^{23,45–48} Cement extravasation or embolization (Fig. 11A, B) can increase patient mortality and may necessitate hospitalization and may require open surgical removal of the extravasated cement. Great care should be taken to prevent or limit the amount of extravasated cement even into adjacent soft tissues and intervertebral discs as long-term effects of these “nonsymptomatic” complications still need to be evaluated in the long term. As kyphoplasty has a reduced rate of cement extravasation and subsequent complications (Fig. 12), it may prove to be a safer method of treating painful VCFs. Double-blind randomized trials of these two procedures need to be undertaken to assess this. Initial claims of kyphoplasty being a significantly more expensive procedure were

Figure 12 Same patient as in Fig. 10 following subsequent kyphoplasties at levels above and below previous vertebroplasty at T8. Note the more controlled application of the polymethyl methacrylate cement at the kyphoplasty levels and in particular the lack of any extravasation or embolization compared with vertebroplasty.

based on the premise that it was done using CT guidance, under general anesthesia, and required inpatient status of patients. The procedure has evolved to being done under fluoroscopy (preferably biplane), using conscious sedation and on an outpatient basis. Now the only price difference lies in the price of the materials (kits) to perform the procedure. Although higher cost, kyphoplasty kits are expected to gradually decrease as the patents Kyphon holds expire with time and more competitors are allowed into the market. The stated advantage of increase in vertebral body height initially championed by the Kyphon Corporation have not been borne out according to Mathis.⁴⁹ As previously stated, this is a secondary ancillary benefit and not the primary reason for performance of the procedure. Other complications that fortunately occur far less frequently include development of infection, including cellulitis, abscess, and worse yet, osteomyelitis^{50,51} as well as hemorrhage and hematoma. These are probably rare due to the use of proper sterile technique and monitoring of blood coagulation parameters prior to any procedure. In the recently published results of the FREE Trial, it is reported that kyphoplasty was superior to nonsurgical treatment of VCFs as far as improved quality of life, quicker return to physical function, and faster relief of pain. There was no difference in the adverse effects between the two groups. The kyphoplasty-treated patients had an average of 60 fewer restricted activity days per year compared with the nonsurgically treated patients. The kyphoplasty group also had reduced needs for narcotic analgesia, decreased overall body pain, and improved social function throughout the yearlong follow-up. There was no evidence of any increased risk of additional VCFs in the kyphoplasty group compared with the nonsurgical group of patients.⁵²

CONCLUSION

The introduction of kyphoplasty as an adjunctive treatment to vertebroplasty for treatment of symptomatic VCFs is still somewhat controversial as to its indications. These are slowly evolving and are increasing primarily

due to the apparent inherent increased safety of kyphoplasty as far as extravasated and embolized cement is concerned. As the majority of complications associated with vertebral interventions are related to nontarget cement deposition, it appears that kyphoplasty may offer a higher margin of safety. This is particularly true in cases where the integrity of the vertebral body may be compromised including pathological fractures. The stated advantage of height restoration has not been borne out in the literature, but this may be an advantage in the younger population where the long-term effects restoring height and alignment have not been assessed. Myeloma patients seem to do much better with kyphoplasty versus vertebroplasty as far as outcomes are concerned.⁵³ The bilateral access for biopsy purposes increases the chance of obtaining significant pathological

specimens compared with the single-side access used in vertebroplasty. Both procedures have similar results as far as outcome of treatment of osteoporotic fractures, but there may be a small advantage to kyphoplasty related to the reduced rate of complication of nontarget cement deposition (Fig. 13A–C). The cost of kyphoplasty has significantly decreased over time, so that now the only difference from vertebroplasty is in the cost of the kit. This kit should continue to decrease in price as more competitors are allowed into the market. Both vertebroplasty and kyphoplasty have revolutionized the treatment of painful VCFs. Patients around the world are ecstatic with the rapid reduction of such severe debilitating pain that it is hard to believe the recently published results of Kallmes et al are accurate.⁵⁴ This report only stimulates further questions and answers few. New

Figure 13 (A) Application of bilateral balloon tampers to T6 vertebral compression fracture. (B) Inflated balloon bone tampers with creation of bilateral bone voids. (C) Filling of created voids with application of polymethyl methacrylate cement resulting in good distribution of cement horizontally and vertically.

double-blind prospective trials comparing vertebroplasty to kyphoplasty need to be designed and performed.^{55,56} These must include such parameters as degree of pain control, cost of ongoing care, and performance status including time away from work and should include, short, intermediate, and long-term follow-up. The medical community needs to be convinced scientifically that these new interventions are better than conventional symptomatic treatment. The challenge of designing and implementing the trials to assess this lies in our hands.

REFERENCES

- Galibert P, Deramond H, Rosat P, Le Gars D. [Preliminary note on the treatment of vertebral angioma by percutaneous acrylic vertebroplasty]. *Neurochirurgie* 1987;33:166–168
- Deramond H, Darrasson R, Galibert P. Percutaneous vertebroplasty with acrylic cement in the treatment of aggressive spinal angiomas. *Rachis* 1989;1:143–153
- Jensen ME, Evans AJ, Mathis JM, Kallmes DF, Cloft HJ, Dion JE. Percutaneous polymethylmethacrylate vertebroplasty in the treatment of osteoporotic vertebral body compression fractures: technical aspects. *AJNR Am J Neuroradiol* 1997;18:1897–1904
- Gangi A, Guth S, Imbert JP, Marin H, Dietemann JL. Percutaneous vertebroplasty: indications, technique, and results. *Radiographics* 2003;23:e10
- McGraw JK, Lippert JA, Minkus KD, Rami PM, Davis TM, Budzik RF. Prospective evaluation of pain relief in 100 patients undergoing percutaneous vertebroplasty: results and follow-up. *J Vasc Interv Radiol* 2002;13(9 Pt 1):883–886
- Evans AJ, Jensen ME, Kip KE, et al. Vertebral compression fractures: pain reduction and improvement in functional mobility after percutaneous polymethylmethacrylate vertebroplasty retrospective report of 245 cases. *Radiology* 2003;226:366–372
- Rao RD, Singrakha MD. Painful osteoporotic vertebral fracture. Pathogenesis, evaluation, and roles of vertebroplasty and kyphoplasty in its management. *J Bone Joint Surg Am* 2003;85-A:2010–2022
- Tong SC, Eskey CJ, Pomerantz SR, Hirsch JA. “SKyphoplasty”: a single institution’s initial experience. *J Vasc Interv Radiol* 2006;17:1025–1030
- Lieberman IH, Dudeney S, Reinhardt MK, Bell G. Initial outcome and efficacy of “kyphoplasty” in the treatment of painful osteoporotic vertebral compression fractures. *Spine (Phila Pa 1976)* 2001;26:1631–1638
- Phillips FM, Ho E, Campbell-Hupp M, McNally T, Todd Wetzell F, Gupta P. Early radiographic and clinical results of balloon kyphoplasty for the treatment of osteoporotic vertebral compression fractures. *Spine (Phila Pa 1976)* 2003;28:2260–2265; discussion 2265–2267
- Taylor RS, Taylor RJ, Fritzell P. Balloon kyphoplasty and vertebroplasty for vertebral compression fractures: a comparative systematic review of efficacy and safety. *Spine (Phila Pa 1976)* 2006;31:2747–2755
- Robinson Y, Tschöke SK, Stahel PF, Kayser R, Heyde CE. Complications and safety aspects of kyphoplasty for osteoporotic vertebral fractures: a prospective follow-up study in 102 consecutive patients. *Patient Saf Surg* 2008;2:2
- Choe DH, Marom EM, Ahrar K, Truong MT, Madewell JE. Pulmonary embolism of polymethyl methacrylate during percutaneous vertebroplasty and kyphoplasty. *AJR Am J Roentgenol* 2004;183:1097–1102
- Masala S, Fiori R, Massari F, Simonetti G. Kyphoplasty: indications, contraindications and technique. *Radiol Med (Torino)* 2005;110:97–105
- Peh WC, Gilula LA. Percutaneous vertebroplasty: indications, contraindications, and technique. *Br J Radiol* 2003;76:69–75
- Gangi A, Guth S, Imbert JP, Marin H, Dietemann JL. Percutaneous vertebroplasty: indications, technique, and results. *Radiographics* 2003;23:e10
- Gangi A, Wong L, Guth S, Dieterman J. Percutaneous vertebroplasty: indications, technique, and results. *Semin Intervent Radiol* 2002;19:265–270
- Fourney DR, Schomer DF, Nader R, et al. Percutaneous vertebroplasty and kyphoplasty for painful vertebral body fractures in cancer patients. *J Neurosurg* 2003;98(1 Suppl):21–30
- Pflugmacher R, Taylor R, Agarwal A, et al. Balloon kyphoplasty in the treatment of metastatic disease of the spine: a 2-year prospective evaluation. *Eur Spine J* 2008;17:1042–1048
- Hussein MA, Vrionis FD, Allison R, et al; International Myeloma Working Group. The role of vertebral augmentation in multiple myeloma: International Myeloma Working Group Consensus Statement. *Leukemia* 2008;22:1479–1484
- Hillmeier J, Meeder PJ, Noeldge G, et al. Minimally invasive reduction and internal stabilization of osteoporotic vertebral body fractures (balloon Kyphoplasty). *Eur J Trauma* 2005;3:280–290
- Voggenreiter G. Balloon kyphoplasty is effective in deformity correction of osteoporotic vertebral compression fractures. *Spine (Phila Pa 1976)* 2005;30:2806–2812
- Nussbaum DA, Gailloud P, Murphy K. 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* 2004;15:1185–1192
- Kallmes DF, Jensen ME. Percutaneous vertebroplasty. *Radiology* 2003;229:27–36
- Peh WC, Gilula LA. Percutaneous vertebroplasty: an update. *Semin Ultrasound CT MR* 2005;26:52–64
- Crandall D, Slaughter D, Hankins PJ, Moore C, Jerman J. Acute versus chronic vertebral compression fractures treated with kyphoplasty: early results. *Spine J* 2004;4:418–424
- Karlsson MK, Hasserius R, Gerdhem P, Obrant KJ, Ohlin A. Vertebroplasty and kyphoplasty: new treatment strategies for fractures in the osteoporotic spine. *Acta Orthop* 2005;76:620–627
- Zoarski GH, Snow P, Olan WJ, et al. Percutaneous vertebroplasty for osteoporotic compression fractures: quantitative prospective evaluation of long-term outcomes. *J Vasc Interv Radiol* 2002;13(2 Pt 1):139–148
- Lavelle W, Carl A, Lavelle ED, Khaleel MA. Vertebroplasty and kyphoplasty. *Anesthesiol Clin* 2007;25:913–928
- Maynard AS, Jensen ME, Schweickert PA, Marx WF, Short JG, Kallmes DF. Value of bone scan imaging in predicting pain relief from percutaneous vertebroplasty in osteoporotic vertebral fractures. *AJNR Am J Neuroradiol* 2000;21:1807–1812

31. Della Puppa A, Andreula C, Frass M. Assisted sedation: a safe and easy method for pain-free percutaneous vertebroplasty. *Minerva Anestesiol* 2008;74:57–62
32. White SM. Anaesthesia for percutaneous vertebroplasty. *Anaesthesia* 2002;57:1229–1230
33. Gangi A, Sabharwal T, Irani FG, Buy X, Morales JP, Adam A; Standards of Practice Committee of the Society of Interventional Radiology. Quality assurance guidelines for percutaneous vertebroplasty. *Cardiovasc Intervent Radiol* 2006;29:173–178
34. Barr JD, Mathis JM, Barr MS, et al. Standard for the performance of percutaneous vertebroplasty. In: American College of Radiology Standards 2000–2001 Reston, VA: American College of Radiology; 2000:441–448
35. Mathis JM, Barr JD, Belkoff SM, Barr MS, Jensen ME, Deramond H. Percutaneous vertebroplasty: a developing standard of care for vertebral compression fractures. *AJNR Am J Neuroradiol* 2001;22:373–381
36. Gangi A, Kastler BA, Dietemann JL. Percutaneous vertebroplasty guided by a combination of CT and fluoroscopy. *AJNR Am J Neuroradiol* 1994;15:83–86
37. Vogl TJ, Proschek D, Schwarz W, Mack M, Hochmuth K. CT-guided percutaneous vertebroplasty in the therapy of vertebral compression fractures. *Eur Radiol* 2006;16:797–803
38. Seibert JA. Vertebroplasty and kyphoplasty: do fluoroscopy operators know about radiation dose, and should they want to know? *Radiology* 2004;232:633–634
39. Kruger R, Faciszewski T. Radiation dose reduction to medical staff during vertebroplasty: a review of techniques and methods to mitigate occupational dose. *Spine (Phila Pa 1976)* 2003;28:1608–1613
40. Gill JB, Kuper M, Chin PC, Zhang Y, Schutt R Jr. Comparing pain reduction following kyphoplasty and vertebroplasty for osteoporotic vertebral compression fractures. *Pain Physician* 2007;10:583–590
41. Mathis JM, Ortiz AO, Zoarski GH. Vertebroplasty versus kyphoplasty: a comparison and contrast. *AJNR Am J Neuroradiol* 2004;25:840–845
42. McGirt MJ, Parker SL, Wolinsky JP, Witham TF, Bydon A, Gokaslan ZL. Vertebroplasty and kyphoplasty for the treatment of vertebral compression fractures: an evidenced-based review of the literature. *Spine J* 2009;9:501–508
43. Taylor RS, Taylor RJ, Fritzell P. Balloon kyphoplasty and vertebroplasty for vertebral compression fractures: a comparative systematic review of efficacy and safety. *Spine (Phila Pa 1976)* 2006;31:2747–2755
44. Eck JC, Nachtigall D, Humphreys SC, Hodges SD. Comparison of vertebroplasty and balloon kyphoplasty for treatment of vertebral compression fractures: a meta-analysis of the literature. *Spine J* 2008;8:488–497
45. Laredo JD, Hamze B. Complications of percutaneous vertebroplasty and their prevention. *Skeletal Radiol* 2004;33:493–505
46. Ratliff J, Nguyen T, Heiss J. Root and spinal cord compression from methylmethacrylate vertebroplasty. *Spine (Phila Pa 1976)* 2001;26:E300–E302
47. Choe DH, Marom EM, Ahrar K, Truong MT, Madewell JE. Pulmonary embolism of polymethyl methacrylate during percutaneous vertebroplasty and kyphoplasty. *AJR Am J Roentgenol* 2004;183:1097–1102
48. Harrington KD. Major neurological complications following percutaneous vertebroplasty with polymethylmethacrylate: a case report. *J Bone Joint Surg Am* 2001;83-A:1070–1073
49. Mathis JM. Percutaneous vertebroplasty or kyphoplasty: which one do I choose? *Skeletal Radiol* 2006;35:629–631
50. Vats HS, McKiernan FE. Infected vertebroplasty: case report and review of literature. *Spine (Phila Pa 1976)* 2006;31:E859–E862
51. Söyüncü Y, Özdemir H, Söyüncü S, Bigat Z, Gür S. Posterior spinal epidural abscess: an unusual complication of vertebroplasty. *Joint Bone Spine* 2006;73:753–755
52. Wardlaw W, Cummings SR, Van Meirhaeghe J, et al. Efficacy and safety of balloon kyphoplasty compared with non surgical care for vertebral compression fracture (FREE): a randomized controlled trial. *Lancet* 2009; vol. 373 Available at: www.thelancet.com. accessed February 24, 2009
53. McDonald RJ, Trout AT, Gray LA, Dispenzieri A, Thielen KR, Kallmes DF. Vertebroplasty in multiple myeloma: outcomes in a large patient series. *AJNR Am J Neuroradiol* 2008;29:642–648
54. Kallmes DF, Comstock BA, Heagerty PJ, et al. A randomized trial of vertebroplasty for osteoporotic spinal fractures. *N Engl J Med* 2009;361:569–579
55. Wagner AL. Vertebroplasty and the randomized study: where science and ethics collide. *AJNR Am J Neuroradiol* 2005;26:1610–1611
56. Liu JT, Liao WJ, Tan WC, et al. Balloon kyphoplasty versus vertebroplasty for treatment of osteoporotic vertebral compression fracture: a prospective, comparative, and randomized clinical study. *Osteoporos Int* 2010;21:359–364