ELSEVIER

CrossMark

The Spine Journal 15 (2015) 721–732

THE SPINE JOURNAL

Basic Science

# Is kyphoplasty better than vertebroplasty at restoring form and function after severe vertebral wedge fractures?

Priyan R. Landham, MD, FRCS (Tr&Orth)[a], Holly L.A. Baker-Rand, BSc, BM BS[a], Samuel J. Gilbert, BSc[a], Phillip Pollintine, PhD[a], Deborah J. Annesley-Williams, MD, FRCR[b], Michael A. Adams, PhD[a], Patricia Dolan, PhD[a,*]

[a]*Centre for Comparative and Clinical Anatomy, University of Bristol, Southwell St, Bristol BS2 8EJ, UK*
[b]*Department of Neuroradiology, Queen's Medical Centre, Derby Rd, Nottingham NG7 2UH, UK*

Received 25 July 2014; revised 6 November 2014; accepted 21 November 2014

**Abstract**

**BACKGROUND CONTEXT:** The vertebral augmentation procedures, vertebroplasty and kyphoplasty, can relieve pain and facilitate mobilization of patients with osteoporotic vertebral fractures. Kyphoplasty also aims to restore vertebral body height before cement injection and so may be advantageous for more severe fractures.

**PURPOSE:** The purpose of this study was to compare the ability of vertebroplasty and kyphoplasty to restore vertebral height, shape, and mechanical function after severe vertebral wedge fractures.

**STUDY DESIGN/SETTING:** This is a biomechanical and radiographic study using human cadaveric spines.

**METHODS:** Seventeen pairs of thoracolumbar ''motion segments'' from cadavers aged 70–98 years were injured, in a two-stage process involving flexion and compression, to create severe anterior wedge fractures. One of each pair underwent vertebroplasty and the other kyphoplasty. Specimens were then compressed at 1 kN for 1 hour to allow consolidation. Radiographs were taken before and after injury, after treatment, and after consolidation. At these same time points, motion segment compressive stiffness was assessed, and intervertebral disc ''stress profiles'' were obtained to characterize the distribution of compressive stress on the vertebral body and neural arch.

**RESULTS:** On average, injury reduced anterior vertebral body height by 34%, increased its anterior wedge angle from 5.0° to 11.4°, reduced intradiscal (nucleus) pressure and motion segment stiffness by 96% and 44%, respectively, and increased neural arch load bearing by 57%. Kyphoplasty caused 97% of the anterior height loss to be regained immediately, although this reduced to 79% after consolidation. Equivalent gains after vertebroplasty were significantly lower: 59% and 47%, respectively ($p<.001$). Kyphoplasty reduced vertebral wedging more than vertebroplasty ($p<.02$). Intradiscal pressure, neural arch load bearing, and motion segment compressive stiffness were restored significantly toward prefracture values after both augmentation procedures, even after consolidation, but these mechanical effects were similar for kyphoplasty and vertebroplasty.

FDA device/drug status: Not applicable.

Author disclosures: ***PRL:*** Grant: Royal College of Surgeons of England (Research Fellowship) (E), Gloucestershire Arthritis Trust (C, Paid directly to institution). ***HLAB-R:*** Nothing to disclose. ***SJG:*** Nothing to disclose. ***PP:*** Nothing to disclose. ***DJA-W:*** Nothing to disclose. ***MAA:*** Royalties: Churchill Livingstone (B, Paid directly to institution); Speaking and/or Teaching Arrangements: NASS (A); Trips/Travel: Sir Run Run Shaw Hospital, Zhejiang University (A); Grants: Technology Strategy Board, UK (D, Paid directly to institution). ***PD:*** Grant: Royal College of Surgeons of England (E, Research Fellowship for PRL, PD named on grant), Gloucestershire Arthritis Trust (C); Royalties: Churchill Livingstone (B, Paid directly to institution); Speaking and/or Teaching Arrangements: European Spine Society (A), University of Coventry (A); Trips/Travel: Sir Run Run Shaw Hospital, Zhejiang University (A).

The disclosure key can be found on the Table of Contents and at www.TheSpineJournalOnline.com.

Ethics: Research was approved by the National Research Ethics Service Ethics Committee, Frenchay Hospital, Bristol, UK.

The study was funded by the Royal College of Surgeons of England and the Gloucestershire Arthritis Trust, UK.

Authors of this study have no conflicts of interest to disclose.

* Corresponding author. Centre for Comparative and Clinical Anatomy, University of Bristol, Southwell St, Bristol BS2 8EJ, UK. Tel.: (44) (0) 117-928-8363.

*E-mail address*: Trish.Dolan@bristol.ac.uk (P. Dolan)

http://dx.doi.org/10.1016/j.spinee.2014.11.017

**CONCLUSIONS:** After severe vertebral wedge fractures, vertebroplasty and kyphoplasty were equally effective in restoring mechanical function. However, kyphoplasty was better able to restore vertebral height and reverse wedge deformity. 

*Keywords:* Vertebroplasty; Kyphoplasty; Anterior wedge fracture; Spinal deformity; Cadaver; Spinal mechanics

## Introduction

Osteoporotic vertebral compression fractures are a growing problem in aging populations. Patients suffer pain and deformity and are susceptible to consequences of immobility (such as pressure sores, infections, venous stasis, and disuse atrophy) that can make subsequent mobilization more difficult. The vertebral augmentation techniques vertebroplasty [1] and kyphoplasty [2] were introduced to reduce these clinical problems.

Vertebroplasty involves the percutaneous transpedicular injection of cement into the vertebral body. The mechanism of action probably involves stabilization of fractured bone fragments [3] and thermal ablation of nerves because of the exothermic cement-setting process [4]. Clinical case series [5–10] and a nonrandomized trial [11] have reported excellent pain relief in patients after vertebroplasty, but results from randomized trials are conflicting, with significant improvements being observed in comparison with conservative care [12,13] but not in comparison with placebo [14,15]. Furthermore, several studies have reported adverse events such as cement leakage [16] and increased risk of adjacent vertebral fracture [17–23].

Kyphoplasty is a modification of vertebroplasty that involves the inflation of balloon tamps within the vertebral body before cement injection. The balloons elevate the vertebral end plate and create a cavity into which relatively thick cement can be injected. This may reduce the risk of cement leakage [24,25] and help to restore vertebral height, thereby reversing deformity [26–31]. Kyphoplasty also has been reported to reduce pain compared with conservative care [27,32–34] but has not yet been subjected to a placebo-controlled trial. The only clinical randomized controlled trial to compare kyphoplasty and vertebroplasty reported small differences in outcomes [35].

Given the practical and ethical difficulties involved in clinical trials, much research effort has been devoted to understand the influence of both cement augmentation procedures on the physical and mechanical properties of cadaveric spines. Factors such as cement type [36,37], volume [38], and placement [39] have been shown to affect mechanical outcomes such as stiffness and strength, and some comparisons have been made between vertebroplasty and kyphoplasty [40,41]. Many of the earlier experiments involved isolated vertebrae or vertebral bodies [36,39,41–43] and were unable to assess interactions between adjacent structures, including the neural arches. More recent studies involving larger spine specimens [37,38,40,44] have shown that vertebral fracture decompresses the adjacent intervertebral disc and transfers compressive load bearing from the central vertebral body toward the outer cortex and from the vertebral bodies and discs to the neural arches. All these effects can be partially reversed by vertebral augmentation [40,44]. Most recently, these techniques have shown small but significant differences between the effects of vertebroplasty and kyphoplasty: in particular, kyphoplasty (only) was shown to be capable of reversing small angular deformities induced by minor vertebral body fractures [40]. In practice, however, the extra expense and effort involved in kyphoplasty can only be justified if it is superior to vertebroplasty in reversing (or preventing) severe vertebral deformity. This has not yet been established.

The purpose of the present cadaveric study is to compare the efficacy of vertebroplasty and kyphoplasty in reversing the deformity and abnormal load sharing caused by severe vertebral ‘‘wedge’’ fractures. This required us to develop a reproducible method of creating such fractures in vitro and to use a sensitive ‘‘matched-pair’’ experimental design that was capable of detecting consistent differences between vertebroplasty and kyphoplasty, despite the large interindividual differences that characterize old human spines.

## Materials and methods

### *Experimental design*

Each cadaver spine was dissected to obtain a pair of ‘‘motion segments’’ consisting of two vertebrae and the intervening disc and ligaments. Motion segments were loaded to create major osteoporotic wedge fractures, and then one of each pair was treated with vertebroplasty and the other with kyphoplasty. To minimize bias, the upper specimen from each pair was alternately assigned to one procedure or the other. Morphologic and mechanical properties were measured on each motion segment before and after fracture and again after vertebroplasty or kyphoplasty. To increase clinical relevance, the same properties were reassessed after a period of sustained compressive loading, which caused consolidation of the treated motion segment. All measurements were compared between each stage of the experiment and between the matched pairs of motion segments.

### *Cadaveric material*

Seventeen thoracolumbar spines were obtained from cadavers, aged 70 to 98 years, that were donated for medical