Safety of fluoroscopy guided percutaneous access to the thoracic spine

Jonathan A. Clamp · Edward J. Bayley ·
Firooz V. Ebrahimi · Nasir A. Quraishi ·
Bronek M. Boszczyk

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Abstract

Background Fluoroscopy-guided percutaneous access to thoracic vertebrae is technically demanding due to the complex radiological anatomy and close proximity of the spinal cord, major vessels and pleural cavity. There is a trend towards computed tomography (CT) guidance due to a perceived reduction in the risk of spinal canal intrusion by instrumentation causing neurological injury. Due to limited access to CT guidance, there is a need for safe fluoroscopy-guided percutaneous access to the thoracic spine.

Purpose To evaluate the safety of a strict radio-anatomical protocol in avoiding access-related neurological complications due to tool misplacement in fluoroscopy-guided percutaneous procedures on the thoracic spine.

Method A combined two-surgeon prospective case series of 444 procedures (biopsy, vertebroplasty or kyphoplasty) covering all thoracic vertebral levels T1–T12. Clinical examination and routine observations were used to identify

access-related complications including neurological, vascular and visceral injury using physiological parameters.

Results No patient in our series was identified to have sustained a neurological deficit or deterioration of preoperative neurological status.

Conclusion Percutaneous access to the thoracic spine using fluoroscopic guidance is safe. The crucial step of the protocol is not to advance the tool beyond the medial pedicle wall on the anterior–posterior projection until the tip of the instrument has reached the posterior vertebral cortex on the lateral projection.

Keywords Thoracic spine · Percutaneous · Trans-costovertebral

Background context

The developments of kyphoplasty, vertebroplasty and continued need for diagnostic biopsy have substantially increased the volume of percutaneous procedures being performed. The thoracic spine is considered to be more hazardous to access percutaneously than the lumbar spine due to the more complex radiological anatomy and close proximity to the spinal cord, major vessels and the pleural cavity. Radiographic visualisation for percutaneous access is achieved via computed tomography (CT) or fluoroscopy. CT is generally viewed as being superior with regard to risk of tool malplacement. In many institutions CT is not as readily accessible as fluoroscopy. Further disadvantages of CT guidance include radiation dose [1] and the frequent absence of a sterile working environment. To date, large series of percutaneous approaches to the thoracic spine under fluoroscopic guidance, which would allow a realistic risk appraisal of approach-related complications, have not been published.

J. A. Clamp (✉) · E. J. Bayley · F. V. Ebrahimi ·
N. A. Quraishi · B. M. Boszczyk
Department of Spinal Surgery and Studies,
University Hospital Nottingham, Queen's Medical Centre
Campus, Nottingham, UK
e-mail: jclamp@doctors.org.uk

E. J. Bayley
e-mail: ejb1@doctors.org.uk

F. V. Ebrahimi
e-mail: firooz@hotmail.com

N. A. Quraishi
e-mail: nasir.quraishi@nuh.nhs.uk

B. M. Boszczyk
e-mail: bronek.boszczyk@nuh.nhs.uk

Purpose

The purpose of this investigation is specifically to analyse the access-related complication rate of fluoroscopically guided percutaneous thoracic procedures (vertebroplasty, kyphoplasty and biopsy). A consecutive series of 444 fluoroscopically guided percutaneous approaches to the thoracic spine performed by two spine surgeons over a 10-year period is reviewed. A strict radio-anatomic protocol using a transcostovertebral approach, as described previously, was followed [2, 3].

Study design

A consecutive series of 444 fluoroscopically guided percutaneous procedures (vertebroplasty, kyphoplasty or biopsy) of all levels of the thoracic spine (Table 1) were performed by or under direct supervision of the two senior authors between January 2000 and December 2010.

Data on the type of procedure and complications were collected prospectively by the senior authors. The data collected are clinical audit: a key component of clinical governance, and is considered exempt from formal ethics committee approval. Access was achieved with either a kyphoplasty cannula or a Jamshidi needle (for biopsies or vertebroplasty). Both tools have the same external diameter of 4.2 mm, allowing data from the three procedures to be combined.

Patient sample

This comprised a consecutive series from the two senior authors over a 10-year time period.

Table 1 Breakdown of the number of vertebrae accessed per thoracic spine level

Level	Number of procedures
T1	2
T2	2
T3	6
T4	9
T5	20
T6	39
T7	62
T8	56
T9	44
T10	51
T11	70
T12	83
Total	444

The total number of vertebrae amounts to 444 vertebrae

Outcome measures

Access-related complications were identified by clinical examination. All patients were thoroughly assessed and their neurological status examined before, immediately post-operatively and prior to discharge. All examinations were performed by the operating surgeon or the assisting surgeon. Any deterioration in neurological status prompted further imaging with CT (to assess for compressive cement leakage) and/or magnetic resonance imaging (MRI) (to assess for epidural haematoma or spinal cord contusion). Routine postoperative CT scans were only performed early on in the series to assess the cement distribution in the vertebrae at a time, when limited information on thoracic augmentation procedures was available, but were not performed as a routine for the majority of this case series.

In addition, vital parameters were recorded post-operatively including a clinical evaluation and respiratory assessment for pneumothorax. Routine postoperative chest radiographs were not obtained. Clinical outcome data are not presented here as immediate complications arising through fluoroscopically guided access were the objective of this study.

Methods

The presenting pathologies included osteoporotic or low grade traumatic vertebral fractures (type AO A1.2, AO A1.3 or A3.1 with minor posterior wall disruption [4]) and osteolytic vertebral lesions. Only patients with absence of thoracic spinal cord compression and extensive osteolysis or traumatic disruption of the posterior wall were treated percutaneously and included in the case series. Patients who had pre-existing thoracic spinal cord compression or were judged to be at risk of spinal canal compromise due to extensive osteolytic lesions involving the posterior wall or extensive traumatic disruption, were treated with microsurgical open augmentation procedures [5] or conventional instrumented decompression and reconstruction. One patient with pre-existing traumatic paraplegia was excluded. The procedures were performed under general anaesthesia or under sedation combined with local anaesthetic according to the preference of the anaesthetist. Most kyphoplasty procedures were performed under general anaesthetic.

For procedures at T6 and below, conventional prone positioning was used with arms abducted and flexed at the elbow. For procedures at T5 and above, the arms were adducted and a longitudinal bolster placed under the sternum to allow the shoulder girdle to drop anteriorly. This significantly reduced superimposition of the scapula on the thoracic spine in the lateral image [6].

All procedures were performed using standard mobile image intensifiers. When available, biplanar imaging was employed. The majority of procedures was performed using a single image intensifier. Biopsy and vertebroplasty procedures were routinely performed unilaterally. Kyphoplasty was routinely performed bilaterally in the lower three vertebral levels (T10–T12) and unilaterally in the remaining levels. In one patient, the T1 vertebra was accessed bilaterally as the first inflatable balloon tamp did not converge sufficiently to provide a central fill. The transcostovertebral approach [2] (Fig. 1) was routinely used for vertebrae of the upper and mid-thoracic spine and where the pedicle was judged to be too small to accommodate transpedicular placement of the tool in the lower thoracic spine.

Results

444 thoracic vertebrae were accessed (Table 1). The majority of procedures was performed at the low thoracic levels T9–T12 (248 vertebrae), followed by the mid-thoracic levels T5–T9 (177 vertebrae) and high thoracic levels T1–T4 (19 vertebrae). No procedure needed to be aborted

due to inadequate visualisation and no procedure needed to be converted to open surgery.

No patient sustained a neurological deficit or deterioration of preoperative neurological status. Three postoperative MRI scans were performed. These were requested for worsening of pain in the first 48 h and not for neurological deficit. In two cases, new adjacent fractures were revealed and in one case re-fracture of an inadequately filled vertebra was detected. In two cases, cement leakage was estimated to be more than 0.5 ml and postoperative CT was performed. Neither patient had a neurological deficit. In one case, cement was found to have leaked through an osteolytic region in the base of the pedicle; in the other leakage was presumed via a previously unidentified venous malformation. No cement leakage required decompressive surgery and the leakage was considered unrelated to instrument malplacement.

In one patient who underwent a right sided approach to T6 for kyphoplasty, a pneumothorax was identified immediately post-operatively. A chest CT was performed which showed regular needle tracks into the vertebral body. A respiratory physician reviewed the patient and unreported chronic obstructive pulmonary disease was identified. The pneumothorax was viewed as a likely

Fig. 1 Illustration of stepwise instrument placement in thoracic vertebrae. An axial (*ax*) view (not obtained during the procedures) is provided for clarity in addition to the standard anterior–posterior (*ap*) and lateral (*lat*) fluoroscopic views. **a** The instrument tip is passed over the transverse process (alternatively through the transverse process) and forwarded between the neck of the rib and the lateral wall of the pedicle. The tip of the instrument projects at the cranio-lateral circumference of the pedicle in the *ap* view. In the *lat* view the tip is anterior to the facet joint (superior articular process), close to the base of the pedicle. **b** The instrument is advanced in the *ap* view until the tip projects onto the medial pedicle wall. In the *lat* view the tip is

verified to have passed the posterior vertebral wall (the instrument should not be advanced more than 2 cm in the *ap* view to prevent inadvertent anterior perforation due to under-convergence). **c** As the instrument has safely passed the spinal canal, it is now advanced in the *lat* view to the anterior third of the vertebral body. In the *ap* view convergence toward the midline is confirmed. For vertebroplasty this would constitute the final position. **d** For performing kyphoplasty or biopsy, the instrument (kyphoplasty balloon or biopsy needle/cannula) can be advanced to the anterior cortex in the *lat* view after verification of sufficient convergence towards the midline on the *ap* view

consequence of sub-pleural bullae and not due to instrument malplacement.

Discussion

Our results compare favourably to previous reports indicating neurological deficit in up to 3.5% [7] of cases with CT guidance. This report provides reassurance to clinicians who need to perform fluoroscopy-guided percutaneous access to the thoracic spine, for biopsy or cement augmentation procedures without CT guidance. The first paper to fully advocate fluoroscopy-guided percutaneous biopsy above T9 was published as recently as 1969 [8]. Several techniques have since been described, whereby the transpedicular approach [9] and the transcostovertebral approach [3] have become the most established. The transpedicular route is perceived to be the less difficult option as a clearly defined anatomical structure (the pedicle) guides the instrument into the vertebral body and provides an osseous border against the spinal canal and the pleural cavity. The slender morphology of the thoracic pedicles of the mid- and high-thoracic spine [10], however, restricts the transpedicular technique when large gauge instruments are used. Such instruments have been shown to improve biopsy yield [11] and facilitate the injection of highly viscous bone cement when used for vertebral augmentation techniques. Accordingly, the transcostovertebral approach has an advantage over the transpedicular route, because it allows access to the vertebral body independently of the diameter of the pedicles. The disadvantage is the relative complexity of the radio-anatomical landmarks. Transcostovertebral access mandates precise passage of the instruments along the neck of the rib to the base of the pedicle where the cortex is entered. This approach was initially described using CT guidance [8] and has more recently been fully described using fluoroscopic guidance [2]. The fluoroscopic technique has retained a dubious reputation for use in the mid and higher thoracic levels of T1–T8 and the perception prevails that it remains inferior to CT guidance with respect to safe instrument placement [7, 12–15].

All procedures in this series were performed in accordance with the stepwise approach set out by Boszczyk et al. [2] with strict adherence to the radiographic landmarks. The most pertinent point is not to cross the projection of the medial pedicle cortex in the antero-posterior plane until the tip of the instrument has been verified to have reached the posterior vertebral wall in the lateral projection (Fig. 1). Adherence to these landmarks reliably prevents tool malplacement into the spinal canal. Violation of the pleural cavity is reliably avoided by passing the tool along the neck of the rib to the base of the pedicle under fluoroscopic guidance. The key point here is to make early

contact with the rib under fluoroscopic visualisation without passing the tool between the ribs.

Despite our favourable results, several limitations need to be realised in this report: The postoperative clinical and neurological investigations were performed by the members of surgical team and bias can not be excluded. The data on complications were collected prospectively by the senior surgeons involved in this publication, but has not been confirmed by an independent clinician. Postoperative CT or MRI was not obtained routinely; therefore, the instrument track can not be used to prove that malplacement did not occur. Routine chest radiographs were not obtained and occurrence of minor pneumothoraces through over- or under-convergence cannot be excluded, although there was no intraoperative radiological or postoperative clinical suspicion hereof with the exception of the reported case. This report specifically looks at the rate of tool placement-related complications and does not report on cement leakage, or delayed complications such as wound infection or adjacent vertebral fractures which are unrelated to the technical aspect of passing the instrument into the vertebral body.

Conclusion

Thoracic vertebral biopsy and percutaneous cement augmentation procedures via the transcostovertebral approach can be performed safely using fluoroscopic guidance. The Clinicians with limited access to CT are reassured that fluoroscopic guidance is a safe alternative.

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Conflict of interest None.

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