Injury, Int. J. Care Injured xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Fluoroscopically assisted computer navigation enables accurate percutaneous screw placement for pelvic and acetabular fracture fixation

James Min-Leong Wong [a,*], Sam Bewsher [a], Jielin Yew [b], Andrew Bucknill [a], Richard de Steiger [c]

[a] Department of Orthopaedics, Royal Melbourne Hospital, Grattan Street, Parkville 3050, VIC, Australia
[b] Department of Internal Medicine, Singapore General Hospital, Outram Rd, Singapore 169608, Singapore
[c] Department of Surgery, Epworth Healthcare, University of Melbourne, 89 Bridge Rd, Richmond 3121, VIC, Australia

ARTICLE INFO

Article history:
Accepted 23 January 2015

Keywords:
Pelvic fracture
Navigation
Sacroiliac screws

ABSTRACT

Percutaneous fixation of pelvic and acetabular fractures are technically demanding procedures, and high rates of screw misplacement and potential neurovascular complications have been reported.

One hundred and sixty two screws from a prospectively collected database were analysed to evaluate the accuracy of a fluoroscopically assisted computer navigated technique to insert a cannulated screw to treat pelvic and acetabular fractures. Actual screw position and trajectory with the intraoperative surgical plan stored in the navigation computer.

The actual screw position differed from the surgical plan by a mean of 3.9 mm, with a mean 1.4 degree difference in screw trajectory. Post operative CT analysis of patients showed 10 screws perforated cortical bone.

Our results show that the use of computer navigation can aid in the accurate placement of percutaneous screws along a predefined plan. It is still possible to incorrectly place a screw and great care needs to be taken with the surgical plan and also to understand the complex anatomy of the bony pelvis.

Introduction

Severe pelvic ring and acetabular fractures are high-energy injuries resulting from significant forces such as motor vehicle and motorcycle crashes and falls from height. Surgical management of these complex fractures has undergone a steady evolution over the past 50 years, with advances in the understanding of pelvic anatomy and concepts of surgical fixation leading to improved operative approaches [1–3]. The aim of surgery remains the restoration of anatomical integrity and function [4]. The overall goal of treatment and rehabilitation is to return the patient to pre-injury levels of functioning.

Due to the anatomical complexity of the pelvis and intrapelvic structures, internal fixation of pelvic ring and acetabular fractures can be technically demanding, often requiring large operative exposures to allow safe and accurate reduction and fixation. Complication rates as high as 25% have been reported, with the majority of these associated with operative exposure, rather than initial injury [4,5]. The morbidity associated with extensile surgical approaches has led surgeons to explore alternate means of fixation.

Percutaneous insertion of cannulated sacroiliac, anterior column and supraacetabular screws can be used to manage amenable pelvic and acetabular fractures after closed reduction. This minimally invasive approach has been shown to be a safe alternative to open fixation, with lower rates of bleeding and infection [6–8].

Percutaneous screw insertion, however, is a demanding procedure requiring adequate reduction of the fracture and accurate screw fixation across narrow safe corridors. In the case of sacroiliac screws, insertion requires repetitive alterations in C-Arm position to acquire inlet, outlet and lateral views whilst drilling or passing guide wires. As corrections in one plane may also cause deviations in others, insertion may require extensive fluoroscopy and multiple passes with a drill or guide wire [9], with potential complications from an erroneous pass.

The narrowest part of the safe corridor for sacroiliac screws, the sacral pedicle, has been measured in 3D CT reconstruction studies

* Corresponding author at: 33 Kynaston Road, Bromley, Kent BR1 5AN, UK. Tel.: +0044 7908778600.
E-mail address: minleong@doctors.org.uk (J.-L. Wong).

http://dx.doi.org/10.1016/j.injury.2015.01.038
0020–1383/

with a mean width of only 15.6 mm (range 11.6 to 20.2 mm) [10,11], with a 4 degree deviation of screw angle being sufficient to perforate the sacral foramina or anterior cortex [11]. This is significantly decreased in the presence of any fracture malreduction [12]. Furthermore, the complexity and variability of the sacral alar shape and slope must be recognised prior to planning a screw. Misplacement of screws and malunion are commonly reported complications [13–16], with some series reporting neurological complications.

After CT guided navigation systems were shown to improve accuracy of pedicle screw insertion in spinal surgery [17], CT and fluoroscopy based navigation systems were developed to improve the safety and accuracy of sacroiliac screw placement. These systems can also be used to insert percutaneous supraacetabular, anterior column and iliac wing screws.

The aim of this study was to determine the accuracy and safety of pelvic ring and acetabular fracture fixation using a computer navigated cannulated screw technique. We have performed an analysis of our prospectively collected database of intraoperative fluoroscopic images and navigation computer data to assess deviation of the implanted screw from the operative plan.

Patients and methods

Participants

All patients undergoing operative treatment of pelvic or acetabular fractures using percutaneous cannulated screws inserted with the aid of computer navigation were recorded on a prospective database. All patients were included in the study if they required operative intervention with a pelvic fracture Abbreviated Injury Scale (AIS) 2005 update code of 856,171.4, 856,163.4, 856,172.4, 856,164.5 or 856,174.5 between July 21st 2006 and December 31st 2012.

All patients were operated under the supervision of one of the senior authors (RdS, AB).

This project was submitted to the Royal Melbourne Hospital ethics committee and received full approval as a Quality Assurance research project.

Operative procedure

Patients were positioned supine on a radiolucent table. For sacroiliac fixation a radiolucent pad was placed under the sacrum to assist screw placement. Reduction of the pelvic ring was achieved by closed methods, usually with the addition of an anteriorly placed external fixator. Once satisfactory reduction had been achieved, a reflective array was attached to a 5 mm Schanz pin inserted into the contralateral anterior superior iliac spine or onto an external fixator frame rod or pin on the contralateral side to the fracture. Multiple fluoroscopic views were then registered to the Brainlab fluoroscopically assisted navigation system (Brainlab Vector Vision trauma software, Brainlab AG, Feldkirchen, Germany). The first 60 screws in this series utilised the Brainlab Fluoro Registration kit to register fluoroscopic images, which was later superseded by the Brainlab X-Spot C-Arm registration device (Fig. 1). The images were taken with a fluoroscopic C-Arm fitted with an anti-distortion grid allowing the navigation system to warp the acquired images to remove any optical distortion prior to use. The views required vary with the type of screw. For sacroiliac screws pelvic anteroposterior, inlet, outlet and lateral views were obtained.

These images were displayed on the computer navigation monitor and used to plan a safe trajectory for a cannulated screw (see Fig. 2). This plan was stored onto the navigation system and a 2.8 mm drill tip guide wire (Advanced Surgical Design and Manufacture, St Frederick's NSW, Australia) was then inserted utilising Brainlab Computer Assisted Surgery Drill sleeves. A 6.5 or 7.3 mm Synthes cannulated screw was then passed over the wire. Washers were used when it was felt necessary due to poor bone quality, and the decision to use fully or partially threaded screws was based on fracture comminution on preoperative CT scans.

Fig. 1. Registration of fluoroscopic imaging using the "X-Spot" registration device.

After placement of the screw, fluoroscopic images were then reacquired and registered to the computer navigation system. The planned screw path was mapped onto the new fluoroscopic images by the computer, allowing the position of the inserted screw to be compared with that of the plan. These images were captured as screenshots and assessed using OsiriX DICOM image processing software (Pixmeo, Geneva, Switzerland). In each case, the projection showing the largest divergence between the planned and actual screw was selected for analysis. The angle of divergence was measured using a dynamic angle function of the OsiriX software (Fig. 3). The distance between the actual screw tip and the planned screw axis was also measured. This distance was initially measured in pixels, and then referenced against the known screw shaft or washer diameter.

From September 2008, all patients underwent a post operative CT scan to assess reduction and screw position. These scans were also analysed to assess cortical screw perforation.

Results

One hundred and seventy three percutaneous cannulated screws were used to treat pelvic and acetabular fractures in 124 patients between the 21st of July, 2006 and the 31st of December, 2012. Patients had a mean age of 42.4 (range 15–87), 59.7% were males and the mean time to surgery of 4.6 days (range 0–25 days). It was not possible to analyse the accuracy of 11 screws because the array was placed on the ipsilateral ASIS to the fracture. Although this allowed accurate screw planning and insertion, it was not possible to analyse accuracy as any compression across the fracture results in a "reference shift", making it impossible to compare the final screw position with the preoperative plan. These 11 screws were excluded, leaving 162 screws available for analysis. There were no cortical perforations or complications associated with the excluded screws. Of the remaining screws, 115 sacroiliac screws had been inserted, 26 into the anterior column and 21 into other sites around the pelvis (see Table 1). Posterior column fractures were not treated with percutaneous screws but with open reduction and internal fixation via plating. Two screws in this series backed out requiring further surgery. There were no