

■ TRAUMA

Accurate placement of a pelvic binder improves reduction of unstable fractures of the pelvic ring

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The aim of this study was to assess the accuracy of placement of pelvic binders and to determine whether circumferential compression at the level of the greater trochanters is the best method of reducing a symphyseal diastasis.

Patients were identified by a retrospective review of all pelvic radiographs performed at a military hospital over a period of 30 months. We analysed any pelvic radiograph on which the buckle of the pelvic binder was clearly visible. The patients were divided into groups according to the position of the buckle in relation to the greater trochanters: high, trochanteric or low. Reduction of the symphyseal diastasis was measured in a subgroup of patients with an open-book fracture, which consisted of an injury to the symphysis and disruption of the posterior pelvic arch (AO/OTA 61-B/C).

We identified 172 radiographs with a visible pelvic binder. Five cases were excluded due to inadequate radiographs. In 83 (50%) the binder was positioned at the level of the greater trochanters. A high position was the most common site of inaccurate placement, occurring in 65 (39%). Seventeen patients were identified as a subgroup to assess the effect of the position of the binder on reduction of the diastasis. The mean gap was 2.8 times greater (mean difference 22 mm) in the high group compared with the trochanteric group ($p < 0.01$).

Application of a pelvic binder above the level of the greater trochanters is common and is an inadequate method of reducing pelvic fractures and is likely to delay cardiovascular recovery in these seriously injured patients.

Pelvic fractures are potentially life-threatening, demanding prompt pre-hospital care and robust emergency assessment. Patients may need significant resuscitation and subsequent operative intervention.¹ The mechanism of injury frequently involves high-energy trauma, such as a motor vehicle accident, a fall from a height or, more recently, an explosion.^{2,3} The mortality from these injuries remains considerable, at nearly 10%,^{1,4} despite advances in resuscitation, damage control surgery and intensive care. Although the cause of death may be the result of injuries to several systems, haemorrhage remains the key reversible contribution to mortality in these patients.⁴

Control of haemorrhage after a pelvic fracture is challenging because of the many potential sources of bleeding. The pre-sacral venous complex, iliac vessels and their branches, soft tissues and fractured cancellous bone may all contribute to blood loss. However, the anatomical location of these sources often means that they are difficult to approach and control.⁵ Custom-designed circumferential pelvic binders have been developed by several manufacturers to allow rapid closure of the pelvic

ring in unstable fractures. They have particular value in pre-hospital care because of their strong construction, ease of application, and ability to be tightened to a known tension.⁶ Their use is endorsed by the Advanced Trauma Life Support (ATLS) guidelines, particularly for the emergency management of open-book fracture patterns.⁷ Clinical reports have shown that pelvic binders improve cardiovascular function, reduce transfusion requirements and reduce the risk of subsequent pulmonary complications in the shocked patient with an unstable pelvic fracture.^{6,8}

Despite evidence to support the benefits of pelvic binders, there is little information about either the accuracy of their application or their ability to reduce a fracture. One cadaveric study has suggested that the best method of achieving accurate reduction of the symphyseal diastasis is to apply the pelvic binder at the level of the greater trochanters.⁹ However, to our knowledge, there have been no clinical reports to assess the validity of this biomechanical evidence. The aim of this retrospective study was to assess the accuracy of placement of pelvic binders, and to determine whether

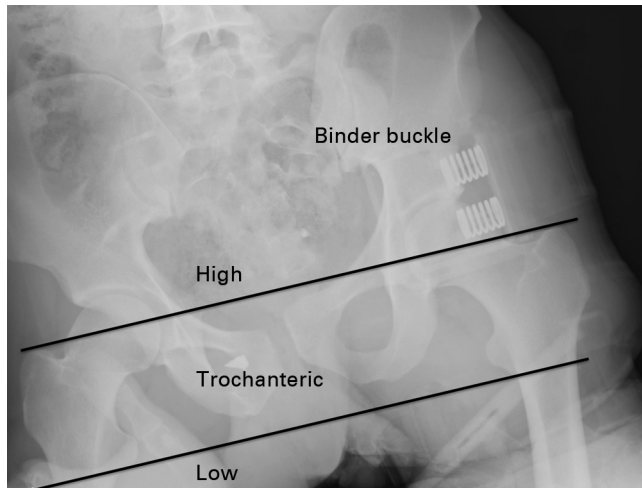


Fig. 1

A plain pelvic radiograph showing the appearance of the buckle. The transverse lines represent the division between the high, trochanteric and low groups.

circumferential compression at the level of the greater trochanters is the best method of achieving reduction of the symphyseal diastasis.

Patients and Methods

Accuracy of pelvic binder positioning. Permission to conduct this study was received from the United Kingdom's Royal Centre for Defence Medicine. All patients who presented to a UK military field hospital in Afghanistan and survived to undergo pelvic radiography were assessed for inclusion in the study. Cases were identified by retrospective review of all digital pelvic radiographs performed at this hospital between January 2008 and July 2010. We analysed any pelvic radiograph where the buckle of a SAM Pelvic Sling (SAM Medical Products, Wilsonville, Oregon) was clearly visible. The buckle is easily identified by two metallic springs within the 'Autostop' system, which is designed to allow the user to gauge the correct force needed to reduce the symphyseal diastasis (Fig. 1).

The position of the binder was assessed on plain radiographs using the digital Picture Archiving and Communication System (PACS). Its anatomical level was assessed by drawing two transverse lines between the superior limits of both greater trochanters and the inferior limits of both lesser trochanters. The binder was deemed to be at the level of the trochanters if more than half of either spring within its buckle lay between these two lines (Fig. 1). The patients were divided into three groups, high, trochanteric and low, according to whether the buckle springs were above, within or below the area between the two transverse lines.

Pelvic binder position and reduction of the diastasis. An orthopaedic surgeon (TJB) and a senior consultant radiologist (IG) reviewed each patient's plain radiographs and subsequent CT images from the initial resuscitation, both

Table I. The locations of pelvic binder in the 167 patients with adequate radiographs in this study (27% of these patients had a pelvic fracture)

Position	Number of patients (%)
High	65 (39)
Trochanteric	83 (50)
Low	19 (11)

during surgery and post-operatively. Pelvic ring fractures were identified and classified, using all available imaging, according to the AO/OTA comprehensive system.¹⁰ Reduction of the symphyseal diastasis was measured in patients with an open-book pattern of injury, which consists of a significant injury to the symphysis and disruption of the posterior pelvic arch (AO/OTA 61-B/C).¹⁰ Measurements of the diastasis were taken from plain radiographs performed during the initial trauma resuscitation with the pelvic binder in place. However, significant disruption of the pubic symphysis was sometimes only recognised on later imaging, when the binder was removed or replaced. The reduction was measured as the mean of two values, each taken as the gap between corresponding superior and inferior margins of the pubis at their articulation with the pubic symphysis.

Statistical analysis. A normal distribution of the measurements of the diastasis gap was verified using a Kolmogorov-Smirnov test. The mean diastasis gap reduction was compared between the trochanteric and high groups using an independent-samples two-tailed Student's *t*-test, with the significance level set at $p < 0.05$. A two-tailed comparison was appropriate because there were no open-book injuries in the low group. *Post-hoc* power analysis for the measurement of the diastasis gap showed that a sample size of 17 measurements had a power of 97% to detect the observed difference between the two groups ($\alpha < 0.05$). Statistical analysis was performed using SPSS version 18.0 software (SPSS Inc., Chicago, Illinois).

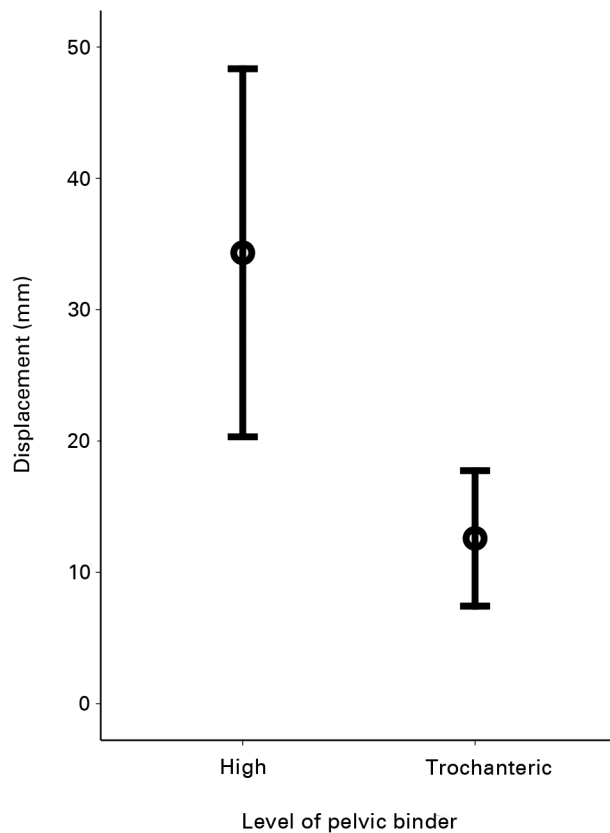
Results

Accuracy of pelvic binder positioning. During the study period we identified 172 patients with a standard plain pelvic radiograph and clearly visible springs of the buckle of the pelvic binder. Five cases were excluded because the radiographs were inadequate. The binder was positioned at the level of the trochanters in 83 (50%) patients (Table I). Placement of the binder above the greater trochanters (high group) was the most common site for inaccurate application, and occurred in 65 patients (39%).

Pelvic binder position and symphyseal diastasis reduction. Radiological evidence of a significant pelvic fracture and a pelvic binder was found in 45 patients (27%). The incidence and pattern of different types of pelvic, acetabular and combined fractures are listed in Table II. From these

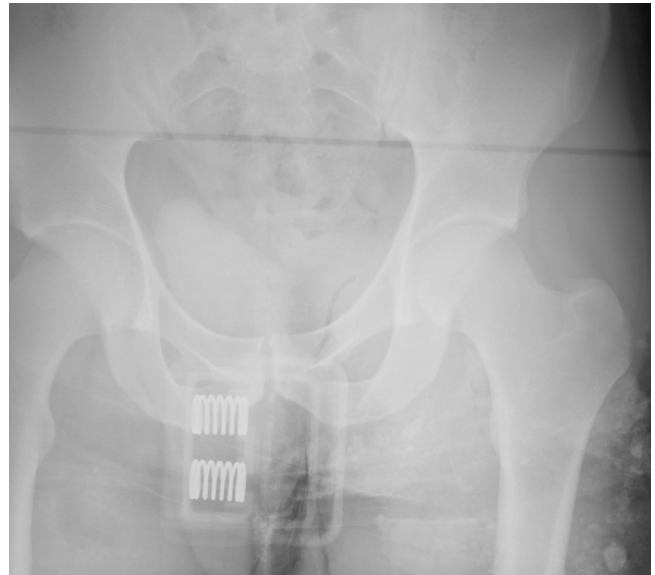
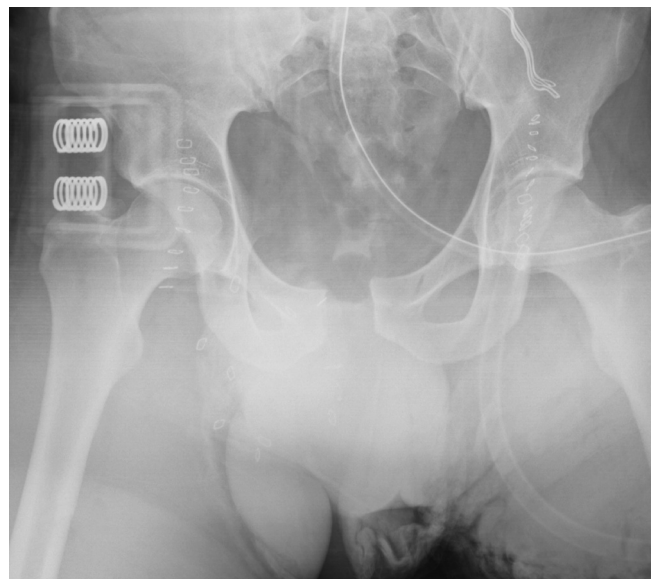
Table II. The incidence and pattern of pelvic injuries analysed in the study (five patients had combined injuries)

Fracture type	Pelvic ring (AO/OTA 61-)	Acetabulum (AO/OTA 62-)
A	9	5
B	22	1
C	10	3

**Fig. 2**

A means plot showing that the symphyseal diastasis gap is significantly greater in the high group than when pelvic binders are placed at the level of the greater trochanters in open-book injury patterns ($n = 17$) ($p < 0.01$). The error bars denote the 95% confidence intervals.

patients, a subgroup of 17 was identified who had sustained an open-book injury (AO/OTA 61-B/C). The mean gap in the diastasis of the symphysis was 2.8 times greater (mean difference 22 mm) in the high group ($n = 6$) than in the trochanteric group ($n = 11$) ($p < 0.01$) (Fig. 2). The variability of reduction of the diastasis was less in the trochanteric group than in the high group (Fig. 2). Figure 3 is an example of two radiographs of the same patient illustrating that reduction of the diastasis is markedly improved when the pelvic binder is placed at the level of the trochanters rather than in the high position.

**Fig. 3a****Fig. 3b**

Radiographs of a patient showing a) excellent reduction of an open-book injury when the binder is placed at the level of the trochanters, and b) showing that the reduction of the symphysis is lost when it is placed above the level of the trochanters.

Discussion

Pelvic fractures are challenging to manage because they are often caused by high-energy trauma and associated with significant injuries to other organs.^{4,11} Early stabilisation of the fracture in a haemodynamically compromised patient improves survival and has become one of the cornerstones of damage control in the management of these patients.^{12,13} Strategies to provide early stabilisation include improvised circumferential bed sheets, pelvic C-clamps, external fixation, iliosacral screws and early definitive fixation.^{11,14-16} However, many of these

techniques have significant disadvantages, such as the need for specialist skills, complications of malpositioned screws, limited access for other interventional procedures, or uncertainty about the tension needed for reduction of the diastasis.

Custom-designed circumferential pelvic binders can be used with minimal training and allow rapid stabilisation of the pelvis at the scene of injury or in the emergency department. Their use is supported by recent reports which describe haemodynamic recovery after closure of the diastasis in patients with an unstable pelvic fracture.^{8,17} One previous biomechanical study in cadavers found that pelvic binders placed at the level of the greater trochanters required less tension to reduce a diastasis of the symphysis than when placed in other positions, and a near-anatomical reduction could be achieved.⁹ Despite the apparent advantages of placing the pelvic binder at the level of the greater trochanters, the results in Table I show that it is commonplace in clinical practice for binders to be placed above this level. Our findings reflect the practice of a large multinational group of experienced paramedics, nurses and doctors. It is, therefore, highly likely that these findings are also relevant to all civilian clinicians who manage pelvic trauma.

The effect of the position of the pelvic binder on reduction of a diastasis of the symphysis pubis in clinical practice has not previously been described. Our results show that the mean residual gap in the diastasis was 2.8 times greater in the high group than when the binder was placed at the level of the trochanters (mean difference 22 mm). The relatively wide confidence intervals of the diastasis gap in the high group are evidence of large residual gaps in some of these patients. Therefore, accurate placement of binders at the level of the greater trochanters is very important and likely to support cardiovascular resuscitation and recovery. Inadequate reduction of the diastasis may be addressed by checking that the pelvic binder is at the correct level, rather than increasing the risk of skin necrosis by further tightening.⁶ The biomechanical advantages of placing the binder at the level of the trochanters can also be explained by considering the geometry of the pelvis. The compressive forces and bending moment required to reduce the diastasis are relatively low when transferred through the proximal femur because there is little soft tissue between the binder and the trochanter, and the acetabulum is a relatively anterior structure in the pelvis. Placement of the binder in the high position is a disadvantage because this applies compressive forces to the gluteal muscles and posterior pelvis, thereby significantly reducing the transferred force and bending moment available for closure of the diastasis.

Placement of a pelvic binder in a high position may be due to the way in which it is applied or to difficulty in identifying the greater trochanters as an anatomical landmark. These challenges may be compounded at the roadside or in a combat environment, when the practitioner could be

faced with a difficult extraction and resuscitation or many layers of clothing. Consequently, it is important that all practitioners are trained to apply the SAM pelvic sling by placing it beneath the upper legs and sliding it up to the level of the trochanters, as recommended by the manufacturer. Our experience shows that alternative techniques where the binder is placed beneath the lumbar spine and moved inferiorly are more likely to result in a high position. Furthermore, reliable and easy techniques for locating appropriate landmarks for correct placement of pelvic binders need to be taught on trauma care training courses.

The value of this study is somewhat limited because it is a radiological study that does not include data about the effect of reduction of the diastasis on control of haemorrhage. However, it is known that reduction of the diastasis increases pelvic stability and promotes haemodynamic recovery.^{8,9} Stability of a pelvic fracture is also important because it reduces pain and promotes platelet-dependent clot formation.¹⁸ Other significant limitations of this study include the unusual clinical environment, retrospective identification of patients by plain radiographs, and the assessment of only one manufacturer's pelvic binder. The severity of the fractures in the groups is also difficult to compare because radiographs from which measurement of the displacement of the symphysis could be made before the binder was applied were rarely available. A small error in the measurement of the gap may be expected due to some magnification, but this is likely to be insignificant because the symphysis is close to the centre of the field and radiographs were performed from a fixed distance above the patient on a standard-height emergency department trolley. The small sample size used to assess the reduction of the diastasis may risk a type II error, but the magnitude of the difference between the groups and power calculation are evidence that this risk is insignificant.

This study provides the first clinical evidence to show that placement of a pelvic binder at the level of the greater trochanters achieves the best reduction of the symphyseal diastasis in an unstable fracture of the pelvic ring. Application of a binder above the greater trochanters is common and associated with inadequate reduction of the fracture: this is likely to delay cardiovascular recovery in these significantly injured casualties. Application of the SAM pelvic sling using the manufacturer's recommended technique and checking the position against anatomical landmarks will help to ensure appropriate early management. Despite being performed in the military environment on casualties with ballistic injuries and using a single manufacturer's pelvic binder, these findings are very relevant to civilian trauma practice and other types of pelvic binder.

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