Clinical Radiology 74 (2019) 649.e19–649.e26

Contents lists available at ScienceDirect

Clinical Radiology

journal homepage: www.clinicalradiologyonline.net

Pelvic fractures: experience of pelvic ring fractures at a major trauma centre

S.E.T. Leach*, V. Skiadas, C.E. Lord, N. Purohit

Southampton General Hospital, Tremona Road, Southampton, Hampshire SO16 6YD, UK

ARTICLE INFORMATION

Article history:
Received 4 December 2018
Accepted 26 April 2019

In this review, we discuss the imaging classification of pelvic ring fractures in the context of our experience of reporting trauma computed tomography (CT) in a major trauma centre. Pelvic ring fractures are potentially significant injuries with risk of significant haemorrhage and morbidity. This review details the use of classification systems in determining the mechanism and severity of injury, with discussion of the features of the Young and Burgess classification system. We demonstrate the different types of pelvic ring fracture with examples from trauma CT, and with reference to the distribution and frequency of these injuries in trauma patients. This review will allow the reader to assess trauma CT for significant pelvic ring injury and identify features of instability.

Introduction

Fractures of the pelvis are a common consequence of major trauma, and can be associated with significant increased morbidity and mortality. A long-term study of all trauma patients in England and Wales between 1989 and 2001 demonstrated that 8% of trauma patients suffer from a pelvic ring fracture[1] and that there is an increased 3-month mortality of 14% versus 6% in patients without this injury. In a retrospective study of 2,550 patients with pelvic ring injury,[2] the most common cause was road traffic collision, responsible for 60% of pelvic ring fractures, followed by falls. Therefore, it is important for the radiologist to be able to identify pelvic ring fractures. Using a classification system can aid the radiologist in identifying a pattern of pelvic ring fractures, including unstable injuries.

In 1980, Pennal and Tile first published a system for classifying pelvic ring fractures based on the mechanism of injury.[3] Several imaging classification systems were set up based on this mechanism structure[4] with the aim of identifying unstable injuries and planning management. These include the Young and Burgess, Tile, and Orthopaedic Trauma Association (OTA) systems. Studies using these classifications have demonstrated an association between the mechanism of a fracture and non-pelvic injury patterns,[5] as well as with increased risk of major haemorrhage after trauma.[6] Young also demonstrated an increased risk of mortality with certain fracture mechanisms,[5] although it is unclear if all specific fracture mechanisms have a direct relationship with mortality[7,8]; however, classifying pelvic fractures conveys prognostic information and is of benefit in planning surgery.[9] It also helps the radiologist in identifying associated injuries, which may be subtle.

In England, in April 2012, management of trauma was re-organised nationally with regional trauma networks formed around major trauma centres. Research comparing

* Guarantor and correspondent: S. E. T. Leach, Salisbury District Hospital, Odstock Road, Salisbury, Hampshire, SP2 8BJ, UK. Tel.: +44 1722336262.
E-mail address: sam.leach1@nhs.net (S.E.T. Leach).

https://doi.org/10.1016/j.crad.2019.04.020

trauma care before and after this re-organisation has demonstrated an increase in the number of trauma patients treated at these major trauma centres, as well as improvement in care quality indicators.[10] Trauma units have a key role in appropriately referring patients to major trauma centres, and therefore, it is important for the radiologist to have key skills in identifying major injuries, such as pelvic ring fractures.

Anatomical and biomechanical considerations when assessing pelvic fractures

The pelvis is a ring-like structure composed of three bones: the sacrum and paired innominate bones. There are two arches in the pelvic ring. The anterior arch is formed by the pubic bones and pubic symphysis, and the posterior arch comprises the ilium and sacrum, forming the sacroiliac joints.[11] The ring-like structure of the pelvis means that fractures of the anterior arch will often involve concomitant injury at the posterior arch. This has been confirmed in an autopsy study demonstrating undisplaced sacral fractures and injuries to the sacroiliac ligaments of the posterior ring, even when the only radiologically apparent injury was in the anterior arch.[12]

The stability of the pelvis is more reliant upon the posterior arch than the anterior arch, and therefore, the pelvis is predominantly stabilised by the sacroiliac joints and the pelvic floor ligaments.[13] The sacroiliac joint ligaments are made up of the anterior sacroiliac ligaments, interosseous ligaments, and the posterior sacroiliac ligaments. The pelvic floor ligaments, which aid in stabilising the posterior arch, are the sacrospinous and the sacrotuberous ligaments. The radiographical criteria of unstable injury reflect the importance of the posterior ligamentous complex including sacroiliac joint disruption >5 mm, posterior fracture gap, and posterior ligamentous avulsion fractures.[14]

Computed tomography

Southampton General Hospital is a major trauma centre. As per National Institute for Health and Care Excellence guidelines, whole-body computed tomography (CT) is used for adult patients with blunt trauma and suspected multiple injuries.[15] Trauma CT is performed using a GE Discovery 750 HD using a modified Camp Bastion protocol of unenhanced CT head and CT cervical spine, followed by thorax, abdomen, and pelvis CT with a split bolus injection of 60 ml iopamidol (Niopam 370) at 2.5 ml/s, followed by 80 ml at 3.5 ml/s, acquisition at 65 seconds. Raw data are acquired at 0.625 mm section thickness with 2 mm sagittal and coronal bone reconstructions. As per Royal College of Radiologists guidelines,[16] trauma CT examinations are reported by a consultant radiologist within an hour of being performed.

In order to identify the scanned trauma patients who had pelvic fractures, a data request was sent to the Trauma Audit and Research Network (TARN) to provide us with a list of patients who were treated for pelvic injury at Southampton General Hospital. TARN is a national organisation that independently monitors trauma care in England and Wales. These data are used to conduct national audits and comprise the largest trauma registry in Europe.[17]

After receiving the data, the radiology information system (CRIS) and picture archiving and communication system (Sectra PACS) were used to review the images and classify the injuries based on the Young and Burgess classification system. This classification system is recommended by the *Journal of Bone and Joint Surgery*[18] and defines recommended surgical management. Fracture classification has been confirmed at independent review by two consultant radiologists with a subspecialty interest in musculoskeletal radiology.

The Young and Burgess classification divides pelvic injury mechanisms into anteroposterior compression,[19] lateral compression, and vertical shear types, as well as a combined category, where two or more different mechanisms are present. Anteroposterior compression and lateral compression injuries are further subdivided into three gradations of severity. Table 1 details the features and grading of each mechanism of injury, while Fig 1 demonstrates anatomical basis of imaging features.

Demographics

During a 1-year period between March 2015 and March 2016, the data for trauma patients at Southampton General Hospital entered into the TARN database were reviewed. During this period, 1,377 patients were initially captured, of which 96 (7%) patients had a pelvic ring fracture. For patients with pelvic ring fractures, the mean age was 58, the average length of hospital stay was 18.7 days, and the average length of intensive treatment unit (ITU) stay was 3.3 days. The mortality as outcome of admission was 7.3%. The most common mechanism of pelvic ring fracture was falls (61%); 22% from falls >2 m height and 38% <2 m.

Table 1
Young and Burgess classification and grading.[20,21]

Grade	Lateral compression	Anteroposterior compression	Vertical shear
I	Horizontal pubic rami fractures Compression fracture of ipsilateral anterior sacrum	Vertical pubic rami fractures Symphysis pubis widening <2.5 cm	
II	Posterior fracture of ipsilateral iliac bone and/or sacroiliac joint widening	Symphysis pubis widening >2.5 cm Anterior widening of sacroiliac joint due to anterior ligament injury	Vertical displacement involving both anterior and posterior arches, vertical pubic rami fractures and disruption of sacroiliac joint
III	Windswept pelvis, fracture or sacroiliac joint injury to contralateral hemipelvis	Widening of posterior sacroiliac joint due to posterior ligament injury; “open book”	

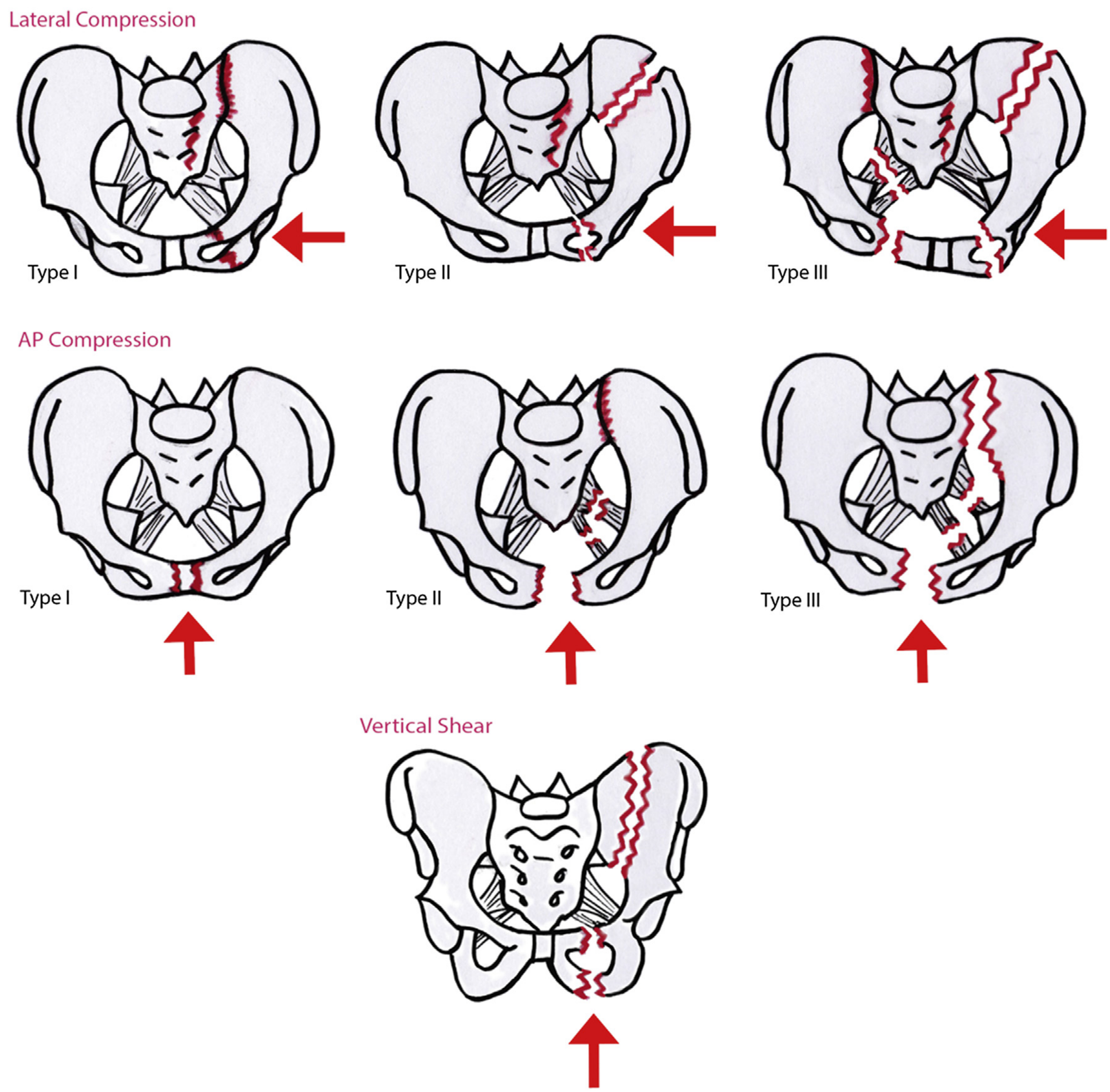

Figure 1 Diagram representing anatomical abnormalities described in Young and Burgess classification system.

Vehicle accidents accounted for 38% of pelvic injuries with 2% due to crush injury.

Eighty-nine percent of the 96 pelvic ring fractures were lateral compression injuries, 3% anterior–posterior compression, 3% vertical shear, and 5% combined mechanism. Of the lateral compression injuries, 62% were Grade I, 12% Grade II, and 16% Grade III. Seventeen out of 96 pelvic ring fractures (18%) underwent surgical fixation. The most commonly fixed fractures were the vertical shear (all fixed) and Grade II anteroposterior compression fractures (two out of three fixed). Less commonly fixed were Grade III lateral compression (seven of 15), combined mechanism (two of five), with only three out of 11 lateral compression Grade II injuries fixed. No Grade I injuries were fixed, for either lateral or anteroposterior compression.

Of the 96 patients with pelvic ring fracture, five patients (5.2%) had evidence of pelvic haemorrhage with active extravasation on their trauma CT. Only one of these had a specific vessel injury identified, and this did not require immediate intervention. Abdominal visceral injuries were also seen in 10 patients, the most common injury being splenic laceration in five patients, with three patients demonstrating renal laceration, and three patients having hepatic lacerations. One of the splenic injuries required urgent embolization under interventional radiology. None of the patients in this cohort had significant bladder injury.

Thirty-one out of 96 pelvic ring fracture patients went to the ITU (32%). The mechanism of injury for the ITU patients varied slightly in comparison to the overall cohort with 81% of fractures being due to lateral compression, whereas other fracture mechanisms were slightly more common than in the whole pelvic ring fracture cohort, with 6% anteroposterior compression, 6% vertical shear, and 6% combined mechanism. There was also some difference in the grading of the lateral compression injuries; 48% Grade I, 6% Grade II, and 26% Grade III, indicating a higher proportion of Grade III lateral compression injuries in the ITU patients.

Examples of young and burgess classification

Lateral compression

Lateral compression injuries are divided into three grades of severity, based on the degree of disruption of the posterior arch of the pelvis. Grade I injury is demonstrated in Figs 2 and 3, where there are fractures of the pubic rami and a typical compression fracture of the anterior ipsilateral edge of the sacrum.

Figs 4 and 5 show a Grade II injury, which differs in that further lateral compression causes an unstable injury of the posterior arch. This is typically a crescentic fracture crossing the iliac bone; however, as can be seen in this case, the fracture can also extend into, and directly disrupt, the sacroiliac joint. In this case, there is dislocation of the pubic symphysis in addition to the pubic rami fractures.

A Grade III lateral compression injury is illustrated in Fig 6. Previously described features of Grade II injury were present, but in Grade III injury, there is additional internal rotation of the ipsilateral hemipelvis and consequent impaction upon the contralateral hemipelvis and injury to the contralateral posterior arch. This is seen as widening of the contralateral sacroiliac joint. The contralateral injury can be relatively subtle, but is significant in determining operative management; therefore, understanding the mechanism and expected associated injuries will allow identification of this unstable injury.

Figure 2 Axial CT of the pelvis in Grade I lateral compression injury: compression fracture of the left anterior sacrum.

Figure 3 Axial CT of the pelvis in Grade I lateral compression injury: fracture of the left inferior pubic ramus.

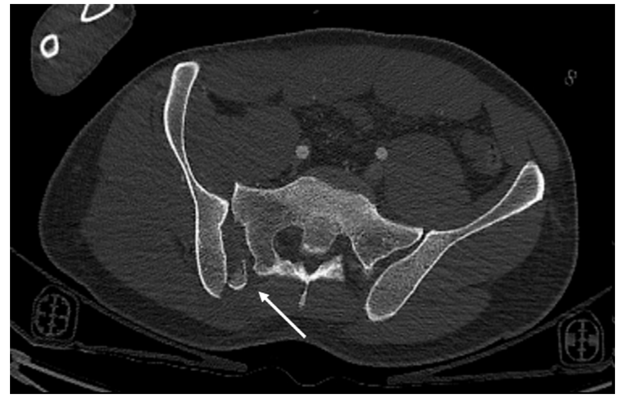

Figure 4 Axial CT of the pelvis in Grade II lateral compression injury: fracture of posterior right iliac bone with fracture dislocation of sacroiliac joint.

Figure 5 Axial CT of the pelvis in Grade II lateral compression injury: dislocation of pubic symphysis with overriding of pubic bones.

Figure 6 Axial CT of the pelvis in Grade III lateral compression injury: posterior widening of both sacroiliac joints.

Anteroposterior compression

Anteroposterior compression injuries are subdivided into three grades of severity, based on the degree of injury to the posterior arch. Grade I injury involves either fractures of the pubic rami or pubic diastasis. Although the pubic symphysis in most cases will show some degree of malalignment, these images demonstrate that some Grade I injuries may not be appreciated on trauma CT, as with the pelvic binder in place (Fig 7) diastasis of the pubic symphysis is reduced. The full extent of injury can only be appreciated with the binder removed (Fig 8).

In a Grade II anteroposterior compression injury (Figs 9 and 10), there is not only injury to the anterior arch, but anterior widening of the sacroiliac joint, indicating concomitant injury to the posterior arch. Surgical fixation of the sacroiliac joint may then be necessary. A Grade III anteroposterior compression injury (Figs 11 and 12) differs in that there is additional disruption of the posterior sacroiliac joint implying significant injury to the posterior arch.

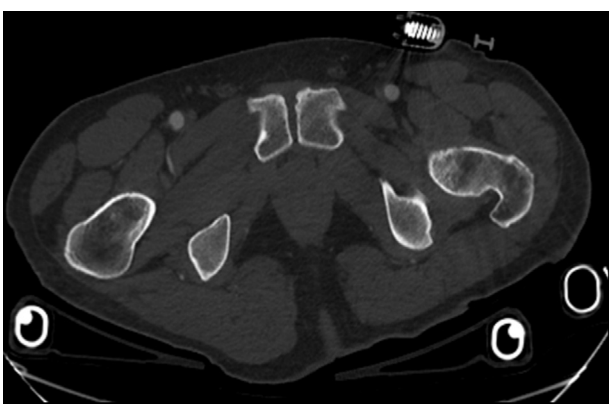

Figure 7 Axial CT of the pelvis in Grade I anteroposterior compression injury: original trauma CT demonstrating reduction of pubic diastasis in pelvic binder.

Figure 8 Axial CT of the pelvis in Grade I anteroposterior compression injury: pubic diastasis evident on follow-up CT without binder.

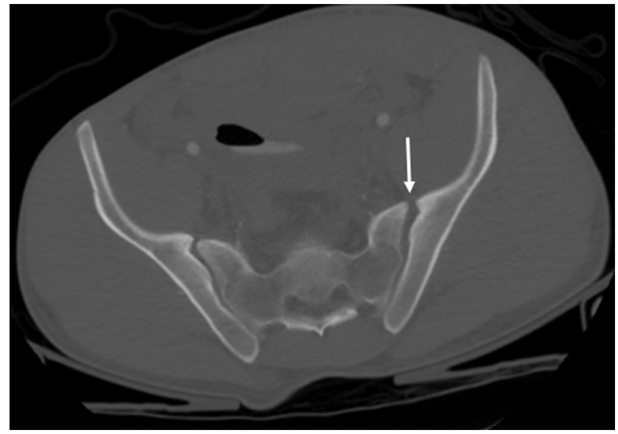

Figure 9 Axial CT of the pelvis in Grade II anteroposterior compression injury: anterior widening of left sacroiliac joint.

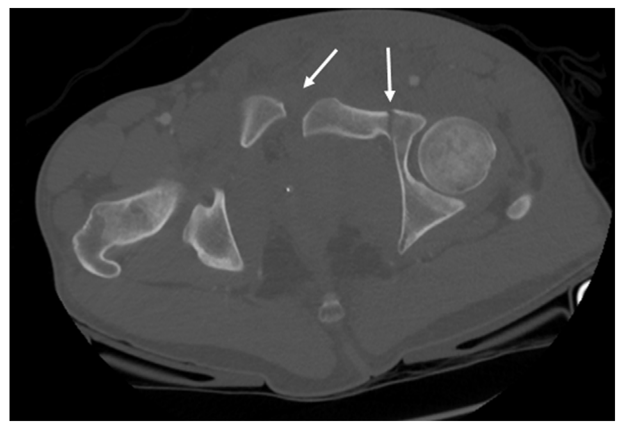

Figure 10 Axial CT of the pelvis in Grade II anteroposterior compression injury: diastasis of pubic symphysis and left pubic ramus fracture with posterior displacement of ramus fragment.

Vertical shear

Vertical shear injuries are not subclassified as the mechanism implies involvement of both the anterior and

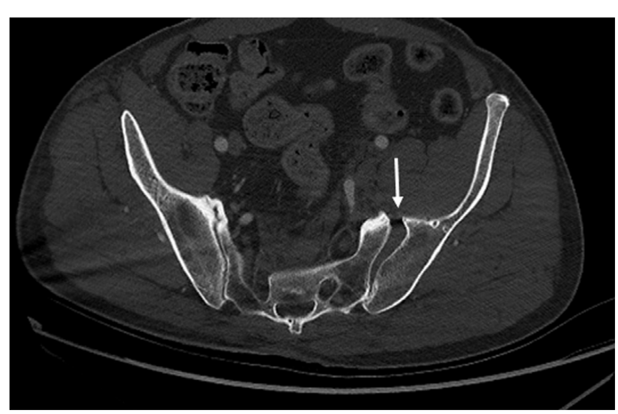

Figure 11 Axial CT of the pelvis in Grade III anteroposterior compression injury: anterior widening of left sacroiliac joint.

Figure 12 Axial CT of the pelvis in Grade III anteroposterior compression injury: posterior subluxation of left sacroiliac joint.

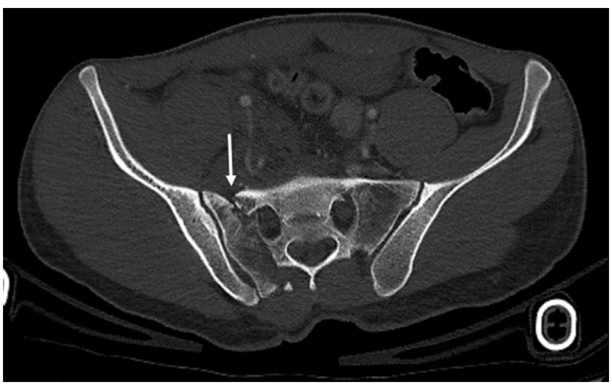

Figure 13 Axial CT of the pelvis in vertical shear injury: fracture though right sacral ala.

posterior arch, and therefore, significant instability. Posterior arch injury can involve either the sacroiliac joint or the sacrum itself (Fig 13). The anterior arch injury can involve either the pubic rami or the pubic symphysis, as in Fig 14). Although the fractures can be easily identified on the axial CT, note that, as in the case in Fig 15, the vertical displacement can be more easily appreciated on three-dimensional

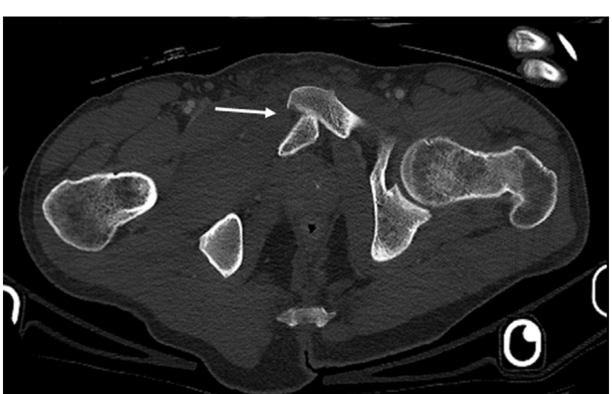

Figure 14 Axial CT of the pelvis in vertical shear injury: dislocation of pubic symphysis.

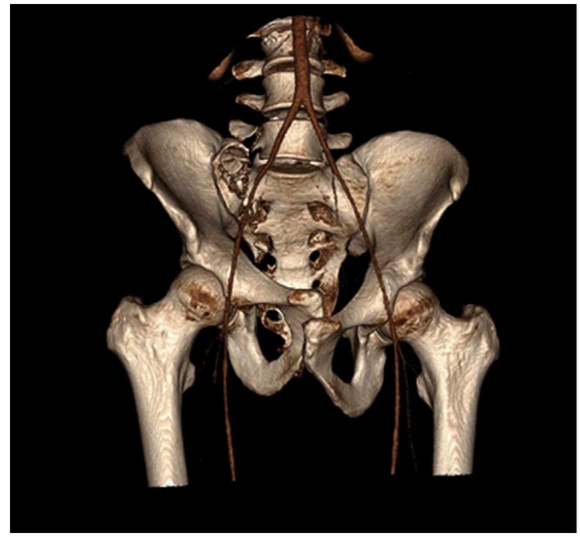

Figure 15 Axial CT of the pelvis in vertical shear injury: 3D reconstruction demonstrating vertical displacement of right hemipelvis.

(3D) reconstruction or coronal reconstruction, which can aid classification.

Combined mechanism

Fig 16 shows a case of combined mechanism injury where there are elements of both lateral compression injury, as indicated by the injury to the left sacral alar and contralateral sacroiliac joint, and of vertical shear injury, with vertical displacement of the left hemipelvis (Fig 17). In addition to the bone injury, it is also important when reporting trauma studies to be aware of the risk of associated injury to viscera or vessels. A different combined mechanism case, Fig 18 demonstrates a blush of contrast medium adjacent to the opacified superior gluteal artery, indicating significant injury, and this indicates the importance of looking for associated vascular, visceral, and soft-tissue injury on trauma studies.

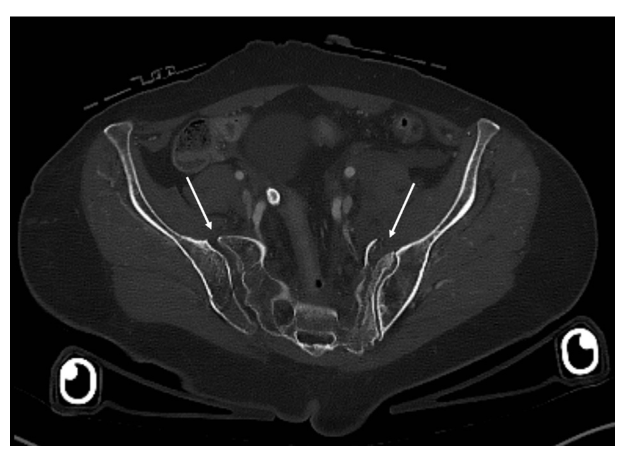

Figure 16 Axial CT of the pelvis in combined mechanism injury: fracture of left sacral alar and widening of right sacroiliac joint anteriorly due to lateral compression component.

Figure 17 Axial CT of the pelvis in combined mechanism injury: 3D reconstruction demonstrating superior displacement of left hemipelvis due to vertical shear component.

Figure 18 Axial CT of the pelvis in combined mechanism injury: blush of contrast medium reflecting active extravasation from superior gluteal artery.

Discussion

Pelvic ring fractures at Southampton General Hospital are more commonly associated with falls than vehicle accidents, contrary to a previous large cohort study.[2] This is likely, at least, partially related to subsequent improvements in vehicle and road safety, given that this previous study of mechanism of injury was published in 1996 and that UK government figures[22] have demonstrated an interim decrease in fatalities and injuries from road traffic collisions. This may also reflect differing local distributions in patients referred to major trauma centres given that Southampton General Hospital, while based in a major city, covers a more rural region than some other trauma centres.

Mortality rates for the pelvic fracture cohort were also lower (7.3%) than in the previous large cohort study of pelvic fracture patients in the UK (14.2%).[1] This may also reflect improvements in road safety; however, factors, such as improvements in treatment such as using pelvic binders, and use of dedicated trauma centres, are also likely to have contributed.

Our experience has demonstrated lateral compression injury as the most common mechanism of pelvic ring fracture at Southampton General Hospital, with relatively little incidence of anteroposterior compression, vertical shear, and combined mechanism injuries; although these other mechanisms were slightly more common in patients sent to the ITU; however, given that the high-grade anteroposterior compression injuries and vertical shear injuries were likely to undergo fixation, this review highlights the importance of identifying these other mechanisms.

Sixteen percent of the patients with pelvic ring fracture had either active extravasation or significant visceral injury on their trauma scan. Although only one of the patients required urgent intervention, it is therefore fundamental to review the trauma CT closely for features of significant haemorrhage, soft-tissue injury, or visceral laceration, especially in the context of pelvic ring fracture.

Conclusion

In this review, we have demonstrated the value of Young and Burgess classification systems in identifying fracture mechanism and in using this to identify more subtle injuries, which can be associated with pelvic instability. We hope this will aid the radiologist in reporting trauma studies and provide a useful and detailed assessment of pelvic injuries.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

The authors thank Dr Roshini Kulanthaivelu for producing Fig 1.

References

1. Giannoudis PV, Grotz MRW, Tzioupis C, *et al*. Prevalence of pelvic fractures, associated injuries and mortality: the United Kingdom perspective. *J Trauma* 2007;**63**:875–83.
2. Gansslen A, Pohlemann Paul CH, Lobenhoffer PH. Epidemiology of pelvic ring injuries. *Injury* 1996;**27**(Suppl. 1):13–20.
3. Pennal GF, Tile M, Waddell JP, *et al*. Pelvic disruption: assessment and classification. *Clin Orthop Realt Res* 1980 Sep;(151):12–21.
4. Young JW, Resnik CS. Fracture of the pelvis: current concepts in classification. *AJR Am J Roentgenol* 1990 Dec;**155**(6):1169–75.
5. Dalal SA, Burgess AR, Siegel JH, *et al*. Pelvic fracture in multiple trauma: classification by mechanism is key to pattern of organ injury, resuscitative requirements and outcome. *J Trauma* 1989;**29**(7):981–1002.
6. Blackmore CC, Cummings P, Jurkovich GJ, *et al*. Predicting major haemorrhage in patients with pelvic fracture. *J Trauma* 2006;**61**:346–52.
7. O'Sullivan RE, White TO, Keating JF. Major pelvic fractures: identification of patients at high risk. *J Bone Jt Surg Br* 2005;**87**(4):530–3.

8. Kido A, Inoue F, Takakura Y, *et al*. Statistical analysis of fatal bleeding pelvic fracture patients with severe associated injuries. *Orthop Sci* 2008;**13**(1):21–4.
9. McCormack R, Strauss EJ, Alwattar BJ, *et al*. Diagnosis and management of pelvic fractures. *Bull NYU Hosp Jt Dis* 2010;**68**:281–91.
10. Metcalfe D, Perry D, Boumara O, *et al*. Regionalisation of major trauma services in England: a post-implementation analysis. *Lancet* 2016;**387**:S73.
11. Khurana B, Seehan SE, Sodickson AD, *et al*. Pelvic ring fractures: what the orthopaedic surgeon wants to know. *AJR Am J Roentgenol* 1990 Dec;**155**(6):1169–75.
12. Bucholz RW. The pathological anatomy of malgaigne fracture-dislocations of the pelvis. *J Bone Jt Surg Am* 1981 Mar;**63**(3):400–4.
13. Schatzker J, Tile M, Axelrod TS. *The rationale of operative fracture care*. 3rd edn. Berlin: Springer; 2005.
14. Haq RU, Dhammi IK, Srivastava A. Classification of pelvic fractures and its clinical relevance. *J Orthop Traumatol Rehabil* 2014;**7**:8–13.
15. Glen J, Constanti M, Brohi K. Assessment and initial management of major trauma: summary of NICE guidance. *BMJ* 2016;**353**:i3051.
16. The Royal College of Radiologists. *Standards of practice and guidance for trauma radiology in severely injured patients*. London: The Royal College of Radiologists; 2011.
17. Edwards A. Top 10 TARN research publications. *Emerg Med J* 2015;**32**:966–8.
18. Guthrie HC, Owens R, Bircher MD. Focus on pelvic fractures. *J Bone Jt Surg Br* 2010 Nov;**92**(11):1481–8.
19. Burgess AR, Eastridge BJ, Young JW, *et al*. Pelvic ring disruptions: effective classification system and treatment protocols. *J Trauma* 1990;**30**:848–56.
20. Kanakaris NK, Giannoudis PV. *Trauma and orthopaedic classifications: a comprehensive overview*. 1st edn. New York: Springer-Verlag; 2015. p. 268–70.
21. Alton TB, Gee AO. Classifications in brief, Young and Burgess classification of pelvic ring injuries. *Clin Orthop Realt Res* 2014;**472**:2338–42.
22. Department for Transport. *Testing for statistically significant changes in road accident and casualty numbers*. 2018. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/437785/Testing_for_statistically_significant_changes.pdf. [Accessed 11 March 2019].