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ORIGINAL PAPER

Occult injuries of the contralateral sacroiliac joint in operatively treated pelvis fractures: incidence, root cause analysis, and proposal of treatment algorithm

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Abstract

Purpose To determine the most common injury patterns, root cause, and the frequency with which unrecognized contralateral posterior ring injury occurs in patients presenting with surgically treated pelvic fractures.

Methods The medical records of 73 patients presenting to our level I trauma center (52 male and 21 female patients; mean age 41.8 years; range 18–89 years) with surgically treated pelvic ring fractures between January 1, 2016 and January 1, 2018 were reviewed. Patient demographics, mechanism of injury, associated injuries, imaging prior to binder or external fixation, use of temporary stabilization with pre-peritoneal pelvic packing (PPP) and anterior pelvic external fixation, and fracture pattern were recorded and analyzed to identify independent risk factors contributing to occult contralateral missed posterior ring injury.

Results Occult contralateral pelvic ring injuries occurred in 6/72 patients (8.2% incidence). Pelvis fractures in multiply traumatized patients with associated orthopaedic injuries were associated with higher prevalence of occult contralateral pelvic ring injury (relative risk 1.85, 95% CI 1.13–3.02) as compared to patients with isolated pelvic fractures.

Conclusions There is an 8.2% incidence of unrecognized contralateral SI joint instability in patients presenting with unstable pelvic ring injuries. Multiply traumatized patients with multiple orthopaedic injuries were an independent risk factor for this injury pattern.

Keywords Occult pelvis fracture · Pelvic ring fracture · Missed pelvic injury · Contralateral injury · SI dislocation · Pelvic binder · EUA · External fixation of pelvis

Introduction

Unstable pelvic ring injuries and associated haemorrhage may represent a life-threatening condition in the polytrauma patient. Early recognition and management of these injuries are critical in the patients' initial evaluation [1, 2]. Based upon intra-institutional protocol and clinical presentation, temporary stabilization of the pelvis with binders, sheets, or external fixation may be used alone or in combination with haemorrhage control measures such as pre-peritoneal pelvic packing or angio-embolization [3]. Following clinical stabilization and resuscitation of the patient, definitive fixation can be planned. Careful scrutiny of the injury radiographs and CT scans is an essential part of this process, the ultimate goal of which is to restore the anatomy of the pelvis and provide stable fixation to allow early mobilization [1, 2].

Radiographs and CT scans obtained at one moment in time may limit the surgeons understanding of the severity of the pelvic injury, as the degree of displacement observed in any one study may not represent the magnitude of displacement which occurred at the time of injury [4]. Moreover, the application of pelvic binders, sheets, external fixators, or any other device used in the process of initial stabilization of the patient may mask the injury pattern partially or altogether, leading to a misinterpretation of the severity of injury [5, 6]. To aid in diagnosis and help prevent occult instability of the pelvic ring in such cases, several authors have advocated the use of

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examination under anaesthesia (EUA) at the time of definitive fixation to more accurately delineate the degree of instability in order to guide treatment [7, 8].

There is a paucity of literature regarding incidence and recognition of occult contralateral sacroiliac (SI) joint injury. Although cases have been reported, the rate of occurrence and the root causes are not described. These missed injuries represent a significant burden for patients, often requiring an unplanned return to the operating room for potentially more complex surgical procedures than if the diagnosis had been made pre-operatively. We sought to determine the incidence of unrecognized contralateral SI joint disruptions, and we hypothesize that the rate of occurrence may be increased when external pelvic stabilization is in place. Lastly, we seek to find a more effective way to analyze the pelvic ring disruption and propose a treatment algorithm to more effectively recognize and treat potentially occult pelvic ring injuries.

Materials and methods

Data collection

Following Institutional Review Board (IRB) approval, a registry of trauma patients at our level 1 institution was queried to identify all unstable pelvis fractures treated operatively between January 1, 2016 and January 1, 2018 under the care of a single fellowship-trained orthopaedic trauma surgeon. Patients were included in the study if they were greater than 18 years of age and sustained a pelvic ring injury requiring surgical fixation of any kind. Subjects were excluded if they were less than 18 years of age, or sustained a pelvic ring injury not requiring internal fixation. The primary outcome measure was the presence of undiagnosed contralateral hemipelvis injuries in patients with operatively treated unstable pelvic ring injuries.

Radiographs, computed tomography (CT) scans, and operative reports were scrutinized to confirm appropriate inclusion and prospectively classified by the treating orthopaedic traumatologist using the Young-Burgess classification [1]. In addition, we analyzed the preoperative imaging conditions, which included the presence of external pelvic ring stabilization to help establish a root cause for the missed injury. Subsequent surgical details were noted, to include the time to definitive pelvic fixation and method of internal fixation. Finally, surgical and diagnostic imaging data pertaining to missed injuries was recorded. Post-operative CT scan findings, from which a new diagnosis was made, were analyzed and the injuries were reclassified. This evaluation helped characterize the nature and variety of missed injuries and which patterns were likely to be missed. Subsequent interventions, if performed, were reviewed.

Medical records were reviewed to determine patient, injury, and treatment characteristics. Demographic variables included age and sex of the patients. Injury characteristics including injury severity (Injury Severity Score, Revised Trauma Score), admission haemodynamic instability (defined at our institution as haemodynamically unstable if admission systolic blood pressure < 80), Glasgow Coma Scale score, mechanism of injury, fracture type, lack of adequate imaging prior to binder or external fixation, use of temporary stabilization with pre-peritoneal pelvic packing (PPP) and anterior pelvic external fixation, and injury mechanism associated traumatic injuries including abdominal visceral (bowel or solid organs) injury, head injury, and urogenital injury were evaluated as independent risk factors for missed contralateral pelvic ring injuries.

A total of 73 patients were identified (Table 1). We included only those patients who had operatively treated pelvis fractures. The average age was 41.8 years (± 16.9 years, range 16–89 years). There were 52 (69.8%) males and 21 (30.1%) females. Fracture patterns (AO/OTA pelvic ring) included 42 (57.6%) 61B patterns and 31 (42.4%) 61C patterns. Most common injury mechanisms were motor vehicle collision (29), automobile-pedestrian accident (16), and fall from height (10). Sixty-six patients (90.4%) presented with one or more associated injuries. Thirty-four patients (46.6%) presented with haemodynamic instability requiring transfusion. Forty-two patients (57.5%) underwent damage control surgical management of the pelvic ring injury with pelvic packing and anterior pelvic external fixation. Twenty-one patients (28.8%) underwent CT scan with pelvic binder or external fixator in place, and 52 patients (71.2%) had imaging out of external immobilization. Forty-nine patients (67.1% presented with a pelvic binder in place upon arrival).

Statistical analysis

Odds ratios of presumed independent risk factors were calculated to evaluate the relative contribution of associated clinical parameters to occult contralateral pelvic ring injuries in the multiply traumatized patient. Variables analyzed were those hypothesized to be independent risk factors of subsequent unrecognized contralateral pelvic ring injuries, including (1) age; (2) gender; (3) injury characteristics including injury severity (Injury Severity Score, Revised Trauma Score); (4) admission haemodynamic instability (defined at our institution as haemodynamically unstable if admission systolic blood pressure < 80); (5) the Glasgow Coma Scale score; (6) mechanism of injury; (6) fracture type; (7) lack of adequate imaging prior to binder or external fixation; (8) use of temporary stabilization with pre-peritoneal pelvic packing (PPP) and anterior pelvic external fixation; and (9) associated traumatic injuries. The significance was established as $P < 0.05$ and odds ratios with 95% confidence intervals were calculated.

Table 1 Characteristics of patients identified with missed contralateral pelvic ring injuries. *APC* anterior-posterior compression, *VS* vertical shear, *LC* lateral compression, *CT* computed tomography, *MVC* motor vehicle collision, *MCC* motorcycle collision

Patient	Age/ sex	Injury mechanism	AO classification	Final diagnosis Young and Burgess	Injury severity score	Haemodynamic instability requiring initiation of massive transfusion protocol	Pelvic packing and external fixation on presentation	Pelvic imaging obtained prior to application of pelvic binder or external fixation	Associated orthopaedic injuries present
1	24, M	MVC	61C2.3	LC III	43	Yes	Yes	No	Yes
2	28, M	Ski accident	61C2.2	Right APC III, contralateral external rotation lesion	38	Yes	No	No	Yes
3	49, M	MVC	61B3.3	Bilateral APC II	57	Yes	Yes	Yes, CT	Yes
4	52, M	Auto v pedestrian	61C2.3	Bilateral APC II	42	Yes	Yes	Yes, AP radiograph and CT	Yes
5	41, M	MVC	61C3.1	APC III	45	Yes	Yes	No	Yes
6	21, M	MCC	61C3.2	Combined mechanism VS/LC	57	Yes	Yes	Yes, AP radiograph	Yes

Results

During this time period, a total of 73 operatively treated pelvis fractures were identified. There were a total of six missed contralateral occult pelvic ring injuries, representing a missed injury rate of 8.2%. Pelvis fractures in multiply traumatized patients with associated traumatic injuries were associated with higher prevalence of missed contralateral pelvic ring injury (relative risk 1.85, 95% CI 1.13–3.02) as compared to patients with isolated pelvic fractures. There was a strong correlation, though no statistically significant association to age, fracture classification, the presence of imaging prior to binder or external fixation, temporary stabilization with preperitoneal pelvic packing (PPP) and anterior pelvic external fixation, or injury mechanism. There was no correlation with haemodynamic instability requiring transfusion on arrival.

For the six patients with missed injuries, upon initial presentation, four of the six patients (67%) were taken to the operating room for pelvic packing and anterior pelvic external fixation. Five of the 6 (83%) patients had some form of external immobilization in place prior to obtaining pelvic CT scans, including an external fixator in three (50%) and a binder in two (33%). Four of the six (67%) patients had some form of external immobilization in place at the time initial AP pelvic radiographs were taken.

Discussion

In our series, diagnosis of occult contralateral pelvic injury was made in all cases with routine post-operative CT scan. In all six cases, the pre-operative diagnosis included a unilateral pelvic ring injury, when a bilateral injury was present and unrecognized. Two of the six missed injuries involved incorrectly diagnosing an LC3-type pelvic ring injury as a unilateral LC2 pattern. These included an AO/OTA 61B3.1 (internal rotationally unstable on side and external rotationally unstable on the contralateral side) treated as a 61B2.1 (unilateral lateral compression fracture of the sacrum with internal rotation instability) and one 61C2.3 (bilateral posterior ring injury with complete disruption through the sacrum on one side with partial disruption of the contralateral side [sacroiliac joint]) treated as 61C1.3 (unilateral complete disruption of posterior ring through sacrum). Another three of the six injuries involved incorrectly diagnosing bilateral antero-posterior compression (APC) injuries as unilateral APC injuries. These three injuries included two 61C2.2 injuries (bilateral posterior ring injury with complete disruption through the sacroiliac joint on ones side with partial disruption of the contralateral side [sacroiliac joint]) treated as 61C1.2 (unilateral complete disruption of posterior ring at sacroiliac joint) and one 61C3.1 (bilateral complete disruption of posterior ring at sacroiliac joint) treated as 61C1.2 (unilateral complete disruption of posterior

ring at sacroiliac joint). In these five cases, the missed injury was an external rotation-type, with ligamentous disruption sacroiliac joint, which was minimally or non-displaced on pre-operative imaging (Fig. 1). In the remaining patient, lateral compression (LC)-type compression injury was incorrectly diagnosed and treated as a unilateral LC-type pelvic ring injury (e.g., 61B3.2 [bilateral lateral compression sacral fracture] treated as 61B2.1 [unilateral lateral compression fracture of the sacrum with internal rotation instability]) (Table 2).

Of those six missed pelvic ring injuries, three patients were taken back to the OR for the addition of fixation or revision of previously placed fixation. In two patients, iliosacral screws were placed on the side of the missed injury. In one patient with a missed bilateral LC pattern, an iliosacral screw was replaced with a trans-sacral screw at the same level (Fig. 1). In three patients, no further operative intervention was performed. In one patient, a trans-sacral screw was felt to stabilize the injury satisfactorily and in the other two, anterior ring fixation was felt to sufficiently stabilize the unrecognized contralateral APC2-type trans-sacral dislocations (Table 2).

Multiple studies have previously shown that missed injuries can occur in up to 40% of patients presenting following high-energy trauma [9–12]. Although the widespread use of whole-body CT has improved the ability to detect multi-organ pathology, numerous injuries may remain undetected. The static nature of CT scans and pelvic radiographs may at times underestimate the severity of initial/potential degree of displacement of pelvic fractures, especially with a pelvic binder or sheet [5, 6]. To avoid missed injury, surgeons must carefully scrutinize pre-operative radiographs and CT scans, though findings in even severe injuries may be subtle. Though our results were not significant, strong trends were observed when comparing the relative risks of patients in whom pre-operative imaging was obtained with immobilization in place compared to those who were not and in whom anterior pelvic external fixation and PPP was performed compared to those who were treated without (RR 2.7 CI 0.53–13.87). Therefore, when the reduction of the pelvic ring volume with external stabilization or pelvic binders is used in the initial management of unstable pelvic ring injuries, one must be aware of the pitfall of potentially masking pelvic ring injury.

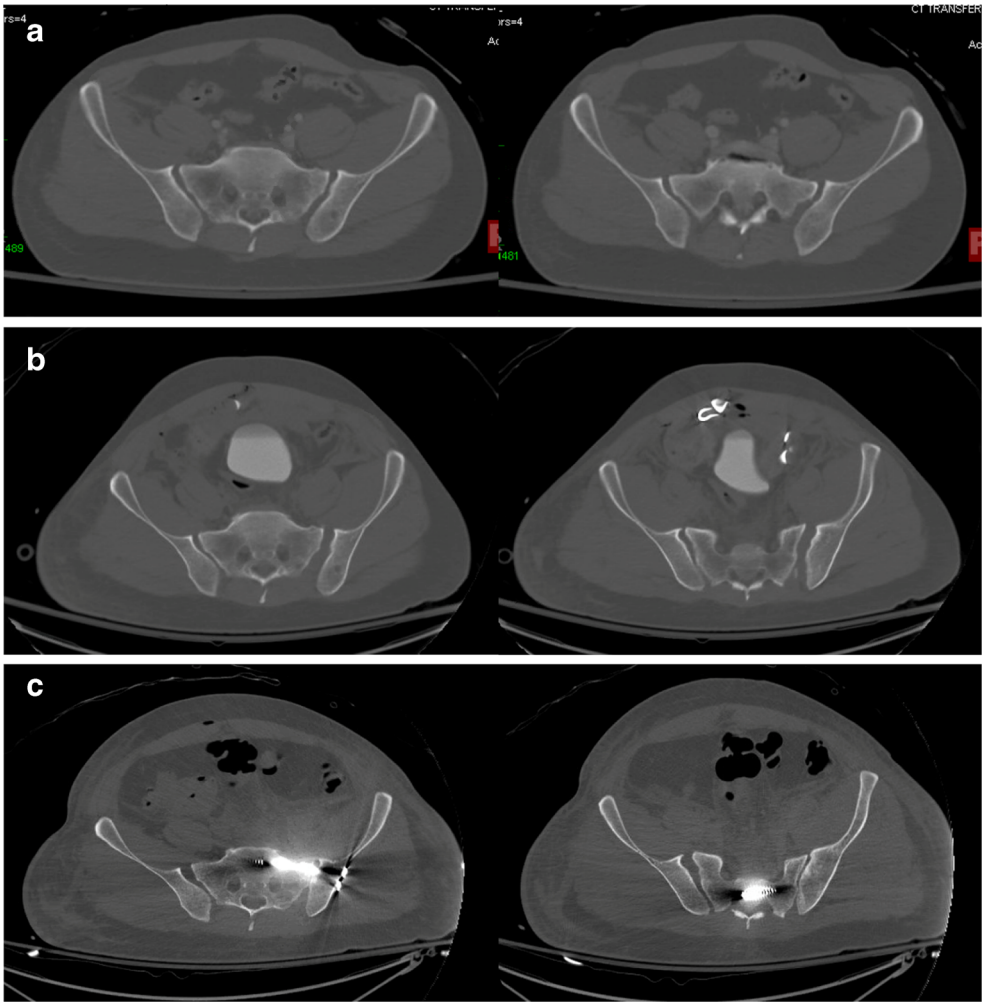

Fig. 1 Axial computed tomography sections of polytraumatized patient involved in high-speed MVC. **a** Initial presentation in pelvic binder. **b** Following pelvic external fixation placement and pre-peritoneal pelvic packing protocol. **c** CT scan obtained after initial fixation. Previous right-sided occult SI joint injury now apparent

Table 2 Diagnosis, classification, and definitive fixation of missed pelvic ring injuries. *APC* anterior-posterior compression, *VS* vertical shear, *LC* lateral compression

Patient	Initial diagnosis	Initial fixation	Missed injury	Final diagnosis	Method of diagnosis of missed injury	Revision surgery
1	Left LC II	Left S1 sacroiliac screw	Contralateral right APC II	LC III	Post-operative CT scan	Left S1 trans-iliac/trans-sacral screw
2	Left APC III	Left S1/S2 sacroiliac screw	Contralateral right APC II	Right APC III, contralateral APC II	Post-operative CT scan	Right S1/S2 sacroiliac screw
3	Right APC II	Left S2 sacroiliac screw	Contralateral left APC II	Bilateral APC II	Post-operative CT scan	None
4	Left APC III	Left S1 sacroiliac screw	Contralateral right APC II	Left APC III, right APC II	Post-operative CT scan	Right S1 sacroiliac screw
5	Right APC III	Right S1/S2 sacroiliac screw, ORIF pubic symphysis	Contralateral left APC II	Right APC III, left APC II	Post-operative CT scan	No
6	Left VS	Left S1 sacroiliac screw, ORIF pubic symphysis	Contralateral right APC II	Combined mechanism VS/APC II	Post-operative CT scan	No

When evaluating these studies, the entire pelvic ring should be analyzed to discern overall injury pattern, and the surgeon should also consider each hemipelvis separately to explore all possibilities, as the radiographic findings of contralateral injury may be subtle. In this way, we find the AO/OTA pelvic ring injury classification useful as designated groups within each type of posterior arch disruption are specified. For example, L5 transverse process fractures on the side of an apparently uninjured hemipelvis, which correlates to an avulsion injury from the iliolumbar ligaments, should alert the surgeon to an ipsilateral posterior ring injury even when no other fractures are present, and the sacroiliac joint appears well-reduced [13]. Another such marker, which to our knowledge has not been formally described, is the sacroiliac "fleck sign" observed anteriorly or posteriorly in the region of the sacroiliac joint correlating to a bony avulsion of the sacral or iliac attachment of the anterior or posterior sacroiliac ligaments, respectively. This bony avulsion may be compared to and treated with as much diligence as the fleck sign seen in the tarsometatarsal Lisfranc dislocations in the foot (Fig. 2).

In the setting of a previously identified injury pattern to the pelvis, some authors have suggested the use of examination under anesthesia (EUA), to further delineate the degree of instability imparted to the hemipelvis, which can alter subsequent treatment plans in the operation [7, 8]. There is however a paucity of data regarding occult injuries to the contralateral hemipelvis. To our knowledge, only two such cases of missed occult contralateral pelvic ring injuries have been reported in the literature [2], and we presume that it occurs more than what is reported.

To effectively address these potentially missed injuries, we propose an algorithmic approach to diagnosis and treatment.

First, the surgeon must carefully scrutinize pre-operative imaging, correctly classifying pelvis fractures and identifying those that are rotationally unstable or exhibit characteristics that may be associated with an occult contralateral injury such as the "fleck sign" or bilateral pubic rami fractures. There should be a heightened suspicion for occult injury when pelvic binders or external fixators are in place on initial imaging, particularly when there is no imaging available out of external pelvic stabilization.

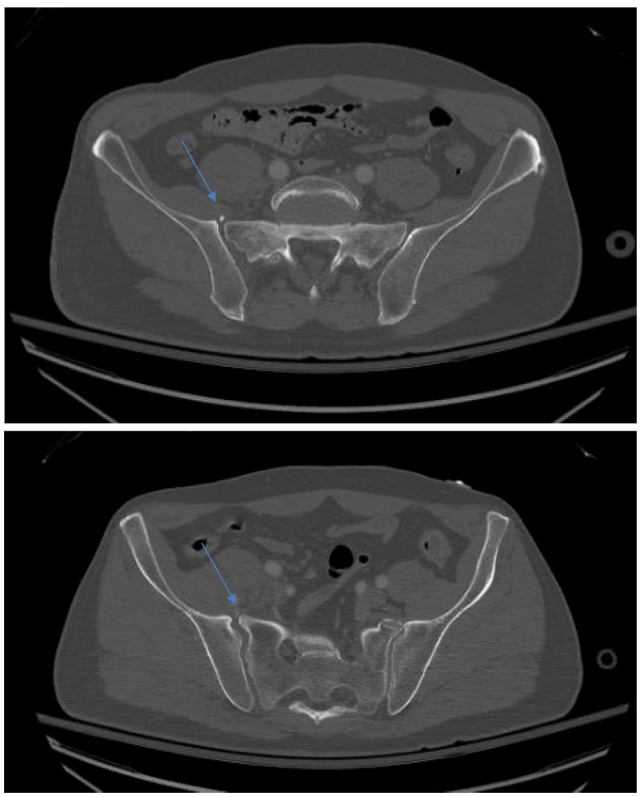

Fig. 2 Axial computed tomography sections of two different patients demonstrating the "fleck" sign as a potential radiographic marker demonstrating lateral compression type injury with potential for unrecognized rotational injury of contralateral hemipelvis

Following careful evaluation of pre-operative imaging, the surgeon should execute a formal evaluation under anaesthesia as previously described by Sagi and colleagues, either at the time of damage control orthopaedics (DCO), or at the time of definitive internal fixation in order to correctly identify any instability of the presumably uninjured contralateral hemipelvis.

At our institution, pelvic fracture protocol for haemodynamically (i.e., those that do not respond to two units of packed red blood cells) unstable patients with pelvic ring injuries calls for immediate operative intervention with pre-peritoneal pelvic packing and pelvic ring external fixation [14–16]. It is the practice of the senior author to use supra-acetabular pin placement, which aside from providing a more stable construct, allows for reliable manipulation of the hemipelvis with the use of a T-handle chuck. Once the pin is in place, it is now our practice to dynamically image the posterior pelvic ring, looking at each sacroiliac joint individually in the pelvic inlet, pelvic outlet, or obturator inlet views, while manipulating the respective hemipelvis with the supra-acetabular pin. In our practice, it is with this technique that occult instability of the contralateral ring injury may be diagnosed.

If such DCO is not practiced in the particular case, the same method can be used during definitive fixation with temporary placement of a supra-acetabular pin, which may aid in reduction during definitive fixation, or with simple manipulation techniques, such as those described by Sagi et al. for each hemipelvis [7]. We believe that the adherence to these techniques at the time of DCO, or definitive fixation, can accurately identify occult injuries and decreased the burden of re-operation and often more challenging revision fixation. Finally, we recommend post-operative pelvic CT scans or intraoperative three-dimensional imaging, which can not only accurately identify misplaced implants, but also delineate these missed injuries while still in the acute period or even in the same anaesthetic period.

Weaknesses of our study include its retrospective nature as well as the small number of patients included in the study. A further prospective study with the use of our treatment algorithm will be useful to expand upon the epidemiology of these injuries. Outcome data was not reported.

Unrecognized contralateral pelvic ring injuries are relatively uncommon. There is an 8.2% incidence of unrecognized contralateral SI joint instability in patients presenting with unstable pelvic ring injuries. Multiply traumatized patients with multiple orthopaedic injuries were an independent risk factor for this injury pattern. In the modern healthcare systems driven by costs, outcome, quality, and patient safety [17], careful scrutiny of pre-operative imaging may help detect these injuries, and an algorithmic approach to diagnosis, involving an examination under anaesthesia (EUA) of each hemipelvis during temporary or definitive fixation, may help prevent these complications. Intra-operative three-dimensional imaging or post-operative computed tomography (CT) scans could identify these injuries when initially unrecognized.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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