MINI-SYMPOSIUM: PELVIC FRACTURES

(i) Injuries to the pelvic ring: Incidence, classification, associated injuries and mortality rates

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Summary
High energy injuries to the pelvic ring often result from motor vehicle collisions. The incidence of severe pelvic ring injuries may be increasing in some areas. They are often associated with significant injuries to other major bodily organ systems resulting in high degrees of both morbidity and mortality.

Introduction
Pelvic ring injuries commonly result from high energy trauma, with motor vehicle accidents accounting for up to 73\% of injuries.\textsuperscript{1-3} The National Trauma Registry of major injury in Canada which collects data on all those with ISS > 12, has reported that for the years 2001–2002 motor vehicle collisions accounted for 47\% of all cases.\textsuperscript{4} Mortality rates following pelvic trauma have ranged from 9 to 27\%.\textsuperscript{2,5,6} Morbidity following pelvic injuries is high—often the result of the high energy trauma and a number of associated injuries. In this article we will address the incidence and classification of high energy injuries to the pelvic ring as well as associated injuries.

Incidence
Pelvic injuries include approximately 3\% of all skeletal injuries and can occur in 4–18\% of those sustaining high energy injuries (ISS > 12).\textsuperscript{7-10} Males are twice as likely to sustain a pelvic injury compared to females (66\% vs. 34\%, respectively).\textsuperscript{2,7} The Canadian National Trauma Registry have recorded that out of 109,738 major injuries occurring in 1999, 4531 had a pelvis fracture (4\%).\textsuperscript{11} At the Hamilton Health Sciences, General Division, a Level 1 Tertiary trauma centre, pelvic

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injuries made up 13.3% of orthopaedic injuries seen in the trauma population with ISS > 12 over a 10 year period. This correlates with reports from other North American centres. Clancy et al. found an incidence of pelvic fractures in trauma patients admitted to a US level 1 trauma centre to be 11.9%. This was relatively consistent with the level 2 trauma centres in the area with an incidence of 12.1%. Figures derived from UK data have shown an incidence of 8–14% depending on the ISS included in the respective databases. An increase in the number of severe pelvic injuries, those with a pelvic abbreviated injury severity score (pelvic AIS) of ≥4 in those vehicle occupants involved in a motor vehicle collision (MVC) has occurred in Canada. The incidence increased from 3.9% to 7.5% from 1994 to 1999, respectively. Suggested reasons for this are an increase in motor vehicle speed as well as an increase in subcompact and sports utility vehicles (SUV). Also, lateral impact crashes, which are known to be associated with an increased incidence of pelvic injuries, increased during the study period. Similarly, other North American and German data echo this trend and report that 59.7–73.4% of those sustaining a high energy pelvic ring injury were involved in an MVC.

In an evaluation of the risk factors associated with severe pelvic injuries (AIS ≥ 4), Demetriades et al. suggest that motorcycle injuries result in the highest incidence of pelvic fractures (15.5%) followed by pedestrian injuries (13.8%), falls from height > 15 ft (12.9%) and car occupants (10.2%). Muir et al. agreed that pedestrians had the highest incidence of pelvic injuries (44%), however this was followed by occupant MVC’s (35%), falls from height and motorcycle accidents. Within the group of occupants involved in an MVC, the highest incidence of pelvic fracture was seen in the driver, followed by the front seat passenger and then the rear seat passenger.

Although geographic differences may exist, most reports support motor vehicle collisions, either occupant, pedestrian or motorcycle as the major source of pelvic injuries worldwide.

Open pelvic injuries

Open pelvic fractures occur in approximately 2–4% of pelvic injuries and, as with high energy pelvic ring injuries in general, occur more frequently in males. Several reports reveal that automobile or motorcycle accidents cause the highest proportion of open pelvic injuries. Brenneman et al. report this to be as high as 49% with automobile–pedestrian accidents following a close second (31%). Other reports have either an MVC, motorcycle or pedestrian accident as the primary cause of open pelvic fractures in over 50% of cases. Clearly, a high proportion of open pelvic fractures are the result of an MVC or related cause.

A high incidence of Gustilo and Anderson Type 3 injuries has been reported—up to 60% in some reports. Strict categorical classification is difficult with pelvic injuries due in part to the complex anatomical relationship of soft tissues around the bone and also its proximity to potential levels of high bacterial contamination. In order to help with classification, some reports place those open pelvic fractures with wounds extending into the perineum or rectum as automatically Gustilo and Anderson type 3 injuries.

Classification

Pelvic injuries are most commonly classified either mechanistically (that of Young and Burgess) or based on stability and mechanism (that of Tile and Pennal, adopted, modified and recommended by the Orthopaedic Trauma Association). The OTA classification groups pelvic injuries into three main divisions: A-type injuries have a stable pelvic ring, B-type have a partial posterior disruption and C-type have a complete posterior disruption. Gansslen et al. using the OTA classification, reported a series of 2551 pelvic ring injuries. They found that 54.8% were type A fractures, 24.7% were type B fractures and 15.7% were type C fractures. However, Rommens and Hessman reviewed 222 patients with either B or C type injuries and found a higher proportion of C type injuries (55%). Within this classification, the severity of injury increases from type A to type C. Reports have shown that C type injuries have a higher injury severity score (ISS); as well, documented injuries in those motor vehicle collisions that were rapidly fatal have shown a predominance of C type patterns in those who had pelvic fractures.

Using the classification of Young and Burgess, initial reports found an incidence of 41.4% for lateral compression injuries, 25.7% for anteroposterior compression, 4.7% for vertical shear, and 9.9% had a combined mechanism. This is consistent with other case series reviews of high energy pelvic injuries which have shown lateral compression injuries to have the highest incidence and vertical shear injuries to have the lowest.
In open pelvic fractures, studies have reported differing incidences of A, B or C injuries. A type injuries range from 11% to 31%, B type (with the majority being B1 or open book injuries) range from 26% to 43% and C type injuries range from 43% to 45%. These figures again correlate with an increased preponderance of severe pelvic ring injuries in the open fracture subgroup.

Classification systems for open pelvic fractures have also been described. Jones et al., have classified open pelvic injuries into three major categories: class 1 injuries are open pelvic fractures with a stable pelvic ring, class 2 are injuries in which the pelvic ring is either rotationally or vertically unstable and there is no rectal or perineal wound with the potential for fecal contamination and class 3 are open pelvic fractures that are either rotationally or vertically unstable but have a rectal or perineal wound present with the potential of fecal contamination. In their series, class 1 injuries accounted for 30% of open pelvic fractures, class 2 injuries accounted for 46% and class 3 injuries accounted for 23%. They found this classification to be predictive of both sepsis and mortality. Bircher and Hargrove classify open pelvic fractures into one of three categories, each with three subsets. A type injuries are predominantly 'outside–in' injuries, B type injuries are predominantly 'inside–out' injuries and C type injuries are those associated with severe soft tissue injury or loss and fecal contamination. Further studies are needed both to determine the specific incidence of each type and subtype and for further validation.

A further subgroup of open fractures, which have a very high energy variant of the C type pelvic fracture pattern, is the traumatic hemipelvectomy. This lesion can be characterized by significant soft-tissue disruption, avulsion or occlusion of the iliac or femoral vessels and wide separation of the hemipelvis. The incidence has been reported to be 0.55%. However, the true incidence may be an unknown as a significant number of cases may be fatal at the scene. In a review of the survivors of this injury, most were injured on motorcycles, were pedestrians or were occupants involved in MVC's (driver most commonly). Once again this reveals the significant association of motor vehicle trauma and high energy injury patterns.

### Associated injuries

Injuries to other organ systems are commonly seen with high energy pelvic ring injuries (Table 1). The incidence of associated injuries varies with reports ranging from 30% to 93%. Some authors have shown an increased constellation of associated injuries as the severity of the pelvic fracture increases. In this review we will focus on significant injuries to other major bodily systems.

### Thoracic and abdominal injuries

Thoracic injuries occur in 27–65% of those with high energy pelvic injuries. Some have found this the most common extrapelvic lesion while others suggest it is more commonly associated with certain fracture types. Initial reports found the incidence of thoracic injury to range from 19% to 39% depending on the fracture pattern, with the Young and Burgess anteroposterior compression (APC) type 2 injury (39%) and the lateral compression (LC) type 2 injury (36%) having the highest association. Documentation on the severity of thoracic injury suggests that severe thoracic trauma is more commonly seen with an incidence up to 30%.

Intra-abdominal injuries can take the form of solid organ damage or damage to the bowel. Initial reports documented splenic injuries as the most common with an incidence ranging from 9% to 24% depending on the fracture pattern, the highest being associated with the vertical shear injury. More recent reports suggest that liver injuries are the most common intra-abdominal organ injury with an incidence of approximately 6%. This is followed by splenic injuries with an approximate incidence of 5% and injuries to the bowel with an incidence of 4%. This pattern is consistent throughout the range of pelvic AIS. Using stepwise logistic regression Demetriades et al., found that involvement in an MVC and a pelvic injury of at least AIS = 4 were predictors of liver injury. Thus those with severe pelvic injuries (AIS ≥ 4) had a

### Table 1 Associated injuries and their respective reported incidences.

<table>
<thead>
<tr>
<th>Associated Injuries</th>
<th>Reported incidences (%)</th>
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<tbody>
<tr>
<td>Head</td>
<td>33.3–69.2</td>
</tr>
<tr>
<td>Chest</td>
<td>27–56.4</td>
</tr>
<tr>
<td>Abdomen</td>
<td>17–58</td>
</tr>
<tr>
<td>Genitourinary</td>
<td>6.3–44.6</td>
</tr>
<tr>
<td>Anorectal</td>
<td>0.95–2.3</td>
</tr>
<tr>
<td>Neurologic</td>
<td>3–46</td>
</tr>
<tr>
<td>Requiring angiography</td>
<td>4.7–9.1</td>
</tr>
<tr>
<td>Other MSK injuries</td>
<td>27–83</td>
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relative risk of liver injury of 1.9 and this combined with MVC as the mechanism of injury increased the relative risk to 3.15

Urogenital and rectal injuries

Reports of bladder and urethral injuries range from 6% to 21% depending on the fracture morphology.3,5 Some series have found the APC injury pattern to be significantly associated with these injuries.3 Recent reports have focused on determining predictors of associated bladder and urethral injuries.15 Male gender and a pelvic AIS \( \geq 4 \) have been documented to be independent risk factors associated with bladder or urethral injuries. Males and those patients with AIS \( \geq 4 \) are 1.9 and three-fold more likely to have a urethral injury following pelvic trauma compared to controls. Both risk factors together resulted in an incidence of 4.8% for bladder or urethral injury.15 Aihara et al., reported that of bladder and urethral injuries, bladder injuries were the most commonly associated injury, with an incidence of 4.6%.28 Urethral injuries occurred in 1.1% of pelvic ring injuries and combined injuries occurred in 0.8%.28 Widening of the SI joint, widening of the symphysis pubis and fractures of the sacrum were associated with a bladder injury with widening of the symphysis pubis the strongest predictor of bladder injury.28 In regard to urethral injury, fractures of the inferior rami, widened symphysis pubis and SI joint widening were associated, however only symphysis pubis widening and fracture of the inferior pubic ramus were independently predictive of urethral injury.28

Within the subcategory of open pelvic fractures the incidence of urogenital injuries has been reported to be as high as 61.4%.16 Jones et al., in a multicentre retrospective review reported the incidence of vaginal lacerations to be 33%, bladder injuries to be 23% and urethral injuries to be 10%.19

Urethral injuries may be associated with decreases in sexual function, as well, sexual function may be decreased in the absence of obvious urethral injuries.29,30 In a review of 90 patients, King et al., found the incidence of sexual dysfunction to be 5% in those without urologic injury and 42% in those with urologic injury.30 Rates can be higher as seen in those with documented posterior urethral injuries referred for late reconstruction.31 Seventy-two per cent had sexual dysfunction as demonstrated by nocturnal tumescence studies.31 When looking at all high energy pelvic fractures, an incidence of erectile dysfunction of 12% and dyspareunia in 2% of women has been reported.32 When looking specifically at male sexual function using validated outcome measures for this, the complaints of erectile dysfunction range from mild to severe. This was shown to correlate with a significant decrease in overall sexual satisfaction. Interestingly, 20% of those with complaints of erectile dysfunction had no previously associated urethral disruption. The only factor identified by Malavaud et al. to be associated with this decrease in erectile function was pubic diastasis.29 Copeland et al. reviewed two groups of female multitrauma patients: those with pelvic fractures and those with only fractures to the extremities.33 They found increased urinary complaints in those with pelvic fractures than in those without (21% compared to 7%, respectively). Dyspareunia was seen in those with pelvic fractures and was more common when the residual displacement of the fracture was \( \geq 5 \text{ mm} \) (43% compared to a 25% incidence in those with displacement < 5 mm).33 Between groups there was no difference in the rates of miscarriage or infertility.33

Anorectal injury

Anorectal injuries occur with an incidence of 0.95–2.3%.16,18,28 Although infrequent they are a significant source of both morbidity and mortality.34 Reviews of open fractures have found rectal and perineal injuries to occur in 23–64% of patients with open pelvic injuries.18,19,35,36 The presence of perineal injuries incurs a high rate of sepsis—up to 77% in some reports.19 Aihara et al., have shown that the primary and independent predictor of rectal injuries was a widened symphysis with a relative risk of 3.3.28

Head and neurologic injuries

Head injury occurs in 37–69% of high energy pelvic fractures.3,7,10 The higher percentages are often seen in those patients with pelvic AIS \( \geq 4 \). Early reports suggested an association with the anteroposterior compression injury pattern.5 Most head injuries are closed injuries, with subdural hematoma and cerebral contusion making up approximately 6% and 9%, respectively.7

Peripheral neurologic injuries have been reported to occur with an incidence ranging from 3% to 46% depending in part on the severity of the injury, fracture morphology and the presence of an associated sacral fracture.2,37–39 A higher incidence of neurologic injury has been reported with a completely unstable injury pattern (OTA C type injury).3 With the partially unstable pattern (OTA B type), a higher incidence of neurologic injuries are...
seen in the B1 (APC equivalent) as compared to the B2 (LC equivalent) pattern.\(^3\) When looking at the type of nerve injury, the majority (60%) are a mixed motor and sensory loss, while the rest have a sensory deficit alone.\(^39\) Approximately half of these injuries may go on to recover.\(^39\)

Sacral fractures, in association with fractures of the pelvic ring have been shown to increase the likelihood of neurologic injury.\(^40\) – \(^42\) Denis et al. classified these injuries as being either in zone 1 (involving the sacral ala, lateral to the foramina), zone 2 (transforaminal) or zone 3 (extending into the sacral canal).\(^41\) The incidence of neurologic injury increased accordingly from zone 1 (5.9%), to zone 2 (28%) to zone 3 (56%). The type of neurologic injury also correlates with placement, as injury to the L5 nerve root is most frequent in zone 1, unilateral sacral root lesions occur in zone 2 and injuries to the cauda equina are most frequent in zone 3.\(^40\) – \(^42\)

An uncommon variant of sacral fracture that has been reported is the midline sagittal fracture associated with anterior–posterior compression type injuries.\(^43\) These fractures occur with an incidence of 0.6% of pelvic fractures and 1.4% of sacral fractures as seen in a review of 10 cases.\(^40\) Interestingly, there were no objective neurologic deficits at 31 months of follow-up with this type of injury. This type of fracture pattern may protect the nerve roots from injury by hinging open through the posterior aspect of the canal.\(^40\)

**Hemodynamic complications**

The incidence of those requiring transfusion of blood products in patients with high energy pelvic ring injuries ranges from 38% to 75%.\(^15\) Transfusion rates can increase significantly as severity of pelvic injury increases and as the number of other associated major organ injury increases.\(^5\) – \(^7\),\(^15\),\(^44\)

Indeed it has been suggested that the requirement for major blood transfusions and threat of hemorrhage is significantly due to associated non-pelvic injuries.\(^44\) Recent reports have determined factors found to be predictive of the risk of undergoing a transfusion. Using information available at presentation as factors in a logistic regression model predictors of transfusion include increasing age (>60), shock on arrival (systolic blood pressure <90 mmHg), revised trauma score and base deficit.\(^23\) In a similar report, age >55, ISS >25, pelvic AIS ≥4 and angiographic embolization have also been identified as significant independent risk factors associated with major blood transfusions (>2 L).\(^15\)

Open fractures have been also been shown to have higher initial 24 h transfusion requirements as compared to closed injuries.\(^16\) Indeed, in some reports of open pelvic fractures, exsanguination was as high as 7% with documented transfusion rates as high as 33.6 units.\(^16\),\(^45\)

Pelvic angiography is reported to be necessary in 4.7–9.1% of pelvic injuries.\(^7\),\(^15\),\(^46\) Of these up to 18.8% may require a repeat angiography and embolization.\(^47\) Shapiro et al., found that predictors of repeat angiography were continued or recurrent hypotension (SBP<90), absence of intra-abdominal injury, and persistent base deficit of 10 for greater than 6 h.\(^47\) Early reports revealed that APC type injuries were significantly associated with hemodynamic instability and transfusion requirements and this continues to be the case.\(^5\),\(^48\) In comparing an APC group to an LC group in a series of pelvic fractures treated with angiography, the APC group was found to be more commonly hemodynamically unstable on arrival.\(^48\) The APC group contained the highest number of posterior division arterial injuries (52%) while the LC group contained a higher proportion of anterior division arterial injuries (59%). When converting to the OTA classification, all type A injuries had internal iliac posterior division injuries, type B had a high proportion of anterior division injuries (56%) and Type C had a high proportion of posterior division injuries (40%). Previous reports have shown a high degree of internal iliac posterior division arterial injury, most commonly the superior gluteal artery, with unstable posterior injury patterns. Similarly anterior division injury patterns result in anterior division arterial injury, most commonly the pudendal.\(^46\)

**Other soft tissue injuries**

Closed soft tissue injuries can also occur with pelvic trauma. The closed internal degloving injury associated with acetabular fractures and occurring over the greater trochanter as described by Morel-Lavallee can also be seen in pelvic injuries.\(^49\) – \(^50\) Degloving may also occur over the trunk, buttock or thighs.\(^49\) Hak et al., reviewed 24 patients with this lesion. In their series, six patients (25%) had lateral compression fractures with sacral and ramus fractures and six patients (25%) had sacroiliac disruptions. The rest were associated with acetabular fractures.\(^49\) These injuries may initially be missed and indeed Hudson et al. found that one-third were missed with the majority resulting from a motor vehicle accident.\(^51\)
Mortality

Rates of mortality associated with high energy pelvic fractures range between 9% and 28% and are composed of an early mortality, usually due to hemorrhage and a later mortality commonly associated either with sepsis or multiple organ failure.2,15,23,52 In a certain number of patients the pelvic injury is determined to be the primary cause of death and this has been reported to be from 0.8% to 1.4%.1,2,15

Mortality increases as the severity of the injury increases.2,15,23 Indeed, type A injuries are associated with the lowest mortality rate of ~9%.2 This increases to ~14–28% in those with type B or C injuries and those with a pelvic AIS > 4.2,15,27 Predictors of mortality have been determined using logistic regression analysis and they include presentation to the trauma suite with a revised trauma score less than 11, age > 60 or in shock.23 Those who have one or more of these factors are at significant risk of dying regardless of fracture pattern.23 Starr et al., found that mortality was highest within the first 24h.

Open pelvic fractures have an increased mortality when compared to closed pelvic injuries.16,19,36 Jones et al., report an overall incidence of mortality of 25% in their open fracture series, and Brenneman et al., report an incidence of mortality of 25% of those with open pelvic fractures compared to 16% in those with closed pelvic injuries. The incidence of death increased from 0% in Jones et al., class 1 open pelvic fractures to 33% in class 2 and 44% in class 3 injuries. Half of the patients died early as a result of hemorrhage and 10% died later due to multiple organ failure.19 Factors seen to influence this rate are ISS, age in years and associated significant soft tissue damage.2,36 With these factors mortality rates reach over 30%.2,36

In those patients requiring angiography, the overall mortality rate is also seen to be higher and is reported to be as high as 57%.23,46 Those presenting with shock on arrival (systolic blood pressure < 90 mmHg) were seen to have the highest mortality.46

Conclusion

Significant injuries to the pelvic ring, most commonly the result of high energy trauma, carry with them high rates of both morbidity and mortality. This is in part due to their frequent association with other injuries.

References

11. Canadian Institute for Health Information. National Trauma Registry. 1999 (GENERIC).
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