



Classification, management and outcomes of severe pelvic ring fractures

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Project Background

Unstable pelvic ring fractures are associated with a high risk of mortality (1, 2). Where patients survive these injuries, the potential for long term morbidity such as lost health-related quality of life (HRQoL), pain and functional loss is significant.

Because of the high risk of fracture-related haemorrhage associated with severe pelvic ring fracture, most studies have focused on establishing predictors of mortality. The risk of haemorrhage, combined with the propensity for severe associated injuries, highlight the clinical challenge of managing unstable pelvic fractures. While guidelines exist, there is no clear consensus about the optimal management approach for haemodynamically unstable patient with pelvic fracture (3-8). In Victoria, the two adult major trauma services (MTS) favour different protocols for the management of these patients. A preliminary study, using data only from the Victorian State Trauma Registry, found no difference in risk-adjusted mortality between the MTS hospitals (9). However, limitations were noted and the need for additional data regarding resuscitation practices, and fracture classification, were acknowledged as necessary for a full evaluation of the MTS approaches to management.

Studies assessing the long term outcomes of patients are few and largely limited to small samples ($n < 50$), single centre studies (10-12), and specific sub-sets of the population (e.g. surgically managed, female patients). These studies confirm the poor long term outcomes but have not investigated the relationship between management, fracture classification and outcome. The most effective method of fixation for maximising long term outcomes remains unknown.

Optimal fixation requires high quality imaging to guide surgical management and decision making, while research studies of the pelvic ring require accurate and reliable classification of fractures to enable valid and appropriate comparisons of study populations and patient outcomes. The major classifications for pelvic ring fracture are the Young-Burgess and Tile/AO. Both systems were developed in the 1980s for fracture classification based on plain radiographs of the pelvis, but computed tomography (CT) is at the forefront of modern imaging. Two studies have investigated the reliability of classification of pelvic ring fractures and have found fair to substantial agreement using plain radiographs and 2D axial CT scans, which is not sufficient for research and clinical purposes.

This project comprised three distinct studies:

- i. A study to establish the inter- and intra-tester reliability of the classification of severe pelvic ring fractures using plain radiographs and 3D CT reconstruction imaging of the pelvis.
- ii. A detailed comparison of the early acute management of severe pelvic ring fractures between the MTS hospitals to further explore the association between protocols and risk-adjusted mortality.
- iii. A prospective cohort study to establish the relationship between approaches to pelvic fracture fixation, fracture classification and long term functional, return to work, pain and health-related quality of life outcomes.

Study 1: Reliability of pelvic ring fracture classification

Introduction

Optimal fixation of fractures requires high quality imaging to guide surgical management and decision making, while research studies of the pelvic ring require accurate and reliable classification of fractures to enable valid and appropriate comparisons of study populations and patient outcomes. The two commonly used classification systems for pelvic ring fractures are the Tile/AO and the Young-Burgess systems (13-15). Both systems were developed in the 1980s for fracture classification based on plain radiographs of the pelvis. Since this time, there have been rapid and significant advancements in imaging of the pelvis based on computed tomography (CT), including the development of three dimensional (3D) CT reconstructions of the pelvis. For many institutions, 3D CT reconstructions have become a standard imaging tool for pelvis fractures, providing valuable additional information not available from plain radiographs and 2D axial CT scans (13, 16, 17).

Two studies have investigated the reliability of pelvic ring fracture classification. One study investigated the inter-rater and intra-rater reliability using five raters and 89 pelvic fracture patients (14). The second study investigated the inter-rater reliability of the Young-Burgess and Tile/AO classifications using six raters and 30 pelvic ring fracture patients (15). Both studies used plain radiographs and 2D axial CT scans, and demonstrated moderate agreement, but there were limitations to these studies with respect to inadequate sample size and sampling approaches. The use of 3D CT reconstructions for pelvic ring fracture classification was not studied, despite the recognised benefit of this technique for the complex skeletal anatomy of the pelvis, and the fact that these views are widely used in the evaluation planning and management of pelvic ring fractures.

Project aims

The aim of this project was to establish the inter- and intra-tester reliability of the classification of severe pelvic ring fractures using plain radiographs and 3D CT reconstruction imaging of the pelvis.

Methods

Setting

Cases were drawn from the two adult major trauma service (MTS) hospitals in Victoria; The Alfred, and the RMH. The project was approved by the following Human Research Ethics Committees: Monash University (Project number CF11/3004 – 2011001687); Alfred Health (Project number 68/11); and Melbourne Health (Project number 2011.089).

Fracture classification systems

The Tile/AO system classifies pelvic ring fractures into three classes of injury based on mechanism of injury and fracture stability (13-15). The Tile/AO system has three main categories, each with three sub-categories:

- i. Type A fractures are the most common. These fractures are considered stable, and the entire pelvic rim remains intact anteriorly and posteriorly. Type A1 fracture involves apophyseal avulsion, type A2 represents a stable iliac wing fracture, and type A3 involves a sacro-coccygeal fracture.
- ii. Type B fractures involve complete fracture of the anterior pelvic structures (the anterior arch) but incomplete disruption of the posterior elements or arch, and there is partial stability. Type B1 fractures relates to “open book” injuries generally resulting from violent external rotation of the femur, or an anterior-posterior compression force. Type B2 fractures represent internal rotation injuries from a lateral compression force, and type B3 involves bilateral external rotation (bilateral “open book”) injuries with widening of the sacroiliac joints through an anterior compression mechanism.
- iii. Type C fractures involve complete disruption of the sacroiliac complex and anterior pelvic structures, and the pelvis is unstable, usually from vertical shearing forces. For C1 fractures, there is complete unilateral rupture. A C2 fracture involves bilateral injury of B and C types, while a C3 fracture represents a bilateral complete rupture.

The Young-Burgess classification system for pelvis fractures divides the injuries into four major types: anterior-posterior compression (APC); lateral compression (LC); vertical shear (VS) and; combined mechanism injury (CMI) (14, 15).

- i. The APC class involves symphyseal diastasis or longitudinal rami fractures and can be further divided into the sub-types APC I, APC II, and APC III depending on the structures involved.
- ii. The LC class includes transverse fractures of the pubic rami, ipsilateral or contralateral to the posterior injury. These injuries can also be further subdivided into LC I, LC II and LC III.
- iii. The VS class involves symphyseal diastasis or vertical displacement in the anterior or posterior direction, typically through the sacroiliac joint, but occasionally through the sacrum or iliac wing.
- iv. The CMI class of injuries includes those with a combined injury pattern, usually the LC/VS combination.

Participants and sample size

Patients meeting the following criteria were included:

- i. A date of injury from July 2007 to June 2011 (inclusive), captured by the VSTR and definitively managed at the state's adult major trauma services (The Alfred and Royal Melbourne Hospital)
- ii. An Abbreviated Injury Scale (AIS) pelvis fracture coded as 852606.4, 852608.4, or 852610.5 were selected for this study.
- iii. Plain radiographs and 3D CT reconstruction images available.

The date of injury inclusion criterion was extended to include an additional year for this study to obtain sufficient cases with both imaging modalities available.

The Young-Burgess classification system has eight categories while the Tile/AO classification has three major categories (and 9 sub-categories). The focus on severe pelvic ring fractures for this study was likely to exclude Type A Tile/AO fractures, limiting the Tile/AO classification to six categories. The minimum sample size requirement for a study with a classification system with more than two categories is $2k^2$, where k is the number of categories (18). Based on the categories of the Young-Burgess system, the target sample size for this study was 128.

Procedures

Profile of eligible cases

Data for eligible cases were extracted from the VSTR/VOTOR database and the medical record review to describe the profile of cases included in this study. Data extracted included; patient demographics, injury event details, injury severity and early management.

Imaging

For each case, the relevant plain radiographs and 3D CT reconstruction images were extracted from the imaging databases at The Alfred and Royal Melbourne Hospitals by a member of the research team who was not a rater (CH). Identifying information was removed from the images. The sets of images were randomly ordered and distributed to the raters. The raters were provided with an information pack outlining the classification systems prior to receiving the images, and were asked to independently classify each fracture using both the Tile/AO and Young-Burgess systems using the plain radiographs and 3D CT images provided. Rater classifications for each case were recorded in an Excel spreadsheet which was returned to the principal investigator (BG) when complete.

Raters

Three orthopaedic specialists with extensive experience in the management of severe pelvic ring fracture reviewed and classified the images. The years of experience of the specialists rating the images ranged from 17 to 27 years.

Analysis

Kappa (K) statistics were used to describe absolute agreement between raters. Reliability was assessed for:

- (i) All nine categories of the AO/Tile classification;
- (ii) AO/Tile collapsed to the commonly used three category system of “A”, “B”, and “C” type fractures;
- (iii) All eight categories of the Young-Burgess;
- (iv) The commonly used four category version of the Young-Burgess classification (APC, LC, Vertical Shear, CMI), and;

- (v) The Young-Burgess categorised as “stable” (APC1 and LC1) or “unstable” (all other categories) (19).

Ninety-five percent confidence intervals (95% CI) were calculated using the 95th percentile interval from 1,000 bootstrap replications. For the purposes of this study, the guidelines for interpretation recommended by Landis and Koch were used (20). Values less than zero suggest poor agreement, 0 to 0.20 represent slight agreement, 0.21 to 0.40 fair agreement, 0.41 to 0.60 moderate agreement, 0.61 to 0.80 substantial, and 0.81 to 1.00 reflect almost perfect agreement (20). A Stuart-Maxwell test of marginal homogeneity was performed to establish if there was evidence of unidirectional response shift (i.e. if one rater consistently classified fractures more or less severe than the other rater). All analyses were performed using Stata Version 11.2 (StataCorp Inc., College Station, TX) and a p-value <0.05 was considered significant.

Results

Profile of cases

From July 2007 to June 2011, there were 187 severe pelvic ring fracture cases registered by the VSTR. There were 115 with a plain radiograph and 3D CT reconstruction (61.5%), 52 with a plain radiograph only (27.8%), 12 with 3D CT reconstructions only (6.4%), and 8 cases had no images on file (4.3%). Fifteen cases with both 3D CT reconstruction and plain radiograph images were distributed too late to the raters for use in this classification study. A brief profile of cases in each imaging group is shown in Table 1. Cases with only plain radiographs available were more severely injured, as measured by the ISS and in-hospital death rate, than cases with both plain radiographs and 3D CT reconstructions available (Table 1). The in-hospital mortality rate for cases without pre-intervention (i.e. pelvic binders applied in the prehospital or ED setting) imaging available was 63%. Cases with imaging, and particularly 3D CT reconstructions, represent the less critically injured end of the severe pelvic ring fracture spectrum.

Table 1: Profile of severe pelvic ring fracture cases according to availability of imaging

		Plain XR and 3D CT (n=115)	Plain XR only (n=52)	3D CT only (n=12)	No imaging (n=8)
Age	Mean (SD) years	43.8 (20.6)	37.6 (19.8)	45.6 (16.9)	57.8 (29.4)
Gender	n (%) male	84 (73.0)	39 (76.5)	11 (91.7)	5 (62.5)
Cause	n (%) transport-related	89 (77.4)	41 (80.4)	10 (83.3)	3 (37.5)
Outcome	n (%) in-hospital death	11 (9.6)	14 (27.4)	0 (0.0)	5 (62.5)
ISS	Median (IQR)	29 (24-41)	34 (29-43)	24 (20-32)	42 (29-57)
Length of stay	Median (IQR) days	14.8 (9.0-27.7)	19.2 (1.1-39.3)	14.8 (8.8-20.6)	1.5 (0.2-27.7)

Inter-rater reliability

Young-Burgess classification

The distribution of rater classifications of the 100 cases using the Young-Burgess system differed considerably (Table 2). More than half of the cases were classified as Vertical Shear or CMI by Rater 3, but accounted for only 3 per cent of Rater 1 and 10 per cent of Rater 2 classifications. Rater 2 was able to classify all cases, while Rater 1, and Rater 3 did not classify five, and 13, cases respectively.

Table 2: Distribution of rater classifications using the Young-Burgess classification

Category		Rater 1 n (%)	Rater 2 n (%)	Rater 3 n (%)
APC	APC 1	26 (27.4)	4 (4.0)	5 (5.7)
	APC 2	10 (10.5)	16 (16.0)	8 (9.2)
	APC 3	7 (7.4)	9 (9.0)	3 (3.4)
	<i>All</i>	43 (45.3)	29 (29.0)	16 (18.4)
LC	LC 1	26 (27.4)	18 (18.0)	9 (10.3)
	LC 2	18 (18.9)	17 (17.0)	8 (9.2)
	LC 3	5 (5.3)	26 (26.0)	7 (8.1)
	<i>All</i>	49 (51.6)	61 (61.0)	24 (27.6)
Vertical Shear		1 (1.0)	8 (8.0)	26 (29.9)
CMI		2 (2.1)	2 (2.0)	21 (24.1)
<i>Total</i>		95 (100.0)	100 (100.0)	87 (100.0)

The level of agreement between raters was only slight for the complete Young-Burgess classification and the abbreviated, four category version. Consistent with Table 2, the test of symmetry showed unidirectional bias in classification for each rater pair. When the Young-Burgess was dichotomised into “stable” and “unstable”, there was no demonstrable improvement in agreement, although unidirectional bias was absent for one rater pair (Table 3).

Table 3: Level of Agreement between Raters – Young-Burgess classification

<i>Young-Burgess</i>	<i>Raters</i>	<i>% Agreement</i>	<i>Kappa (95% CI)</i>	<i>Test of symmetry (p-value)</i>
Complete classification	1 vs. 2	20.0	0.09 (0.01, 0.17)	$\chi^2_7=40.8$ (<0.0001)
	1 vs. 3	14.0	0.06 (-0.01, 0.14)	$\chi^2_7=52.5$ (<0.0001)
	2 vs. 3	23.0	0.14 (0.06, 0.24)	$\chi^2_7=38.3$ (<0.0001)
Four category	1 vs. 2	53.7	0.17 (0.01, 0.33)	$\chi^2_3=9.5$ (0.024)
	1 vs. 3	37.2	0.18 (0.09, 0.29)	$\chi^2_3=43.8$ (<0.0001)
	2 vs. 3	39.1	0.19 (0.09, 0.31)	$\chi^2_3=36.2$ (<0.0001)
Stable vs. unstable	1 vs. 2	57.9	0.21 (0.06, 0.35)	$\chi^2_1=28.9$ (<0.0001)
	1 vs. 3	55.8	0.16 (0.01, 0.30)	$\chi^2_1=26.9$ (<0.0001)
	2 vs. 3	75.9	0.17 (-0.07, 0.42)	$\chi^2_1=0.4$ (0.513)

AO/Tile Classification

Consistent with the Young-Burgess classification, the distribution of ratings based on the AO/Tile classification differed between the raters (Table 4). The majority of cases were classified as B-type fractures by Rater 1 and Rater 2, while Rater 3 classified the majority of cases as C-type fractures. No rater used all categories of the Tile/AO classification (Table 4).

Table 4: Distribution of rater classifications using the Tile/AO classification

Category		Rater 1 n (%)	Rater 2 n (%)	Rater 3 n (%)
A	A1	0 (0.0)	0 (0.0)	0 (0.0)
	A2	18 (18.9)	0 (0.0)	2 (2.2)
	A3	0 (0.0)	0 (0.0)	0 (0.0)
	<i>Total Category A</i>	<i>18 (18.9)</i>	<i>0 (0.0)</i>	<i>2 (2.2)</i>
B	B1	25 (26.3)	20 (20.2)	10 (11.1)
	B2	38 (40.0)	35 (35.4)	15 (16.7)
	B3	6 (6.3)	30 (30.3)	5 (5.6)
	<i>Total Category B</i>	<i>69 (72.6)</i>	<i>85 (85.9)</i>	<i>30 (33.4)</i>
C	C1	7 (7.4)	12 (12.1)	44 (48.9)
	C2	1 (1.1)	2 (2.0)	44 (12.2)
	C3	0 (0.0)	0 (0.0)	3 (3.3)
	<i>Total Category C</i>	<i>8 (8.5)</i>	<i>14 (14.1)</i>	<i>58 (64.4)</i>
<i>Total</i>		<i>95 (100.0)</i>	<i>99 (100.0)</i>	<i>90 (100.0)</i>

Similar to the Young-Burgess, the agreement between raters for the main categories, and all sub-categories of the AO/Tile classification was slight (Table 5). There was clear unidirectional bias for all rater comparisons (Table 5).

Table 5: Level of Agreement between Raters – Tile/AO classification

Young-Burgess	Raters	% Agreement	Kappa (95% CI)	Test of symmetry (p-value)
Complete classification	1 vs. 2	35.1	0.17 (0.07, 0.29)	$\chi^2_5=32.8$ (<0.0001)
	1 vs. 3	27.0	0.15 (0.07, 0.24)	$\chi^2_6=55.5$ (<0.0001)
	2 vs. 3	25.8	0.12 (0.03, 0.21)	$\chi^2_6=47.4$ (<0.0001)
Three main categories	1 vs. 2	68.1	0.12 (-0.03, 0.30)	$\chi^2_5=18.8$ (<0.0001)
	1 vs. 3	37.1	0.10 (0.02, 0.20)	$\chi^2_6=52.8$ (<0.0001)
	2 vs. 3	48.3	0.17 (0.06, 0.28)	$\chi^2_6=46.0$ (<0.0001)

Discussion

The accurate classification of pelvic ring fractures requires quality imaging obtained prior to intervention to treat the fracture. This study assessed the inter-rater agreement of three consultant orthopaedic surgeons with specific expertise in the management of severe pelvic ring fracture, using the Young-Burgess and Tile/AO classifications. In particular, the study focused on the inter-rater reliability using plain radiographs and 3D CT reconstructions of 100 severe pelvic ring fracture patients. Inter-rater agreement was slight for both the Young-Burgess and Tile/AO classifications, and the findings highlight particular challenges for classification of this serious sub-group of pelvic ring fractures.

Only two studies have investigated the reliability of pelvic ring fracture classification. Koo *et al* studied the inter-rater reliability of six reviewers (of varying experience) of 30 pelvic fracture cases and found fair agreement for the Tile classification using plain radiographs alone and when 2D axial CT scans were provided, while the agreement for the Young-Burgess classification was substantial for plain radiographs alone, and moderate when 2D axial CT scans were also used (15). Furey *et al* studied the inter- and intra-rater reliability of the Tile and Young-Burgess classification systems using five orthopaedic surgeon reviewers and the combined plain radiographs and 2D CT scans of 89 pelvic fracture cases. These authors found moderate agreement for the Tile classification and substantial agreement for the Young-Burgess system (14). In our study, the inter-rater agreement between three experienced pelvic and acetabular surgeons was much lower than the results of Furey *et al* and Koo *et al* although there are a number of plausible explanations for this.

For both previous studies, cases were selected based on the availability and quality of films, potentially excluding cases where imaging of the pelvis was less clear. Furey *et al* specifically excluded cases without “adequate” plain radiographs and CT scans. In our study, we included all cases with both imaging modalities available, irrespective of the quality of images, as this represents the clinical conditions under which classification of these cases occur. It is likely that this approach results in reduced inter-rater reliability but the findings are more representative of everyday clinical practice.

The Young-Burgess and Tile/AO classifications were developed for use with AP, inlet and outlet view plain radiographs. The inclusion for both previous studies required three plain

radiograph views; antero-posterior (AP), inlet and outlet. In our setting, trauma patients are routinely CT scanned at each major trauma service. Inlet and outlet views are no longer routine clinical practice at the major trauma services, with a single AP view usually the only plain radiograph available for each case. In addition, the plain AP radiograph is of highly variable quality with a number of raters commenting on this in the comments section of the classification spreadsheets (see Figure 1 and Figure 2 for examples of poor and better quality AP radiographs).



Figure 1: Example of a poor quality AP radiograph

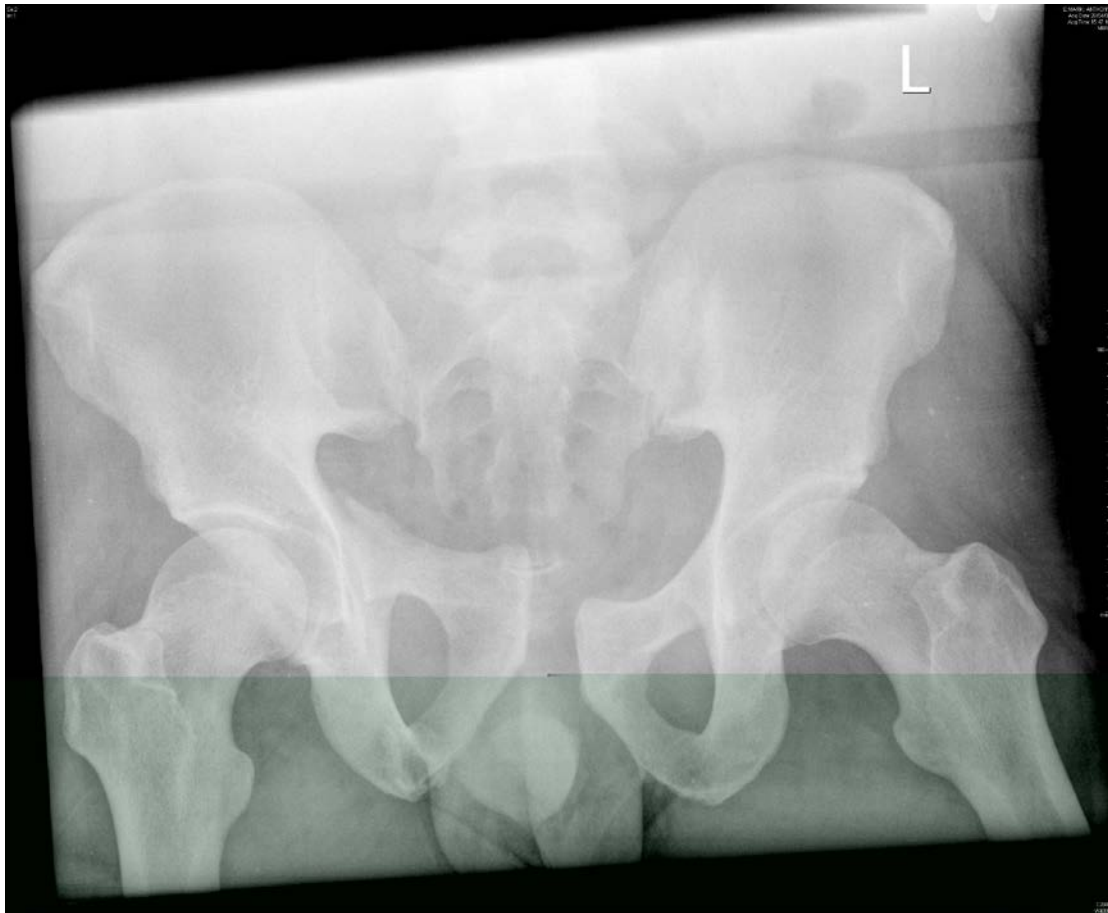


Figure 2: Example of a better quality AP radiograph

Koo *et al* compared the agreement between surgeons using plain radiographs alone, and using 2D axial CT scans and plain radiographs. For the Young-Burgess classification, inter-rater agreement was higher when using plain radiographs (kappa 0.72) compared to combined CT and radiographs (Kappa 0.63) (15). There was little difference between the two approaches for the Tile/AO classification (Kappa 0.33 vs. 0.30) (15). However, these authors also included five additional questions for the raters relating to: (i) posterior displacement >1cm; (ii) avulsion at either end of the sacrospinous ligament; (iii) avulsion of the transverse process of L5; (iv) associated acetabular fracture; and (v) pelvis stability. The agreement between plain radiographs and 2D CT imaging was consistent for posterior displacement and acetabular fracture, but inter-rater agreement increased substantially when using 2D CT images to ascertain sacrospinous ligament avulsion, and pelvic stability (15). The low agreement using 3D CT reconstruction noted in our study, and questionable value of 2D CT axial scans in previous studies, suggest that the Young-Burgess and Tile/AO classification may no longer be ideal for current clinical practice. However, Koo *et*

a's findings suggest that CT scans may assist with an overall rating of pelvic ring stability and classification of specific features of pelvic ring disruption. Classification using a combination of 3D CD reconstructions and 2D axial CT scans may warrant future investigation, as these modalities are usually available together, and the 2D axial CT scans do have advantages when assessing specific features such as sacral fractures. In addition, the use of 2D axial CT scans may be needed where the quality of the 3D reconstruction is poor (see Figure 3 and Figure 4 for contrasting quality of images).

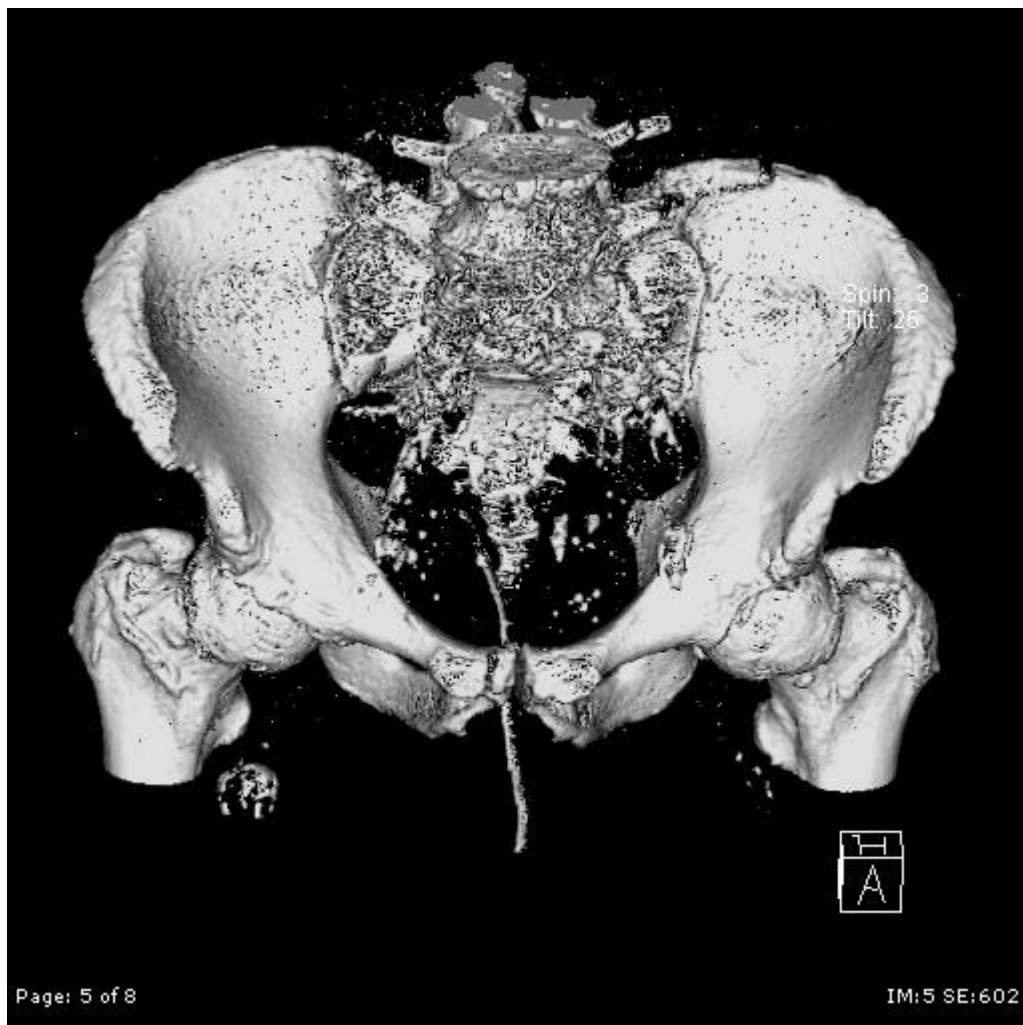


Figure 3: Example of poor quality 3D CT reconstruction

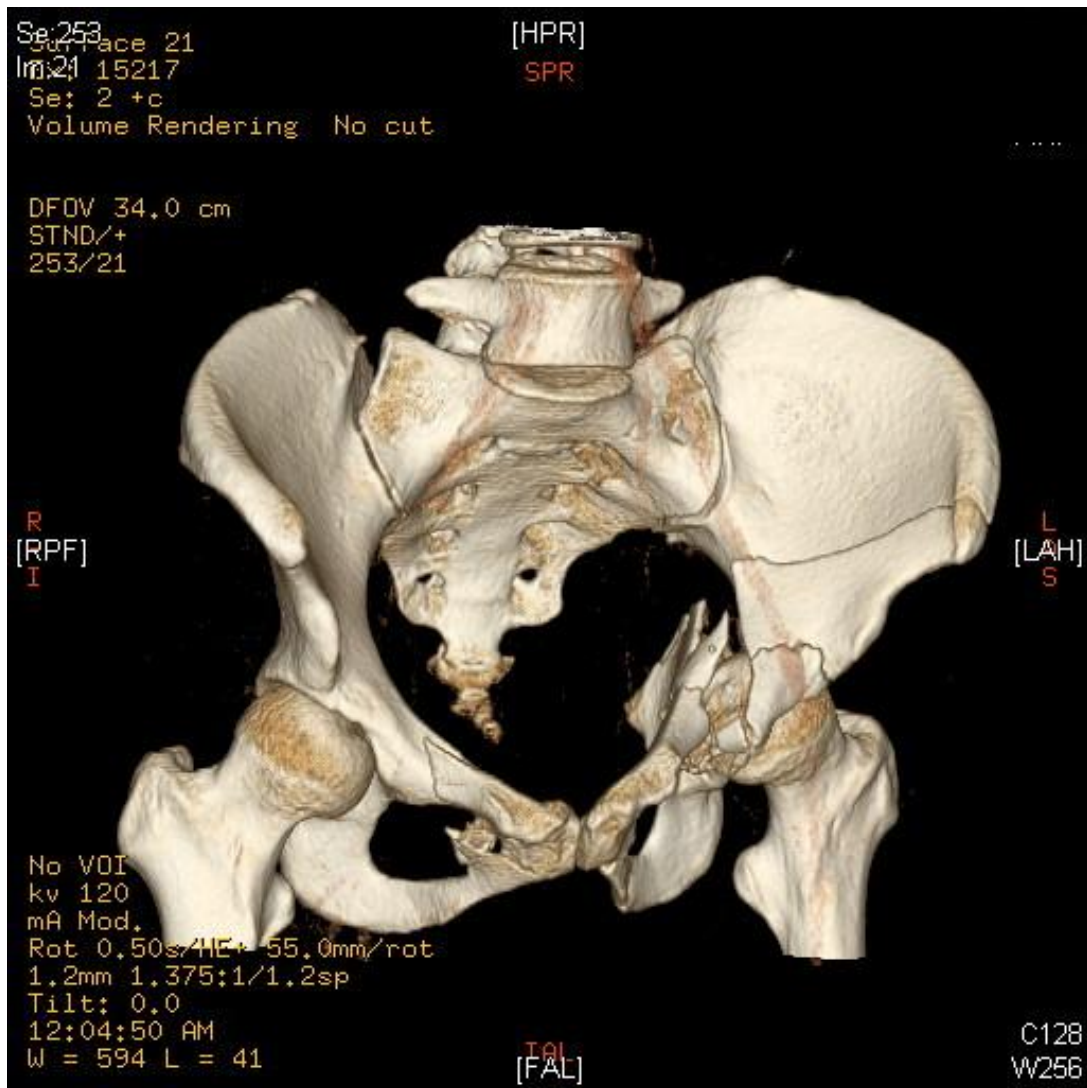


Figure 4: Example of better quality 3D CT reconstruction

The group of patients in our study represent the most severe pelvic ring fractures, who demonstrate a high risk of mortality and long term disability. Many of these patients arrive in the emergency department clinically unstable, requiring rapid treatment and decision making. More than a third of cases arrive in the ED with a binder in situ, which is usually not removed for imaging purposes, and limits the capacity to accurately classify the extent of the pelvic ring fracture (21) (see Figure 5).

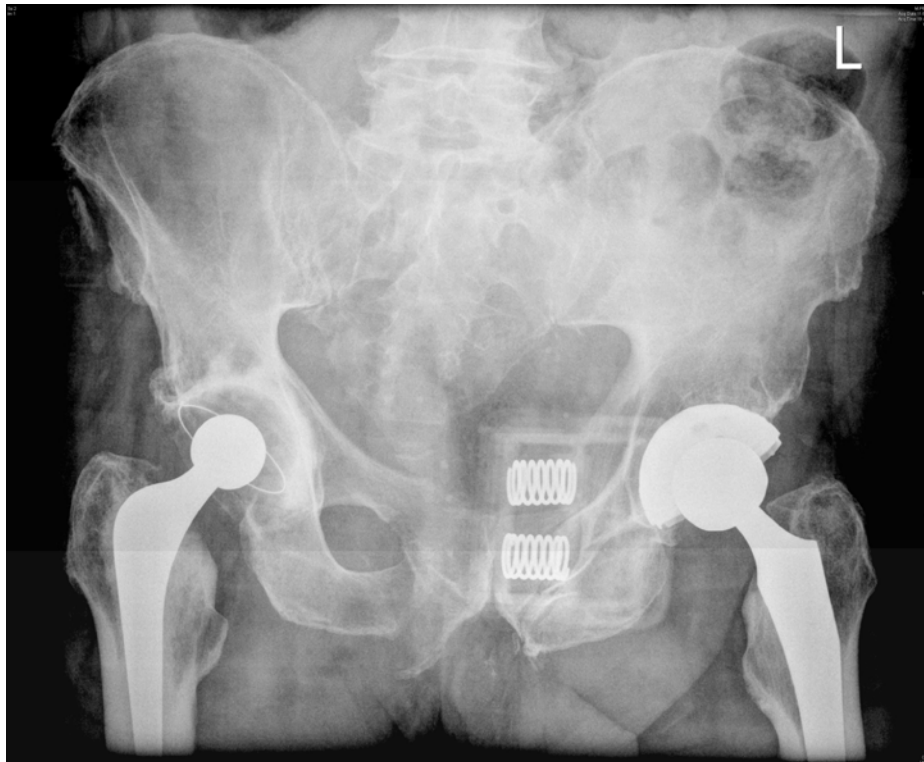


Figure 5: Plain radiograph of patient with binder in situ

Similarly, the decision to intervene (e.g. emergency placement of an external fixateur) can be made prior to routine CT scanning in the ED due to urgent need to control haemorrhage, again impacting on the capacity to classify the pelvic ring fracture. Previous classification studies have not focused specifically on severe fractures. Koo *et al* randomly selected 30 cases from a Level 1 trauma facility database (15). No attempt was made to include a representative sample of fractures. Given the small sample size and the low prevalence of severe pelvic ring fractures in trauma patients, it is highly likely that Koo *et al*'s sample included very few severe fractures. As the distribution of each rater's classifications was not provided, it is difficult to ascertain the patient group studied by Koo *et al*. Furey *et al* aimed to include a wide range of pelvic ring fractures in their classification study, with 28% classified as Tile A, 54% as Tile B, and 18% as Tile C. Our study included almost exclusively Tile B and C-type fractures. It is reasonable to assume that simple pelvic ring fractures are more amenable to reliable classification, potentially contributing to the higher reliability of previous studies.

While Koo *et al* did not specify the software or screen resolution used for classification, Furey *et al* ensured that all images were viewed with the specialist picture archiving and communication system (PACS) software. In our study, images were downloaded from

PACS at the major trauma services as jpeg files for viewing on personal computers consistent with the standard computers available in ED, operating theatres and outpatient consulting rooms. Radiologists at the major trauma services view the images on specialist high resolution equipment when reporting. Whether the use of improved resolution would have resulted in better inter-rater reliability is not known. However, the methods used in this study are consistent with what is available to orthopaedic surgeons, and therefore more representative of the clinical environment in which fracture classification would occur.

The original sample size for the study was 128 which assumed that all categories of the Young-Burgess classification would be utilised. While the number of pelvic fractures cases far exceeded the proposed sample size, obtaining cases with pre-intervention plain radiographs **and** 3D CT reconstructions was difficult for many of the reasons discussed. The study was more than adequately powered to assess the reliability of the Tile/AO classification, but was under-powered for the Young-Burgess classification. Nevertheless, this study still represents the largest inter-rater reliability study of pelvic ring fractures undertaken to date. The low kappa scores and the resulting 95% CI suggest that even with an additional 28 cases, the findings would be consistent – slight to fair agreement.

The participating surgeons were from three separate institutions, but were all consultant orthopaedic surgeons with extensive experience in managing pelvic fractures, and received the same documentation describing the classification systems. There was strong, unidirectional bias between the raters, suggesting that each rater's application of the classification guidelines differed. Furey *et al* studied the reliability of surgeons from a single institution, and the institution where the Young-Burgess classification was developed and is used exclusively, but still showed substantial differences between raters in the distribution of cases to categories of the Young-Burgess and AO/Tile. For example, in their study, Rater 2 classified 18% of cases as CMI and 27% of cases as C-type fractures, compared to Rater 4 who classified no cases as CMI and 4% of cases as C-type fractures (14). Furey *et al* acknowledged that their results could represent a “best case scenario” for reliability of rating, further explaining the much lower inter-rater agreement observed in our study.

Finally, the initial study plan was to include a component assessing intra-rater reliability. We chose not to complete this aspect of the study given the clear issues with the classification systems in this group of patients, the low inter-rater reliability, and the

amount of time required from consultant orthopaedic surgeons to complete the classifications. Pelvic ring fracture classification is a time consuming process, with consultants providing their time “in kind” to the project. The 3D CT reconstruction can produce up to 42 single images, resulting in more than 4000 images requiring review from 100 cases. The results from the inter-rater reliability study were sufficient to suggest that the classifications have limited clinical and research relevance for severe pelvic ring fractures. Therefore, the need to assess intra-rater reliability was not considered necessary for this project.

Conclusions

Using plain radiographs and 3D CT reconstructions of the pelvis, inter-rater agreement of the Young-Burgess and Tile/AO classifications was fair at best for severe pelvic ring fractures. Current clinical practice at the MTS hospitals does not routinely provide the plain radiograph views for which the Young-Burgess and Tile/AO classifications were developed. Severe pelvic ring fracture patients represent a difficult classification prospect for existing classification systems due to the prevalence of interventions pre-hospital (e.g. binders) and in the emergency department. The results of this study, and previous reliability studies, confirm that the Young-Burgess and Tile/AO classifications are insufficient for clinical and research purposes. Without a reliable classification system, valid comparison of interventions and patient outcomes is extremely limited. The development of a classification system specifically for CT images is needed to support current clinical practice.

Study 2: Mortality following severe pelvic ring fracture: Does hospital of definitive care matter?

Introduction

The primary reason for the elevated risk of death following pelvic ring disruption is the potential for fracture-related haemorrhage through direct injury to the adjacent vasculature (venous and arterial) from bony fragments, disruption of vessels by shear forces, and bleeding from the bone surfaces (3-5, 22). In the majority of cases, bleeding is venous in nature. The risk of haemorrhage, combined with the propensity for severe associated injuries, increases the risk of mortality in these patients and highlights the need for quality, evidence-based early management.

While guidelines exist, there is no clear consensus about the optimal management approach for haemodynamically unstable patient with pelvic fracture (3-8). Protocols tend to favour either early interventional radiography (i.e. angiography to identify the source of bleeding and embolization to stop the bleeding) or immediate laparotomy for surgical control of bleeding and pelvic packing with large sponges.

In Victoria, the major trauma service (MTS) hospitals manage more than 90% of severe pelvic ring fractures in the state (9). While both hospitals have implemented similar massive transfusion protocols, each has implemented a different protocol for the management of the haemodynamically unstable pelvic fracture patient. Each MTS hospital uses a different indication for angiographic embolisation, with The Alfred embolising patients who demonstrate an arterial “blush” on CT scan as a priority (Figure 6). In contrast, the RMH uses a protocol that advocates angiography ± embolisation if haemodynamically unstable and in the presence of a pelvic haematoma (Figure 7).

A preliminary study, using data only from the Victorian State Trauma Registry, found no difference in risk-adjusted mortality between the MTS hospitals (9). However, limitations were noted and the need for additional data regarding resuscitation practices, and fracture classification, were acknowledged as necessary for a full evaluation of the MTS approaches to management.

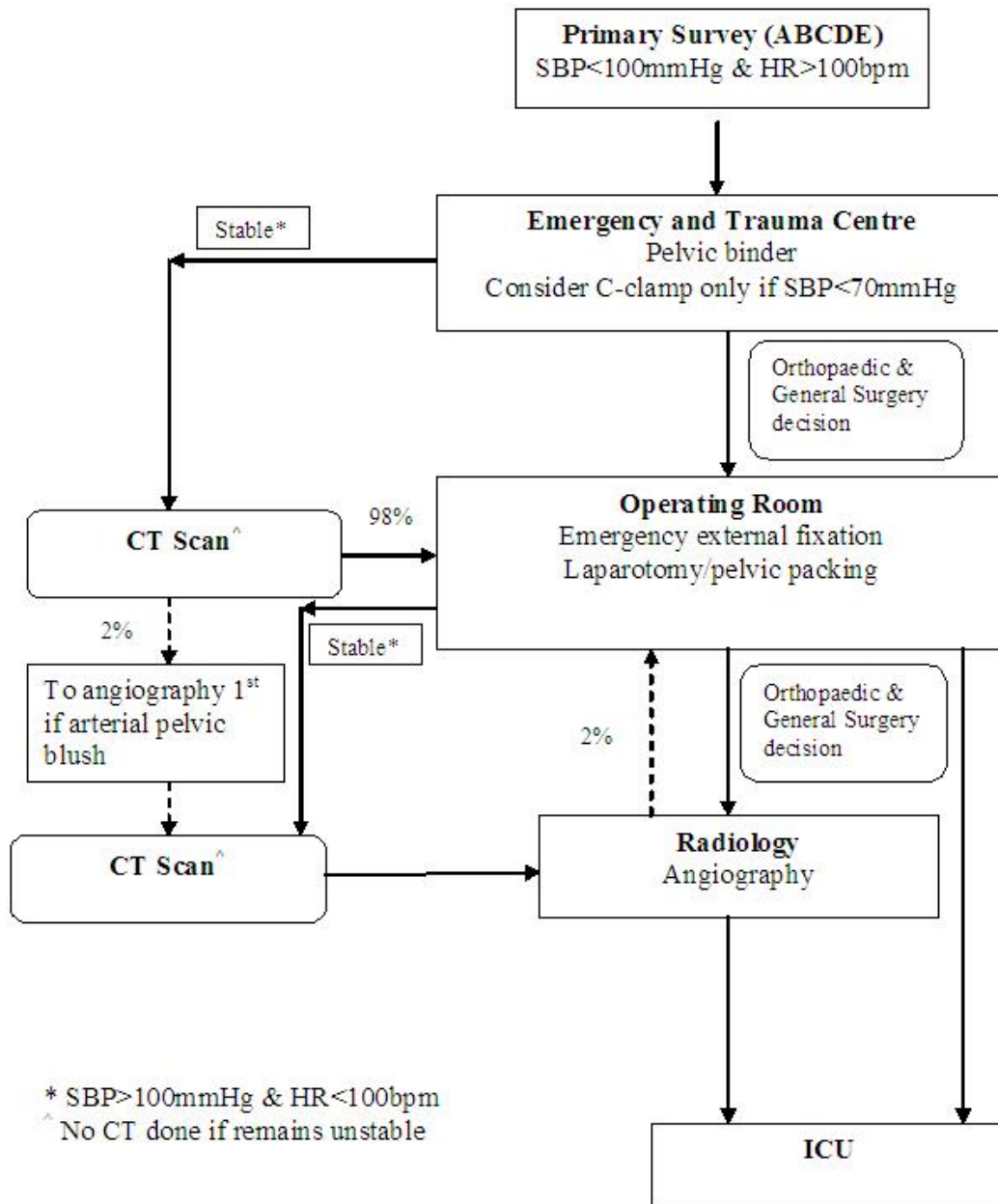


Figure 6: Protocol for management of the haemodynamically unstable patient with pelvic fracture (The Alfred)

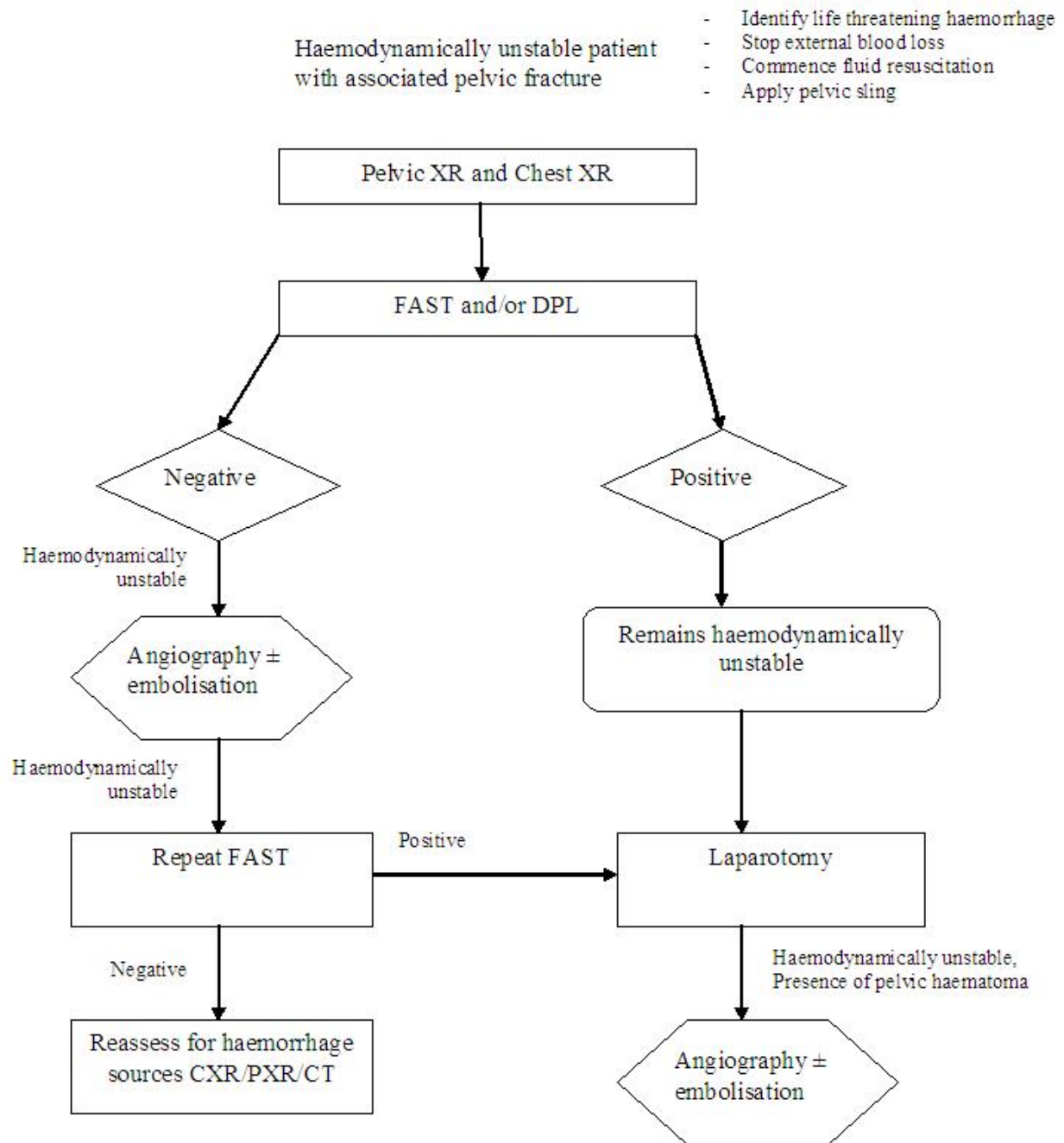


Figure 7: Protocol for management of the haemodynamically unstable patient with pelvic fracture (RMH)

Project aims

The aims of this study were to:

- i. Describe the profile of severe pelvic ring fracture cases definitively managed at The Alfred and RMH
- ii. Describe the early management practices of the MTS hospitals for severe pelvic ring fracture
- iii. Establish the association between definitive hospital of management and in-hospital mortality.

Methods

Setting

The state of Victoria, Australia has a population of approximately 5.4 million and operates a regionalised, inclusive trauma system. The trauma system is monitored by the Victorian State Trauma Registry (VSTR) and the Victorian Orthopaedic Trauma Outcomes Registry (VOTOR). The VSTR is a population-based registry collecting data about all major trauma patients in Victoria (23). Since 2007, the VSTR has followed-up all adult survivors to discharge at 6, 12 and 24-months post-injury by telephone interview (24). VOTOR is a sentinel site registry, integrated within the VSTR, collecting data about all adult orthopaedic trauma patients with a length of stay >24 hours, and admitted to The Alfred, Royal Melbourne, Geelong and Northern Hospitals. All VOTOR patients are followed-up by telephone interview at 6 and 12-months post-injury using the same methodology as the VSTR patients.

Participants

Patients with a date of injury from July 2007 to June 2010 (inclusive), captured by the VSTR and definitively managed at the state's adult major trauma services (The Alfred and Royal Melbourne Hospital), were included. All cases with an Abbreviated Injury Scale (AIS) pelvis fracture coded as 852606.4, 852608.4, or 852610.5 were selected for this study. The selected AIS codes related to pelvic fractures with substantial "deformation or displacement" and a severity score of "4" (severe) or "5" (critical).

VSTR and VOTOR data

Data for all eligible cases were extracted from the VSTR and VOTOR databases and included:

- i. Patient demographics
- ii. Comorbid status
- iii. Injury event details
- iv. Pre-hospital management observations
- v. Inter-hospital transfer and transfer times
- vi. Status on arrival in the emergency department (ED)
- vii. Injury diagnoses and severity
- viii. Admission to ICU, ICU length of stay, hospital length of stay, discharge destination and in-hospital mortality.

Medical record review

Individual patient medical records and hospital surgical systems were reviewed to collect more detailed data about the haemodynamic status of the patient, resuscitation data, operative management, complications and readmission. The full data collection form is attached as Appendix A, but key data items abstracted from the medical record and hospital systems included:

- i. Markers of haemodynamic instability such as the base excess (BE) on arrival, lowest international normalised ratio (INR) and fibrinogen levels. Low BE, measured in mEq/L, suggests metabolic acidosis resulting from a shortage of circulating oxygen. The INR is a measure of clotting time with higher values representing longer time to clotting of the blood, and is therefore a marker of coagulopathy. Fibrinogen (measured in g/L) is also a measure of coagulopathy with low fibrinogen levels suggesting systemic activation of the clotting system and consumption of clotting factors faster than they can be reproduced.
- ii. Use of blood products including the type and units used. In particular, units used of packed red blood cells (PRBC), fresh frozen platelets (FFP) and platelets were recorded.

- iii. Use of fluid products including the type and volume given
- iv. Use and timing of binders, C-clamps, and external fixateurs. Binders are a non-invasive method of applying strong compressive force to the pelvis to assist in controlling bleeding and reduction of the fracture. External fixation is a form of surgical management where holes are drilled into the bone from outside the body and a metal frame inserted to reduce the fracture. The C-clamp is a metal clamp applied to rapidly reduce and stabilise the posterior pelvic ring.
- v. Use and timing of angiography and embolisation. Angiography provides a method of identifying arterial bleeding sources and embolisation is employed to slow or stop bleeding from the source.
- vi. Use and timing of surgical fixation of the pelvis fracture
- vii. Documented complications and readmission to hospital.

Fractures were classified using the Young-Burgess and Tile/AO systems. Given the low inter-tester reliability established in Study 1, classification by consensus was used. A consensus of two orthopaedic surgeons was required to record a classification for the pelvic fracture.

Data analysis

Data were summarised using percentages for categorical, and mean and standard deviations (SD) or median and interquartile range (IQR) for continuous variables. Comparison of groups (e.g. in-hospital deaths vs. survivors, RMH vs. The Alfred) was conducted using chi-square tests for categorical variables, and independent t-tests or Mann-Whitney U-tests for continuous variables.

Hospital of definitive care was the primary exposure of interest. Therefore, establishing an accurate estimate of the association between hospital of definitive care and in-hospital mortality requires adjustment for key confounders. Variables were considered to be confounders of the association between hospital of definitive management and in-hospital mortality if they differed between hospital, and were also associated with in-hospital mortality. Univariate logistic regression was used to establish the unadjusted odds of mortality at one hospital relative to the other. Multivariate logistic regression was used to establish the association between hospital of definitive care and in-hospital mortality,

adjusted for established confounders. Variables with a p-value <0.10 were considered to be potential confounders and included in the multivariate model. Adjusted odds ratios (AOR) and 95% confidence intervals (CI) were calculated, and a p-value <0.05 was considered significant for all statistical tests. All analyses were performed using Stata Version 11.2 (StataCorp, College Station, TX).

Results

Comparison of cases managed at The Alfred and RMH

There were 145 severe pelvic ring fracture patients definitively managed at The Alfred and RMH from July 2007 to June 2010 (inclusive). Ninety cases were managed at The Alfred and 55 cases at RMH. Almost half of severe pelvic ring cases were aged 15-34 years, and the vast majority were male (Table 6). Eighty per cent were the result of transport crashes, predominantly motor vehicle, motorcycle and pedestrian incidents (Table 6).

The demographic and injury event profile of cases definitively managed at each MTS hospital was similar (Table 6). There was no difference between the hospitals with respect to age group ($X^2_2=0.23$ $p=0.89$), gender ($X^2_1=0.20$ $p=0.66$), intent of injury ($X^2_1=0.52$ $p=0.47$), or compensable status ($X^2_1=0.85$ $p=0.36$). The proportion of transport-related cases across the two hospitals was similar ($X^2_1=0.49$ $p=0.48$), but the proportion of motor vehicle related cases was higher at The Alfred (48% vs. 29%) and the proportion of pedestrian cases was higher at RMH (26% vs. 8.9%). The proportion of cases with a documented comorbidity was higher for The Alfred ($X^2_1=4.5$ $p=0.03$).

Table 6: Characteristics of patients

Descriptor		The Alfred (n=90)	RMH (n=55)
Age	N (%)		
	15-34 years	44 (48.9)	25 (45.4)
	35-64 years	32 (35.6)	20 (36.4)
	≥ 65 years	14 (15.5)	10 (18.2)
Gender	N (%)		
	Male	70 (77.8)	41 (74.6)
	Female	20 (22.2)	14 (25.4)
CCI comorbid condition	N (%)		
	No	55 (61.1)	43 (78.2)
	Yes	35 (38.9)	12 (21.8)
Transport related?	N (%)		
	No	19 (21.1)	9 (16.4)
	Yes	71 (78.9)	46 (83.6)
Mechanism	N (%)		
	Motor vehicle	43 (47.8)	16 (29.1)
	Motorcycle	18 (20.0)	14 (25.5)
	Pedestrian	8 (8.9)	14 (25.5)
	High fall	7 (7.8)	4 (7.3)
	Other	14 (15.6)	7 (12.7)
Intent	N (%)		
	Unintentional	86 (95.5)	51 (92.7)
	Intentional self-harm	4 (4.5)	4 (7.3)
Compensable status	N (%)		
	Compensable	67 (74.4)	45 (83.3)
	Non-compensable	23 (25.6)	9 (16.7)

Almost 40 per cent of cases were hypotensive (SBP <90 mmHg) on arrival of the paramedics at the scene, over a third were fitted with a pelvic binder, and the majority were given IV fluids in the pre-hospital setting. Only eight cases (6.5%) received blood products prior to arrival at hospital (Table 7).

Table 7: Pre-hospital management, transport to hospital, and ED care

Descriptor		The Alfred (n=90)	RMH (n=55)
Hypotensive on arrival at the scene of injury ^a	N (%)		
	No	42 (58.3)	35 (67.3)
	Yes	30 (41.7)	17 (32.7)
Binder used pre-hospital ^b	N (%)		
	No	54 (61.4)	32 (61.5)
	Yes	34 (38.6)	20 (38.5)
Blood given pre-hospital ^c	N (%)		
	No	80 (91.9)	43 (97.7)
	Yes	7 (8.1)	1 (2.3)
Fluid given pre-hospital ^d	N (%)		
	No	13 (16.1)	4 (9.1)
	Yes	73 (83.9)	40 (90.9)
Inter-hospital transfer	N (%)		
	No	65 (72.2)	53 (96.4)
	Yes	25 (27.8)	2 (3.6)
Hypotensive on arrival in ED ^e	N (%)		
	No	74 (86.1)	38 (73.1)
	Yes	12 (13.9)	14 (26.9)
Binder in ED ^f	N (%)		
	No	23 (25.6)	14 (27.5)
	Yes	67 (74.4)	37 (72.5)
Blood given in ED ^g	N (%)		
	No	35 (49.8)	12 (26.7)
	Yes	53 (60.2)	33 (73.3)
Base Excess	Median (IQR) mEq/L	-4.0 (-7.0 to -1.0)	-6.7 (-12.4 to -3.2)
Fibrinogen	Median (IQR) g/L	1.6 (1.1 to 2.3)	1.8 (1.0 to 2.7)
INR	Median (IQR)	1.3 (1.2 to 1.6)	1.2 (1.1 to 1.5)
24-hour PRBC requirements	Median (IQR) units	4 (0 to 8)	5 (1 to 9)

^a Data missing for n=21 cases; ^b Data missing for n=5 cases; ^c Data missing for n=14 cases; ^d Data missing for n=15 cases; ^e Data missing for n=7 cases; ^f Data missing for n=4 missing; ^g Data missing for n=12 cases

There was no difference in the proportion of cases hypotensive (SBP <90 mmHg) at the scene of injury ($X^2_1=0.01$ $p=0.95$), administered blood products ($X^2_1=1.32$ $p=0.25$), given IV fluids ($X^2_1=2.51$ $p=0.12$), or fitted with a pelvic binder by paramedics ($X^2_1=1.03$ $p=0.31$), between the hospitals (Table 7). The proportion of cases experiencing an inter-hospital transfer was significantly higher at The Alfred ($X^2_1=0.13.13$ $p<0.001$). The proportion of cases arriving at The Alfred ED in hypotension was lower ($X^2_1=3.56$ $p=0.06$), and the first arterial base excess taken in the ED was significantly lower for RMH patients ($z=2.88$ $p=0.004$), suggesting greater haemodynamic instability (Table 7).

Table 8: Fracture severity and associated injuries

Descriptor		The Alfred (n=90)	RMH (n=55)
Injury Severity Score	Median (IQR)	29 (24-41)	34 (26-45)
Associated head injury (AIS severity >3)	N (%)		
	No	78 (86.7)	43 (78.2)
	Yes	12 (13.3)	12 (21.8)
Associated thoracic injury (AIS severity >3)	N (%)		
	No	80 (88.9)	51 (92.7)
	Yes	10 (11.1)	4 (7.3)
Associated abdominal injury (AIS severity >3)	N (%)		
	No	77 (85.6)	46 (83.6)
	Yes	13 (14.4)	9 (16.4)
Associated femoral shaft fracture	N (%)		
	No	75 (83.3)	43 (78.2)
	Yes	15 (16.7)	12 (21.8)
GCS on arrival in ED	N (%)		
	9-15	71 (85.5)	42 (80.8)
	3-8	12 (14.5)	10 (19.2)
Young and Burgess classification	N (%)		
	APC1	4 (4.7)	2 (3.9)
	APC2	11 (12.8)	8 (15.7)
	APC3	7 (8.1)	4 (7.8)
	LC1	9 (10.5)	14 (27.5)
	LC2	13 (15.1)	3 (5.9)
	LC3	33 (38.4)	13 (25.5)
	Vertical Shear	5 (5.8)	4 (7.8)
	CMI	4 (4.7)	3 (5.9)
Tile/AO classification	N (%)		
	A1	1 (1.2)	1 (1.9)
	B1	12 (14.3)	11 (21.1)
	B2	30 (35.7)	17 (32.7)
	B3	24 (28.6)	11 (21.2)
	C1	15 (14.9)	6 (11.5)
	C2	1 (1.2)	4 (7.7)
	C3	1 (1.2)	2 (3.9)

The INR was higher for cases at The Alfred ($z=1.86$, $p=0.06$), but there was no difference in the 24-hour packed red blood cell requirements ($z=-0.95$, $p=0.35$), or fibrinogen levels ($z=-0.26$, $p=0.80$), between the hospitals. The ISS was higher for cases definitively managed at RMH ($z=-2.02$, $p=0.04$). However, the proportion of cases with severe associated head ($X^2_1=1.78$, $p=0.18$), thoracic ($X^2_1=0.58$, $p=0.45$) or abdominal ($X^2_1=0.10$, $p=0.76$) injuries did not differ between the hospitals (Table 8). The proportion of B-type

and C-type fractures definitively managed at The Alfred (78.6% and 20.2%) was similar to the proportion managed at RMH (75.0% and 23.1%). Similarly, there was no difference in the profile of fractures classified using the Young-Burgess system between the hospitals ($\chi^2_3=0.95$, $p=0.81$).

Table 9: Fracture management

Descriptor		The Alfred (n=90)	RMH (n=55)
Angiography?	N (%)		
	No	70 (77.8)	26 (47.3)
	Yes	20 (22.2)	29 (52.7)
Embolisation?**	N (%)		
	No	8 (40.0)	1 (3.5)
	Yes	12 (60.0)	28 (96.5)
Time to angiography	Median (IQR) hours	5.1 (3.7-10.5)	2.8 (1.6-4.1)
C-clamp used?	N (%)		
	No	85 (94.4)	54 (98.2)
	Yes	5 (5.6)	1 (1.8)
External fixateur?	N (%)		
	No	48 (53.3)	38 (69.1)
	Yes	42 (46.7)	17 (30.9)
Time to external fixation	Median (IQR) hours	2.9 (1.9-5.2)	4.8 (3.7-24.0)
Pelvic packing used?	N (%)		
	No	81 (90.0)	51 (92.7)
	Yes	9 (10.0)	4 (7.3)
ORIF?	N (%)		
	No	20 (22.2)	31 (56.4)
	Yes	70 (77.8)	24 (43.6)
Laparotomy?	N (%)		
	No	62 (68.9)	42 (76.4)
	Yes	28 (31.1)	13 (23.6)
Time to ORIF	Median (IQR) days	1.5 (1.0-2.5)	4.0 (2.5-8.0)

** Patients referred for angiography only

Consistent with the different protocols implemented, there were significant differences between the hospitals with respect to early fracture management. The proportion of cases referred for angiography was significantly higher ($\chi^2_1=14.20$, $p<0.001$), and the time to angiography was much lower ($z=3.49$, $p<0.001$), at RMH (Table 9). The rate of embolisation was higher at RMH compared to The Alfred ($\chi^2_1=10.55$, $p=0.001$). The one case at RMH where embolisation was not performed was due to calcification of the femoral artery, preventing access for embolisation.

The proportion managed with external fixation was higher ($X^2_1=3.51$, $p=0.06$), and the time to external fixation much lower ($z=-2.71$, $p=0.007$), at The Alfred (Table 9). Similarly, a higher proportion of cases were definitively managed at The Alfred using open reduction and internal fixation (ORIF) ($X^2_1=17.45$, $p<0.001$), and the time to ORIF was much lower at The Alfred compared to RMH ($z=-4.01$, $p=0.0001$). There was no difference in the admission rates to ICU ($X^2_1=0.94$, $p=0.33$), length of ICU stay ($z=0.39$, $p=0.70$) or hospital length of stay ($z=-0.15$, $p=0.88$) between the hospitals (Table 10). No neurological, and only four vascular, complications resulting from the fracture or fracture treatment were recorded. The infection ($X^2_1=1.33$, $p=0.25$), and re-operation ($X^2_1=1.37$, $p=0.24$), rates were consistent between the hospitals (Table 10).

Table 10: In-hospital outcomes and complications

Descriptor		The Alfred (n=90)	RMH (n=55)
ICU stay	N (%)		
	No	28 (31.1)	13 (23.6)
	Yes	62 (68.9)	42 (76.4)
ICU length of stay*	Median (IQR) days	7 (4-13)	6 (3-13)
Hospital length of stay	Median (IQR) days	19.8 (12.1-33.8)	20.1 (10.3-39.5)
In-hospital death	N (%)		
	No	78 (86.7)	41 (74.6)
	Yes	12 (13.3)	14 (25.5)
Destination at discharge**	N (%)		
	Inpatient rehabilitation	70 (89.7)	38 (92.7)
	Home	8 (10.3)	3 (7.3)
Infection	N (%)		
	No	77 (86.5)	51 (92.7)
	Yes	12 (13.5)	4 (7.3)
Re-operation within first 12-months	N (%)		
	No	66 (73.3)	45 (81.8)
	Yes	24 (26.7)	10 (18.2)

* For patients admitted to ICU; ** Of survivors to hospital discharge

The unadjusted odds of in-hospital mortality was 2.22 (95% CI: 0.94, 5.24) times higher at RMH compared to The Alfred although this was not significant. The demographic, injury severity, and measures of haemodynamic instability that differed ($p<0.10$) between the hospitals, and were associated with in-hospital mortality (and therefore potential

confounders), were the presence of comorbid conditions, transfer status, hypotension on arrival at the definitive hospital, base excess on arrival at the definitive hospital, the highest INR recorded, and the ISS. Adjusting for these factors, there was no elevated risk of mortality at one hospital relative to the other (Table 11). The strongest predictor of in-hospital mortality was the base excess level on arrival in the ED (Table 11). For every unit increase in base excess, the odds of in-hospital mortality increased by 15% (Table 11).

Table 11: Association between hospital and in-hospital mortality (multivariate model results)

Predictor		AOR (95% CI)
Hospital	The Alfred (reference)	1
	RMH	1.52 (0.42, 5.48)
ISS		1.01 (0.97, 1.07)
Lowest INR		1.54 (0.84, 2.80)
Base excess on arrival in the ED		0.85 (0.77, 0.95)
Transferred?	No (reference)	1
	Yes	0.62 (0.07, 5.78)
CCI comorbid condition	No (reference)	1
	Yes	0.57 (0.14, 2.30)

Discussion

In Victoria, the major trauma service (MTS) hospitals manage more than 90% of severe pelvic ring fractures in the state (9). While both hospitals have implemented similar massive transfusion protocols, each has implemented a different protocol for the management of the haemodynamically unstable pelvic fracture patient. Most research in the field is from single institution studies which generally employ a single protocol, preventing comparison of the outcomes of treatment approaches. Where comparisons have occurred, only 20 patients managed with each protocol were compared, and these patients were managed in difference time periods (25). The capacity for contemporaneous comparison of the outcomes of difference protocols, across a population is rare, highlighting the importance of this study.

Consistent with previous studies of unstable and severe pelvic ring fractures, the population were predominantly young, male, working prior to injury, injured in transport

accidents, and involving other associated injuries (11, 26, 27). All had sustained other associated injuries and the mean ISS (31.8) was consistent with other studies (22, 28, 29).

The results of this study highlight substantial differences in the early management of severe pelvic ring fractures between the hospitals despite relatively few differences in patient case-mix. The key differences between severe pelvic ring fracture patients managed at The Alfred and RMH were a higher prevalence of pre-existing comorbidity in The Alfred cohort, and almost all cases directly transported from the scene of injury to RMH compared to 28% of The Alfred patients arriving via inter-hospital transfer. A higher proportion of RMH cases arrived in the ED exhibiting signs of haemodynamic shock (e.g. decreased base excess, hypotensive, etc.), potentially reflecting the higher proportion of direct transports from the scene. However, in data not shown, restricting analysis to patients transported directly from the scene ($n=65$ Alfred vs. $n=53$ RMH), the differences in highest INR and first base excess levels persisted.

More than half of RMH cases were referred for angiography (and almost all cases subsequently embolised) compared to 22% of The Alfred cases referred for angiography (of which 60% were embolised). Despite the differences in protocols, the prevalence of pelvic packing and laparotomy were consistent between the hospitals, but marked differences in pelvic fracture fixation noted. External and internal fixation use was more prevalent at The Alfred, and the time to fixation much shorter, when compared to RMH. Consistent with the previous preliminary study (9), unadjusted in-hospital mortality rates were higher at RMH but there was no difference in the risk of mortality between The Alfred and RMH when adjusted for potential confounders. Again, when restricting the analysis to direct transports to the MTS hospitals from the scene, the unadjusted odds of mortality at RMH compared to The Alfred was 1.76 (95% CI: 0.72, 2.49). Similarly, adjusting for the differences in INR and BE levels, the overall finding was consistent (AOR 1.53, 95% CI: 0.48, 4.88).

The only previous study to directly compare a pelvic packing approach with early angiography involved 40 patients (20 in each group) from a single institution at different times (25). Osborn *et al* found no difference in mortality between the treatment approaches, but reported a decrease in the proportion of cases requiring transfusion in the pelvic packing group in the 24 hours after the intervention and less early deaths (25). The 24-hour packed red blood cell requirements were lower at The Alfred, the institution

favouring pelvic packing, but the number of patients receiving pelvic packing was low (and consistent) at both institutions, and the reduced PRBC requirements for The Alfred cases could reflect greater haemodynamic stability on arrival in the ED.

Accounting for differences in the prevalence of comorbidity, hypotension on arrival in the ED, transfer status, clotting times (INR), and base excess (BE) on arrival in the ED, there was no difference in the risk of mortality between the hospitals, suggesting much of the noted difference in mortality was explained by differences in the condition of patients on arrival at hospital, rather than the protocol employed. The base excess on arrival was the strongest predictor of in-hospital mortality in this group of severe pelvic ring fractures, with each unit decrease resulting in a 15% increase in the odds of mortality. Jeske *et al*, in their study of 45 haemodynamically unstable patients with pelvic fractures, also found that that BE and ISS were associated with survival (30). Similarly, Siegel *et al* found that BE was a highly significant early predictor of outcome in pelvic fracture (31), while multiple studies have identified BE as a predictor of mortality in trauma patients (32, 33). The BE reflects the disturbances in the physiologic status of the patient. A low value indicates metabolic acidosis, which is an imbalance between oxygen delivery and consumption resulting in anaerobic metabolism. The base deficit (i.e. low BE) represents the nett result of the oxygen demand and delivery to the cells, thus representing the respiratory combined with the hemodynamic pathophysiologic findings of the patient. A highly negative base deficit indicates a patient in whom one or both systems are failing to deliver with consequences for morbidity and mortality, explaining the high risk of mortality in patients with a low BE.

The difference in the proportion of patients undergoing angiography and subsequent embolisation, and external fixation, reflects the different protocols employed by the hospitals. Many papers have described the role of angiography in haemodynamically unstable patients with pelvic fractures. The prevalence of patients requiring embolisation is reported to be less than 10% (34-36). However, in a select group of patients (e.g. persistent hypotension, high revised trauma score and older age), the proportion requiring embolisation ranges from 57-75% (19, 37). At the RMH, the protocol describes early angiography, 53% of patients were referred for angiography and 98% were subsequently embolised. In contrast, only 22% of cases at The Alfred were referred to angiography and 60% were subsequently embolised. The higher rate of embolisation could reflect the

earlier referral to angiography of RMH patients, with embolisation of bleeding sources that may or may not have resolved without embolisation.

Early angiography and subsequent embolisation has been advocated by many authors to reduce mortality in this challenging patient population (30, 34, 38, 39). A key point to make about angiography is that it can only address arterial sources of bleeding. Where bleeding occurs from the surface of the fracture fragments or venous vessels, angiography will have no impact on control of bleeding. Another disadvantage of angiography is that it is not easy accessible, and Gansslen *et al* highlighted that even in a Level-I trauma centres, there can give considerable delays (6). Angiography can be time-consuming and delayed treatment of associated injuries can occur. At the RMH the median time to angiography was 2.8 hours, which is consistent with the literature (6, 34, 40), but whether this was the time to arrival at the angiography suite or the time to embolisation was difficult to ascertain from the patient record. Aside from the potential for delays in treatment, angiography and embolisation has been associated with cases of gluteal necrosis (41). However, others have suggested that this complication is related to trauma to the gluteal region along with protracted hypotension rather than a direct complication of embolisation (40).

Less has been published about the effectiveness, and limitations, of external fixation and pelvic packing of severe pelvic ring fractures. Advocates of early external fixation of pelvic fractures highlight the capacity of this approach to reduce the bleeding occurring from fracture surfaces, and associated pain relief, as the key benefits. While these results can be achieved with binders, binders cannot be left in situ for prolonged periods due to compromise of soft tissue structures around the pelvis. Where time to operating theatre for definitive fracture fixation is unknown, external fixation may be a sensible choice. However, as with all invasive procedures, there are disadvantages. Pin site infections are relatively common.

Historically, pelvic packing was performed as a trans-peritoneal procedure after an exploratory laparotomy late in the resuscitation phase with poor results (42). Opening of the peritoneum can potentially alter the tamponade effect of the retroperitoneal space. The tamponade effect occurs where pressure from bleeding within the confined space of the retroperitoneal cavity acts to compress the vessels and slow bleeding naturally. Opening the peritoneum releases the pressure, allowing more bleeding to occur. The

more recent development of a controlled retroperitoneal approach is considered quicker, easier to perform and less invasive (43), which is potentially less likely to result in an altered tamponade effect, and also considered to have similar mortality rates to emergency angiography (44). However, there is a risk of infection with this invasive approach and additional surgery is always required to remove the sponges used for pelvic packing.

Papakostidis *et al* explored the efficacy of pelvic packing and arterial embolisation for managing pelvic fractures using a systematic review approach (45, 46). These authors concluded that an emergency-treatment protocol based on prompt pelvic ring stabilisation, pelvic tamponade through a minimal extraperitoneal approach followed, when necessary, by pelvic angiography and selective embolisation could offer the best chances for survival (46). However, there were no randomised controlled trials to review, and the systematic review focused exclusively on cases series, limiting the conclusions that could be drawn. Suzuki *et al*, in their review of the literature, concluded that the two interventions are complementary but that the haemodynamically unstable patients should first go to theatre for pelvic stabilization and packing and other procedures required for associated injuries (47). The findings of our study found no clear superiority of one protocol over the other, and the incidence of complications such as reoperation and infection were consistent between the hospitals. However, the use of pelvic packing was rare, accounting for 10% of cases managed at The Alfred and 7% of cases at RMH, with the greater diversity in management related to external fixation and angiography.

There were a number of strengths to this study. The study included more than 90% of eligible cases within the defined population, and involved contemporaneous comparison of outcomes between the hospitals. Pre-hospital data were able to be included, providing information about the pelvic fracture care provided prior to arrival at hospital.

Nevertheless, limitations to the study were evident. The collection of fluid management, resuscitation and detailed clinical management data directly from the medical record is challenging. Seven records from the RMH could not be obtained for coding, despite repeated requests. Whilst this is not likely to have introduced substantial bias as there were no clear patient-related details that defined the missing medical records, it did reduce the completeness of the data, and the power of the study, particularly with respect to assessing the resuscitation details of these patients. From Study 1, there were a number

of patients with insufficient imaging for classification, and the reliability of the classification was low. To address this, a consensus approach was used for classification. There was difficulty ascertaining the incidence of complications due to inconsistent reporting in the medical record. In particular, separating treatment (i.e. iatrogenic) complications from complications resulting from the injury itself was challenging. The study was observational in design. While a randomised controlled trial (RCT) would be the design of choice for assessing the effectiveness and efficacy of treatment approaches, this would not be feasible due to the need to staff, train and equip both hospitals to implement both protocols simultaneously.

Conclusions

The MTS hospitals have implemented different protocols for managing the haemodynamically unstable pelvic fracture patient. Key differences between the hospitals were clear with RMH favouring early referral to angiography and embolisation of virtually all cases referred to angiography. In contrast, early external fixation was a feature of cases managed at The Alfred. The in-hospital mortality rate was slightly higher at RMH, but adjusted for key confounders, there was no difference in the risk-adjusted odds of mortality following severe pelvic ring fracture between the MTS hospitals. There was no clearly superior treatment approach, continuing the controversy that exists regarding best practice management of these cases. Ongoing monitoring and review is required.

Study 3: Factors associated with long term patient-reported outcomes after severe pelvic ring fracture

Introduction

Severe pelvic ring fractures are high-energy injuries, resulting from significant force such as motor vehicle and motorcycle crashes, pedestrian struck by a car, and falls from height. The primary aim of fracture management is to restore the anatomical integrity of the pelvic ring (11), while the overall goal of treatment and rehabilitation is the return to pre-injury levels of functioning for the patient. In the past, most pelvic fractures were managed conservatively, but advances in surgical fixation and understanding of the anatomy of the pelvic ring have led to the development of operative approaches (48).

Historically, pelvic fracture outcomes have been limited to assessment of radiological and selected clinical outcome measures (11), which are generally poorly correlated with patient function and quality of life. Studies assessing the long term patient-reported outcomes of patients are few and have been largely limited to very small samples, often from single centre studies (10-12), limiting the capacity to assess the contribution of pelvic fracture severity and treatment to patient outcome in this group of often multiply injured patients. Other pelvic fracture outcome studies have focused on patients only managed surgically or managed using a specific technique, or have focused on specific patient sub-sets such as unstable sacral fractures and female patients (11, 27, 49-53). Overall, there is insufficient evidence in the literature to describe the long term outcomes of severe pelvic ring fractures, the factors that predict outcome, and the contribution of fracture management to patient-reported outcomes.

Project Aims

- i. Establish the relationship between approaches to pelvic fracture fixation, fracture classification and long term functional, return to work, pain and HRQL outcomes.
- ii. Independent of fixation type, identify predictors of poor long term patient outcomes following severe pelvic ring fracture.

Methods

Participants

Patients meeting the following inclusion criteria were included in this study:

- i. Date of injury from July 2007 to June 2010 (inclusive) and captured by the VSTR
- ii. Definitively managed at the state's adult major trauma services (The Alfred and Royal Melbourne Hospital)
- iii. An Abbreviated Injury Scale (AIS) pelvis fracture coded as 852606.4, 852608.4, or 852610.5, relating to pelvic fractures with substantial "deformation or displacement" and a high severity code (4 or 5).
- iv. Survived to hospital discharge.

Procedures

Data were extracted from the VSTR/VOTOR database, medical records, hospital information systems, and imaging databases.

VSTR/VOTOR Data

Patient demographics, injury event details; pre-hospital management, inter-hospital transfer information, and in-hospital management and outcomes were extracted from the VSTR and VOTOR databases. Data from the 6, 12 and 24-month post-injury follow-up interviews were also extracted for analysis and included the 12-item Short Form Health Survey (SF-12), pain scores, extended Glasgow Outcome Scale (GOSE-E), return to work and work disability questions.

The GOS-E classifies patients into eight levels of function, from death to upper good recovery. The GOS-E can be administered by proxy if the patient is not able to participate in the interview. The SF-12 captures information about health-related quality of life and has both a mental component summary score (MCS-12) and a physical component summary score (PCS-12). A numerical rating scale (NRS) asks the patient to rate their level of pain from zero (no pain at all) to 10 (worst possible pain), with a score of five or greater considered moderate to severe pain. Information about whether the patient was working prior to injury is collected at each time point. Both the SF-12 and the NRS are administered to the patient only.

Definitive fracture management and fracture classification

Individual patient medical records and hospital surgical systems were reviewed to collect more detailed data about the management of the pelvic fracture, readmission to hospital and complications experienced by the patient. Definitive management of the pelvic ring fracture was categorised as: (i) conservative (no operative management); (ii) external fixation only; (iii) internal fixation of the anterior elements only; (iv) internal fixation of the posterior elements with or without external fixation; and (v) Internal fixation of the anterior and posterior pelvic elements.

Images of the pelvic ring fracture were extracted from the hospital electronic databases for imaging. Plain radiographs and 3D CT reconstructions of the pelvic ring were reviewed where available (see Study 1). The images were reviewed by experienced orthopaedic surgeons and classified using the Young-Burgess and Tile/AO classification systems using a consensus approach. Agreement by two orthopaedic surgeons was taken as consensus.

Data analysis

Due to small numbers in some sub-categories, the Young-Burgess classification was collapsed into three groups (APC, LC and CMI/VS) for analysis, while the AO/Tile classification was analysed according to major sub-type only (Type B vs. Type C). The definitive management of the fracture was categorised as “conservative” (no internal or external fixation), “anterior element fixation” (either external or internal fixation), and “posterior element fixation” (internal fixation of the posterior elements \pm external or internal fixation of the anterior elements). The number of intentional self-harm cases was too low to include as a potential predictor of outcome.

Data were summarised using percentages for categorical, and mean and standard deviations (SD) or median and interquartile range (IQR) for continuous variables. Comparison of groups (e.g. RMH vs. The Alfred, good outcome vs. poor outcome) was conducted using chi-square tests for categorical variables, and independent t-tests or Mann-Whitney U-tests for continuous variables. SF-12 summary scores were also compared with population norms using independent t-tests. Generalised Estimating Equations (GEE) analysis was used to model long term outcomes, providing a “population-average” (or marginal) approach to modelling data with repeated measures. An

exchangeable working correlation was used. Variables demonstrating an association with a p-value <0.20 on univariate testing were included in the multivariate model. Multivariate GEE models were used to identify important predictors of outcome in this patient group. Linear models were applied to the PCS-12 and MCS-12 summary scores of the SF-12, and logistic models for used for return to work, persistent pain and the GOS-E. Odds ratios (OR) and adjusted odds ratios (AOR), with corresponding 95% confidence intervals (CI), were reported. For linear models, coefficients and 95% CI of the coefficients were reported. A p-value <0.05 was considered significant for all statistical tests. All analyses were performed using Stata Version 11.2 (StataCorp, College Station, TX).

Results

Profile of participants

There were 119 patients who survived to hospital discharge, of which 114 (95.8%) were successfully followed-up for at least one time point; 94 at all time points, 16 at two time points, and 4 at one time point.

Table 12: Profile of participants

Descriptor		n (%)
Age group	15-34 years	51 (44.7)
	35-64 years	46 (40.4)
	≥ 65 years	17 (14.9)
Gender	Male	86 (75.8)
	Female	28 (24.6)
Intent of injury	Unintentional	109 (95.6)
	Intentional self-harm	5 (4.4)
Transport-related?	No	22 (19.3)
	Yes	92 (80.7)
Compensation status	Not compensable	16 (14.2)
	Compensable	97 (85.8)
Working prior to injury?	No	33 (30.0)
	Yes	77 (70.0)
Comorbid condition?	No	73 (64.0)
	Yes	41 (36.0)
Pre-injury disability?	No	95 (85.6)
	Yes	16 (14.4)
Highest level of education	University degree	16 (15.4)
	Advanced diploma, diploma or certificate	24 (23.1)
	Completed high school	19 (18.3)
	Did not complete high school	45 (43.3)

Table 12 shows the profile of cases followed-up. Consistent with study, patients were predominantly young, male, injured in transport incidents, and healthy prior to injury (Table 12). Seventy per cent of patients were working prior to injury.

Severity, management and complications

The median ISS was consistent with Study 1 despite the exclusion of in-hospital deaths. However, the proportion with a severe head injury (GCS 3-8) was lower (Table 13). More than 80 per cent of cases were Tile/AO Type B, and 61 per cent were lateral compression fractures according to the Young-Burgess classification (Table 13). The pelvic ring fracture was treated conservatively in 11% of cases; 40% were managed using external fixation or internal fixation of the anterior arch; and 49% were managed using internal fixation of the posterior pelvic arch (with or without fixation of the anterior pelvic arch). Ninety-one per cent (n=68) of cases at The Alfred were managed with open reduction and internal fixation, compared to 59% (n=23) at RMH. Twenty-two cases required a return to the operating theatre in the first 12-months; 13 due to infection, and nine due to a loss of fracture position or fixation.

As expected, the type of fracture was associated with fracture management. Eighty-two per cent of fractures classified as vertical shear (VS) or combined mechanism (CMI) using the Young-Burgess system required internal fixation of posterior \pm anterior elements, and none were managed conservatively. Sixteen per cent of Young-Burgess classified lateral compression fractures were managed conservatively, compared to 3 per cent of anterior-posterior compression (APC) type fractures, although the proportion requiring internal fixation of the posterior elements \pm anterior elements was similar across the categories (45% for LC and 48% for APC).

Table 13: Severity and management of injuries

Descriptor		n (%)
Hospital	Alfred	75 (65.8)
	RMH	39 (34.2)
Head injury severity ^a	GCS 9-15	99 (89.2)
	GCS 3-8	12 (10.8)
Injury Severity Score	Median (IQR)	29 (24-41)
AO/Tile classification ^b	Type B1	21 (19.3)
	Type B2	39 (35.8)
	Type B3	28 (25.7)
	Type C1	17 (15.6)
	Type C2	3 (2.8)
	Type C3	1 (0.9)
	Young-Burgess classification ^c	
	APC1	6 (5.4)
	APC2	18 (16.2)
	APC3	8 (7.2)
	LC1	17 (15.3)
	LC2	14 (12.6)
	LC3	37 (33.3)
	Vertical Shear	6 (5.4)
Definitive fracture management	CMI	5 (4.5)
	Conservative	12 (10.7)
	External fixation	12 (10.7)
	Internal fixation of anterior elements	33 (29.5)
	Internal fixation of posterior elements	10 (8.9)
	Internal fixation of anterior and posterior elements	45 (40.2)
Re-operation in first 12-months?	No	92 (80.7)
	Yes	22 (19.3)

^a Data missing for 3 cases; ^b Data missing for 5 cases; ^c Data missing for 3 cases;

No AO/Tile Type C fractures were managed conservatively, and 85% required internal fixation of the posterior elements \pm anterior elements. The surgical management of Type B fractures was variable with 13% managed conservatively, 45% through external fixation or internal fixation of the anterior elements, and 43% requiring internal fixation of the posterior elements \pm anterior elements.

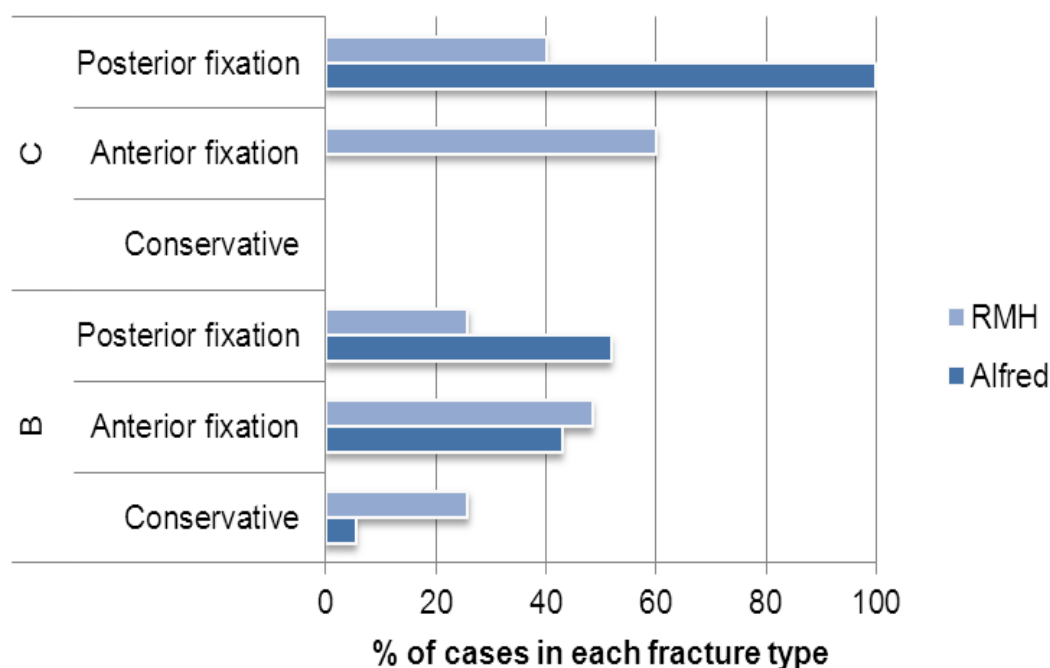


Figure 8: Definitive fracture management by Tile/AO classification and hospital

There was no association between the distribution of fracture types and hospital of definitive management for the Young-Burgess ($X^2_2=0.39$, $p=0.82$) or AO/Tile ($X^2_1=0.45$, $p=0.50$) classifications, suggesting similar severity of fractures at both sites. Nevertheless, definitive fracture management differed between hospitals, with a higher percentage of C-type and B-type cases treated at The Alfred managed with internal fixation of the posterior elements \pm fixation of the anterior elements (Figure 8). Consistent with the Tile/AO classification, a higher proportion of LC and APC type fractures were definitively managed using internal fixation of the posterior elements \pm fixation of the anterior elements at The Alfred compared to the RMH (Figure 9). Comparison of treatment approaches for the fractures classified as vertical shear or combined mechanism according to the Young-Burgess system was difficult due to the low numbers in these categories.

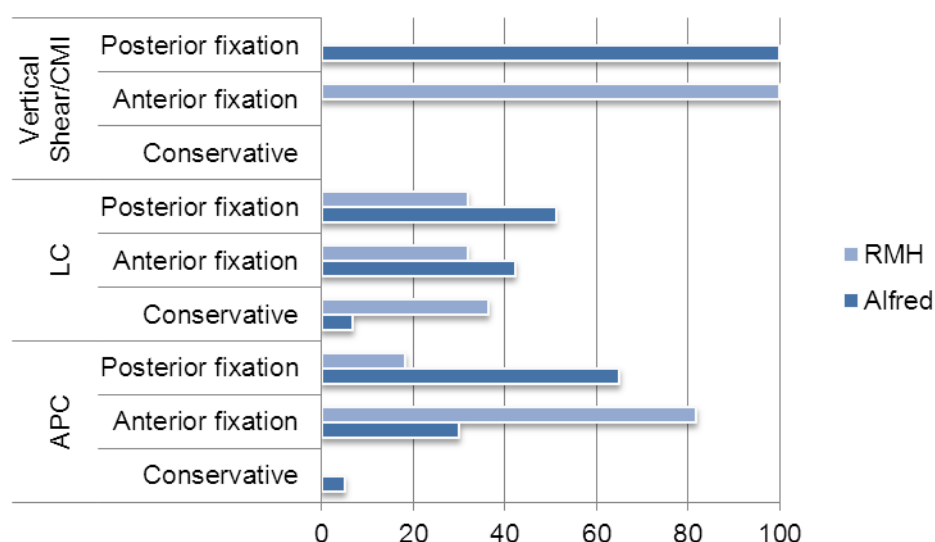


Figure 9: Definitive fracture management by Young-Burgess classification and hospital

There was no association between compensation status ($X^2_1=0.30$, $p=0.59$), transport status ($X^2_1=0.29$, $p=0.59$), comorbid status ($X^2_1=0.37$, $p=0.54$), ISS, head injury severity ($X^2_1=1.72$, $p=0.19$), sex ($X^2_1=2.79$, $p=0.10$), and whether the pelvic ring fracture was managed operatively or not. The percentage of patients aged 65 years and over receiving operative management of their pelvic ring fracture was 71%, compared to 94% of 35-64 year olds, and 89% of 15-34 year olds ($X^2_2=6.24$, $p=0.04$). The percentage of RMH cases where the pelvic ring was fixed operatively was 77% compared to 94% at The Alfred ($X^2_1=6.86$, $p=0.001$).

Functional outcomes (GOS-E)

There were three deaths in the cohort between hospital discharge and 24-months post-injury. Improvement in functional outcome was evident over time, particularly from 6 to 12-months post-injury (Table 14 and Figure 10), although only 10 per cent of patients had fully recovered, according to the GOS-E scale (upper good recovery), at 24-months.

Table 14: Severity and management of injuries

GOS-E score	6-months (n=109)	12-months (n=106)	24-months (n=106)
Death	2 (1.8)	3 (2.8)	3 (2.8)
Lower severe disability	22 (20.2)	11 (10.4)	12 (11.3)
Upper severe disability	16 (14.7)	13 (12.3)	9 (8.5)
Lower moderate disability	26 (23.9)	24 (22.6)	22 (20.8)
Upper moderate disability	31 (28.4)	36 (34.0)	38 (35.8)
Lower good recovery	6 (5.5)	8 (7.6)	11 (10.4)
Upper good recovery	6 (5.5)	11 (10.4)	11 (10.4)

The proportion of patients living independently according to the GOS-E scale (lower moderate disability or above) was 63% at 6-months, 75% at 12-months, and 77% at 24-months. The proportion who had experienced a good recovery was much lower – 11% at 6-months, 18% at 12-months, and 21% at 24-months (Figure 10).

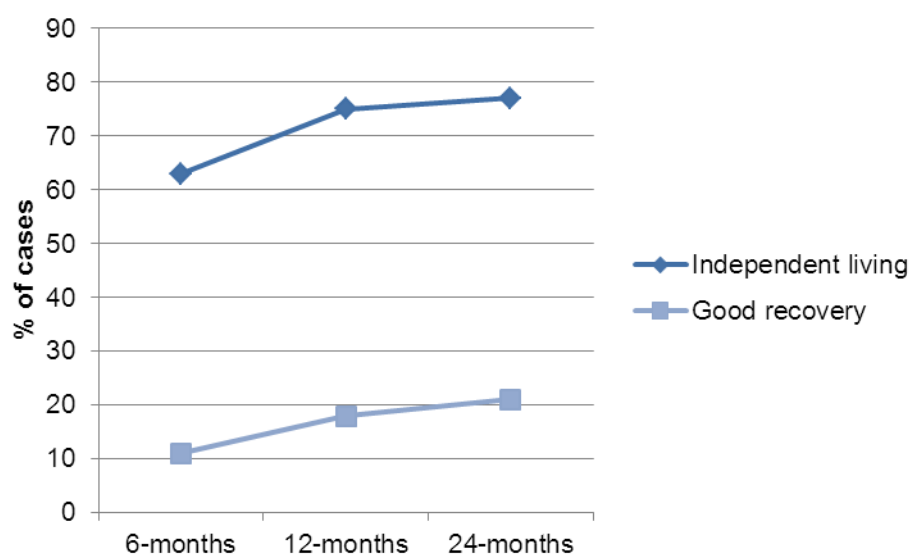


Figure 10: Longer term functional outcomes of severe pelvic ring fractures

The results of univariate analyses to identify predictors of a good recovery (GOS-E score of lower or upper good recovery) are shown in Table 15. Compared to 6-months post-injury, the odds of a good recovery increased at 12-months (OR 1.65, 95% CI: 0.90, 3.01), and 24-months (OR 1.97, 95% CI: 1.08, 3.57), post-injury. Factors associated ($p < 0.20$) with a good recovery at any time post-injury were the hospital of management, mechanism of injury, compensable status, GCS group, and the ISS (Table 15). The unadjusted odds of a good recovery were lower for cases definitively managed at RMH, compensable

patients, transport-related cases, those with a higher ISS, and patients with a low GCS on arrival at hospital (Table 15). Fracture type and management were not associated with a good recovery.

Table 15: Factors associated with a good functional recovery over time (univariate)

Descriptor		OR (95% CI)	p-value
Gender	Male (reference)	1	0.37
	Female	1.48 (0.63, 3.47)	
Age group	15-34 years (reference)	1	0.27
	35-64 years	0.58 (0.25, 1.36)	
	≥ 65 years	0.40 (0.10, 1.54)	
Comorbidity?	No (reference)	1	0.24
	Yes	0.60 (0.25, 1.41)	
Compensable?	No (reference)	1	0.002
	Yes	0.24 (0.10, 0.59)	
Transport-related?	No (reference)	1	0.04
	Yes	0.41 (0.17, 0.95)	
Working prior to injury?	No (reference)	1	0.79
	Yes	0.89 (0.39, 2.07)	
Highest level of education	University degree (reference)	1	0.66
	Advanced diploma, diploma or certificate	2.50 (0.57, 11.03)	
	Completed high school	1.61 (0.33, 8.02)	
	Did not complete high school	1.85 (0.45, 7.62)	
Hospital	Alfred (reference)	1	0.04
	RMH	0.36 (0.13, 0.95)	
Head injury severity	GCS 9-15 (reference)	1	0.13
	GCS 3-8	0.13 (0.01, 1.77)	
Injury Severity Score		0.95 (0.91, 0.99)	0.01
AO/Tile classification	Type B (reference)	1	0.86
	Type C	1.09 (0.41, 2.89)	
Young-Burgess classification	APC (reference)	1	0.88
	LC	1.13 (0.46, 2.75)	
	Vertical shear/CMI	0.78 (0.16, 3.89)	
Definitive pelvic fracture management	Conservative (reference)	1	0.57
	Fixation of anterior elements	2.51 (0.46, 13.55)	
	Fixation of posterior elements (± anterior)	2.20 (0.41, 11.73)	

Hospital of definitive management, ISS, compensation and transport status, and GCS group were entered into the multivariate GEE model for predicting a good recovery. Because of the strong association between compensable and transport status, an interaction term was included to determine if the rate of recovery of transport and non-transport cases differed according to compensable status. The results of this multivariate

model are shown in Table 16. After adjusting for other factors, the hospital of definitive management, GCS group and ISS were not predictors of a good recovery. There was a strong interaction between compensable status and transport status, with compensable, transport-related cases demonstrating lower adjusted odds of a good recovery at any time point when compared to non-compensable, non-transport related cases (Table 16).

Table 16: Predictors of a good functional recovery over time (multivariate)

Descriptor		AOR (95% CI)	p-value
Compensable and transport status	Neither (reference)	1	
	Not compensable transport cases	0.60 (0.03, 13.24)	0.75
	Compensable but non-transport cases	0.14 (0.01, 2.01)	0.15
	Compensable and transport cases	0.39 (0.15, 0.99)	0.047
Hospital	Alfred (reference)	1	
	RMH	0.47 (0.18, 1.24)	0.13
Head injury severity	GCS 9-15 (reference)	1	
	GCS 3-8	0.24 (0.02, 3.17)	0.28
Injury Severity Score		0.97 (0.93, 1.01)	0.21

Return to work

Of the 77 patients who were working prior to injury, 32% (n=23) had returned to work at 6-months, 55% (n=38) at 12-months, and 60% (n=42) had returned to work at 24-months post-injury (Figure 6). Compared to 6-months post-injury, the odds of return to work at 12-months were 2.438 (95% CI: 1.82, 3.71) higher, and the odds of return to work at 12-months were 3.13 (95% CI: 2.00, 4.89) times higher.

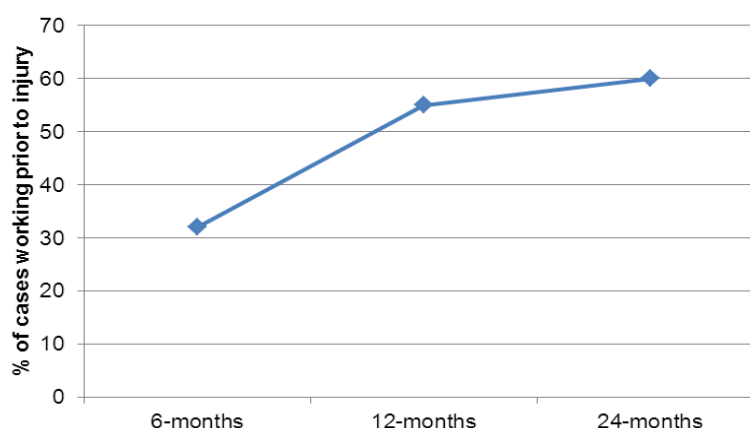


Figure 11: Return to work outcomes of severe pelvic ring fractures

Table 17: Factors associated with return to work over time (univariate)

Descriptor		OR (95% CI)	p-value
Gender	Male (reference)	1	0.60
	Female	0.80 (0.33, 1.89)	
Age group	15-34 years (reference)	1	0.53
	35-64 years	1.06 (0.48, 2.34)	
	≥ 65 years	0.43 (0.09, 2.10)	
Comorbidity?	No (reference)	1	0.14
	Yes	0.53 (0.23, 1.23)	
Compensable?	No (reference)	1	0.18
	Yes	0.42 (0.12, 1.51)	
Transport-related?	No (reference)	1	0.42
	Yes	0.65 (0.23, 1.82)	
Highest level of education	University degree (reference)	1	0.24
	Advanced diploma, diploma or certificate	1.09 (0.33, 3.63)	
	Completed high school	0.58 (0.17, 1.92)	
	Did not complete high school	0.42 (0.14, 1.27)	
Hospital	Alfred (reference)	1	0.88
	RMH	1.06 (0.48, 2.37)	
Head injury severity	GCS 9-15 (reference)	1	0.01
	GCS 3-8	0.11 (0.02, 0.63)	
Injury Severity Score		0.91 (0.87, 0.96)	<0.001
AO/Tile classification	Type B (reference)	1	0.11
	Type C	0.38 (0.12, 1.25)	
Young-Burgess classification	APC (reference)	1	0.17
	LC	0.65 (0.30, 1.44)	
	Vertical shear/CMI	0.10 (0.01, 1.41)	
Definitive pelvic fracture management	Conservative (reference)	1	0.12
	Fixation of anterior elements	1.72 (0.36, 8.17)	
	Fixation of posterior elements (± anterior)	0.74 (0.16, 3.53)	

Factors associated with return to work at any time point post-injury, were injury severity, head injury severity (GCS), comorbid status, compensation status, pelvic fracture severity and the definitive management of the pelvic fracture (Table 17).

The multivariate analysis identified injury severity (ISS) as the most important predictor of return to work. Adjusted for comorbid status, compensable status, head injury severity, pelvic fracture management, and pelvic fracture severity, the odds of return to work at any time point decreased 5% for every point increase in the ISS (Table 18).

Table 18: Predictors of return to work over time (multivariate)

Descriptor		AOR (95% CI)	p-value
Injury Severity Score		0.94 (0.89, 0.99)	0.04
Head injury severity	GCS 9-15 (reference)	1	0.18
	GCS 3-8	0.27 (0.04, 1.79)	
Compensable?	No (reference)	1	0.24
	Yes	0.38 (0.08, 1.90)	
Definitive pelvic fracture management	Conservative (reference)	1	0.25
	Fixation of anterior elements	1.43 (0.26, 7.91)	
	Fixation of posterior elements (\pm anterior)	0.63 (0.11, 3.64)	
AO/Tile classification	Type B (reference)	1	0.34
	Type C	0.53 (0.14, 1.96)	
Comorbidity?	No (reference)	1	0.96
	Yes	1.03 (0.36, 2.95)	

Pain

A pain scale score is collected when direct interview of the patient is possible, and therefore is limited to patients without pre-existing or post-injury cognitive deficit or other disability affecting completion of the interview. Pain scores were obtained from 67 patients at 6-months, 74 at 12-months and 68 patients at 24-months. The increase in pain score completion at 12-months is likely to reflect overall improvement of the patient's condition, allowing direct interview.

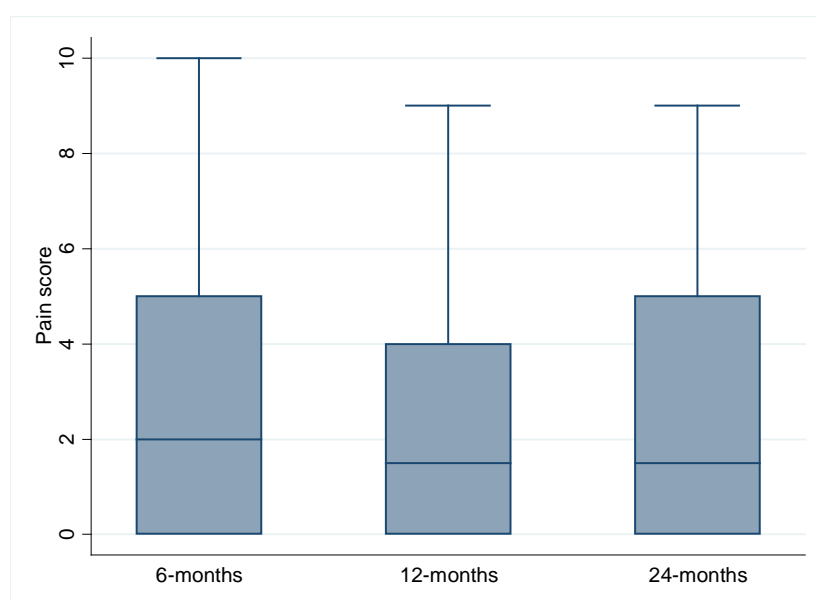


Figure 12: Distribution of pain scores at follow-up

The distribution of pain scores shown in Figure 12 suggests little improvement in pain over time. The proportion of patients reporting no pain (pain score 0) at follow-up was 43% at 6-months, 42% at 12-months and 43% at 24-months. The proportion of patients reporting persistent moderate to severe pain (pain score 5-10) was 31%, 24%, and 29% at 6-, 12-, and 24-months, respectively. The odds of reporting moderate to persistent pain were not significantly lower at 12-months (OR 0.72, 95% CI: 0.39, 1.33), or 24-months (OR 0.86, 95% CI: 0.46, 1.59), compared to 6-months post-injury.

Table 19: Factors associated with persistent moderate to severe pain (univariate)

Descriptor		OR (95% CI)	p-value
Gender	Male (reference)	1	0.32
	Female	1.54 (0.66, 3.59)	
Age group	15-34 years (reference)	1	0.61
	35-64 years	1.18 (0.53, 2.64)	
	≥ 65 years	0.62 (0.18, 2.11)	
Comorbidity?	No (reference)	1	0.42
	Yes	1.39 (0.63, 3.05)	
Working prior to injury?	No (reference)	1	0.66
	Yes	1.22 (0.57, 2.92)	
Compensable?	No (reference)	1	0.12
	Yes	2.69 (0.77, 9.42)	
Transport-related?	No (reference)	1	0.09
	Yes	2.50 (0.86, 7.29)	
Highest level of education	University degree (reference)	1	0.88
	Advanced diploma, diploma or certificate	0.71 (0.21, 2.40)	
	Completed high school	0.93 (0.25, 3.43)	
	Did not complete high school	0.67 (0.21, 2.14)	
Hospital	Alfred (reference)	1	0.31
	RMH	0.65 (0.29, 1.49)	
Injury Severity Score		1.01 (0.98, 1.05)	0.47
AO/Tile classification	Type B (reference)	1	0.45
	Type C	1.42 (0.57, 3.58)	
Young-Burgess classification	APC (reference)	1	0.08
	LC	1.45 (0.61, 3.47)	
	Vertical shear/CMI	4.74 (1.22, 18.46)	
Definitive pelvic fracture management	Conservative (reference)	1	0.34
	Fixation of anterior elements	0.47 (0.14, 1.54)	
	Fixation of posterior elements (± anterior)	0.82 (0.28, 2.46)	

* Head injury severity excluded as pain score not administered to severe head injury patients

Factors associated ($p < 0.20$) with persistent moderate to severe pain at any time point were fracture type (measured using the Young-Burgess system), cause of injury, and

compensable status (Table 19). The most important predictor of persistent moderate to severe pain was the type of pelvic ring fracture (Table 20). Patients sustaining CMI or vertical shear fractures demonstrated an almost six-fold increase in the adjusted odds of moderate to severe persistent pain when compared to APC type fractures (Table 20).

Table 20: Predictors of persistent moderate to severe pain over time (multivariate)

Descriptor		AOR (95% CI)	p-value
Young-Burgess classification	APC (reference)	1	0.048
	LC	1.37 (0.57, 3.28)	
	Vertical shear/CMI	5.99 (1.43, 25.05)	
Transport-related?	No (reference)	1	0.38
	Yes	2.19 (0.38, 12.45)	
Compensable?	No (reference)	1	0.65
	Yes	1.58 (0.21, 11.66)	

Health-related quality of life

As noted for the pain score, the SF-12 is not administered where the interview is completed by proxy. The number of patients completing the SF-12 was 67 at 6-months, 73 at 12-months, and 70 at 24-months post-injury. Table 21 summarises the PCS-12 and MCS-12 scores reported by patients at each time point, and the Australian population norms for each SF-12 summary score. A difference of 2 to 3 points between populations is generally considered significant. The mean PCS-12 score was 15.0 points below the population norm at 6-months ($t=11.85$, $p<0.0001$), 14.2 points lower at 12-months ($t=11.66$, $p<0.0001$), and 10.8 points lower at 24-months ($t=8.67$, $p<0.0001$). Mean MCS-12 scores were also significantly lower than population norms at all time points. The mean MCS-12 score was 5.3 points lower at 6-months ($t=4.77$, $p<0.0001$), 3.3 points lower at 12-months ($t=3.12$, $p=0.002$), and 3.3 points lower at 24-months ($t=3.06$, $p=0.002$).

Table 21: Physical (PCS-12) and mental (MCS-12) health outcomes for severe pelvic ring fractures

SF-12 summary score	6-months Mean (SD)	12-months Mean (SD)	24-months Mean (SD)	Australian norm Mean (SD)
PCS-12	33.9 (10.1)	34.7 (10.7)	38.1 (11.6)	48.9 (10.2)
MCS-12	47.1 (11.9)	49.1 (11.1)	49.1 (10.9)	52.4 (8.8)

Figure 13 shows the standardised mean difference (SMD) of the PCS-12 and MCS-12 scores at 6, 12 and 24-months post-injury. The SMD provides a method of showing the degree of deviation from the population norm by standardising individual scores by age and gender. The SMD is effectively an effect size where an SMD of zero suggests no difference to population norms and a score above zero suggests health-related quality of life of severe pelvic ring fracture patients above population norms. The size of the SMD represents the magnitude of difference between the SF-12 scores of the Australian population and severe pelvic ring fracture patients patients, with values >0.8 considered to be large.

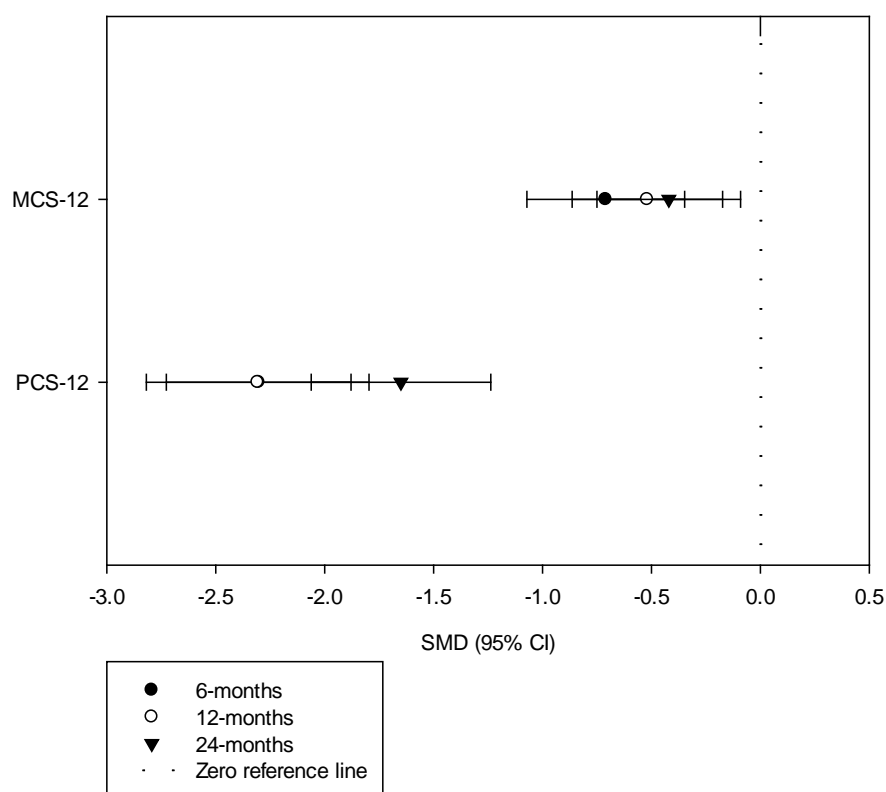


Figure 13: Age and gender adjusted standardised mean differences (95% CI) for PCS-12 and MCS-12 scores over time

Predictors of physical health scores (PCS-12)

There was no significant increase in mean PCS-12 scores at 12-months compared to 6-months (mean difference 0.84, 95% CI: -1.60, 3.27), but clear evidence of improved physical health at 24-months compared to 6-months (mean difference 4.23, 95% CI: 1.35,

7.10). Without adjusting for other factors, fracture type was not associated with physical health at any time point, but type of definitive fracture management was (Table 22). Other factors univariately associated ($p < 0.20$) with PCS-12 scores were age, compensable status and the ISS (Table 22), and all were included in the multivariate model (Table 23).

Table 22: Factors associated with physical health (PCS-12 scores) over time (univariate)

Descriptor		Mean difference (95% CI)	p-value
Gender	Male (reference)	-	0.99
	Female	0.02 (-4.59, 4.63)	
Age group	15-34 years (reference)	-	0.12
	35-64 years	-3.45 (-7.54, 0.64)	
	≥ 65 years	-4.58 (-9.54, 0.39)	
Comorbidity?	No (reference)	-	0.55
	Yes	-1.22 (-5.18, 2.74)	
Working prior to injury?	No (reference)	-	0.56
	Yes	1.16 (-2.77, 5.09)	
Compensable?	No (reference)	-	0.04
	Yes	-5.46 (-10.78, -1.14)	
Transport-related?	No (reference)	-	0.46
	Yes	-1.69 (-6.22, 2.84)	
Highest level of education	University degree (reference)	-	0.40
	Advanced diploma, diploma or certificate	2.44 (-3.16, 8.04)	
	Completed high school	4.96 (-0.73, 10.65)	
	Did not complete high school	2.14 (-3.17, 7.46)	
Hospital	Alfred (reference)	-	0.28
	RMH	-2.04 (-4.59, 4.63)	
Injury Severity Score		-0.14 (-0.32, 0.04)	0.13
AO/Tile classification	Type B (reference)	-	0.37
	Type C	-2.07 (-6.57, 2.43)	
Young-Burgess classification	APC (reference)	-	0.21
	LC	-0.62 (-4.89, 3.65)	
	Vertical shear/CMI	-5.10 (-11.03, 0.82)	
Definitive pelvic fracture management	Conservative (reference)	-	0.12
	Fixation of anterior elements	5.83 (-0.55, 12.21)	
	Fixation of posterior elements (± anterior)	-2.37 (-3.61, 8.35)	

* Head injury severity excluded as SF-12 not administered to severe head injury patients

After adjusting for other potential confounders, compensable patients demonstrated adjusted mean PCS-12 scores more than 7.5 points below non-compensable patients (Table 23), while operatively managed severe pelvic ring fractures reported adjusted mean PCS-12 scores above the scores reported by patients managed conservatively (Table 23).

Table 23: Predictors of physical health (PCS-12 scores) over time (multivariate)

Descriptor		Adjusted mean difference (95% CI)	p-value
Compensable?	No (reference)	-	0.004
	Yes	-7.50 (-12.64, -2.37)	
Definitive pelvic fracture management	Conservative (reference)	-	0.04
	Fixation of anterior elements	6.44 (-0.78, 13.66)	
	Fixation of posterior elements (\pm anterior)	1.57 (-4.88, 8.02)	
Age group	15-34 years (reference)	-	0.08
	35-64 years	-4.04 (-7.91, -0.16)	
	≥ 65 years	-4.15 (-9.22, 0.91)	
Injury Severity Score		-0.04 (-0.21, 0.14)	0.66

Predictors of mental health outcomes (MCS-12)

There was no improvement in MCS-12 scores at 12-months (mean difference 1.00, 95% CI: -1.63, 3.63) or 24-months (mean difference 1.13, 95% CI: -1.48, 3.75), compared to 6-months. This is consistent with Figure 13. Factors associated with mental health outcomes at any time point were compensable status, cause of injury (transport vs. non-transport related), whether the person was working prior to injury, and the definitive management of the pelvic ring fracture.

Definitive fracture management, compensable status and transport status were included the multivariate model to identify important predictors of MCS-12 scores over time. An interaction term was included between transport status and compensable status to see if mental health outcomes differed for compensable patients, according to transport status (Table 25).

Table 24: Factors associated with mental health (MCS-12 scores) over time (univariate)

Descriptor		Mean difference (95% CI)	p-value
Gender	Male (reference)	-	0.36
	Female	-2.29 (-7.21, 2.64)	
Age group	15-34 years (reference)	-	0.65
	35-64 years	-1.72 (-6.8, 2.74)	
	≥ 65 years	-2.39 (-9.00, 4.23)	
Comorbidity?	No (reference)	-	0.26
	Yes	-2.52 (-6.92, 1.87)	
Working prior to injury?	No (reference)	-	0.17
	Yes	3.33 (-1.38, 8.03)	
Compensable?	No (reference)	-	0.006
	Yes	-6.33 (-10.85, -1.82)	
Transport-related?	No (reference)	-7.31 (-11.17, -3.45)	<0.001
	Yes		
Highest level of education	University degree (reference)	-	0.20
	Advanced diploma, diploma or certificate	5.74 (-1.49, 13.00)	
	Completed high school	1.57 (-6.91, 10.05)	
	Did not complete high school	1.35 (-5.91, 8.60)	
Hospital	Alfred (reference)	-	0.72
	RMH	0.80 (-3.51, 5.12)	
Injury Severity Score		-0.07 (-0.30, 0.15)	0.53
AO/Tile classification	Type B (reference)	-	0.86
	Type C	0.55 (-5.67, 6.78)	
Young-Burgess classification	APC (reference)	-	0.47
	LC	-2.20 (-6.47, 2.07)	
	Vertical shear/CMI	-5.03 (-15.80, 5.75)	
Definitive pelvic fracture management	Conservative (reference)	-	0.03
	Fixation of anterior elements	9.30 (2.40, 16.21)	
	Fixation of posterior elements (± anterior)	8.10 (1.06, 15.11)	

* Head injury severity excluded as SF-12 not administered to severe head injury patients

Participants who were compensable, and transport-related, reported adjusted mean MCS-12 scores 8 points lower than non-compensable patients injured in via other mechanisms at any time point post-injury. Any type of surgical fixation of the pelvic ring fracture resulted in improved mental health outcomes compared to patients managed conservatively (Table 25).

Table 25: Predictors of mental health (MCS-12 scores) over time (multivariate)

Descriptor		Adjusted mean difference (95% CI)	p-value
Compensable and transport status	Neither (reference)	-	
	Not compensable transport cases	2.69 (-0.93, 6.32)	0.15
	Compensable but non-transport cases	-0.32 (-5.97, 5.33)	0.91
	Compensable and transport cases	-8.01 (-12.46, -3.57)	<0.001
Definitive pelvic fracture management	Conservative (reference)	-	
	Fixation of anterior elements	9.16 (1.90, 16.42)	0.007
	Fixation of posterior elements (\pm anterior)	6.69 (-0.35, 13.74)	0.06
Working prior to injury?	No (reference)	-	0.40
	Yes	1.96 (-2.62, 6.55)	

Discussion

This multi-centre study described the predictors of long term outcomes of 114 severe pelvic ring fracture patients, and represents the largest study of severe pelvic ring fractures to date. The results highlight the variation in definitive fracture management between the major trauma service hospitals, and identified a number of patient, injury and treatment factors predictive of patient outcome. Compensable status was a significant independent predictor of functional and health-related quality of life outcome, with compensable patients demonstrating poorer outcomes. The overall injury severity of the patient was the most important predictor of return to work, while fracture type was a significant independent predictor of persistent pain. Definitive pelvic fracture management was an independent predictor of health-related quality of life, with patients surgically managed demonstrating higher long term physical and mental health outcomes than patients managed conservatively.

Consistent with previous studies of unstable and severe pelvic ring fractures, the population were predominantly young, male, working prior to injury, injured in transport accidents, and involving other associated injuries (11, 26, 27, 54). All had sustained other associated injuries and the mean ISS (31.8) was higher than other studies (11, 53-55). The proportion of cases surgically managed with internal fixation was higher than previously reported. In our study, 11% were managed conservatively, 11% with external fixation only, and 79% with open reduction and internal fixation of the pelvic ring fracture. Suzuki *et al* studied the outcomes of 57 unstable, B- and C-type, fractures from a single centre in Japan and 40% were treated conservatively, 39% with external fixation, and 21%

with internal fixation (43). Comparison of rates of surgery with other studies is difficult as many have focused only on operatively treated patients (11, 27, 50, 54, 56, 57), or have included less severe fractures in their cohort (26, 58).

Disability was prevalent even 24-months post-injury. There was considerable improvement in outcome to 24-months post-injury for return to work, functional outcome, and physical health scores. However, there was no evidence of improvement in pain or mental health scores over time. Comparison of patient outcomes from our cohort requires studies with common outcome measures. The GOS-E has not been used by other severe pelvic ring fractures, despite being used widely in multi-trauma populations, but return to work, health-related quality of life and pain have been used previously by studies investigating the outcomes of severe pelvic ring fractures.

In our study, health-related quality of life, measured using the PCS-12 and MCS-12 of the SF-12 instrument, was significantly below age and gender adjusted population norms, with the PCS-12 11 points lower, and the MCS-12 3 points lower, at 24-months post-injury. Other studies of severe pelvic ring fractures have largely used the SF-36, but also found physical health scores well below population norms (11, 43, 54, 55). Suzuki *et al*, in their study of 57 unstable pelvic ring fractures patients, found PCS scores 13.4 points lower than population norms more than 2 years after injury (43). Oliver *et al* studied 46 B- and C-type pelvic ring fractures, and found PCS-36 scores 11 points, and MCS-36 scores 4.1 points, below US population norms. Together, these studies highlight the large and significant reductions in health-related quality of life experienced by patients sustaining severe pelvic ring fractures even 2-years following injury.

The 60% return to work rate at 24-months for severe pelvic ring fracture patients who were working prior to injury is relatively consistent with the published literature. Suzuki *et al* studied 57 unstable pelvic ring fractures and found only 9 (16%) were unable to return to work more than 2-years after injury (43). However, most other studies have found lower return to work rates for severe pelvic ring fracture patients. Madhu *et al* studied 30 patients with combined pelvic and spinal fracture and reported that 57% had returned to work at a mean follow-up of 57 months (10). Van den Bosch *et al* and Tornetta *et al* reported return to work rates of 68% and 67% in their studies of 37 and 46 operatively treated pelvic ring fractures, respectively (53, 59).

In our study, we found that the prevalence of moderate to severe persistent pain was 30% at 24-months post-injury. Gerbershagen *et al* studied 69 patients with pelvic and acetabular fractures using the Mainz Pain Staging System, and found the prevalence of pain was high (64%) and many patients experience long term pain chronification and associated biopsychosocial implications (60). While compensable status has been identified as a predictor of persistent pain in trauma patients previously (61, 62), the strongest predictor of persistent moderate to severe pain in our study was the type of fracture sustained. Patients with vertical shear or combined mechanism fractures, classified according to the Young-Burgess system, demonstrated a six-fold increased risk of reporting moderate to severe pain at any follow-up time point.

Factors such as age, gender, associated severe head injury, the presence of comorbidity, the Tile/AO classification of fractures, and the level of education of patients were largely not important predictors of outcome in this cohort. The type of fracture sustained was only a significant independent predictor of persistent pain; compensable status was an important predictor of function and quality of life; the overall injury severity (ISS) of patients predicted return to work; and fracture management was a strong predictor of health-related quality of life.

A key aim of our study was to explore the relationship between type of fracture, fracture management and long term patient outcomes. Fracture type, as measured using the Young-Burgess and Tile/AO classifications, was not associated with many of the outcomes measured. Similarly, the type of fracture management did not impact on functional, return to work or pain outcomes. However, patients managed operatively demonstrated improved mental health scores, as measured by the MCS-12, than patients managed conservatively. Fixation of the anterior elements of the pelvic ring also resulted in adjusted mean PCS-12 scores 6.6 points higher than conservatively managed patients, while patients managed with external fixation or internal fixation of the anterior elements reported adjusted mean PCS-12 scores 4.8 points higher than patients with fixation of the posterior \pm anterior ring. Van Loon *et al* compared the functional outcomes of 38 “open book” (Type B1) pelvic fractures according to surgical approaches and concluded that outcomes tended to be worse for patients receiving additional posterior stabilisation but the number of cases receiving additional posterior stabilisation was low ($n=6$) (55). Our study provides some support for the findings of Van Loon *et al*, but caution in interpretation

is needed. It is possible that the requirement to fix the posterior ring elements suggests a more serious fracture which could go on to worse outcomes anyway, and that other patient factors could impact on the decision to operate or manage conservatively. There are no clear clinical indications for particular surgical approaches, with the surgeon generally applying judgement based on the patient's general condition, local soft tissue condition, and factors such as the degree of fracture displacement. Fracture displacement is not measured in either the AO/Tile or Young-Burgess systems for classifying fracture type.

Papakostidis *et al*, published a systematic review of treatment modalities and outcomes of pelvic ring fractures, and concluded that fixation of all injured elements of the pelvic ring led to better radiological outcomes but there was no clear benefit with respect to patient function (48). However, the quality of studies included was poor, outcome measures used were limited, and the studies were insufficient to provide clear guidance about optimal treatment for unstable pelvic ring fractures (48).

Eighty-six per cent of severe pelvic ring fracture cases in this study were compensable (predominantly TAC) patients. Compensable patients demonstrated significantly higher odds of poorer functional outcome and markedly lower health-related quality of life scores. This is consistent with data from other studies of serious injury (61-67). Observational studies, such as this prospective cohort study, cannot identify the reasons for the poorer outcomes of compensable patients. However, results from two qualitative studies provide insight into the experiences of patients with compensable agencies that could contribute to the poorer outcomes noted (68, 69). Factors such as a lack of trust, difficulty accessing post-acute treatment services, delays in approval of treatment services, and pre-existing conditions such as anxiety and depression, could all contribute to poorer outcomes of compensable cases (68, 69). The potential for patients to overstate their limitations for secondary gain cannot be excluded as a possible reason for poorer outcomes in this patient group (63).

There were a number of strengths to this study. Previous studies have almost exclusively focused on pelvic fractures managed at a single institution. We studied a large number of severe pelvic ring fracture patients from two major trauma services, representing more than 90% of all hospitalised, severe pelvic fractures in Victoria, and were able to show variation in practice between the hospitals. Cases were prospectively followed-up at multiple, standardised time points. Published studies have retrospectively identified cases

and followed up cases at inconsistent time points post-injury. The follow-up rate of 96% was much higher than previously reported studies (10, 11, 26, 43, 54), minimising bias in reporting of patient outcomes.

Nevertheless, there were limitations to the study. Compared to previous studies, the sample size ($n=114$) was large, but was insufficient to identify all but the largest effects. In Study 1, we showed that the inter-rater reliability of fracture classification using the Young-Burgess and AO/Tile systems was low, and due the relatively low number of cases in the study, these classification systems needed to be collapsed into broad categories for analysis. In doing so, there is a loss of information and subtle differences in outcomes between sub-categories of fracture types could not be shown. Radiological outcomes were not included in this study despite previous studies showing an association between radiological outcomes (i.e. displacement) and functional outcome (57, 59, 70), and should be considered for future studies. Only a limited range of complications could be collected retrospectively from the medical record and standardised reporting is not used. Finally, pelvic-specific outcome measures were not collected in this study. While a number of pelvic-specific outcome measures are available, none have been sufficiently validated (71). In addition, all patients were multi-trauma patients, sustaining significant associated injuries. Disentangling disability associated with the pelvic ring fracture from the disability of other sustained injuries is challenging, with studies previously showing that region-specific measures do not discriminate disability related to other injuries (72).

Conclusions

This study of 114 severe pelvic ring fractures shows that disability is prevalent even at 2-years post-injury. There was marked variation in practice between the major trauma service hospitals. Fracture classification impacted little on patient outcome, but the results provide some evidence for improved patient quality of life following surgical fixation of fractures. The complexity of these patients, the prevalence of disability, and the variation in practice noted highlight the need for ongoing monitoring and benchmarking of these patients if care and outcomes are to be optimised.

Summary of key findings

This project comprised three distinct studies to: establish the reliability of the classification of severe pelvic ring fractures; compare the early clinical management of severe pelvic ring fractures between the MTS hospitals and the impact on in-hospital mortality, and; establish the relationship between approaches to pelvic fracture fixation, fracture classification and long term functional, return to work, pain and health-related quality of life outcomes. Severe pelvic ring fractures represent a challenging patient group to research but there were clear findings from this research:

1. Accurate and reliable classification of fractures is necessary to enable valid and appropriate comparisons of study populations and patient outcomes. Previous studies of pelvic ring fracture classification have found inter- and intra-tester reliability too low for clinical and benchmarking purposes. In this project, the use of 3D CT reconstruction images was explored as a potential imaging source that could result in improved reliability of classification. The study findings identified clear issues with the reliability of fracture classification in this group of severe pelvic ring fractures. Inter-tester reliability was low and current clinical practice at the MTS hospitals does not routinely provide the plain radiograph views for which the Young-Burgess and Tile/AO classifications were developed. Severe pelvic ring fracture patients represent a difficult classification prospect for existing classification systems due to the prevalence of interventions pre-hospital (e.g. binders) and in the emergency department.
2. There were profound variations in practice between the MTS hospitals with respect to the early and definitive management of severe pelvic ring fractures. The Alfred hospital favours rapid stabilisation of the fracture with external fixation, and a higher prevalence of definitive management using open reduction and internal fixation. RMH favours early referral to angiography and embolisation to reduce bleeding, and lower rates of open reduction and internal fixation. . The in-hospital mortality rate was slightly higher at RMH, but adjusted for key confounders, there was no difference in the risk-adjusted odds of mortality following severe pelvic ring fracture between the MTS hospitals. There was no clearly superior treatment approach,

continuing the controversy that exists regarding best practice management of these cases.

3. This project included the largest cohort study of the long term outcomes of severe pelvic ring fractures. Disability was prevalent even 24-months after injury and there were a number of predictors of poor outcome. There was marked variation in definitive fracture management between the major trauma service hospitals. While fracture classification impacted little on patient outcome, the results provide some evidence for improved patient quality of life following surgical fixation of fractures.

Recommendations

The primary recommendations from this project are:

1. The development of a pelvic ring fracture classification system based on current imaging practices is needed to support current clinical practice. Without a reliable classification system, clinical research and benchmarking of patient outcomes will be limited.
2. There was no difference in mortality or long term outcomes, but substantial differences in treatment approaches between the MTS hospitals. Fixation of fractures was associated with better health-related quality of life outcomes for patients. Consideration should be given to using linked TAC claims and VSTR/VOTOR data to explore treatment costs as vast majority are TAC compensable cases.
3. Overall, there is extreme variation in practice at the MTS hospitals, highlighting the lack of evidence-based care in severe pelvic ring fractures. These hospitals provide an ideal ecological study of the management of severe pelvic fractures due to the variation in practice, the comparability of patients managed at both hospitals, and the relatively complete case capture across the population. While the low incidence of cases limited the capacity to identify differences in outcomes in this study, the mortality and disability experienced by patients is high, justifying ongoing monitoring. Further monitoring and evaluation is critical for establishing best practice care for these patients.

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