

Trends in the Nature and Management of Serious Abdominal Trauma

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Abstract

Background There have been recommendations for increased non-operative management (NOM) of abdominal trauma in adults. To assess the impact of this trend and changes in the epidemiology of trauma, we examined the management of serious abdominal injuries and mortality, in Victorian major trauma patients 16 years or older, between 2007 and 2016.

Methods Using data from the population-based Victorian Trauma Registry, characteristics of patients who underwent laparotomy, embolisation, laparotomy and embolisation, or NOM, were compared with the Chi-square test. Poisson regression was used to determine whether the incidence of serious abdominal injury changed over time. Temporal trends in the management of abdominal injury and in-hospital mortality were analysed using, respectively, the Chi-square test for trend, and multivariable logistic regression.

Results Of 2385 patients with serious abdominal injuries, 69% ($n = 1649$) had an intervention; predominantly a laparotomy ($n = 1166$). The proportion undergoing laparotomy decreased from 60% in 2007 to 44% in 2016 ($p < 0.001$), whilst embolisation increased from 6 to 20% ($p < 0.001$). Population-adjusted incidence of abdominal injury increased 1.6% per year (IRR 1.016, 95% CI 1.002–1.031; $p < 0.024$), predominantly in people aged 65 years and over (4.6% per year). Adjusted odds of in-hospital mortality declined 6.0% per year (adjusted odds ratio 0.94; 95% CI 0.89, 1.00; $p = 0.04$).

Conclusions Whilst the incidence of major abdominal trauma increased during the study period, there was a reduction in the proportion of patients managed with laparotomy and reduction in the adjusted odds of in-hospital mortality. Older patients, for whom management is influenced by the complex interplay of frailty and co-morbidities, had lower laparotomy rates.

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Introduction

The epidemiology of major trauma in high-income countries is changing. The archetypal young male presenting with major injuries following a motor vehicle collision (MVC) [1–3] is being superseded by an older individual falling from a standing height, who may nonetheless sustain an equally severe pattern of injury. These marked changes in population and mechanisms of injury have resulted in an increased incidence of head and long bone injuries [4, 5]. However, the influence of an ageing major

trauma population on the incidence and pattern of abdominal injuries is unknown. This information is required when designing management protocols for major abdominal trauma.

In addition to temporal changes in the epidemiology of major trauma, the management of abdominal trauma has evolved over time. Serious abdominal injuries have historically been managed with emergency laparotomy [6]. However, the morbidity associated with non-therapeutic laparotomies (defined as laparotomy with no abdominal injuries identified [7]) led to the increased, use of selective, non-operative management (NOM) [8]. Non-invasive investigation and active monitoring are now recommended for haemodynamically stable patients with no signs of peritonitis [9–11].

In addition, the increasing availability and advances in angiography and embolisation have changed the management of trauma patients [12]. NOM in serious solid organ injury has also been enhanced by the use of damage-control resuscitation [13, 14].

Unsurprisingly, as these changes are implemented, reported rates of laparotomy vary widely. Most come from retrospective, single-centre studies, or examine specific types of abdominal traumatic injuries [15–17]. Additionally, although NOM and use of embolisation have become more widespread [18–21], there is limited evidence linking this trend to the incidence of trauma laparotomies.

Therefore, this study aimed to examine trends in the incidence, pattern, and management of serious abdominal injuries between 2007 and 2016, in all hospitalised major trauma patients in Victoria, Australia.

Materials and methods

Study design and population

This was a review of all adult (aged 16 years and older) cases of major trauma with serious abdominal injuries (AIS score of three or greater [22]) using data from the Victorian State Trauma Registry (VSTR) from 01 January 2007 to 31 December 2016. The VSTR is a population-based registry that collects data about all hospitalised major trauma patients in Victoria [23]. A case is considered to be ‘major trauma’, and is included in the VSTR if any of the following criteria are met: (1) death due to injury; (2) an injury severity score (ISS) > 12 as determined by the Abbreviated Injury Scale (AIS) (2005 version 2008 update); (3) admission to an intensive care unit (ICU) for more than 24 h and requiring mechanical ventilation for at least part of their ICU stay; and (4) urgent surgery for intracranial, intrathoracic, or intra-abdominal injury, or fixation of pelvic or spinal fractures. An ISS of 12 was used

as an ISS 15 was shown to exclude a substantial number of patients with significant trauma [24]. Patients with both isolated abdominal injury and multi-trauma were included in the study. Isolated abdominal injury was defined as the absence of an AIS injury with a severity score of 3 or greater in any other body region. The VSTR has approval from the Department of Health and Human Services Human Research Ethics Committee and all participating hospitals. Patients injured outside Victoria, and subsequently transported to Victorian hospitals for care, were excluded from this study.

Data extraction

To characterise trends in patterns and management of traumatic abdominal injuries, we compared patient characteristics between four management groups; laparotomy, embolisation, laparotomy and embolisation, and NOM. Abdominal injuries were classified into solid organ injury only, hollow organ injury only, vascular injury only, other injury, and a group wherein patients had sustained more than one abdominal injury type.

Information on the demographic [age, sex, Accessibility and Remoteness Index of Australia (ARIA), Index of Relative Socio-economic Advantage and Disadvantage (IRSAD)], health status [Charlson Comorbidity Index (CCI)], systolic blood pressure on arrival to the primary hospital, definitive care hospital service level (dichotomised as a major trauma service (MTS) or a non-MTS), mechanism and type of injury were extracted.

Statistical methods

Variables pertaining to demographic, health status, haemodynamic state on arrival, mechanism and type of injury, intervention, and mortality were compared between the four management groups using Chi-square tests. Population-based incidence was calculated for each calendar year based on the Victorian population at June 30 of the corresponding year. Poisson regression, or negative binomial regression, was used to determine whether the incidence rate of major abdominal trauma had changed over the study period with the denominator being the count of the Victorian population for each year. Incidence rate ratios (IRR) with 95% confidence intervals (CI) were reported, using the first year as the reference point. Population-based incidence rates were also calculated for each mechanism of injury, trauma type and for each age group (using the population of each age group per year as the denominator). Data were checked for potential over-dispersion (variance greater than the mean) to ensure that the assumptions of a Poisson distribution were met. The Chi-square test for trend was used to investigate temporal trends in the profile

of injury, the proportion of isolated abdominal injury cases, and the management of serious abdominal injury.

Comparisons between patients who survived to hospital discharge and patients who died in-hospital were made using the Chi-square test (Supplementary Table 1). The Chi-square test was also used to investigate factors that changed over time (Supplementary Table 2). Univariate logistic regression was used to determine variables that were associated with in-hospital mortality. A multivariable logistic regression model was used to investigate temporal trends in in-hospital mortality. The model was adjusted for the abdominal injury AIS score, whether the patient was classified as having an isolated abdominal injury, and factors that both changed over time and were associated with in-hospital mortality at the univariate level (Table 1, and Supplementary Table 1 and 2).

Locally weighted scatter plot smoothing demonstrated a linear relationship between the log odds of in-hospital mortality and year; therefore, year was included as a continuous variable in the multivariable logistic regression model. Locally weighted scatter plot smoothing did not demonstrate a linear relationship between the log odds of in-hospital mortality and age, thus age was included as a categorical variable in the multivariable logistic regression model. Data were analysed using Stata Version 14 (Stata-Corp, College Station, TX, USA). *p* values of < 0.05 were considered significant.

Table 1 Adjusted associations with odds of patient mortality (multivariable logistic regression model included year, age category, Charlson Comorbidity Index, abdomen AIS score, isolated abdominal injury)

Characteristics	Odds ratio (95% confidence interval)	<i>p</i> value
Year	0.940 (0.886, 0.996)	0.036
Age category (years)		
16–29	<i>Reference</i>	
30–44	1.011 (0.633, 1.614)	0.965
45–64	1.541 (0.963, 2.468)	0.072
65 or more	6.292 (3.957, 10.007)	< 0.001
Charlson Comorbidity Index		
None	<i>Reference</i>	
One	0.331 (0.187, 0.585)	< 0.001
2 or more	1.348 (0.869, 2.094)	0.183
Abdominal injury AIS score		
3	<i>Reference</i>	
4	1.470 (1.006, 2.147)	0.047
5 or 6	4.821 (3.064, 7.585)	< 0.001
Isolated abdominal injury	0.261 (0.174, 0.390)	< 0.001

p values reaching significance are indicated in bold. The area under the ROC curve was 0.8

Table 2 Incidence rate ratios over the study period for age category, mechanism, and type of injury amongst major trauma patients with serious abdominal injury

Characteristics	Rate ratio (95% confidence interval)	<i>p</i> value
Age group (years)		
16–29	0.994 (0.973–1.016)	0.607
30–44	1.028 (1.001–1.055)	0.041
45–64	1.033 (1.008–1.066)	0.044
≥ 65	1.046 (1.002–1.093)	0.042
Trauma type		
Blunt	1.019 (1.004–1.035)	0.012
Penetrating	0.997 (0.960–1.035)	0.868
Mechanism of injury		
MVC	0.998 (0.974–1.022)	0.845
MBC	1.045 (1.008–1.082)	0.016
Cyclist	1.088 (1.013–1.170)	0.022
Pedestrian	0.999 (0.944–1.057)	0.964
Low falls (≤ 1 m)	1.066 (1.005–1.129)	0.032
High falls (> 1 m)	1.027 (0.969–1.090)	0.366
Struck/collision with person/object	0.990 (0.922–1.061)	0.756

Denominator is whole population of Victoria for trauma type and mechanism of injury; and specific sub-population for each age group
p values reaching significance are indicated in bold

Results

Between 2007 and 2016, there were 2385 cases of hospitalised major trauma with a serious abdominal injury, representing 8.4% of all major trauma cases over the study period. Sixty-nine per cent ($n = 1649$) of these patients underwent a surgical and/or a radiological intervention, with 49% ($n = 1166$) undergoing a laparotomy only. Between 2007 and 2016, the population-adjusted incidence of serious abdominal injury increased by 1.6% per year (IRR 1.016, 95% CI 1.002–1.031; $p < 0.024$). Whilst the incidence of serious abdominal injury increased by 2.0% per year for blunt trauma, there was no change in the incidence of penetrating abdominal trauma (Table 2, Fig. 1). A rise in incidence of serious abdominal injury was observed in all age groups except for patients aged 16–29 years. The fastest increase was reported amongst the 65 years and over group, which was 4.6% per year (Table 2, Fig. 2).

There were notable differences between patients within each of the four management groups. NOM was greater amongst individuals aged between 16 and 29 years, compared with other age groups. In contrast, patients aged over 65 years had the highest proportion of injuries managed with embolisation only and had the lowest proportion of laparotomy only (Table 3).

Fig. 1 Population-adjusted incidence of serious abdominal injury between 2007 and 2016

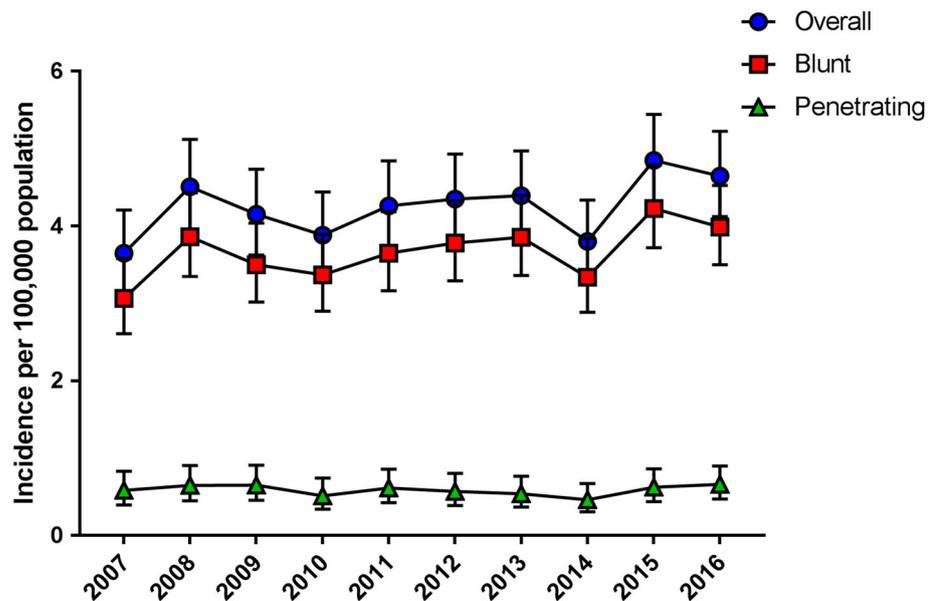
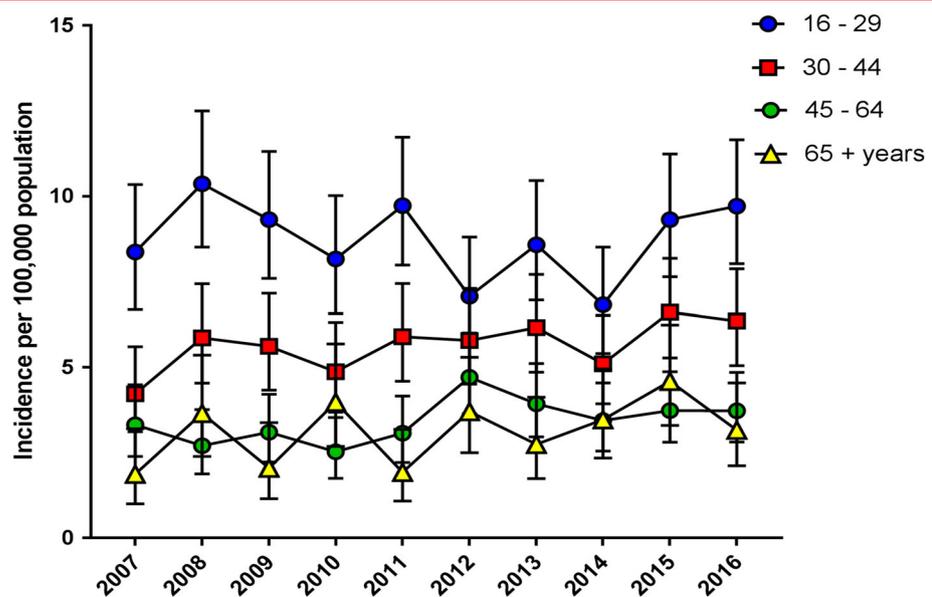


Fig. 2 Population-adjusted incidence of serious abdominal injury between 2007 and 2016, shown by age groups



The majority of patients who sustained injuries secondary to low falls also had a laparotomy and/or embolisation, and these patients were also the group with the highest proportion of embolisation (Table 3).

Half of patients with serious abdominal injury secondary to blunt trauma had a laparotomy. In contrast, the vast majority of patients with penetrating trauma had a laparotomy. In addition, a significantly greater proportion of patients with isolated abdominal injury had a laparotomy, relative to patients with multisystem injuries. Over two-thirds of patients who presented with a systolic blood

pressure less than 90 mmHg received a laparotomy (Table 3).

Analysis of injury groups showed two-thirds of patients aged 16 to 29 years had solid organ injuries only, and patients aged 65 years and over had twice the prevalence of vascular injuries compared with other age groups (Table 4). Approximately, half of patients with solid organ injury only received non-operative management. In contrast, most patients with hollow injuries, multiple types of abdominal injuries and other types of abdominal injuries had a laparotomy. A quarter of patients in both the solid

Table 3 Comparison of demographics and injury profile of abdominal trauma patients by type of management

Characteristics	Laparotomy only N = 1166 (100%)	Embolisation only N = 377 (100%)	Laparotomy/embolisation N = 106 (100%)	NOM N = 736 (100%)	p value
Age category (years)					
16–29	450 (38.6%)	136 (36.1%)	45 (42.5%)	347 (47.1%)	< 0.001
30–44	363 (31.1%)	105 (27.9%)	32 (30.2%)	183 (24.9%)	
45–64	253 (21.7%)	75 (19.9%)	13 (12.3%)	131 (17.8%)	
65 plus	100 (8.6%)	61 (16.2%)	16 (15.1%)	75 (10.2%)	
Sex					
Male	870 (74.6%)	290 (76.9%)	77 (72.6%)	524 (71.2%)	0.17
Female	296 (25.4%)	87 (23.1%)	29 (27.4%)	212 (28.8%)	
Charlson Comorbidity Index weighting					
None	844 (72.4%)	259 (68.7%)	54 (50.9%)	562 (76.4%)	< 0.001
One	207 (17.8%)	81 (21.5%)	24 (22.6%)	125 (17.0%)	
2 or more	115 (9.9%)	37 (9.8%)	28 (26.4%)	49 (6.7%)	
Index of relative socio-economic advantage and disadvantage quintile^a					
1 (most disadvantaged)	210 (18.8%)	47 (12.9%)	12 (12.1%)	108 (15.1%)	0.091
2	169 (15.1%)	51 (14.0%)	18 (18.2%)	113 (15.8%)	
3	248 (22.2%)	84 (23.1%)	26 (26.3%)	170 (23.7%)	
4	250 (22.4%)	84 (23.1%)	28 (28.3%)	175 (24.4%)	
5 (least disadvantaged)	241 (21.6%)	98 (26.9%)	15 (15.2%)	150 (20.9%)	
Accessibility/Remoteness Index of Australia					
Major cities of Australia	801 (71.8%)	265 (73.0%)	78 (79.6%)	488 (68.3%)	0.094
Inner regional	254 (22.8%)	76 (20.9%)	13 (13.3%)	188 (26.3%)	
Outer regional/remote Australia	60 (5.4%)	22 (6.1%)	7 (7.1%)	38 (5.3%)	
Intent of injury					
Unintentional	837 (71.8%)	337 (89.4%)	90 (84.9%)	668 (90.8%)	< 0.001
Intentional—self harm	91 (7.8%)	8 (2.1%)	7 (6.6%)	19 (2.6%)	
Intentional—other	204 (17.5%)	26 (6.9%)	7 (6.6%)	36 (4.9%)	
Intent could not be determined	34 (2.9%)	6 (1.6%)	2 (1.9%)	13 (1.8%)	
Mechanism					
Motor vehicle collision	461 (39.5%)	89 (23.6%)	35 (33.0%)	224 (30.4%)	< 0.001
Motorcycle collision	112 (9.6%)	79 (21.0%)	22 (20.8%)	161 (21.9%)	
Cyclist	31 (2.7%)	19 (5.0%)	3 (2.8%)	41 (5.6%)	
Pedestrian	53 (4.5%)	29 (7.7%)	19 (17.9%)	44 (6.0%)	
Other transported related	2 (0.2%)	3 (0.8%)	0 (0.0%)	3 (0.4%)	
Low fall	46 (3.9%)	41 (10.9%)	2 (1.9%)	53 (7.2%)	
High fall	38 (3.3%)	33 (8.8%)	8 (7.5%)	57 (7.7%)	
Struck or collision with person/object	109 (9.3%)	53 (14.1%)	6 (5.7%)	90 (12.2%)	
Other	314 (26.9%)	31 (8.2%)	11 (10.4%)	63 (8.6%)	
Trauma type					
Blunt	883 (75.7%)	368 (97.6%)	96 (90.6%)	710 (96.5%)	< 0.001
Penetrating	283 (24.3%)	9 (2.4%)	10 (9.4%)	26 (3.5%)	
Definite hospital of care					
Major Trauma Service	908 (77.9%)	345 (91.5%)	105 (99.1%)	582 (79.1%)	< 0.001
Non-Major Trauma Service	258 (22.1%)	32 (8.5%)	1 (0.9%)	154 (20.9%)	
Abdominal injury AIS score					
3	608 (52.1%)	171 (45.4%)	31 (29.2%)	358 (48.6%)	< 0.001
4	403 (34.6%)	178 (47.2%)	54 (50.9%)	331 (45.0%)	
5 or 6	155 (13.3%)	28 (7.4%)	21 (19.8%)	47 (6.4%)	
Injury pattern					

Table 3 continued

Characteristics	Laparotomy only N = 1166 (100%)	Embolisation only N = 377 (100%)	Laparotomy/embolisation N = 106 (100%)	NOM N = 736 (100%)	p value
Isolated abdominal injury	548 (47.0%)	221 (58.6%)	86 (81.1%)	429 (58.3%)	< 0.001
Multi-trauma	618 (53.0%)	156 (41.4%)	20 (18.9%)	307 (41.7%)	
Systolic blood pressure on admission ^c					
> 90	941 (82.5%)	334 (90.0%)	77 (75.5%)	668 (93.2%)	< 0.001
< 90	200 (17.5%)	37 (10.0%)	25 (24.5%)	49 (6.8%)	
Abdominal injury groups					
Solid organ	386 (33.1%)	309 (82.0%)	42 (39.6%)	595 (80.8%)	< 0.001
Hollow organ	427 (36.6%)	2 (0.5%)	15 (14.2%)	35 (4.8%)	
Other organ	177 (15.2%)	1 (0.3%)	8 (7.5%)	29 (3.9%)	
Vascular organ	170 (14.6%)	65 (17.2%)	41 (38.7%)	68 (9.2%)	
Multiple	6 (0.5%)	0 (0.0%)	0 (0.0%)	9 (1.2%)	
Survival to hospital discharge					
Yes	1077 (92.4%)	359 (95.2%)	91 (85.8%)	687 (93.3%)	0.009
No	89 (7.6%)	18 (4.8%)	15 (14.2%)	49 (6.7%)	

^an = 88 missing; ^bn = 95 missing; ^cn = 54 missing

p values reaching significance are indicated in bold

Missing values indicated in footnotes where relevant

organ and vascular injury groups had embolisation only (Tables 3, 4).

A rise in the incidence of abdominal injury was observed amongst pedal cyclists (9.0% per year), followed by low falls (7.0% per year), and motorcyclists (4.0% per year). Despite the observed trends in mechanism of injury, there was no change over time in the proportion of patients with solid organ only ($p = 0.23$), hollow organ only ($p = 0.52$), other ($p = 0.90$), or multiple injuries ($p = 0.64$). There was, however, a decline in the proportion of patients with only vascular injuries ($p = 0.04$).

There was no change over time in the proportion of isolated abdominal injury, compared with multisystem injuries ($p = 0.06$). In contrast, there were changes in the management of abdominal injuries over the study period. Specifically, there was a reduction in the proportion of injuries managed with laparotomy only from 60% in 2007 to 44% in 2016 ($p < 0.001$). In contrast, the proportion of injuries managed with embolisation only increased from 6% in 2007 to 20% in 2016 ($p < 0.001$). The proportion of patients managed non-operatively, or who had both a laparotomy and embolisation ($p = 0.234$ and 0.617 , respectively), did not change over time (Fig. 3). The unadjusted odds of in-hospital mortality did not change over time [odds ratio (OR) = 0.97; 95% confidence interval (CI) = 0.92, 1.02; $p = 0.27$] (Table 1). In contrast, after adjusting for confounders (abdominal AIS score, isolated abdominal injury, age, and CCI), the adjusted odds of in-hospital mortality declined 6% per year (OR = 0.94; 95% CI = 0.89, 1.00; $p = 0.04$) (Table 1).

Discussion

We investigated temporal trends in the incidence, profile of injury, and management of adult patients with serious abdominal injury over a 10-year period in an established and integrated trauma system. We observed an increase in the incidence of serious abdominal injury—greatest amongst patients aged 65 years and older. Overall, the rise in the incidence of serious injury was largely driven by increases in events resulting from motorcycle collision, pedal cycle collisions, and low falls.

There was a reduction over time in the proportion of patients who had a laparotomy, and an increase in the proportion of patients with embolisation—but no change in the proportion of patients managed without intervention. This suggests that the principles of selective NOM are being implemented, and have in part been enabled by an increase in cases managed with embolisation and better supportive management including damage-control resuscitation [13, 14].

Nonetheless, the fact that the proportion of patients managed without invasive intervention has not changed over time, and that many patients had a laparotomy suggests that selective NOM has limitations for patients with serious abdominal trauma. A large proportion of patients in this study were hypotensive on arrival and required urgent laparotomy. Appropriately, patients with hollow organ injury only and with multiple intra-abdominal injuries were seldom managed non-operatively.

Table 4 Comparison of demographics and injury profile of abdominal trauma patients by nature of injury

Characteristics	Solid organ N = 1332 (100%)	Hollow organ N = 479 (100%)	Other organ N = 215 (100%)	Vascular N = 344 (100%)	Multiple N = 15 (100%)	p value
Age category (years)						
16–29	617 (46.3%)	183 (38.2%)	69 (32.1%)	104 (30.2%)	5 (33.3%)	< 0.001
30–44	360 (27.0%)	143 (29.9%)	70 (32.6%)	105 (30.5%)	5 (33.3%)	
45–64	236 (17.7%)	106 (22.1%)	53 (24.7%)	75 (21.8%)	2 (13.3%)	
65 plus	119 (8.9%)	47 (9.8%)	23 (10.7%)	60 (17.4%)	3 (20.0%)	
Sex						
Male	997 (74.8%)	340 (71.0%)	151 (70.2%)	258 (75.0%)	15 (100.0%)	0.045
Female	335 (25.2%)	139 (29.0%)	64 (29.8%)	86 (25.0%)	0 (0.0%)	
Charlson Comorbidity Index weighting						
None	1002 (75.2%)	344 (71.8%)	143 (66.5%)	218 (63.4%)	12 (80.0%)	< 0.001
One	229 (17.2%)	92 (19.2%)	46 (21.4%)	68 (19.8%)	2 (13.3%)	
2 or more	101 (7.6%)	43 (9.0%)	26 (12.1%)	58 (16.9%)	1 (6.7%)	
Index of relative socio-economic advantage and disadvantage quintile^a						
1 (most disadvantaged)	188 (14.5%)	93 (20.4%)	35 (17.2%)	59 (17.8%)	2 (14.3%)	0.43
2	199 (15.4%)	66 (14.5%)	26 (12.8%)	58 (17.5%)	2 (14.3%)	
3	308 (23.8%)	98 (21.5%)	51 (25.1%)	67 (20.2%)	4 (28.6%)	
4	317 (24.5%)	97 (21.3%)	51 (25.1%)	70 (21.1%)	2 (14.3%)	
5 (least disadvantaged)	282 (21.8%)	101 (22.2%)	40 (19.7%)	77 (23.3%)	4 (28.6%)	
Accessibility/Remoteness Index of Australia^b						
Major cities of Australia	884 (68.4%)	333 (73.5%)	149 (73.8%)	254 (77.2%)	12 (85.7%)	0.042
Inner regional	324 (25.1%)	101 (22.3%)	43 (21.3%)	62 (18.8%)	1 (7.1%)	
Outer regional/remote Australia	84 (6.5%)	19 (4.2%)	10 (5.0%)	13 (4.0%)	1 (7.1%)	
Intent of injury						
Unintentional	1162 (87.2%)	336 (70.1%)	182 (84.7%)	244 (70.9%)	8 (53.3%)	< 0.001
Intentional—self harm	31 (2.3%)	50 (10.4%)	11 (5.1%)	31 (9.0%)	2 (13.3%)	
Intentional—other	108 (8.1%)	79 (16.5%)	20 (9.3%)	61 (17.7%)	5 (33.3%)	
Intent could not be determined	31 (2.3%)	14 (2.9%)	2 (0.9%)	8 (2.3%)	0 (0.0%)	
Mechanism of injury						
Motor vehicle collision	373 (28.0%)	207 (43.2%)	127 (59.1%)	101 (29.4%)	1 (6.7%)	< 0.001
Motorcycle collision	295 (22.1%)	21 (4.4%)	19 (8.8%)	37 (10.8%)	2 (13.3%)	
Cyclist	65 (4.9%)	14 (2.9%)	4 (1.9%)	10 (2.9%)	1 (6.7%)	
Pedestrian	68 (5.1%)	26 (5.4%)	12 (5.6%)	39 (11.3%)	0 (0.0%)	
Other transported related	3 (0.2%)	1 (0.2%)	1 (0.5%)	3 (0.9%)	0 (0.0%)	
Low fall	105 (7.9%)	18 (3.8%)	3 (1.4%)	16 (4.7%)	0 (0.0%)	
High fall	99 (7.4%)	9 (1.9%)	6 (2.8%)	22 (6.4%)	0 (0.0%)	
Struck or collision with person/object	195 (14.6%)	34 (7.1%)	11 (5.1%)	15 (4.4%)	3 (20.0%)	
Other	129 (9.7%)	149 (31.1%)	32 (14.9%)	101 (29.4%)	8 (53.3%)	
Trauma type						
Blunt	1267 (95.1%)	341 (71.2%)	189 (87.9%)	253 (73.5%)	7 (46.7%)	< 0.001
Penetrating	65 (4.9%)	138 (28.8%)	26 (12.1%)	91 (26.5%)	8 (53.3%)	
Definitive care						
Major Trauma Service	1052 (79.0%)	381 (79.5%)	196 (91.2%)	301 (87.5%)	10 (66.7%)	< 0.001
Non-Major Trauma Service	280 (21.0%)	98 (20.5%)	19 (8.8%)	43 (12.5%)	5 (33.3%)	
Abdominal injury AIS score						
3	537 (40.3%)	369 (77.0%)	102 (47.4%)	149 (43.3%)	11 (73.3%)	< 0.001
4	612 (45.9%)	97 (20.3%)	104 (48.4%)	149 (43.3%)	4 (26.7%)	
5 or 6	183 (13.7%)	13 (2.7%)	9 (4.2%)	46 (13.4%)	0 (0.0%)	

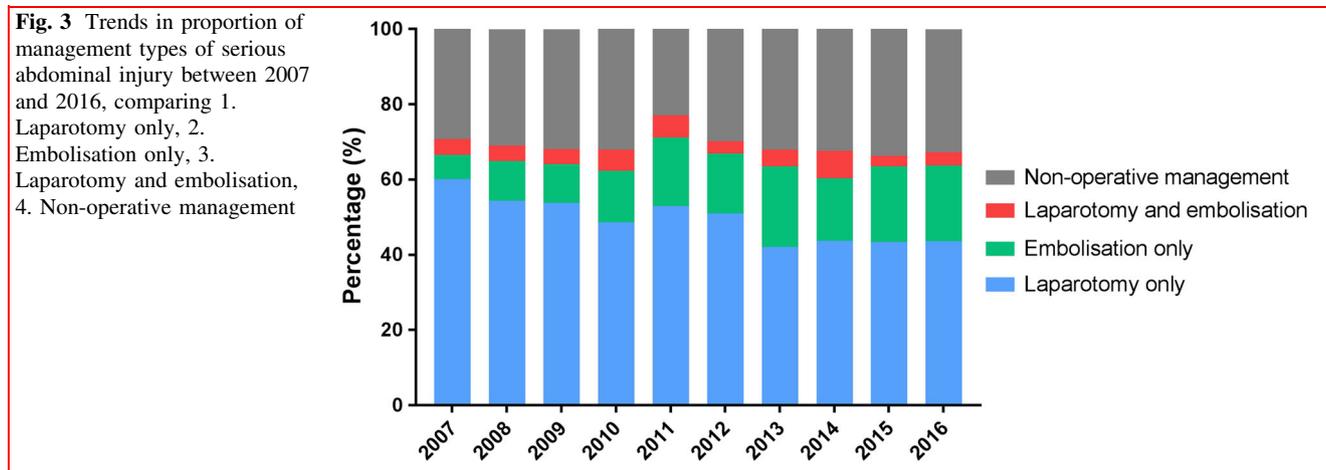
Table 4 continued

Characteristics	Solid organ N = 1332 (100%)	Hollow organ N = 479 (100%)	Other organ N = 215 (100%)	Vascular N = 344 (100%)	Multiple N = 15 (100%)	p value
Injury pattern						
Isolated abdominal injury	736 (55.3%)	217 (45.3%)	117 (54.4%)	209 (60.8%)	5 (33.3%)	< 0.001
Multi-trauma	596 (44.7%)	262 (54.7%)	98 (45.6%)	135 (39.2%)	10 (66.7%)	
Systolic blood pressure on admission^c						
> 90	1160 (89.1%)	416 (89.1%)	174 (82.9%)	257 (76.3%)	13 (86.7%)	< 0.001
< 90	142 (10.9%)	51 (10.9%)	36 (17.1%)	80 (23.7%)	2 (13.3%)	
Procedure groups						
Laparotomy only	386 (29.0%)	427 (89.1%)	177 (82.3%)	170 (49.4%)	6 (40.0%)	< 0.001
Embolisation only	309 (23.2%)	2 (0.4%)	1 (0.5%)	65 (18.9%)	0 (0.0%)	
Laparotomy/embolisation	42 (3.2%)	15 (3.1%)	8 (3.7%)	41 (11.9%)	0 (0.0%)	
Non-operative management	595 (44.7%)	35 (7.3%)	29 (13.5%)	68 (19.8%)	9 (60.0%)	
Survival to hospital discharge						
Yes	1259 (94.5%)	453 (94.6%)	198 (92.1%)	290 (84.3%)	14 (93.3%)	< 0.001
No	73 (5.5%)	26 (5.4%)	17 (7.9%)	54 (15.7%)	1 (6.7%)	

^an = 88 missing; ^bn = 95 missing; ^cn = 54 missing

p values reaching significance are indicated in bold

Missing values indicated in footnotes where relevant



Whilst the incidence of serious injuries amongst individuals aged 16–29 years remained stable, the incidence of injuries rose significantly in all other age groups. Importantly, this rise was greatest amongst older adults aged 65 years or more. Typically, this group has lower functional reserve, and a reduced capacity to respond to the stress of their initial injury and of a trauma laparotomy [25, 26]. Consequently, older patients have worse outcomes and reduced functional recovery following emergency laparotomy [27]. In contrast, angiography and embolisation place considerably less stress on older individuals, and may be a more desirable option, when possible [28, 29]. Moreover, older patients sustained greater rates of

vascular injuries, which may partly account for the observed rise in the proportion of embolisation over the study period. Importantly, despite the rise in incidence of serious abdominal injury, most predominantly amongst older patients, and the change in modality of their management, the adjusted odds of in-hospital mortality declined over time. This may be associated with the decline in the proportion of patients who had a laparotomy. Yet, other non-surgical elements of trauma management, such as early and judicious resuscitation, advances in critical care and implementation of trauma systems, may have also contributed to the observed reduction in mortality [14, 30, 31].

The mechanism of injury causing serious abdominal injury also changed over time. The largest increase in incidence of injury was observed amongst pedal cyclists followed by low falls. These results concur with global trends in epidemiology and pattern of major trauma, showing an increasing proportion of serious injuries amongst older individuals and caused by lower-energy impacts [32, 33]. A surprisingly large number of serious abdominal injuries occur secondary to mechanisms whereby one may not expect such severe injuries, particularly low falls. This may be due to the fact that they occur in a growing number of older and frail individuals, who develop more significant pathology in response to the same amount of force [34]. This has important clinical implications, as older patients are also less likely to present with typical symptoms such as peritonism, or with deranged vital signs, both of which are important determinants of operative versus non-operative management [25]. The risk of missed injuries and delayed diagnoses therefore warrants applying a high index of suspicion for serious injury in older patients presenting with abdominal trauma, including following low-energy impacts.

Strengths and limitations

The VSTR captures all cases of major trauma in the state of Victoria, which enables the estimation of the incidence of hospitalised major trauma patients with abdominal injuries and reduces the risk of selection bias. Our cohort was comparable to populations of major trauma patients previously studied, making results generalisable to countries with equivalent health systems.

An important caveat was that the cause of mortality was unknown. Other outcomes relevant to assessing the impact of the observed trends in management, such as in-hospital complications, were not measured. In addition, patients who died prior to hospitalisation were not captured in this study and the incidence of abdominal trauma may be under-estimated.

Future studies should aim to determine how an older, frail individual who presents with a serious abdominal injury can be managed as safely with a selective non-operative approach, as a younger adult with considerably greater functional reserve. This may entail comparing the impact of operative versus non-operative management on the morbidity and mortality of older patients with serious abdominal trauma.

Conclusions

Whilst the incidence of major abdominal trauma increased during the study period, the proportion of patients managed with laparotomy declined, and the proportion of patients

managed without intervention remained static. Adjusted odds of in-hospital mortality also declined over the same period. Although older trauma patients already have lower rates of laparotomy, it may be possible to reduce this further.

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Compliance with Ethical Standards

Conflict of interest There are no financial or other relationships that may lead to a conflict of interest or influence the content of the manuscript.

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