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Impact of Thoracic Trauma on the Mortality of Multi-trauma Patients: It Matters - Results From a French Road Trauma Registry 1997-2016

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Original research

Keywords: thoracic trauma, multi-trauma, road traffic accident, mortality

Posted Date: July 8th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-682244/v1

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Abstract

Background

Thoracic trauma is the third most common cause of death in multi-trauma patients and is associated with poor short-term outcomes since it is responsible for up to 25% of trauma-related deaths. One of the most frequent mechanism is road traffic accident (RTA), affecting particularly young patients. The primary objective of the present study was to investigate the influence of severe injuries in each body region on the mortality of multi-trauma patients with a particular attention to thoracic trauma. Secondary objectives were to investigate risk factors for mortality in multi-trauma patients but also to describe the epidemiology and injury pattern of these patients when presenting with at least one abbreviated injury scale (AIS) ≥2 thoracic injury (AIS_{Thorax}≥2).

Methods

Retrospective study that included RTA occurring from January 1997 to December 2016. Patients of all ages included in the Rhône RTA registry, with at least one AIS ≥2 injury in any body region were included. Two subgroups were defined according to whether patients presented at least one AIS_{Thorax}≥2 injury or not. Multivariate regression analysis with mortality as outcome was performed.

Results

A total of 46,526 patients had at least one AIS≥2 injury, among them 6,382 (13.7%) had at least one AIS_{Thorax}≥2 injury. In the AIS_{Thorax}≥2 group, the median [IQR] ISS was 14 [6-7] and 16.2% (n=1,031) patients died. Severe (AIS≥3) head (OR=26.8, 95%CI [20.4;35.2]) and thoracic (OR=12.2, 95%CI [8.4;17.7]) injuries were associated with death; as was age [40-59 years (OR=1.3, 95%CI [1.1;1.5]), 60-79 years (OR=2.1, 95%CI [1.7;2.6]), and ≥80 years (OR=5.5, 95%CI [4.2;7.3])], male sex (OR=1.5, 95%CI [1.3;1.7]), RTA occurring in a highway (OR=1.9, 95%CI [1.5;2.4]) or in a rural road (OR=1.8, 95%CI [1.5;2.1]). The most frequent thoracic injury was that of the chest wall (62.1%, n=5,419). The most frequent concomitant AIS≥2 injuries affected the head (29.1%), upper extremities (26.8%), and lower extremities (25.8%).

Conclusions

The present study found that the severity of thoracic trauma was an independent and significant risk factor for death in multi-trauma patients as was age, being a car occupant and having a crash in a rural road or a highway.

Background

Road traffic accidents (RTA) were the tenth leading cause of death in the world in 2000, the eighth in 2016, and could become the fifth by 2030 according to the World Health Organization; it affects in particular those aged 5 to 44 years, and the incidence of fatal RTA in low and middle-income countries is higher than in Europe or the United states [1, 2]. Victims of RTA often suffer multi-trauma and present with thoracic injuries in nearly 50% cases [3]. Furthermore, thoracic trauma is the third most common cause of death after abdominal injury and head trauma in multi-trauma patients [4]. Thoracic injuries are associated with poor short-term outcomes since there are responsible for up to 25% of trauma-related deaths [5, 6] and also poor long-term outcome; for example, persistent reduced 6-min walk distance, impaired pulmonary function, and reduced pulmonary-specific quality of life [7]. Hence, thoracic trauma represents a major medical and economic matter of concern, and a challenge to provide better care. Risk factors for mortality after thoracic trauma, including the influence of specific structural damages of the chest wall and thoracic organs on mortality have been investigated [6, 8, 9]. Furthermore, many studies have shown that thoracic injuries significantly contribute to the mortality of multi-trauma patients, in adults as well as in the paediatric population [10–12]. However, to the best of our knowledge, no study has investigated specifically the influence of severe injuries (abbreviated injury scale, AIS ≥ 3) in each body region in multi-trauma patients' mortality. The primary objective of the present study was therefore to investigate the influence of severe injuries in each body region on the mortality of multi-trauma patients with a particular attention to thoracic injuries. Secondary objectives were to investigate risk factors for mortality in multi-trauma patients and describe the epidemiology and injury pattern of these patients when presenting with at least one thoracic injury AIS ≥ 2 ($AIS_{Thorax} \geq 2$).

Methods

Study setting

This study used prospectively-recorded data from the Rhône RTA registry (*Registre des victimes d'accidents de la circulation du Rhône*) set up in 1995. The registry covers the Rhône area of France (1.83 million inhabitants, 676 inhabitants/km^2) and has been approved by the relevant national authorities (*Comité National des Registres*, CNR) and data protection agency and (*Commission Nationale de l'Informatique et des Libertés*, CNIL; N° 999211). It is part of the Gustave Eiffel university, Lyon. The registry team is in charge of centralization, verification of the data from different sources about the same accident or victim, coding, storage and filing, and statistical analysis. The registry inclusion criteria are as follows: a RTA involving at least one vehicle (motorised or not) occurring in the Rhône area, requiring institutional healthcare from one of the 245 private and public healthcare structures cooperating together, including prehospital primary care teams and forensic medicine institutes. Each injury was coded by a medical physician according to the AIS (version 1990 for years 1996 to 2014, and version 2005 for years 2015 and 2016) which is a severity score, ranging from 1 (minor) to 6 (beyond treatment) [13]. The injury severity score (ISS) was calculated from the three worst-affected body regions as the sum of squares of the respective AIS severity levels. Road users were divided into five categories: car occupants, motorcyclists, bicyclists, pedestrians, and other road users (roller skaters, skate boarders, bus occupants, truck occupants etc.). Death was medically certified at the scene or noted in medical charts during hospital stay.

Study design

We conducted a retrospective study that included RTA occurring during the period from January 1997 to December 2016. As victims could suffer from several injuries in a given body region, the maximum AIS (MAIS) was scored using the injury of the highest severity.

Data collection

The registry collects the demographic characteristics of each RTA casualty and a description of the body injuries sustained. Data are collected prospectively in three consecutive time periods from the accident site until hospital discharge: prehospital scene, emergency room or intensive care unit, and discharge. Several variables were extracted and analysed: patient characteristics (sex, age, road user category), road network, anatomical injuries, severity score (AIS and ISS), and outcome (intensive care unit admission and mortality). Data collection method has been described previously [14].

Population

Inclusion criteria for the present study were patients of all ages included in the registry, with at least one AIS≥2 injury in any body region (AIS≥2 group). Two subgroups were defined: AIS_{Thorax}≥2 group included all patients from AIS≥2 group suffering from at least one thoracic AIS≥2 injury, and AIS_{Thorax}<2 group included those who did not. There was no exclusion criterion.

Statistical analysis

Baseline characteristics were described by frequencies and percentages for categorical variables, and medians and interquartile range [IQR] for continuous variables. Comparisons between groups were made using the Pearson Chi² test for categorical variables. We then performed a logistic regression with mortality as outcome. Significant prognostic variables at 20% significance on the univariate analysis were included in analysis. Because the mechanism of burn injury-related death is specific [15,16] we excluded patients from the logistic regression if they had suffered severe burn injury (n=42). The odds ratio (OR) for each risk factor investigated was calculated as well as the corresponding 95% confidence intervals (CI). Statistical analyses were performed using SAS (Statistical Analysis System v9.4, SAS Institute Inc., Cary, NC, USA). In all analysis, p<0.05 was considered as statistically significant.

Results

Patient characteristics

Over the study period, a total of 176,346 victims were included in the registry; 46,526 (26.4%) had at least one AIS ≥ 2 injury and were included in the present study (AIS ≥ 2 group). Among these, 6,382 (13.7%) had at least one thoracic injury AIS_{Thorax}≥2 (AIS_{Thorax}≥2 group; Fig. 1). The median [IQR] age was greater in the AIS ≥ 2 group (41 [25–58] years) than in the AIS < 2 group (26 [18–42] years, p < 0.001), and there were more females (31.1% vs. 26.9%, p < 0.001). There was a difference in the distribution of road users between those in the AIS_{Thorax}≥2 group and those in the AIS < 2 group (p < 0.001); those in the

$AIS_{Thorax} \geq 2$ group were more frequently car occupants (52.3%) than those in the AIS < 2 group (23.4%). There was also a difference in the distribution of road network ($p < 0.001$); the RTA occurred more frequently on a highway (11.3% vs 5.7%) or a rural road (23.4% vs 10.6%; Table 1). Among females in the $AIS_{Thorax} \geq 2$ group, the maximal incidence of RTA was in the 70–79 years age group (23.1/100,000 inhabitants) and this was found in the 20–29 years age group among males (39.1/100,000 inhabitants; Fig. 2). In the $AIS_{Thorax} \geq 2$ group, the age group with the greatest proportion of car occupants was 70–79 years (67.9% of this category), for motorcyclists this was 30–39 years (35.9%), for pedestrians it was 0–9 years (55.9%), and for bicyclists it was 60–69 years (10.9%; Fig. 3)

Table 1
Demographics and mechanism

	AIS ≥ 2 group (n = 46,526)	**AIS_{Thorax}≥2 group (n = 6,382)**	**$AIS_{Thorax<}$2 group (n = 40,144)**	**p-value**
Age, years	28 [18–45]	41 [25–58]	26 [18–42]	< 0.001
0–9	2,468 (5.3)	93 (1.5)	2,375 (5.9)	
10–19	11,066 (23.8)	658 (10.3)	10,408 (25.9)	
20–39	18,084 (38.9)	2,246 (35.2)	15,838 (39.5)	
40–59	9,808 (21.1)	1,930 (30.2)	7,878 (19.6)	
60–79	4,069 (8.7)	1,157 (18.1)	2,912 (7.3)	
≥ 80	986 (2.1)	291 (4.6)	695 (1.7)	
Missing data	45 (0.1)	7 (0.1)	38 (0.1)	
Sex				< 0.001
Male	33,738 (72.5)	4,400 (68.9)	29,338 (73.0)	
Female	12,778 (27.4)	1,982 (31.1)	10,796 (26.9)	
Missing data	10 (< 0.1)	0 (0)	10 (< 0.1)	
Road user				< 0.001
Car occupant	12,739 (27.4)	3,337 (52.3)	9,402 (23.4)	
Pedestrian	6,011 (12.9)	677 (10.6)	5,334 (13.3)	
Bicyclist	8,783 (18.9)	439 (6.9)	8,344 (20.8)	
Motorcyclist	14,497 (31.2)	1,617 (25.3)	12,880 (32.1)	
Other	4,496 (9.6)	312 (4.9)	4,184 (10.4)	
Missing data	0 (0)	0 (0)	0 (0)	

Statistics presented: n (%); median [IQR]

AIS ≥ 2 group $_2$: multi-trauma patients presenting with at least one injury AIS ≥ 2,

AIS_{Thorax}≥2 group: multi-trauma patients presenting with at least one thoracic injury AIS ≥ 2, AIS_{Thorax}<2 group $_2$: multi-trauma patients presenting with at least one injury AIS ≥ 2 but not in the thoracic region; AIS: abbreviated injury scale

	AIS ≥ 2 group (n = 46,526)	AIS_{Thorax}≥2 group (n = 6,382)	$AIS_{Thorax<}$2 group (n = 40,144)	p-value
Road network				< 0.001
City street	26,238 (56.4)	3,361 (52.7)	22,877 (57.0)	
Highway	3,006 (6.5)	723 (11.3)	2,283 (5.7)	
Rural road	5,745 (12.3)	1,497 (23.4)	4,248 (10.6)	
Other	11,537 (24.8)	801 (12.6)	10,736 (26.7)	
Missing data	0 (0)	0 (0)	0 (0)	
Statistics presented: n (%); median [IQR]				
AIS ≥ 2 group $_2$: multi-trauma patients presenting with at least one injury AIS ≥ 2,				
AIS_{Thorax}≥2 group: multi-trauma patients presenting with at least one thoracic injury AIS ≥ 2, AIS_{Thorax}<2 group $_2$: multi-trauma patients presenting with at least one injury AIS ≥ 2 but not in the thoracic region; AIS: abbreviated injury scale				

In the AIS_{Thorax}≥2 group, the median [IQR] ISS was 14 [6–27], 30.8% (n = 1,968) of patients were admitted to an intensive care unit, and 16.2% (n = 1,031) patients died. Of these patients, 61.5% (634/1,031) died on-scene, 75.8% (782/1,031) did so during the first 24 hours, and 90.6% (934/1,031) within the first three days. Thoracic injuries were the cause of death for 42.7% (440/1,031) victims. According to the road user category, pedestrians had the highest mortality (30.6%, 207/677); there were 17.6% (285/1,617) deaths among motorcyclists, 13.6% (455/3,337) deaths among car occupants, 12.2% (38/312) among other road users and 10.5% (46/439) deaths among bicyclists. There were 1.4% (36/2,541) of patients with $MAIS_{Thorax}$=2 who died, 7.9% (164/2,084) with $MAIS_{Thorax}$=3 died, and 47.3% (831/1757) patients with $MAIS_{Thorax}$ ≥4 died.

Risk factors for mortality

There was a total of 42 patients with severe burn injury who were excluded from multivariate logistic regression analysis. Severe injuries were independently associated with a greater risk of death and this was found in all body regions. Severe head injuries had the highest risk for death (OR = 26.8, 95%CI [20.4;35.2]), and severe thoracic injuries were the second most strongly associated with death (OR = 12.2, 95%CI [8.4;17.7]). Another risk factor for death was age: patients aged 40–59 years (OR = 1.3, 95%CI [1.1;1.5]), 60–79 years (OR = 2.1, 95%CI [1.7;2.6]), and ≥ 80 years (OR = 5.5, 95%CI [4.2;7.3]) had a greater risk of death than those aged 20–39 years; as was male sex (OR = 1.5, 95%CI [1.3;1.7]). No road user was at a greater risk of death compared to car occupants while bicyclists (OR = 0.4, 95%CI [0.3;0.5]) and motorcyclists (OR = 0.8, 95%CI [0.7;0.9]) were at lower risk of death. Compared to RTA occurring in a city street, those occurring in a highway (OR = 1.9, 95%CI [1.5;2.4]) or in a rural road (OR = 1.8, 95%CI [1.5;2.1]) were at greater risk of death in multi-trauma patients (Table 2).

Table 2
Predictors of mortality in univariate and multivariate analysis in AIS ≥ 2 group

		Univariate analysis		Multivariate analysis	
		OR	[95%CI]	OR	[95%CI]
Head	AIS = 2	Reference		Reference	
	AIS ≥ 3	57.9	[44.9;74.5]	26.8	[20.4;35.2]
Face	AIS = 2	Reference		Reference	
	AIS ≥ 3	16.7	[11.9;23.5]	11.5	[7.3;18.1]
Neck	AIS = 2	Reference		Reference	
	AIS ≥ 3	2.3	[1.1;4.6]	2.4	[0.8;6.9]
Thorax	AIS = 2	Reference		Reference	
	AIS ≥ 3	24.3	[17.3;33.9]	12.2	[8.4;17.7]
Abdomen and pelvis	AIS = 2	Reference		Reference	
	AIS ≥ 3	6.9	[5.3;9.2]	10.7	[7.5;15.3]
Spine	AIS = 2	Reference		Reference	
	AIS ≥ 3	4.7	[3.8;5.9]	3.6	[2.6;4.9]
Upper extremity	AIS = 2	Reference		Reference	
	AIS ≥ 3	4.1	[3.4;5.0]	2.8	[2.2;3.6]
Lower extremity	AIS = 2	Reference		Reference	
	AIS ≥ 3	8.9	[7.4;10.9]	5.1	[3.9;6.3]
Age (years)	0–9	0.4	[0.3;0.5]	0.5	[0.3;0.8]
	10–19	0.5	[0.4;0.6]	0.7	[0.5;0.8]
	20–39	Reference		Reference	
	40–59	1.1	[0.9;1.3]	1.3	[1.1;1.5]
	60–79	2.1	[1.8;2.5]	2.1	[1.7;2.6]
	≥ 80	4.9	[4.0;5.9]	5.5	[4.2;7.3]
Sex	Female	Reference		Reference	
	Male	1.2	[1.03;1.3]	1.5	[1.3;1.7]

$\text{Group}_{\text{AIS}\geq 2}$: multi-trauma patients presenting with at least one injury AIS ≥ 2, AIS: abbreviated injury scale. $p < 0.02$ for all variables in the univariate analysis

Road user	Car occupants	Reference		Reference	
	Pedestrians	1.1	[0.9;1.3]	1.1	[0.9;1.3]
	Bicyclists	0.2	[0.1;0.2]	0.4	[0.3;0.5]
	Motorcyclists	0.5	[0.4;0.6]	0.8	[0.7;0.9]
	Other	0.3	[0.2;0.4]	0.7	[0.5;1.002]
Road network	City street	Reference		Reference	
	Highway	2.5	[2.1;2.9]	1.9	[1.5;2.4]
	Rural road	2.5	[2.2;2.8]	1.8	[1.5;2.1]
	Other	0.2	[0.2;0.3]	0.5	[0.4;0.7]

$Group_{AIS\geq2}$: multi-trauma patients presenting with at least one injury AIS ≥ 2, AIS: abbreviated injury scale. $p < 0.02$ for all variables in the univariate analysis

Injury pattern

The most frequent thoracic injury was that of the chest wall (62.1%, n = 5,419); 52.4% of these were multiple rib fractures. The second most frequent thoracic injury was that of the lung (24.7%, n = 2,158); 88.7% of these were lung contusions. Pleural injuries (including pneumothorax and haemothorax) was found in 5.3% (n = 466) of cases (Table 3). The frequency of $MAIS_{Thorax}$=2 injuries increased with age while that of $MAIS_{Thorax}$=3 injuries decreased (Fig. 4). Among those with a thoracic injury, 29.1% suffered concomitant AIS ≥ 2 head trauma, 26.8% upper extremity injuries, and 25.8% lower extremity injuries; in addition, 17.9% suffered concomitant AIS ≥ 2 abdomen and pelvis injuries, 16.3% spine injuries, 7.5% face injuries, 1.1% neck injuries, and 0.08% skin injuries (Table 4).

Table 3
Description of thoracic injuries in the $AIS_{Thorax} \geq 2$ group

Chest wall injuries	**5,419/8,729 (62.1)**
Multiple rib fracture	**2,842/5,419 (52.4)**
Sternal fracture	**1,719/5,419 (31.7)**
Flail chest	**478/5,419 (8.8)**
Single rib fracture	**276/5,419 (5.1)**
Other	**104/5,419 (2)**
Lung injuries	2,158/8,729 (24.7)
Pulmonary contusion	1,914/2,158 (88.7)
Pulmonary laceration	244/2,158 (11.3)
Pleural and mediastinal injuries	466/8,729 (5.3)
Pneumo and/or haemothorax	352/466 (75.5)
Pneumo and/or haemomediastinum	105/466 (22.5)
Other	9/466 (2)
Cardiac or vascular injuries	421/8,729 (4.8)
Cardiac	227/421 (54)
Thoracic aorta	120/421 (28.5)
Pulmonary arteries/veins	46/421 (11)
Coronary artery	12/421 (2.9)
Subclavian artery/vein	10/421 (2.4)
Other	5/421 (1.2)
Other injuries	265/8,729 (3)
Skin injuries	151/265 (57)
Diaphragmatic injuries	83/265 (31.3)
Tracheal and bronchial injuries	21/265 (7.9)
Esophageal injuries	10/265 (3.8)

Statistics presented: n (%). One patient could have suffered from multiple thoracic injuries, therefore the total of injuries (8,729) presented in the table is greater than the number of $AIS_{Thorax} \geq 2$ patients.

$AIS_{Thorax} \geq 2$ group: multi-trauma patients presenting with at least one thoracic injury AIS ≥ 2.

Table 4
Incidence and comparison of thoracic and concomitant extra-thoracic injuries between $\text{AIS}_{\text{Thorax}}\geq 2$ group and $\text{AIS}_{\text{Thorax}}<2$ group.

	AIS ≥ 2 group (n = 46,526)	**$\text{AIS}_{\text{Thorax}}\geq 2$ group (13.8%, n = 6,382)**	**$\text{AIS}_{\text{Thorax}}<2$ group (86.2%, n = 40,144)**	**p-value**
Head				< 0.001
AIS = 2	8,934 (19.2)	587 (9.2)	8,347 (20.8)	
AIS ≥ 3	3,162 (6.8)	1,268 (19.9)	1,894 (4.7)	
No injury	34,430 (74.0)	4,527 (70.9)	29,903 (74.5)	
Face				< 0.001
AIS = 2	1,995 (4.3)	384 (6.0)	1,611 (4.0)	
AIS ≥ 3	186 (0.4)	93 (1.5)	93 (0.2)	
No injury	44,345 (95.3)	5,905 (92.5)	38,440 (95.8)	
Neck				< 0.001
AIS = 2	73 (0.2)	35 (0.5)	38 (0.1)	
AIS ≥ 3	59 (0.1)	33 (0.3)	26 (0.1)	
No injury	46,394 (99.7)	6,314 (98.9)	40,080 (99.8)	
Thorax				-
AIS = 2	2,541 (5.5)	2,541 (39.8)	0 (0.0)	
AIS ≥ 3	3,841 (8.3)	3,841 (60.2)	0 (0.0)	
No injury	40,144 (86.3)	0 (0.0)	40,144 (100)	
Abdomen/pelvis				< 0.001
AIS = 2	1,082 (2.3)	539 (8.4)	543 (1.4)	
AIS ≥ 3	1,005 (2.2)	604 (9.5)	401 (1.0)	
No injury	44,439 (95.5)	5,239 (82.1)	39,200 (97.6)	

Statistics presented: n (%)

AIS ≥ 2 group: multi-trauma patients presenting with at least one injury AIS ≥ 2.

$\text{AIS}_{\text{Thorax}}\geq 2$ group: multi-trauma patients presenting with at least one thoracic injury AIS ≥ 2; $\text{AIS}_{\text{Thorax}}<2$ group: multi-trauma patients presenting with at least one injury AIS ≥ 2 but not in the thoracic region; AIS: abbreviated injury scale.

	AIS ≥ 2 group (n = 46,526)	AIS_{Thorax}≥2 group (13.8%, n = 6,382)	AIS_{Thorax}<2 group (86.2%, n = 40,144)	p-value
Spine				< 0.001
AIS = 2	2,707 (5.8)	717 (11.2)	1,990 (5.0)	
AIS ≥ 3	731 (1.6)	322 (5.0)	409 (1.0)	
No injury	43,088 (92.6)	5,345 (83.7)	37,745 (94.0)	
Upper extremity				< 0.001
AIS = 2	15,675 (33.7)	1,259 (19.7)	14,416 (35.9)	
AIS ≥ 3	3,363 (7.2)	454 (7.1)	2,909 (7.2)	
No injury	37,488 (59.1)	4,669 (73.2)	22,819 (56.8)	
Lower extremity				< 0.001
AIS = 2	10,166 (21.9)	659 (10.3)	9,507 (23.7)	
AIS ≥ 3	5,032 (10.8)	987 (15.5)	4,045 (10.1)	
No injury	31,328 (67.3)	4,736 (74.2)	26,592 (66.2)	
Skin				0.223
AIS = 2	27 (0.06)	3 (0.05)	24 (0.06)	
AIS ≥ 3	42 (0.09)	2 (0.03)	40 (0.09)	
No injury	46,457 (99.85)	6,377 (99.92)	40,080 (99.85)	
Statistics presented: n (%)				
AIS ≥ 2 group: multi-trauma patients presenting with at least one injury AIS ≥ 2.				
AIS_{Thorax}≥2 group: multi-trauma patients presenting with at least one thoracic injury AIS ≥ 2; AIS_{Thorax}<2 group: multi-trauma patients presenting with at least one injury AIS ≥ 2 but not in the thoracic region; AIS: abbreviated injury scale.				

Discussion

In the present study severe thoracic trauma showed the second most strong impact on patient mortality, after severe head trauma and before severe injuries to the abdomen and extremities. In addition, three-quarters of those with a severe thoracic trauma and who died did so within the first 24 hours. Surprisingly, Grubmüller *et al*. found that the presence of a severe thoracic trauma had no influence on mortality [17], contrary to that found herein results and other previous investigation [9]. They hypothesized that this finding could be lead to the high case load of their level I trauma centre (> 100/centre) whereas our study included level I to III trauma centres. Indeed, some authors suggested that the hospital volume of severely injured patients may be an independent predictor of survival [18, 19]. Furthermore, their results are based on a single-centre experience where penetrating trauma were excluded as patients suffering unsuccessful emergency resuscitation. In the present study, road network (highway and rural road compared to city street), road user (car occupant) and sex (male) were significantly associated with a higher risk of death while trauma severity (AIS) was included in the multivariate analysis. Because we dichotomised level of severity in two groups (AIS = 2 *vs* AIS ≥ 3), the distribution of AIS ≥ 3 could not be homogenous between road network categories, user categories and sex and could resulted in higher frequency of severe (AIS 4), critical (AIS 5) and beyond treatment (AIS 6) injuries in some groups among previous cited categories which could explain our results.

In accordance with other studies [8, 17], there was a significant association between age and mortality; older patients (≥ 40 years) having considerably poorer outcome. First because the elderly (≥ 65 years) are more susceptible to develop respiratory failure and other complications such as pneumonia [20]. Secondly, they may also suffer pre-existing chronic conditions especially cardiopulmonary disease and use pre-injury anticoagulants. All these factors have been reported to be significantly associated with death [6, 8, 20]. Battle *et al.*[6] suggested in their meta-analysis a cut-off age of 65 years as the age at which risk of mortality increases significantly.

In the present study, mortality was similar to what is reported elsewhere, Grubmüller *et al*. reported mortality was 13.2% [17], Huber *et al*. reported a 17.5% mortality [9] and Veysi *et al*. mortality was 18.7% in their cohort [5]. In contrast, in the German multicentre database TraumaRegister DGU®, Horst *et al.*. [21] reported an overall mortality rate around 5% in their 10-year-period study. So did Chrysou *et al*. with a reported mortality of 5.5%.[12] However, only patients reaching the hospital with vital signs were included whereas in the present study we did not exclude on-scene dead patients. If we had excluded these patients, we would have found a close mortality rate of 6.2%.

The present study found a lower incidence of thoracic trauma compared to that reported elsewhere [9, 22, 23]. This was probably underestimated herein as those suffering minor thoracic injuries (AIS_{Thorax}=1), including single rib fractures, were excluded. Peek *et al*. recently reported in their nationwide studies that single rib fracture were frequently encountered injuries (20% of rib fractures) [24, 25]. We chose not to include these patients because previous studies have demonstrated that these single rib fractures were not associated with mortality [9]. We also noted that Chrysou *et al.* reported lower incidence of sternal fracture (15.5%) but a higher incidence of concomitant spine injuries (53.6%); which may be explained by the inclusion of patients suffering fall from height and snow sport accidents in their study [12] which have been previously reported as a significant source of traumatic spinal cord injuries [26, 27].

Another interesting finding of the present study is the evolution of AIS_{Thorax} 2 and 3 with age. AIS 3 injuries incidence was the highest in children (0–9 years) and decreased with age. This is in line with Samarasekera *et al*. findings reported a very high incidence of AIS > 2 injuries (88%) among children (< 15years) thoracic injuries with 65% of them being lung contusions [28] and Ostrmann *et al*. recently reported half of thoracic injuries being lung contusions (AIS 3) [29]. One explanation is the difference in anatomy; the thoracic skeleton of children being incompletely calcified and more compressible allowing for the transmission of large forces to the structures of the thoracic cavity, making rib fractures uncommon. Thus, high-energy impact trauma may cause major internal injuries with little evidence of external injuries or fractures of the bony thorax as reported by many authors [29–31]. Furthermore, as children are more frequently involved in RTA as pedestrians they may be at higher risk of projection and severe trauma caused by direct impact with the front bumper because of their smaller height. In contrast, the incidence of AIS = 2 injuries incidence increased with age. We assumed that these injuries are mainly rib fractures. which, in the elderly, have been reported as the most frequent after a RTA [32]. They required less force compared to young patients because of osteoporosis and loss of muscle mass.

This study has a number of limitations. One of them is the update of AIS during the study period [33]. Nevertheless, we chose to base severity assessment on AIS because it has been extensively used in the literature and is an accurate, objective and validated method to independently evaluate each body region impact on mortality [34] contrary to the ISS that evaluates the overall severity [35]. Besides, Hsu *et al.*[36] found that the AIS update had no impact on mean ISS when considering the thoracic body region. Although it is a register study with the known weaknesses, the present multicentre study is based on data prospectively collected over a 20-year-period from level I to III trauma centres and included patients of all ages whereas many studies focused on thoracic trauma are single centre studies and only included patients ≥ 16 years [5, 8, 12, 17, 22, 37]. Thus, our findings are generalisable to other high-income countries. Besides, data were collected by emergency physicians, blinded to which of the risk factors and outcomes were being used in the present study. Another limitation is that the Rhône registry only includes victims of RTA. Therefore, the registry represents a trauma population with a majority of blunt trauma and other reported thoracic mechanisms such as falls, or stab/fire gun injuries, have not been studied here. Also, the database does not report medical management; there is therefore no data regarding prehospital management, time to surgery when needed, intensive care unit management such as airway and ventilation management, use of catecholamines or massive blood transfusion, and no detail on organ and respiratory failure or pre-existing cardiopulmonary disease which have been reported to influence outcome in thoracic trauma patients[6, 8, 9, 17]. It must also be taken into consideration that a significant proportion of deaths occur in the operation theatre, thus, the exact impact of thoracic injury related death is difficult to be calculated. Finally, we did not consider comparing patients whose cause of death was a thoracic trauma to others.

Conclusion

The present study found that the severity of thoracic trauma was an independent and significant risk factor for death in multi-trauma patients as was age, being a car occupant and having a crash in a rural road or a highway.

Abbreviations

AIS: Abbreviated injury scale

ISS: Injury severity score

MAIS: Maximum abbreviated injury scale

RTA: Road traffic accident

Declarations

Ethics approval and consent to participate

The registry has been approved by the relevant French authority and national data protection commission (*Comité National des Registres*, CNR, and *Commission Nationale de l'Informatique et des Libertés*, CNIL, N° 999211).

Consent for publication

Not applicable

Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

The Rhône registry is supported by the Gustave Eiffel university, the French public health agency and the road safety directorate (ministry of the interior). The authors declare that the funding sources had no role in the conduct, analysis, interpretation, or writing of this manuscript.

Authors' contributions

AB and KT conceived and designed the study, interpreted the data, and drafted the manuscript. AN and BG were in charge of the statistical reports. AN, BG, TL, MD, AG and BL interpreted the data, and critically revised the manuscript. All authors read and approved the final manuscript.

Acknowledgments

The authors would like to thank Philip Robinson for his linguistic advice with this manuscript and everyone who participated in the data collection and data recording for the Rhône Road Accident Registry Association (ARVAC: president, E. Javouhey), and University Gustave Eiffel – campus of Lyon – TS2-Umrestte (scientific coordinator, B. Laumon, medical coordinator, A. Ndiaye and administrative

coordinator, B. Gadegbeku) : Ait Idir T, Ait Si Selmi T, Alloatti D, Amoros E, Andrillat M, Artru F, Asencio Y, Assossou I, Auzaneau F, Bagès-Limoges F, Bagou G, Ballout N, ViBalogh C, Banssillon G, Banssillon V, Barraco S, Barnier N, Barth X, Basset M, Beaudry E, Bec JF, Bejui J, Bel JC, Belhadj A, Bérard E, Bérard J, Bergeron I, Bernard JC, Berthet N, Bertrand JC, Besacier Y,Besson L, Biot B, Biot V, Blache D, Blanc C, Blanchard J, Blum O, Bœuf C, Boisson D, Bonjean M, Bost J, Bouchedor C, Bouffet T, Boughatene B, Bouletreau P, Boyer M, Boyer V, Breda Y, Brilland R, Brodsky D, Bussery S, Cabet N, Caillot L, Caillot JL†, Cannamela A, Caregnato B, Caramelle F, Carre M, Catala Y, Chagnon PY, Chambon C, Chambost M, Chantran C, Chapuy P, Charbotel B, Chardon P, Charnay P, Chatelain P, Chattard S, Chaudier P, Chauvin F, Chavane H, Chazot G, Chenani M, Chettouane I, Chevreton N, Chevrillon E, Chevrillon S, Chiron M, Chotel P, Cochard P, Comarmond M, Combe C, Comte G, Contamin B, Coppard E, Cot T, Coutagnieux A, Crettenet Z, Cristini A, Cunin V, Danella-Marguiron C, Dailler F, Dal Gobbo B, Da Silva F, David JS, De Angelis MP, Debrisay MC, Decourt L, Degrange P, Dejour H†, Delfosse A, Demangel N†, Deinite G,Demazière J, Deruty R, Desjardins G, Devaux J, Dewhurst N, Dohin B, Douplat M, Drouet A, Du Besset M, Ducreux B, Ducrozet P, Dufour A, Dumortier C, El Khoury C, Emonet A, Escarment J, Evrard AS, Eyssette M, Fallavier L, Fanton L, Farizon F, Felten D, Feugere S, Feuglet P†, Fifis N, Figura J, Fisher G, Fischer LP, Floccard B, Floret D, Fournier G, Fraisse P, Franchi A, Fredenucci JF, Freidel M, Fuster P, Gagneux C, Galin L, Gaillard P, Gallon M, Garnier N, Garzanti A, Gaussorgues P, Gautheron V, Genevrier M, Gibaud F, Gillet Y, Gilly F, Girard A, Goubsky A, Gougne M, Granger M, Grattard P, Gueugniaud PY, Guenot C, Guérin AC, Guerin T, Guignand M, Guillaudon C, Guillaumée F, Haddak M, Hamel D, Haouas T, Haro J, Heckel T, Herzberg G, Ho-Van-Truc P, Hugen-Schmitt D, Humbert C, Jacquemard C, Jault V, Jouanneau E, Joffre T, Kheniche F, Kohler R, Labed H, Lablanche C, Lafont S, Lagier C, Lapierre B, Laplace MC, La Rosa C, Lassaigne M, Laurent R, Lebel M, Leblay G, Le-Xuan I, Lieutaud T, Lille R, Linné M, Lorge S, Louboutin L, Luauté J, Lucas R, Machin B, Maiello E, Malicier D, Mangola B, Marcotte G, Marduel YN, Marie-Catherine M, Martin JL, Martin YN, Martinand G, Marty F, Matricon P, Mazouzi S†, Melaine R, Menard B, Messikh C, Meyer F, Meyrand S, Mintsa-Eya C, Molard S, Monchanin C, Monneuse O, Morel G, Morel-Chevillet E, Mioulet E, Minjaud F, Mokdadi A, Mollet C, Monnet J, Moyen B, Neidhart JP, Ngandu E, Ny S, Ollagnier F, Ould T, Paget P, Paillot JC, Paris D, Passot G, Patay B, Pauget P, Peillon D, Perrin G, Perrin-Blondeau D, Petit P, Phelip H, Picaud S, Pinelli E, Paparel P, Piriou V, Piton JL, Plantier M, Pornon P, Potinet-Pagliaroli V, Pramayon C, Quelard B, Rakaa A, Raquin L, Ramdani E Remy C, Rerbal D, Rezig M, Rhida Z, Ricard A, Richard A, Rigal F, Rimmelé T, Robert D, Robinet F, Rode G, Romanet JP, Rongieras F, Roset C, Rousson A, Roussouli P, Roux H, Roux S, Ruhl C, Salamand J, Salord F, Sametzky P, Sayegh K, Sayous P, Sbraire N, Scappaticci N, Schiele P, Schneider M, Simonet C, Sigal A, Sindou M, Soldner R, Soudain M, Stagnara J, Stamm D, Suc B, Supernant K, Tardy H, Tasseau F, Taty M, Taveau G, Tazarourte K, Tell L, Theurey O, Thievon R, Thomas M, Tilhet-Coartet S, Tissot E, Toukou JC, Trifot M, Tronc F, Vallee B, Vallet G, Vancuyck A, Vergnes I, Vernet C, Verney MP, Viallon A, Viste A, Voiglio EJ, Vourey G, Vuillard J, Westphal M, Willemen L†.

References

1. World Health Organization, issuing body. Global status report on road safety 2018. Available at: https://www.who.int/publications/i/item/9789241565684. Accessed on April 4th, 2021.

2. World Health Organization. Global status report on road safety 2013: supporting a decade of action. 2013. Available at: https://www.who.int/iris/bitstream/10665/78256/1/9789241564564_eng.pdf. Accessed on April 4th, 2021.
3. Vécsei V, Arbes S, Aldrian S, Nau T. Chest Injuries in Polytrauma. Eur J Trauma Emerg Surg. 2005;31:239–43.
4. Chrysou K, Halat G , Hoksch B, Schmid RA, Kocher GJ. Lessons from a large trauma center: impact of blunt chest trauma in polytrauma patients—still a relevant problem? Scand J Trauma Resusc Emerg Med. 2017;25: 42.
5. Veysi VT, Nikolaou VS, Paliobeis C, Efstathopoulos N, Giannoudis PV. Prevalence of chest trauma, associated injuries and mortality: a level I trauma centre experience. Int Orthop. 2009;33:1425-33.
6. Battle CE, Hutchings H, Evans PA. Risk factors that predict mortality in patients with blunt chest wall trauma: A systematic review and meta-analysis. Injury. 2012;43:8–17.
7. Leone M, Brégeon F, Antonini F, Chaumoître K, Charvet A, Ban LH, et al. Long-term outcome in chest trauma. Anesthesiology. 2008;109:864–71.
8. Battle CE, Hutchings H, Lovett S, Bouamra O, Jones S, Sen A, et al. Predicting outcomes after blunt chest wall trauma: development and external validation of a new prognostic model. Crit care. 2014;18:R98.
9. Huber S, Biberthaler P, Delhey P, Trentzsch H, Winter H, van Griensven M, et al. Predictors of poor outcomes after significant chest trauma in multiply injured patients: a retrospective analysis from the German Trauma Registry (Trauma Register DGU®). Scand J Trauma Resusc Emerg Med. 2014;22:52.
10. TraumaRegister DGU, Bayer J, Lefering R, Reinhardt S, Kühle J, Zwingmann J, et al. Thoracic trauma severity contributes to differences in intensive care therapy and mortality of severely injured patients: analysis based on the TraumaRegister DGU®. World J Emerg Surg. 2017;12:43.
11. Ostermann RC, Joestl J, Lang N, Tiefenboeck TM, Ohnesorg S, Platzer P, et al. Thoracic Injuries in Pediatric Polytraumatized Patients: Epidemiology, Treatment and Outcome. Injury.2021;52:1316-20.
12. Chrysou K, Halat G, Hoksch B, Schmid RA, Kocher GJ. Lessons from a large trauma center: impact of blunt chest trauma in polytrauma patients—still a relevant problem? Scand J Trauma Resusc Emerg Med. 2017;25:42.
13. Association for the Advancement of Automotive Medicine. The Abbreviated Injury Scale, 1990 Revision. Des Plaines, IL: Association for the Advancement of Automotive Medicine, 1990.
14. Paparel P, N'Diaye A, Laumon B, Caillot JL, Perrin P, Ruffion A. The epidemiology of trauma of the genitourinary system after traffic accidents: analysis of a register of over 43 000 victims. BJU Int. 2006;97:338–41.
15. Jeschke MG, van Baar ME, Choudhry MA, Chung KK, Gibran NS, Logsetty S. Burn injury. Nat Rev Dis Primers. 2020;6:11.

16. Callcut RA, Kornblith LZ, Conroy AS, Robles AJ, Meizoso JP, Namias N, et al. The why and how our trauma patients die: A prospective Multicenter Western Trauma Association study. J Trauma Acute Care Surg. 2019;86:864–70.
17. Grubmüller M, Kerschbaum M, Diepold E, Angerpointner K, Nerlich M, Ernstberger A. Severe thoracic trauma – still an independent predictor for death in multiple injured patients? Scand J Trauma Resusc Emerg Med. 2018;26:6.
18. Sewalt CA, Wiegers EJA, Venema E, Lecky FE, Schuit SCE, Hartog DD, et al. The volume-outcome relationship in severely injured patients: A systematic review and meta-analysis. J Trauma Acute Care Surg. 2018;85:810–9.
19. Zacher MT, Kanz KG, Hanschen M, Häberle S, van Griensven M, Lefering R, et al. Association between volume of severely injured patients and mortality in German trauma hospitals. Br J Surg. 2015;102:1213–9.
20. Bergeron E, Lavoie A, Clas D, Moore L, Ratte S, Tetreault S, et al. Elderly Trauma Patients with Rib Fractures Are at Greater Risk of Death and Pneumonia. J Trauma. 2003;54:478–85.
21. Horst K, Andruszkow H, Weber CD, Pishnamaz M, Herren C, Zhi Q, et al. Thoracic trauma now and then: A 10 year experience from 16,773 severely injured patients. PLoS One. 2017;12:e0186712.
22. Beshay M, Mertzlufft F, Kottkamp HW, Reymond M, Schmid RA, Branscheid D, et al. Analysis of risk factors in thoracic trauma patients with a comparison of a modern trauma centre: a mono-centre study. World J Emerg Surg. 2020;15:45.
23. Bayer J, Lefering R, Reinhardt S, Kühle J, Südkamp NP, TramaRegister DGU. Severity-dependent differences in early management of thoracic trauma in severely injured patients - Analysis based on the TraumaRegister DGU®. Scand J Trauma Resusc Emerg Med. 2017;25:10.
24. Peek J, Ochen Y, Saillant N, Groenwold RHH, Leenen LPH, Uribe-Leitz T, et al. Traumatic rib fractures: a marker of severe injury. A nationwide study using the National Trauma Data Bank. Trauma Surg Acute Care Open. 2020;5:e000441.
25. Peek J, Beks RB, Hietbrink F, De Jong MB, Heng M, Beeres FJP, et al. Epidemiology and outcome of rib fractures: a nationwide study in the Netherlands. Eur J Trauma Emerg Surg. 2020.
26. Chen Y, He Y, DeVivo MJ. Changing Demographics and Injury Profile of New Traumatic Spinal Cord Injuries in the United States, 1972–2014. Arch Phys Med Rehabil. 2016;97:1610–9.
27. Chan CW, Eng JJ, Tator CH, Krassioukov A, the Spinal Cord Injury Research Evidence Team. Epidemiology of sport-related spinal cord injuries: A systematic review. J Spinal Cord Med. 2016;39:255–64.
28. Samarasekera SP, Mikocka-Walus A, Butt W, Cameron P. Epidemiology of major paediatric chest trauma. J Paediatr Child Health. 2009;45:676–80.
29. Ostermann RC, Joestl J, Lang N, Tiefenboeck TM, Ohnesorg S, Platzer P, et al. Thoracic Injuries in Pediatric Polytraumatized Patients: Epidemiology, Treatment and Outcome. Injury. 2021;52:1316-20.
30. Balci AE, Kazez A, Eren Ş, Ayan E, Özalp K, Eren MN. Blunt thoracic trauma in children: review of 137 cases. Eur J Cardiothorac Surg. 2004;26:387–92.

31. Bliss D, Silen M. Pediatric thoracic trauma: Crit Care Med. 2002;30:S409–15.
32. Lee WY, Yee WY, Cameron PA, Bailey MJ. Road traffic injuries in the elderly. Emerg Med J. 2006;23:42–6.
33. Loftis KL, Price J, Gillich PJ. Evolution of the Abbreviated Injury Scale: 1990–2015. Traffic Inj Prev. 2018;19:S109–13.
34. Clarke JR, Ragone AV, Greenwald L. Comparisons of survival predictions using survival risk ratios based on International Classification of Diseases, Ninth Revision and Abbreviated Injury Scale trauma diagnosis codes. J Trauma. 2005;59:563–7.
35. Baker SP, O'Neill B, Haddon W, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma. 1974;14:187–96.
36. Hsu SY, Wu SC, Rau CS, Hsieh TM, Liu HT, Huang CY, et al. Impact of Adapting the Abbreviated Injury Scale (AIS)-2005 from AIS-1998 on Injury Severity Scores and Clinical Outcome. Int J Environ Res Public Health. 2019;16:5033.
37. Söderlund T, Ikonen A, Pyhältö T, Handolin L. Factors associated with in-hospital outcomes in 594 consecutive patients suffering from severe blunt chest trauma. Scan J Surg. 2015;104:115–20.

Figures

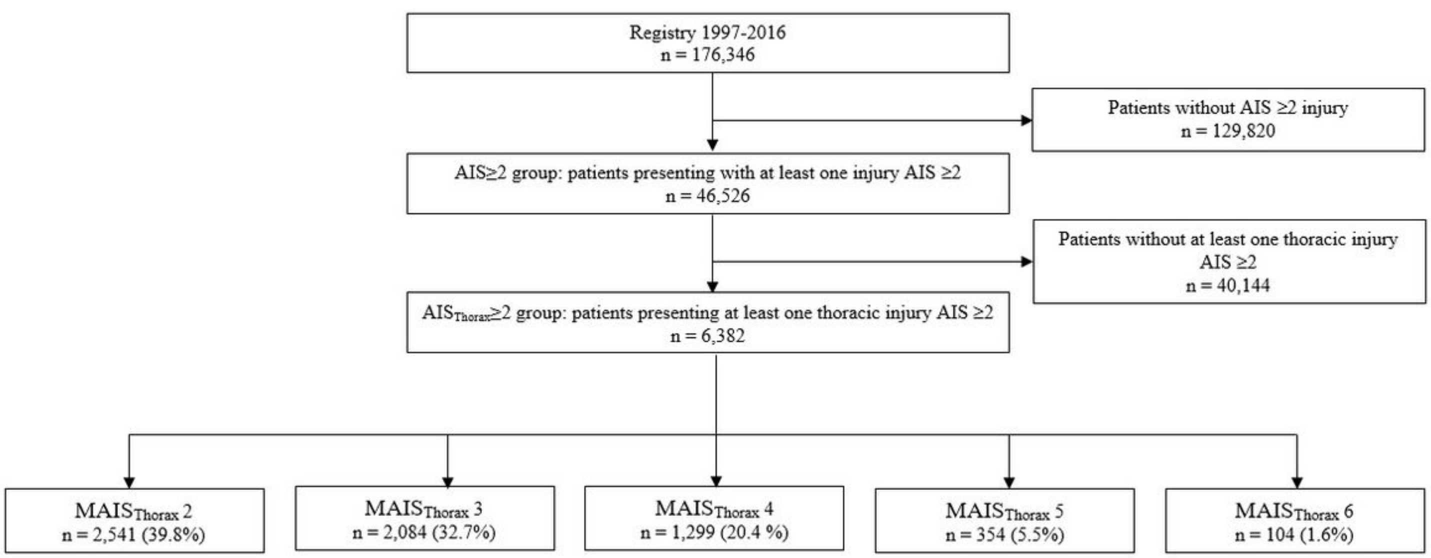

Figure 1

Title: Flow chart of the study Legend: AIS: Abbreviated injury scale; MAIS: Maximum abbreviated injury scale

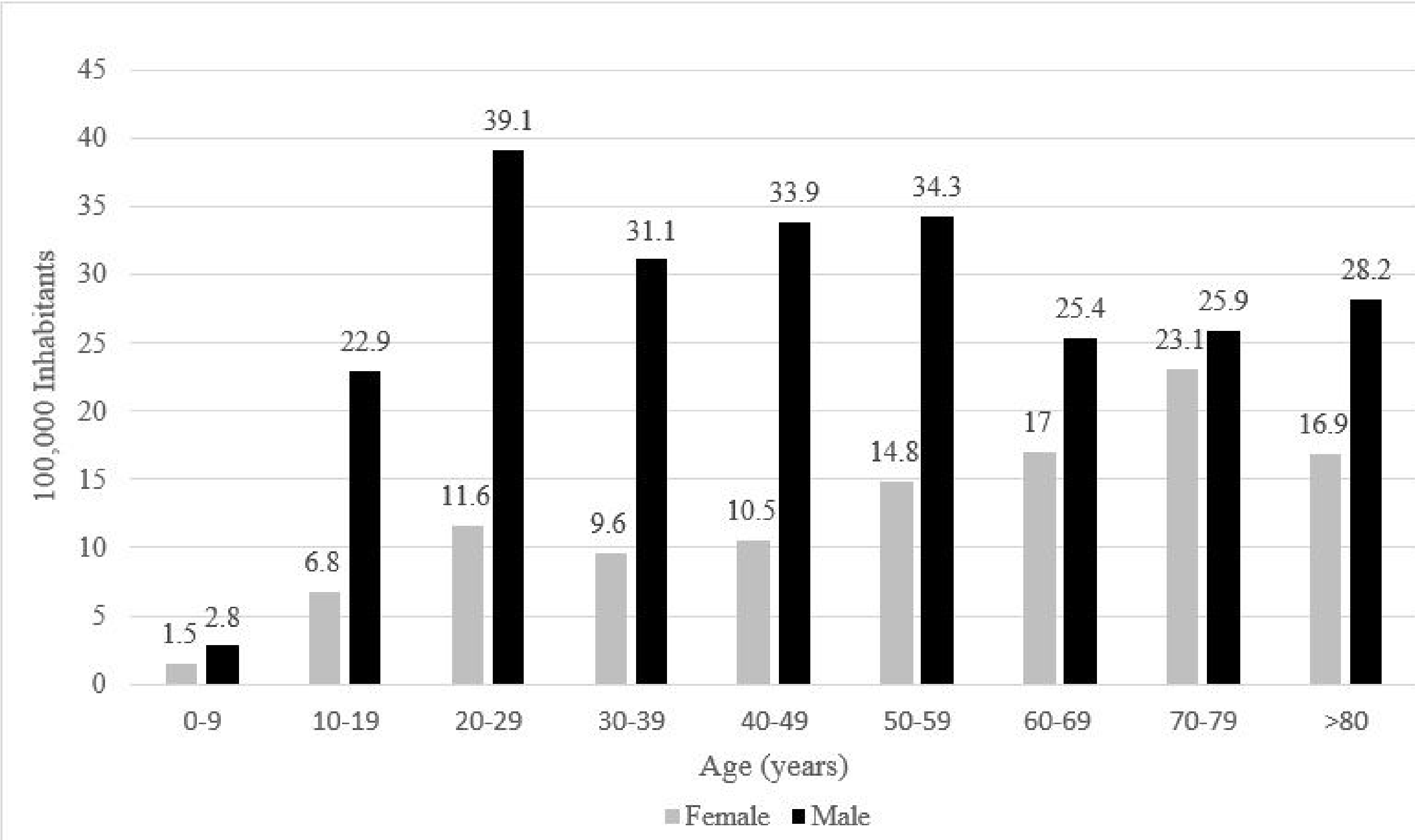

Figure 2

Title: Road traffic accident among AISThorax≥2 group per 100,000 inhabitants in the Rhône area population. Legend: Subgroups according to the age. GroupAISTh+≥2: multi-trauma patients presenting with at least one thoracic injury AIS≥2

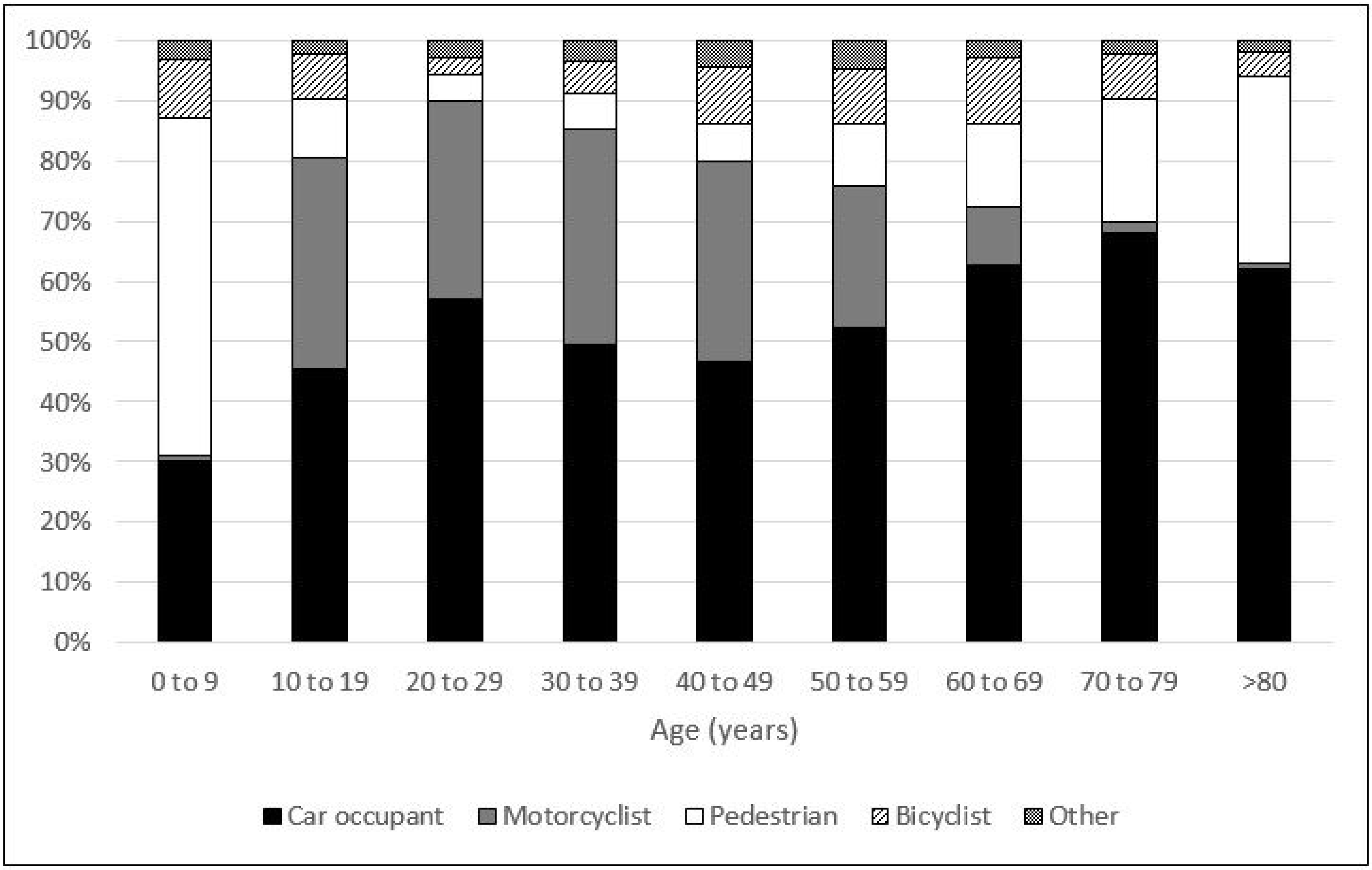

Figure 3

Title: Road user category distribution according to age in the AISThorax≥2 group Legend: AISThorax≥2 group: multi-trauma patients presenting with at least one thoracic injury AIS≥2.

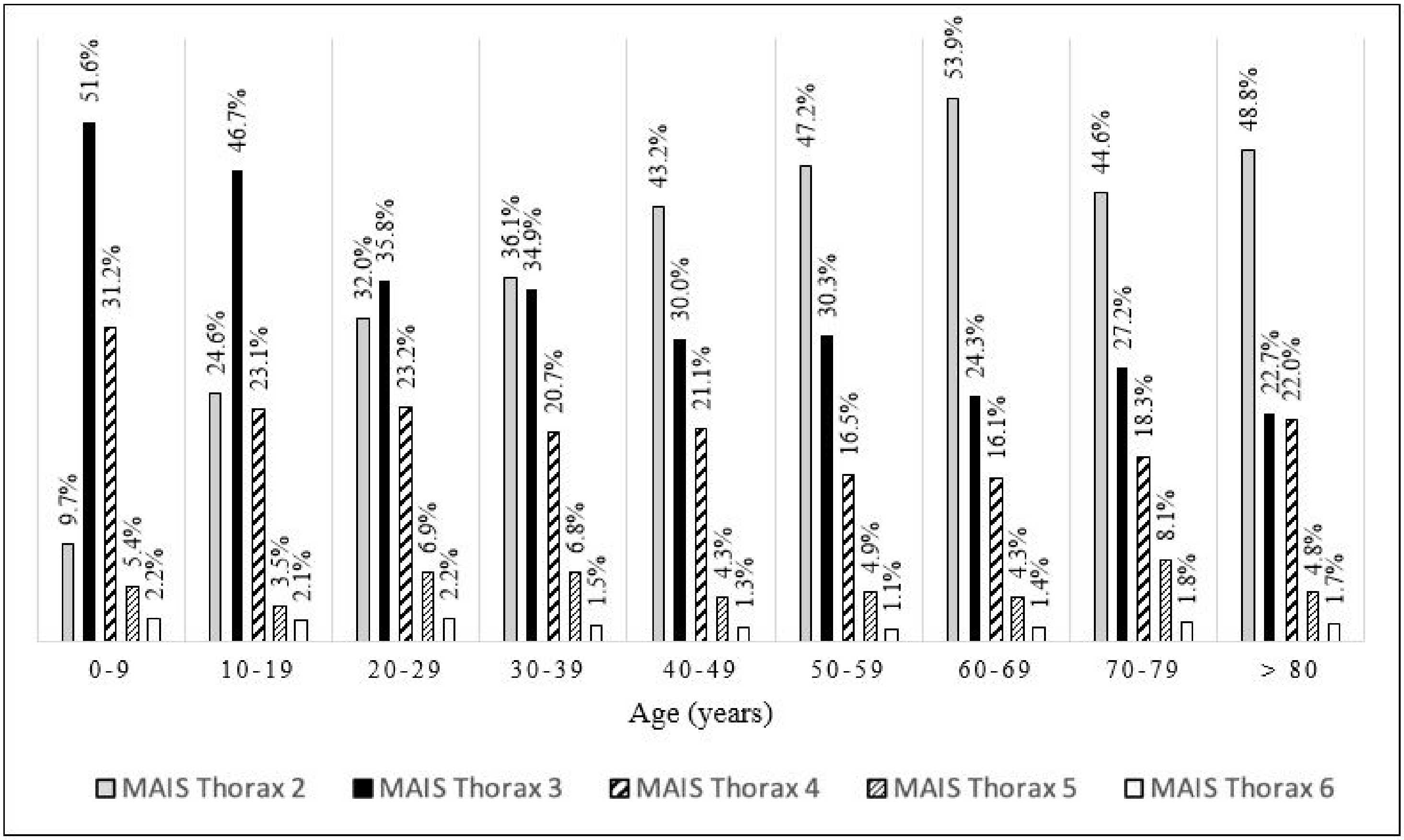

Figure 4

Title: Thoracic maximum abbreviated injury scale distribution according to age in the AISThorax≥2 group. Legend: AISThorax≥2 group: multi-trauma patients presenting with at least one thoracic injury AIS≥2, MAIS: maximum abbreviated injury scale