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Original Article

Motorcycle-related hospitalizations of the elderly

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ABSTRACT

Background: To investigate the injury pattern, mechanisms, severity, and mortality of the elderly hospitalized for treatment of trauma following motorcycle accidents.
Methods: Motorcycle-related hospitalization of 994 elderly and 5078 adult patients from the 16,548 hospitalized patients registered in the Trauma Registry System between January 1, 2009 and December 31, 2013.
Results: The motorcycle-related elderly trauma patients had higher injury severity, less favorable outcomes, higher proportion of patients admitted to the intensive care unit (ICU), prolonged hospital and ICU stays and higher mortality than those adult motorcycle riders. It also revealed that a significant percentage of elderly motorcycle riders do not wear a helmet. Compared to patients who had worn a helmet, patients who had not worn a helmet had a lower first Glasgow Coma Scale (GCS) score, and a greater percentage presented with unconscious status (GCS score $\leq$8), had sustained subdural hematoma, subarachnoid hemorrhage, cerebral contusion, severe injury (injury severity score 16–24 and $\geq$25), had longer hospital stay and higher mortality, and had required admission to the ICU.
Conclusions: Elderly motorcycle riders tend to present with a higher injury severity, worse outcome, and a bodily injury pattern differing from that of adult motorcycle riders, indicating the need to emphasize use of protective equipment, especially helmets, to reduce their rate and severity of injury.

The elderly patients sustain distinct patterns of injuries from causes that differ from those of adults because of their unique anatomical, physiologic, and behavioral characteristics. The rapid growth in the geriatric population has had a considerable impact on healthcare system [1]. Injury in the elderly is increasing at a rate seven times that of adults [2]. In 2010, the elderly accounted for only 17% of the population but 55% of injury-related discharge in the United States [2]. In addition, there is strong evidence that elderly trauma patients are at an increased risk of morbidity and mortality compared with younger patients [3–5].

Motor vehicle collisions are a major cause of trauma among the elderly [6]. In Taiwan, motorcyclists are a major portion of the trauma population. This is of particular concern as the average age of motorcyclists is increasing [1]. However, motorcyclists are 35 times more likely than passenger-car occupants to die in a motor vehicle traffic crash and 8 times more likely to be injured per vehicle mile [7]. The advanced

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At a glance commentary

Scientific background on the subject

With a rapid growth in the geriatric population, identification of high-risk distinct injury patterns in the elderly patients from those of adults may lead to improved health care. The purpose of this study is to investigate the injury pattern, severity, and mortality of the elderly patients treated for injuries sustained in motorcycle accidents in a level I trauma center in southern Taiwan using data from a population-based trauma registry.

What this study adds to the field?

This study revealed that elderly motorcycle riders are injured more severely, present with a different bodily injury pattern, and have higher mortality than adult riders. It also found that no helmet-wearing in a significant percentage of elderly motorcycle riders had put them at high risk of injury with worse outcome.

age had been shown to be an independent predictor of inpatient hospitalization, poor outcome, need for intensive care unit (ICU) care among motorcycle-related trauma patients [1,8]. The identification of high-risk injury patterns may lead to improved care and ultimately further improvements in outcome in the elderly admitted to the hospital with trauma [9]. The purpose of this epidemiologic study is to investigate the injury pattern, severity, and mortality of the elderly patients treated for injuries sustained in motorcycle accidents in a level I trauma center in southern Taiwan using data from a population-based trauma registry.

Methods

Study design

The study was conducted at Kaohsiung Chang Gung Memorial Hospital, a 2400-bed facility and a Level I regional trauma center that provides care to trauma patients primarily from South Taiwan. Approval for this study was obtained by the hospital institutional review board (approval number 103-2571B) before its initiation. This retrospective study was designed to review all the data added to the Trauma Registry System from January 1, 2009 to December 31, 2013 for selection of cases that met the inclusion criteria of (1) age $\geq$ 65 years and (2) hospitalization for treatment of trauma sustained in a motorcycle accident. For comparison, data regarding adults aged 20–64 years old were also collected.

Among the 16,548 hospitalized registered patients entered in the database, 4011 (24.2%) were $\geq$65 years of age (hereafter referred to as elderly) and 10,234 (61.8%) were 20–64 years of old (hereafter referred to as adults). Among them, 994 (24.8%) elderly and 5078 (49.6%) adults had been admitted due to a motorcycle accident [Fig. 1]. Detailed patient information was retrieved from the Trauma Registry System of our institution and included data regarding age, sex, admission vital signs, injury mechanism, helmet use, the first Glasgow Coma Scale (GCS) in the emergency department, Abbreviated Injury Scale (AIS) of each body region, Injury Severity Score (ISS), New Injury Severity Score (NISS), Trauma-Injury Severity Score (TRISS), length of hospital stay (LOS), length of intensive care unit stay (LICUS), in-hospital mortality, and associated complications. The data collected regarding the combined population of drivers and passengers (hereafter referred to as riders) were compared using SPSS v.20 statistical software (IBM, Armonk, NY) for performance of Pearson's chi-squared test, Fisher's exact test, or the independent student's t test, as applicable. All results are presented as the mean $\pm$ standard

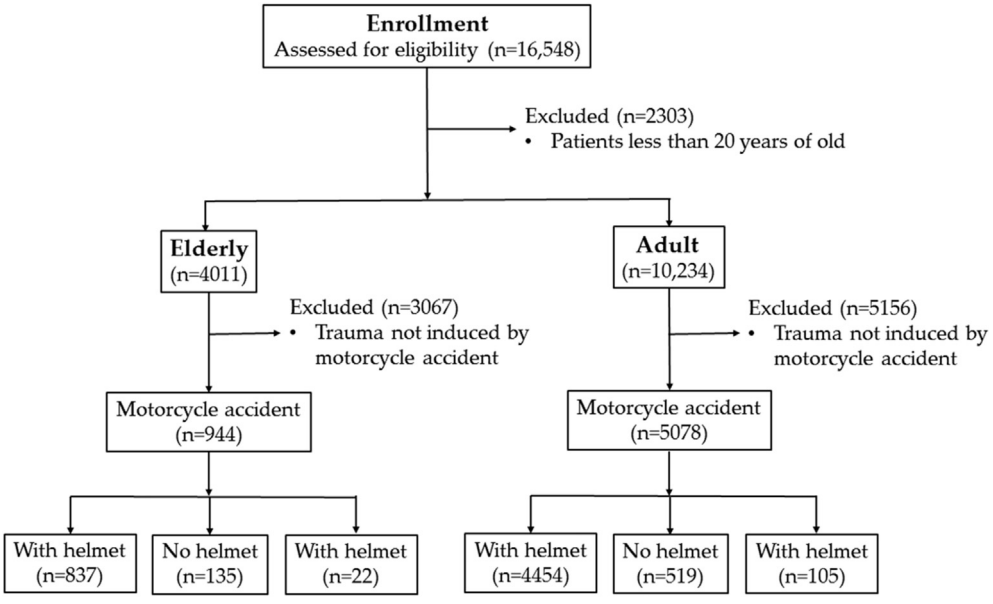

Fig. 1 Flow chart of studied groups of patients.

Table 1 Demographics of hospitalized trauma patients of the elderly and the adults.

Variable	Elderly N = 4011	Adult N = 10,234	p
Age	75.9 ± 7.2	42.8 ± 13.4	<0.001
Gender, n (%)			<0.001
Male	1687 (42.1)	6481 (63.3)	
Female	2324 (57.9)	3753 (36.7)	
Mechanism, n (%)			<0.001
Driver of MV	24 (0.6)	207 (2.0)	
Passenger of MV	11 (0.3)	102 (1.0)	
Driver of Motorcycle	937 (23.4)	4831 (47.2)	
Passenger of Motorcycle	57 (1.4)	247 (2.4)	
Bicycle	245 (6.1)	278 (2.7)	
Pedestrian	122 (3.0)	149 (1.5)	
Fall	2403 (59.9)	1909 (18.7)	
Unspecific	212 (5.2)	2511 (24.6)	
Time, n (%)			<0.001
7:00–17:00	2421 (60.4)	5683 (55.5)	
17:00–23:00	894 (22.3)	2900 (28.3)	
23:00–7:00	685 (17.1)	1646 (16.1)	
Unspecific	11 (0.3)	5 (0.1)	
ISS	9.6 ± 6.1	8.1 ± 7.3	<0.001
ISS			0.014
<16	3404 (84.9)	8832 (86.3)	0.027
16–24	446 (11.1)	972 (9.5)	0.004
≥25	161 (4.0)	430 (4.2)	0.613
NISS	10.8 ± 8.2	9.4 ± 8.9	<0.001
TRISS	0.98 ± 0.16	0.99 ± 0.12	<0.001
Mortality, n (%)	132 (3.3)	145 (1.4)	<0.001

deviation (SD). A *p*-value less than 0.05 was considered statistically significant.

Results

Patient characteristics

The mean age was 75.9 ± 7.2 and 42.8 ± 13.4 years, respectively, in the elderly and adult patient groups [Table 1]. Statistically significant difference was found between the groups regarding sex. More female were found in the elderly patients. Of the 4011 elderly patients, 1687 (42.1%) were male and 2324 (57.9%), female. Of the 10,234 adult patients, 6487 (63.3%) were male and 3753 (36.7%) were female. In the elderly patients, fall presented the major mechanism for admission (59.9%), followed by motorcycle accident (24.8%) and bicycle accident (6.1%). Only 35 (0.9%) of the elderly patients had been riders in an automobile. In contrast, most of the injured adult patients were motorcycle riders, with 4831 (47.24%) adult drivers and 247 (2.4%) adult passengers.

The data regarding the 994 (24.8%) elderly and 5078 (49.6%) adult patients who had been motorcycle riders were further compared for identification of differences regarding motorcycle-related major trauma injury. As shown in Fig. 2, of the 940, 914, 906, 703, 385, and 163 hospitalized patients aged 65–69, 70–74, 75–79, 80–84, 85–89, and ≥90 years, respectively, 399, 290, 197, 81, 20, and 7 patients, respectively, had been admitted for treatment subsequent to a motorcycle

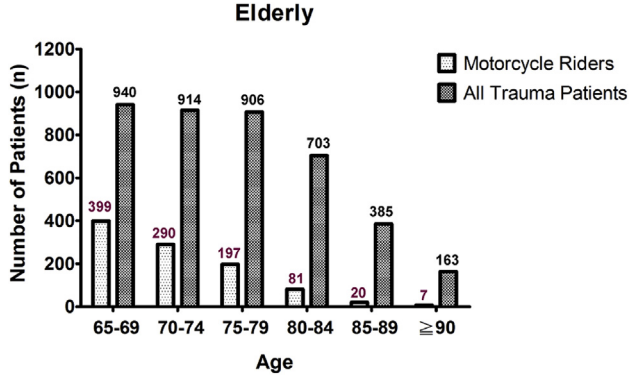

Fig. 2 Number of elderly patients admitted for treatment of all trauma injury and number admitted for treatment of motorcycle-related trauma injury.

Table 2 Injury characteristics of the elderly and adult motorcycle riders.

Motorcycle accident			
Variable	Elderly N = 994	Adult N = 5078	p
Age	72.1 ± 5.5	40.9 ± 14.0	<0.001
Gender, n (%)			0.522
Male	578 (58.1)	2897 (57.1)	
Female	416 (41.9)	2181 (42.9)	
Helmet wearing, n (%)			
Drivers			0.003
Yes	792 (79.7)	4245 (83.6)	
No	125 (12.6)	487 (9.6)	
Passengers			0.347
Yes	45 (4.5)	209 (4.1)	
No	10 (1.0)	32 (0.6)	
Unknown	22 (2.2)	105 (2.0)	
GCS	14.2 ± 2.5	14.2 ± 2.4	0.661
GCS			0.891
≤8	55 (5.5)	296 (5.8)	
9–12	42 (4.2)	225 (4.4)	
≥13	897 (90.3)	4557 (89.7)	
AIS ≥3, n (%)			0.006
Head/Neck	246 (24.7)	970 (19.1)	<0.001
Face	1 (0.1)	21 (0.4)	0.159
Thorax	108 (10.9)	443 (8.7)	0.035
Abdomen	14 (1.4)	130 (2.6)	0.030
Extremity	302 (30.4)	1109 (21.8)	<0.001
ISS	10.6 ± 8.2	9.3 ± 7.4	0.040
ISS			0.001
<16	779 (78.4)	4222 (83.1)	<0.001
16–24	155 (15.6)	600 (11.8)	0.001
≥25	60 (6.0)	256 (5.1)	0.197
NISS	12.4 ± 9.9	10.9 ± 9.0	0.045
TRISS	0.96 ± 0.20	0.99 ± 0.10	<0.001
Mortality, n (%)	30 (3.0)	76 (1.5)	0.001
LOS (days)	11.1 ± 11.5	9.4 ± 10.1	<0.001
ICU			
Patients, n (%)	221 (22.2)	898 (17.7)	0.001
<16	76 (9.8)	315 (7.5)	0.028
16–24	96 (61.9)	370 (61.7)	0.951
≥25	49 (81.7)	213 (83.2)	0.776
LICUS (days)	9.5 ± 12.7	7.0 ± 8.1	<0.001
<16	6.9 ± 9.0	4.9 ± 4.9	<0.001
16–24	9.0 ± 10.6	6.3 ± 5.5	<0.001
≥25	14.5 ± 18.9	11.2 ± 12.8	0.001

accident. Among these elderly motorcycle riders, 89.1% (n = 886) were aged less than 80 years. Comparison of trauma injury scores for the elderly and adult groups indicated significant difference regarding ISS (9.6 ± 6.1 vs. 8.1 ± 7.3, respectively, $p < 0.001$). Significant difference ($p = 0.014$) was found between the elderly and adult patients regarding distribution of patients at different levels of injury severity (ISS < 16, 16–24, or ≥25). There were significant less elderly patients in the subgroup of ISS <16 (84.9% vs. 86.3%, respectively, $p = 0.027$) and more elderly patients in the subgroup of ISS between 16 and 24 (11.1% vs. 9.5%, respectively, $p = 0.004$) in comparison with those of adult patients. In addition, the motorcycle-related elderly trauma patients had higher injury severity regarding NISS (10.8 ± 8.2 vs. 9.4 ± 8.9, respectively, $p < 0.001$), TRISS (0.98 ± 0.16 vs. 0.99 ± 0.12, respectively, $p < 0.001$), and in-hospital mortality (3.3% vs. 1.4%, respectively, $p < 0.001$) than those adult motorcycle riders.

As shown in Table 2, of the 994 elderly and 5078 adult motorcycle riders, the mean age was 72.1 ± 5.5 and 40.9 ± 14.0 years, respectively. No statistically significant difference was found regarding sex was found between the elderly motorcycle riders, of whom 578 (58.1%) were male and 416 (41.9%) female, and the adult motorcycle riders, of whom 2897 (57.1%) were male and 2181 (42.9%) female. Analysis of the data regarding helmet-wearing status, which were recorded for 97.8% of the elderly and 98.0% of the adult patients, revealed that significantly more elderly motorcycle drivers had not been wearing a helmet compared to the adult motorcycle drivers (12.6% vs. 9.6%, respectively, $p = 0.003$). In contrast, no significant difference regarding helmet-wearing status was found between the elderly and adult motorcycle passengers.

No significant difference was found between the elderly and adult patients regarding GCS score (14.2 ± 2.5 vs. 14.2 ± 2.4, respectively, $p = 0.661$) or distribution of patients at different levels of consciousness ($p = 0.891$). Analysis of AIS ≥3 revealed that the elderly patients had sustained significantly higher rates of head/neck (24.7% vs. 19.1%, respectively, $p < 0.001$), thorax injury (10.9% vs. 8.7%, respectively, $p = 0.035$), and extremity injury (30.4% vs. 21.8%, respectively, $p < 0.001$) than adult patients, while the adult patients had sustained higher significantly higher rates of abdomen injury (2.6% vs. 1.4%, respectively, $p = 0.030$). On the other hand, no significant differences regarding injury to the face region between the elderly and adult patients.

The elderly motorcycle riders have a higher severe injury score than the adult motorcycle riders (10.6 ± 8.2 vs. 9.6 ± 6.1, respectively, $p < 0.001$). Likewise, comparison of trauma injury scores for the elderly and adult motorcycle riders indicated significant difference regarding ISS (10.6 ± 8.2 vs. 9.3 ± 7.4, respectively, $p = 0.040$) and distribution of patients at different levels of injury severity ($p = 0.001$). There were significant less elderly patients in the subgroup of ISS <16 (78.49% vs. 83.1%, respectively, $p < 0.001$) and more elderly patients in the subgroup of ISS between 16 and 24 (15.6% vs. 11.8%, respectively, $p = 0.001$) in comparison with those of adult patients. There were also significant difference regarding NISS (12.4 ± 9.9 vs. 10.9 ± 9.0, respectively, $p = 0.045$), TRISS (0.96 ± 0.20 vs. 0.99 ± 0.10, respectively, $p < 0.001$), and in-hospital mortality (3.0% vs. 1.5%, respectively, $p = 0.001$) in these two groups of patients. Significant differences were found between the elderly and adult motorcycle riders regarding hospital LOS (11.1 days vs. 9.4 days, respectively, $p < 0.001$), proportion of patients admitted to the ICU (22.2% vs. 17.7%, respectively, $p = 0.001$), or LICUS (9.5 days vs. 7.0 days, respectively, $p < 0.001$). More elderly patients with ISS <16 (22.2% vs. 17.7%, respectively, $p = 0.001$) had been admitted into the ICU and the elderly patients had a longer LICUS in either subgroup of injury severity (<16, 16–24, ≥25).

Table 3 Associated injuries of the hospitalized elderly and adult motorcycle riders.

Motorcycle accident			
Variable	Elderly N = 994	Adult N = 5078	p
Head trauma, n (%)			
Neurologic deficit+	3 (0.3)	52 (1.0)	0.028
Cranial fracture+	39 (3.9)	437 (8.6)	<0.001
Epidural hematoma (EDH)+	26 (2.6)	272 (5.4)	<0.001
Subdural hematoma (SDH)*	147 (14.8)	492 (9.7)	<0.001
Subarachnoid hemorrhage (SAH)	125 (12.6)	583 (11.5)	0.325
Intracerebral hematoma (ICH)	28 (2.8)	122 (2.4)	0.441
Cerebral contusion	66 (6.6)	305 (6.0)	0.446
Cervical vertebral fracture	4 (0.4)	49 (1.0)	0.081
Maxillofacial trauma, n (%)			
Maxillary fracture+	64 (6.4)	543 (10.7)	<0.001
Mandibular fracture+	5 (0.5)	192 (3.8)	<0.001
Orbital fracture+	9 (0.9)	151 (3.0)	<0.001
Nasal fracture+	6 (0.6)	83 (1.6)	0.013
Thoracic trauma, n (%)			
Rib fracture*	176 (17.7)	596 (11.7)	<0.001
Sternal fracture	2 (0.2)	6 (0.1)	0.509
Hemothorax	24 (2.4)	104 (2.0)	0.462
Pneumothorax	21 (2.1)	103 (2.0)	0.864
Lung contusion	9 (0.9)	82 (1.6)	0.092
Hemopneumothorax	18 (1.8)	83 (1.6)	0.691
Thoracic vertebral fracture	9 (0.9)	39 (0.8)	0.655
Abdominal trauma, n (%)			
Intra-abdominal injury	9 (0.9)	75 (1.5)	0.158
Hepatic injury+	3 (0.3)	140 (2.8)	<0.001
Splenic injury+	3 (0.3)	77 (1.5)	0.002
Retroperitoneal injury	2 (0.2)	10 (0.2)	0.978
Renal injury	4 (0.4)	34 (0.7)	0.329
Urinary bladder injury*	5 (0.5)	8 (0.2)	0.031
Lumbar vertebral fracture	18 (1.8)	58 (1.1)	0.083
Sacral vertebral fracture	2 (0.2)	30 (0.6)	0.121
Extremity trauma, n (%)			
Scapular fracture	32 (3.2)	127 (2.5)	0.195
Clavicle fracture+	100 (10.1)	761 (15.0)	<0.001
Humeral fracture	59 (5.9)	282 (5.6)	0.632
Radial fracture	89 (9.0)	559 (11.0)	0.055
Ulnar fracture	43 (4.3)	276 (5.4)	0.152
Femoral fracture*	159 (16.0)	456 (9.0)	<0.001
Patella fracture	24 (2.4)	143 (2.8)	0.479
Tibia fracture*	128 (12.9)	241 (10.7)	0.041
Fibular fracture*	95 (9.6)	271 (5.3)	<0.001
Metacarpal fracture	34 (3.4)	192 (3.8)	0.583
Metatarsal fracture	29 (2.9)	126 (2.5)	0.425
Calcaneal fracture	65 (6.5)	273 (5.4)	0.144
Pelvic fracture	36 (3.6)	176 (3.5)	0.807

+ and * indicated significant lower and higher incidences of the associated injury, respectively, in elderly motorcycle riders than those adult patients ($p < 0.05$).

Table 3 shows the findings regarding injury associated with motorcycle accidents. As can be observed, a

Table 4 Injury characteristics of the elderly motorcycle riders according to helmet-wearing status.

Motorcycle accident (Elderly)	Helmet+ N = 837	Helmet− N = 135	p
Gender, n (%)			0.299
Male	481 (57.5)	84 (62.2)	
Female	356 (42.5)	51 (37.8)	
GCS	14.4 ± 2.1	13.4 ± 3.5	<0.001
GCS			<0.001
≤8	32 (3.8)	16 (11.9)	<0.001
9–12	30 (3.6)	8 (5.9)	0.426
≥13	775 (92.6)	111 (82.2)	0.327
AIS ≥3, n (%)			<0.001
Head/Neck	169 (20.2)	64 (47.4)	<0.001
Face	1 (0.1)	0 (0.0)	1.000
Thorax	85 (10.2)	19 (14.1)	0.177
Abdomen	11 (1.3)	3 (2.2)	0.428
Extremity	269 (32.1)	28 (20.7)	0.009
Head trauma, n (%)			
Neurologic deficit	3 (0.4)	0 (0.0)	0.486
Cranial fracture	30 (3.6)	7 (5.2)	0.367
Epidural hematoma (EDH)	19 (2.3)	6 (4.4)	0.139
Subdural hematoma (SDH)*	93 (11.1)	43 (31.9)	<0.001
Subarachnoid hemorrhage (SAH)*	82 (9.8)	30 (22.2)	<0.001
Intracerebral hematoma (ICH)	20 (2.4)	7 (5.2)	0.067
Cerebral contusion*	40 (4.8)	21 (15.6)	<0.001
Cervical vertebral fracture	3 (0.4)	1 (0.7)	0.520
Maxillofacial trauma, n (%)			
Maxillary fracture	53 (6.3)	10 (7.4)	0.638
Mandibular fracture*	3 (0.4)	2 (1.5)	0.091
Orbital fracture	8 (1.0)	0 (0.0)	0.254
Nasal fracture	6 (0.7)	0 (0.0)	0.324
ISS	9.8 ± 7.2	13.5 ± 8.7	<0.001
ISS			<0.001
<16	690 (82.4)	78 (57.8)	<0.001
16–24	111 (13.3)	40 (29.6)	<0.001
≥25	36 (4.3)	17 (12.6)	<0.001
NISS	11.5 ± 8.9	15.8 ± 11.1	<0.001
TRISS	0.94 ± 0.12	0.88 ± 0.20	<0.001
Mortality, n (%)	16 (1.9%)	8 (5.9%)	0.005
LOS (days)	10.8 ± 11.0	12.2 ± 13.3	0.019
ICU			
Patients, n (%)	162 (19.4)	46 (34.1)	<0.001
LIS (days)	9.2 ± 12.3	10.3 ± 14.6	0.188

* indicated significant higher incidence of the associated injury in elderly motorcycle riders without helmet-wearing than those patients with helmet-wearing ($p < 0.05$).

significantly higher percentage of elderly motorcycle riders had sustained subdural hematoma (14.8% vs. 9.7%, respectively, $p < 0.001$), rib fracture (17.7% vs. 11.7%, respectively, $p < 0.001$), urinary bladder injury (0.5% vs. 0.2%, respectively, $p = 0.031$), femoral fracture (16.0% vs. 9.0%, respectively, $p < 0.001$), tibia fracture (12.9% vs. 10.7%, respectively, $p = 0.041$), and fibular fracture (9.6% vs. 5.3%, respectively, $p < 0.001$) but a significantly a lower percentage sustained neurologic deficit (0.3% vs. 1.0%, respectively, $p = 0.028$), cranial fracture (3.9% vs. 8.6%, respectively, $p < 0.001$), epidural hematoma (2.6% vs. 5.4%, respectively, $p < 0.001$), maxillary fracture (6.4% vs. 10.7%, respectively, $p < 0.001$), mandibular fracture (0.5% vs. 3.8%, respectively, $p < 0.001$), orbital fracture (092% vs. 3.0%, respectively, $p < 0.001$), nasal fracture (0.6% vs. 1.6%, respectively, $p = 0.013$), hepatic injury (0.3% vs. 2.8%, respectively, $p < 0.001$), splenic injury (0.3% vs. 1.5%, respectively, $p = 0.002$), and clavicle fracture (10.1% vs. 15.0%, respectively, $p < 0.001$) than adult motorcycle riders.

Table 4 shows the results of analysis of helmet-wearing status among elderly riders. As can be observed, elderly riders who had not worn a helmet presented with a significantly lower first GCS score (13.4 ± 3.5 vs. 14.4 ± 2.1, respectively, $p < 0.001$) and distribution of patients at different levels of consciousness ($p < 0.001$) compared to those who had worn a helmet. A significantly greater percentage of elderly riders who had not worn a helmet presented with unconscious status as assessed by GCS score ≤8 (11.9% vs. 3.8%, respectively, $p < 0.001$), more head/neck injury (47.4% vs. 20.2%, respectively, $p < 0.001$) based on AIS ≥3, while a significantly lower percentage presented with extremity injury (20.7% vs. 32.1%, respectively, $p = 0.009$). A significantly greater percentage of elderly riders who had not worn a helmet presented with more subdural hematoma, subarachnoid hemorrhage, and cerebral contusion. In contrast, no significant differences were found between elderly riders who had and had not worn a helmet regarding incidence of maxillofacial trauma, regardless of the type of trauma (maxillary fracture, mandibular fracture, orbital fracture, or nasal fracture). The elderly patients who had not worn a helmet had sustained more severe injury regarding ISS (13.5 ± 8.7 vs. 9.8 ± 7.2, respectively, $p < 0.001$) and distribution of patients at different levels of injury severity ($p < 0.001$) than those who had worn a helmet. While significantly more patients who had not worn a helmet had sustained severe injury (ISS 16–24; 29.6% vs. 13.3%, respectively, $p < 0.001$, and ISS≥25; 12.6% vs. 4.3%, respectively, $p < 0.001$), significantly fewer patients who had not worn a helmet had an ISS less than 16 (57.8% vs. 82.4%, respectively, $p < 0.001$). In those elderly riders who had not worn a helmet, there were significant higher NISS (15.8 ± 11.1 vs. 11.5 ± 8.9, respectively, $p < 0.001$), lower TRISS (0.88 ± 0.20 vs. 0.94 ± 0.12, respectively, $p < 0.001$), and higher in-hospital mortality (5.9% vs. 1.9%, respectively, $p = 0.005$) when compared to those had worn a helmet in the motorcycle accident. Significant differences were also found between the elderly riders with or without helmet-wearing regarding hospital LOS (10.8 days vs. 12.2 days, respectively, $p = 0.019$) and proportion of patients admitted to the ICU (19.4% vs. 34.1%, respectively, $p < 0.001$), but not LICUS (9.2 days vs. 10.3 days, respectively, $p = 0.188$).

Additionally, Table 5 shows the results of analysis of helmet-wearing status among adult riders. As can be observed, adult riders who had not worn a helmet presented with a significantly lower first GCS score (12.5 ± 3.9 vs. 14.4 ± 2.0, respectively, $p < 0.001$) and had a significant distribution of patients in different level of consciousness ($p < 0.001$) compared to those who had worn a helmet. A significantly greater percentage of adult riders who had not worn a helmet presented with unconscious status as assessed by GCS score ≤8 (19.1% vs. 3.7%, respectively, $p < 0.001$) or between 9 and 12 (11.4% vs. 3.4%, respectively, $p < 0.001$), more head/neck injury (45.5% vs. 15.3%, respectively, $p < 0.001$) and face injury (1.2% vs. 0.3%, respectively,

Table 5 Injury characteristics of the adult motorcycle riders according to helmet-wearing status.

Motorcycle accident (Adult)	Helmet+ N = 4454	Helmet− N = 519	p
Gender, n (%)			<0.001
Male	2461 (55.3)	365 (70.3)	
Female	1993 (44.7)	154 (29.7)	
GCS	14.4 ± 2.0	12.5 ± 3.9	<0.001
GCS			<0.001
≤8	167 (3.7)	99 (19.1)	<0.001
9–12	153 (3.4)	59 (11.4)	<0.001
≥13	4134 (92.8)	361 (69.6)	<0.001
AIS ≥3, n (%)			<0.001
Head/Neck	682 (15.3)	236 (45.5)	<0.001
Face	15 (0.3)	6 (1.2)	0.017
Thorax	371 (8.3)	56 (10.8)	0.068
Abdomen	114 (2.6)	13 (2.5)	1.000
Extremity	1027 (23.1)	71 (13.7)	<0.001
Head trauma, n (%)			
Neurologic deficit	41 (0.9)	10 (1.9)	0.039
Cranial fracture*	281 (6.3)	131 (25.2)	<0.001
Epidural hematoma (EDH)*	168 (3.8)	87 (16.8)	<0.001
Subdural hematoma (SDH)*	319 (7.2)	146 (28.1)	<0.001
Subarachnoid hemorrhage (SAH)*	420 (9.4)	134 (25.8)	<0.001
Intracerebral hematoma (ICH)*	84 (1.9)	29 (5.6)	<0.001
Cerebral contusion*	212 (4.8)	74 (14.3)	<0.001
Cervical vertebral fracture	39 (0.9)	9 (1.7)	0.090
Maxillofacial trauma, n (%)			
Maxillary fracture*	445 (10.0)	82 (15.8)	<0.001
Mandibular fracture	160 (3.6)	25 (4.8)	0.176
Orbital fracture	125 (2.8)	20 (3.9)	0.213
Nasal fracture*	63 (1.4)	16 (3.1)	0.007
ISS	8.7 ± 6.7	13.0 ± 9.4	<0.001
ISS			<0.001
<16	3841 (86.2)	323 (62.2)	<0.001
16–24	444 (10.0)	131 (25.2)	<0.001
≥25	169 (3.8)	65 (12.5)	<0.001
NISS	10.1 ± 8.0	15.9 ± 12.5	<0.001
TRISS	0.973 ± 0.084	0.927 ± 0.166	<0.001
Mortality, n (%)	37 (0.8)	21 (4.0)	<0.001
LOS (days)	9.0 ± 9.2	12.0 ± 12.6	<0.001
ICU			
Patients, n (%)	656 (14.7)	195 (37.6)	<0.001
LIS (days)	6.6 ± 7.7	7.5 ± 7.9	0.173

* indicated significant higher incidence of the associated injury in elderly motorcycle riders without helmet-wearing than those patients with helmet-wearing ($p < 0.05$).

$p = 0.017$) based on AIS ≥3, while a significantly lower percentage presented with extremity injury (13.7% vs. 23.1%, respectively, $p < 0.001$). A significantly greater percentage of adult riders who had not worn a helmet presented with more cranial fracture, epidural hematoma, subdural hematoma, subarachnoid hemorrhage, intracerebral hemorrhage, cerebral contusion, maxillary fracture, and nasal fracture. In contrast, no significant differences were found between adult riders who had and had not worn a helmet regarding incidence of mandibular fracture and orbital fracture. The adult patients who had not worn a helmet had sustained more severe injury regarding ISS (13.0 ± 9.4 vs. 8.7 ± 6.7, respectively, $p < 0.001$) and distribution of patients at different levels of injury severity ($p < 0.001$) than those who had worn a helmet. While significantly more patients who had not worn a helmet had sustained severe injury (ISS 16–24; 25.2% vs. 10.0%, respectively, $p < 0.001$, and ISS ≥25; 12.5% vs. 3.8%, respectively, $p < 0.001$), significantly fewer patients who had not worn a helmet had an ISS less than 16 (62.2% vs. 86.2%, respectively, $p < 0.001$). In those adult riders who had not worn a helmet, there were significant higher NISS (15.9 ± 12.5 vs. 10.1 ± 8.0, respectively, $p < 0.001$), lower TRISS (0.93 ± 0.17 vs. 0.97 ± 0.08, respectively, $p < 0.001$), and higher in-hospital mortality (4.0% vs. 0.8%, respectively, $p < 0.001$) when compared to those had worn a helmet in the motorcycle accident. Significant differences were also found between the adult riders with or without helmet-wearing regarding hospital LOS (9.0 days vs. 12.0 days, respectively, $p < 0.001$) and proportion of patients admitted to the ICU (14.7% vs. 37.6%, respectively, $p < 0.001$), but not LICUS (6.6 days vs. 7.5 days, respectively, $p = 0.173$).

Discussion

This study analyzed the demographics and characteristics of injuries observed in a geriatric population with motorcycle-related injuries presenting at a level I trauma center. Analysis of the data indicates that elderly motorcycle riders have a higher severe injury score, present with a different bodily injury pattern, and have worse outcome and higher mortality than those adult motorcycle riders. It also revealed that a significant percentage of elderly motorcycle riders do not wear a helmet, which puts them at high risk of injury with worse outcome.

In the current study, compared to adult patients, there were significant less elderly patients in the subgroup of ISS <16 and more elderly patients in the subgroup of ISS between 16 and 24. In these two groups of patients, there were also significant difference regarding NISS, TRISS, in-hospital mortality, hospital LOS, proportion of patients admitted to the ICU, and longer ICU stay. These results of the motorcycle-related trauma in the elderly are generally in agreement with the reports of literature that higher injury severity, less favorable outcomes, prolonged hospital stays, and higher mortality in the elderly trauma patients [6,10]. Although some reports had indicated that the severe injury rate in the elderly was almost 5 times greater than in adults [2] and there was an overall mortality rate of 14.8% in a meta-analysis of 65,897 pooled geriatric trauma patients [10], we did not found such obvious difference in injury severity and mortality in the motorcycle-related elderly patients in this study. Considering that almost all of motorcycles are forbidden on highways in Asian cities and that most traffic accidents occur in relatively crowded streets in these cities, we hypothesize that the reason for the discrepancy between our findings and those of prior studies is that most motorcycle injuries in the Asian region occur at relatively low velocity. In addition, different trauma mechanism as there are less motorcycles used in the racing, recreation, and off-road use in the Asian cities may also contribute the discrepancy of the reported mortality.

Based on analysis of AIS, the elderly motorcycle riders were found to have presented with a different bodily injury pattern compared to the adult motorcycle riders. Elderly drivers were found to have a higher incidence of potentially fatal injuries such as intracranial hemorrhage and chest injuries when compared with younger individuals [6]. In this study, the elderly motorcycle riders presented with a higher rate of injury to the head/neck, thorax, and extremity region but less to the abdomen area based on AIS ≥3, and a higher rate of subdural hematoma, rib fracture, urinary bladder injury, femoral fracture, tibia fracture, and fibular fracture. In elderly motorcycle riders, a higher rate of injury to the thorax was associated with a higher incidence of rib fracture. Notably, the elderly motorcycle riders sustained a greater incidence of urinary bladder injury than adult motorcycle riders, whereas the latter sustained a significantly higher rate of injuries around the abdomen. Although urinary bladder injury is reported to be associated with a concomitant pelvic fracture, in such condition the blunt force trauma also place the bladder and urethra at risk for injury [11,12], there was no significant difference regarding pelvic fracture in the elderly and adult motorcycle riders (3.6% vs. 3.5%, respectively, $p = 0.807$) in this study [Table 3]. The reason that the adult motorcyclists had a significantly higher rate of abdominal injury in this study is unknown, although we had suspected there may exist a higher impact of handle bar collision of these adult motorcyclists who may drive faster and more recklessly than older motorcyclists [13]; however, further analysis is not possible due to insufficient documentation of the circumstances of injury events and a lack of applicable emergency codes specific for handle bar injury [14]. Addition, with a higher rate of injury to extremity, the elderly motorcycle riders also sustained a greater incidence of bone fractures in the lower extremities than adult motorcycle riders.

In Taiwan, motorcyclist fatality accounts for nearly 60% of all driving fatalities in the country [15]. Analysis of the collected data revealed an association between higher fatality rates and the factors of male sex, advanced age, unlicensed status, not wearing a helmet, riding after alcohol consumption, and alcohol consumption of more than 550 cc [15]. In this current study, 30 of 132 (22.7%) fatalities among the elderly and 76 of 145 (52.4%) among adults were found to have involved motorcycle use; however, there was twice in-hospital mortality of the elderly motorcyclists than the adult motorcyclists (3.0% vs. 1.5%, respectively, $p = 0.001$), which reflect the vulnerability of the elderly motorcyclist and the importance of the protection intervention. Among several preventive measures, helmet wearing in particular has been shown to protect against head and other serious injuries and to be cost effective [16–20]. Recent studies have shown that helmets reduce head injury rates by up to 72 per cent in motorcycle trauma [21–23]. In the current study, elderly motorcycle drivers, but not passengers, were found less likely to wear a helmet than adult motorcycle drivers. In the elderly motorcyclists, compared to patients who had worn a helmet, patients who had not worn a helmet had a lower first GCS score, and a greater percentage presented with unconscious status (GCS score ≤8); had sustained subdural hematoma, subarachnoid hemorrhage, cerebral contusion, and severe injury (ISS 16–24 and ≥25); had longer hospital stay and higher mortality; and had required admission to the ICU. In the adult motorcyclists, the results are similar to those in the elderly motorcyclists. Compared to patients who had worn a helmet, patients who had not worn a helmet had a lower first GCS score, and a greater percentage presented with a GCS score ≤8 or between 9 and 12; had sustained epidural hematoma, subdural hematoma, subarachnoid hemorrhage, intracerebral hematoma, cerebral contusion, and severe injury (ISS 16–24 and ≥25); had longer hospital stay and higher mortality; and had required admission to the ICU. These findings indicate that wearing a helmet may prevent head injury and reduce injury severity among both elderly and adult motorcycle riders.

The limitations of this study include the use of a retrospective design and the lack of availability of data regarding the circumstances of the mechanism of injury. Lack of data regarding the motorcycle speed during accidents, the type of motorcycle, type of helmet material, and the use of any other protective materials, such as knee braces, prevented analysis of motorcycle-related hospitalization based on exposure-based risk. Furthermore, the use of psychoactive drugs or alcohol was not identified and analyzed and may be a confound factor. In addition, the impact of preexisting comorbidities in the elderly on the hospitalization course and on the mortality remained unclarified.

Conclusion

Elderly motorcycle riders tends to present with a higher injury severity compared to adult patients and a bodily injury pattern differing from that of adult motorcycle riders, indicating the need to emphasize the use of protective equipment, especially helmets, to reduce their rate of trauma to head and maxillary regions and the severity of injury.

Conflicts of interest

The authors declare that they have no competing interests.

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REFERENCES

[1] Brown JB, Bankey PE, Gorczyca JT, Cheng JD, Stassen NA, Gestring ML. The aging road warrior: national trend toward older riders impacts outcome after motorcycle injury. Am Surg 2010;76:279–86.

[2] Ciesla DJ, Pracht EE, Tepas 3rd JJ, Cha JY, Langland-Orban B, Flint LM. The injured elderly: a rising tide. Surgery 2013;154:291–8.

[3] Pandya SR, Yelon JA, Sullivan TS, Risucci DA. Geriatric motor vehicle collision survival: the role of institutional trauma volume. J Trauma 2011;70:1326–30.
[4] Caterino JM, Valasek T, Werman HA. Identification of an age cutoff for increased mortality in patients with elderly trauma. Am J Emerg Med 2010;28:151–8.
[5] Min L, Ubhayakar N, Saliba D, Kelley-Quon L, Morley E, Hiatt J, et al. The vulnerable elders survey-13 predicts hospital complications and mortality in older adults with traumatic injury: a pilot study. J Am Geriatr Soc 2011;59:1471–6.
[6] Cevik Y, Dogan NO, Das M, Karakayali O, Delice O, Kavalci C. Evaluation of geriatric patients with trauma scores after motor vehicle trauma. Am J Emerg Med 2013;31:1453–6.
[7] Weiss H, Agimi Y, Steiner C. Youth motorcycle-related brain injury by state helmet law type: United States, 2005–2007. Pediatrics 2010;126:1149–55.
[8] Talving P, Teixeira PG, Barmparas G, Dubose J, Preston C, Inaba K, et al. Motorcycle-related injuries: effect of age on type and severity of injuries and mortality. J Trauma 2010;68:441–6.
[9] Rogers SC, Campbell BT, Saleheen H, Borrup K, Lapidus G. Using trauma registry data to guide injury prevention program activities. J Trauma 2010;69:S209–13.
[10] Hashmi A, Ibrahim-Zada I, Rhee P, Aziz H, Fain MJ, Friese RS, et al. Predictors of mortality in geriatric trauma patients: a systematic review and meta-analysis. J Trauma Acute Care Surg 2014;76:894–901.
[11] Bjurlin MA, Fantus RJ, Mellett MM, Goble SM. Genitourinary injuries in pelvic fracture morbidity and mortality using the National Trauma Data Bank. J Trauma 2009;67:1033–9.
[12] Durrant JJ, Ramasamy A, Salmon MS, Watkin N, Sargeant I. Pelvic fracture-related urethral and bladder injury. J R Army Med Corps 2013;159:i32–9.
[13] Smith BW, Buyea CM, Anders MJ. Incidence and injury types in motorcycle collisions involving deer in Western New York. Am J Orthop (Belle Mead, NJ) 2015;44:E180–3.
[14] Mezhir JJ, Glynn L, Liu DC, Statter MB. Handlebar injuries in children: should we raise the bar of suspicion? Am Surg 2007;73:807–10.
[15] Jou RC, Yeh TH, Chen RS. Risk factors in motorcyclist fatalities in Taiwan. Traffic Inj Prev 2012;13:155–62.
[16] Hundley JC, Kilgo PD, Miller PR, Chang MC, Hensberry RA, Meredith JW, et al. Non-helmeted motorcyclists: a burden to society? A study using the National Trauma Data Bank. J Trauma 2004;57:944–9.
[17] MacLeod JB, Digiacomo JC, Tinkoff G. An evidence-based review: helmet efficacy to reduce head injury and mortality in motorcycle crashes: EAST practice management guidelines. J Trauma 2010;69:1101–11.
[18] Schneider WHt, Savolainen PT, Van Boxel D, Beverley R. Examination of factors determining fault in two-vehicle motorcycle crashes. Accid Anal Prev 2012;45:669–76.
[19] Heldt KA, Renner CH, Boarini DJ, Swegle JR. Costs associated with helmet use in motorcycle crashes: the cost of not wearing a helmet. Traffic Inj Prev 2012;13:144–9.
[20] Jung S, Xiao Q, Yoon Y. Evaluation of motorcycle safety strategies using the severity of injuries. Accid Anal Prev 2013;59:357–64.
[21] Ooi SS, Wong SV, Yeap JS, Umar R. Relationship between cervical spine injury and helmet use in motorcycle road crashes. Asia Pac J Public Health 2011;23:608–19.
[22] Dinh MM, Curtis K, Ivers R. The effectiveness of helmets in reducing head injuries and hospital treatment costs: a multicentre study. Med J Aust 2013;198:415–7.
[23] Philip AF, Fangman W, Liao J, Lilienthal M, Choi K. Helmets prevent motorcycle injuries with significant economic benefits. Traffic Inj Prev 2013;14:496–500.