



## Traumatic Brain Injury in Underage Motorcycle Drivers: Clinical Outcomes and Sociocultural Attitudes from a Lower-Middle-Income Country

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■ **BACKGROUND AND OBJECTIVE:** Poor societal attitudes and inadequate law enforcement have greatly contributed to the increase in underage motorcycle driving in Pakistan. This study reports the burden of traumatic brain injury (TBI), clinical characteristics/outcomes, and reason for driving in underage motorcyclists.

■ **MATERIALS AND METHODS:** A prospective study was conducted throughout 2021. Demographics, mechanism of injury, helmet use, number of passengers, clinical outcomes, reason for driving and parental awareness/consent status, referral pathway, and transport duration were documented.

■ **RESULTS:** Of a total of 1052 motorcyclists with TBI, 112 were underage drivers. The mean age was 14.7 years (range, 10–17 years); 98.2% were male and 17% wore protective helmets. The most common reason for driving was recreational, followed by for domestic chores. In 66 patients, there was parental awareness and 30 of these patients had active parental consent. These patients reported domestic chores as the reason for their journey, whereas recreational purposes were a more prevalent reason in patients without parental awareness/consent ( $P < 0.001$ ). Most patients were brought by provincial ambulance service (response time 12.8 minutes). Some patients

came from peripheral hospitals (26.8%) and private hospitals (14.3%) that lacked neurosurgical cover, and these were associated with severer baseline injuries ( $P < 0.001$ ). The average stay was 6.5 days, and 75.9% of patients were discharged with a good Glasgow Outcome Scale score.

■ **CONCLUSIONS:** Most underage patients with TBI resulting from motorcycle driving are adolescent boys who do not use helmets. Trauma prevention systems and involvement of multiple stakeholders are needed to reduce underage driving. Efficient referral systems must transport patients to appropriate neurosurgical cover, which is lacking outside major cities.

### INTRODUCTION

Traumatic brain injury (TBI) is a leading cause of mortality, long-term disability, and economic loss worldwide.<sup>1,2</sup> Road traffic accidents (RTAs) are the leading cause of TBI globally.<sup>3</sup> TBI is most prevalent in lower-middle-income countries (LMICs), in which 90% of all RTA-associated TBI occurs.<sup>3,4</sup> Patients with TBI in LMICs are generally younger than their higher-income country (HIC) counterparts.<sup>3,5</sup> The Global Burden of Disease data suggest that approximately 2 million

#### Key words

- Head injury
- Motorbike
- Pakistan
- Prevention
- Traumatic brain injury
- Trauma systems
- Underage driving

#### Abbreviations and Acronyms

- DGH:** District general hospital
- GCS:** Glasgow Coma Scale
- GOS:** Glasgow Outcome Scale
- HIC:** Higher-income country
- JPMC:** Jinnah Postgraduate Medical Centre
- LMIC:** Lower-middle-income country
- PINS:** Punjab Institute of Neurosciences
- RTA:** Road traffic accident

**sTBI:** Severe traumatic brain injury

**TBI:** Traumatic brain injury

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fatalities from TBI are preventable in LMICs, and patients with RTA-associated TBI in LMICs are in their most economically productive years of life; thus, their disability and deaths are not only a familial tragedy but a big part of economic loss that is preventable or reduceable.<sup>4,6-8</sup>

Pakistan is a prototypic LMIC, with a population of more than 220 million. The country has seen explosive urbanization and motorization in the 21st century. Road networks are rapidly proliferating but are of a poor standard, coupled with rapid increases in the number of vehicles, many of which are old and not roadworthy.<sup>9-11</sup> Like many South Asian countries, the most unsafe vehicles, motorcycles, have become the primary mode of transport for most of the population, who are socioeconomically poor. Before 2004, the number of motorcycles purchased annually in Pakistan was less than 0.1 million, a figure now sitting at 2 million, meaning that over 5000 new motorcycles are added to traffic daily.<sup>11,12</sup> The government policy for these vehicles is such that there is little to no barrier to acquiring and driving them, making motorcycles the leading mode of transport and an essential piece of equipment to sustain incomes of lower-class and lower-middle-class families.<sup>9-11,13,14</sup>

Pakistan has one of the highest incidences of TBI worldwide. The incidence of RTA-associated TBI was reported to be 1500 per 100,000 people per year in the 2004 National Injury Survey,<sup>15</sup> a figure that is considered an underestimate and believed to have significantly increased as a result of worsening conditions. This can be appreciated from the institutional series of TBI showing significant increases in annual departmental volumes of head injury.<sup>9,10,12-14,16-20</sup> Poor record keeping and a lack of registries have significantly underestimated the scope of the problem.<sup>21</sup> In addition, the country needs a significant overhaul in its trauma systems, which may significantly reduce morbidity and mortality, as shown by literature from Pakistan and other countries.<sup>4,22</sup> Large systematic reviews evaluating neurotrauma care systems have emphasized that literature from the developing world is lacking and that there is a need for studies from LMICs so that context-specific policies for neurotrauma systems can be developed.<sup>4,8</sup> This is necessary because most studies evaluating trauma care systems and policies/preventions are from HICs, and the approaches used may not be applicable because of contextual, environment, population, culture, and infrastructure differences.<sup>4,8</sup>

Underage children driving motorcycles for recreational purposes, household chores, or employment are common knowledge to Pakistan's neurosurgical community and society.<sup>9-12,14,16-20</sup> These children drive in a country in which driver attitudes are exceptionally hostile and aggressive, coupled with a lack of law enforcement and regulation and poor overall traffic infrastructure.<sup>11</sup> The children and adolescents represent an important group of patients who have always been present and reported fleetingly in institutional series of RTA TBI from Pakistan but never explored in detail. This research aims to report a unique segment of patients with TBI within our LMIC: underage drivers. We explored reasons for underage driving, mechanism of injury, protective equipment use, referral pathways, parental awareness and consent, and patient outcome with the aim to provide a foundation to guide future context-specific policies for

neurotrauma care and prevention that may be more applicable in settings such as ours.

## METHODS

This was a prospective study conducted from January to December 2021 at the Department of Neurosurgery, Allama Iqbal Medical College, Jinnah Hospital, Lahore, Pakistan (a large tertiary-care government-funded hospital and a supraregional neurosurgical referral center). The study was commenced after institutional review approval. Trauma is reviewed as a surgical emergency, and all patients with head injury are referred for evaluation by neurosurgery. Our catchment area includes the 12 million population of the city of Lahore and an additional approximately 8 million from the surrounding districts and villages. We studied all patients with TBI whose cause of head injury was motorcycle-associated RTA. Patients were motorbike drivers younger than 18 years, which is the legal age required to obtain a driving license in Pakistan. Parental consent was obtained for this study. Patient data were collected on a proforma, and parental awareness and/or consent of their child's driving was documented by interviewing the patient's parents.

Information documented included demographics (age and sex), injury (type of RTA collision), use of protective helmet, parental awareness and/or parental consent, driving reasons, number of passengers with the patient on their vehicle, and management.

Most referrals come from within our catchment area and are transported by our provincial ambulance first responders' service; however, often, referrals are made from either private hospitals within our city that first received TBI patients or district general hospitals (DGHs) outside our city; none of these hospitals have adequate neurosurgical trauma cover. Therefore, patients are transferred to our department by the ambulance service of these individual hospitals. Thus, the referral source and type of transport for each patient were documented, as was the time taken for the patient to arrive at our department, defined as the time between the call made to the on-call resident and the time at which the patient arrived. The duration of the stay was also documented. The severity of the injury, at presentation, was classified on the Glasgow Coma Scale (GCS) as mild (GCS score 13–15), moderate (GCS score 9–12), and severe (GCS score of  $\leq 8$ ). Patient outcome was classified using the Glasgow Outcome Scale (GOS) as poor (GOS score 1–3) or good (GOS score 4 and 5).

Patient demographics and variables results were entered into and analyzed using SPSS version 27 (IBM Corp., Armonk, New York, USA) to assess the relationship between variables. Descriptive statistics were calculated as frequencies and percentages for categorical variables and means, medians, and standard deviations for continuous variables. The  $\chi^2$  test was used to assess associations between categorical data, and an independent-sample *t* test was used to compare means. A *P* value  $< 0.05$  was considered statistically significant.

## RESULTS

Between January and December 2021, 2184 patients presented to our emergency department with a head injury. Of these head injuries, 1503 were caused by an RTA, 1052 of which were motorcycle RTAs. Of these 1052 patients, 112 were underage motorcycle

drivers with a head injury, making the prevalence of underage motorcycle driving 10.7% of all motorcycle-associated TBI. Baseline patient demographics and descriptive statistics are reported in **Tables 1** and **2**. **Table 3** reports the crosstabulation and associations between variables found to be statistically significant.

Virtually all patients (98.2%) were male, and the median age in our cohort was 15 years (range, 10–17 years). **Figure 1** shows the frequencies of ages within this cohort of underage drivers and the number of those wearing protective helmets by age group. The most common mechanism of injury/RTA was motorcycle collision with another motorcycle (38.4%). Half of the cohort were single passengers (i.e., the driver); 83% of all drivers did not wear a protective helmet. Helmets were predominately worn by 15-year-olds to 17-year-olds. The mean age of those who wore a helmet was approximately 1 year older than that of those who did not, but this difference did not reach statistical significance ( $P = 0.052$ ). Of patients, 77.7% were managed conservatively. Most patients had mild TBI (sTBI) (47.3%). Within our cohort, 23.2% of patients had severe TBI (sTBI) ( $n = 26$ ) and the overall mortality was 13.4% ( $n = 15$ ). All patients who died had sTBI at presentation, making the mortality among patients with sTBI 57.7%.

The most reported reason for the journey was recreational (64.3%), followed by household chores and escorting family members (22.3% and 13.4%, respectively). The last two can be grouped as domestic responsibilities. All recreational reasons were either out to visit friends or on a casual drive. The mean age of patients commuting to fulfill domestic responsibilities was older than that of recreational drivers ( $P = 0.002$ ). There was a significant association between the patients' parents being aware and/or consenting to their child's motorcycle use and the reason for the journey ( $P < 0.001$ ). In 59% of cases ( $n = 66$ ), parents knew that their children were driving a motorcycle. Within this group, 45.5% ( $n = 30$ ) instructed their children to do so/consented to motorcycle use, whereas the other 54.5% ( $n = 36$ ) did not consent to the children using a motorcycle but were aware. Likewise, in 41% of cases ( $n = 46$ ), parents denied having any awareness and thus had not given consent. In cases in which parents were both aware and consented ( $n = 30$ ), 66.7% of journeys ( $n = 20$ ) were for domestic responsibilities when parents had instructed the children to carry out household tasks/escort family. The remaining 10 cases were of a recreational journey. In cases in which there was no parental awareness or consent ( $n = 46$ ), 87% of journeys ( $n = 40$ ) were recreational. In cases in which there was only awareness but no consent ( $n = 36$ ), most journeys were also reported as being for recreational purposes ( $n = 22$ ; 61.1%). Among these 36 cases, when asked why their children drove a household vehicle, despite lack of parental consent, all parents expressed a complacent approach and could not explain the vagary of this behavior.

In most of the study cohort (59%), the referral source and transport service were first responders from our provincial government service, the Punjab Prehospital Emergency and Ambulance Service (abbreviated as 1122, their contact number), followed by a peripheral (out of our city), public sector, DGHs (secondary care hospitals) who transported patients using their ambulances (26.8%). All DGHs reported a lack of neurosurgical cover in their local vicinity. A common perception observed in all DGH referrals was that patients' attendants requested a transfer to a major center

**Table 1.** Baseline Patient Characteristics Regarding Demographics, Accident Mechanism and Severity, Management, Mortality, Helmet Use, Reason for Journey, and Parental Awareness/Consent

Variables and Subvariables		Number (N = 112)		%	
Age (years), mean = 14.7; median = 15; standard deviation = 2.07; range, 10–17					
Age group					
10–13 years		31		27.7	
14–17 years		81		72.3	
Sex					
Male		110		98.2	
Female		2		1.8	
Mechanism of injury					
Motorcycle versus motorcycle		43		38.4	
Motorcycle versus any other vehicle		27		24.1	
Motorcycle slip		22		19.6	
Motorcycle against unknown object		20		17.9	
Number of passengers					
1		56		50	
2		52		46.4	
3		4		3.6	
Protective helmet					
Yes		19		17	
No		93		83	
Severity of injury (Glasgow Coma Scale score)					
Mild TBI (13–15)		53		47.3	
Moderate TBI (9–12)		33		29.5	
Severe TBI ( $\leq 8$ )		26		23.2	
Management					
Surgical		25		22.3	
Conservative		87		77.7	
Mortality					
Alive		97		86.6	
Dead		15		13.4	
Parental awareness	Yes (N = 66; 59%)	Parent consent	Yes	30 (45.5%)	26.7
			No	36 (54.5%)	32.1
	No (N = 46; 41%)	Parent consent	Yes	0	0
			No	46 (100%)	41.1
Reason for journey					
Recreational		72		64.3	
Household chore		25		22.3	
Escorting family		15		13.4	

TBI, traumatic brain injury.

**Table 2.** Arrival Times, Including Stratification by the Referral Source, Duration of Patient Stay, and Outcome at Discharge

Variables and Subvariables	Mean (Standard Deviation)	Median (Range)	Number (N = 112)	%
Time to arrival (minutes)	90 (129)	18 (5–480)	—	—
Referral source				
Punjab prehospital emergency and ambulance service (1122)				
Arrival time (minutes)	12.82 (4.35)	12 (5–20)	66	58.9
Peripheral district general hospital (outside city)				
Arrival time (minutes)	286.3 (94.1)	270 (150–480)	30	26.8
Private hospital (within city)				
Arrival time (minutes)	40.6 (7.9)	42.5 (30–50)	16	14.3
Duration of stay (days)	6.5 (5.1)	5 (1–25)	—	—
Outcome (Glasgow Outcome Scale score)				
Poor (1–3)	—	—	27	24.1
Good (4–5)	—	—	85	75.9

in the nearest major city if possible. We received 16 referrals (14.3%) from private hospitals in our city that transported patients using private ambulances. There was a significant association between the referral source and severity of injury on presentation ( $P < 0.001$ ) and their overall outcome ( $P < 0.001$ ), because 88% of referrals from private hospitals had sTBI at presentation, and private hospitals contributed 53.8% of patients with sTBI in this cohort. Our cohort's median duration of stay was 5 days (range, 1–25 days; 75th quartile 8.7 days). The quickest transport time to our location was by 1122 (mean 12.8 minutes), followed by private hospitals (40.6 minutes), followed by DGH (286.3 minutes/4.8 hours) (Table 2). Time to arrival from a DGH was on average 274 minutes longer than 1122 (95% confidence interval, 250.6–296.4 minutes;  $P < 0.001$ ), and time to arrival from a private hospital was on average 27 minutes longer than by 1122 (95% confidence interval, 25–30.7 minutes;  $P < 0.001$ ).

## DISCUSSION

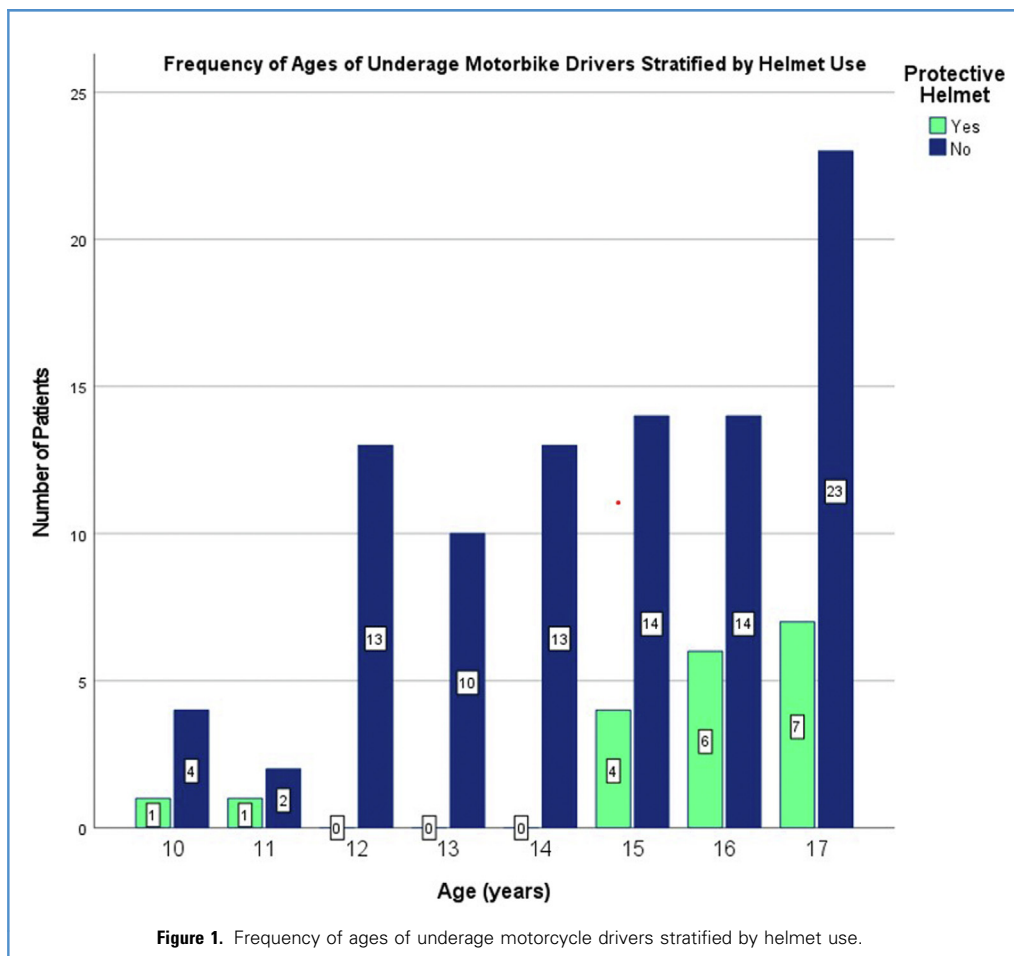
Our series is the first in the literature to report the clinical burden of underage motorcyclists in the sociocultural context of an LMIC. To appreciate our results, it is important to give context. Pakistan has 4 provinces, the most populous of which are Sindh and Punjab. Karachi is the capital of Sindh and Lahore is the capital of Punjab. Both are highly population-dense cities. Neurosurgery is provided for the masses in public sector hospitals free at the point of delivery.<sup>23</sup> Neurosurgery began in Karachi (and in Pakistan) at

**Table 3.** Crosstabulations of Statistically Significant Associations

Variable	Reason For Driving			P Value
	Domestic Responsibility	Recreational	Total	
Parental consent/awareness				
Both	20	10	30	<0.001
Only aware	14	22	36	
Neither aware nor consented	6	40	46	
Referral Source	Severity of Injury at Presentation (Glasgow Coma Scale Score)			P Value
	Mild TBI (13–15)	Moderate TBI (9–12)	Severe TBI (<9)	
Punjab Ambulance Service	39	23	4	<0.001
Peripheral DGH (outside city)	14	8	8	
Private hospital (within city)	0	2	14	
Referral Source	Outcome at Discharge (Glasgow Outcome Scale Score)			P Value
	Good (1–2)	Poor (3–5)	Total Number of Patients	
Punjab Ambulance Service	64	2	66	<0.001
Peripheral DGH (outside city)	5	25	30	
Private hospital (within city)	8	8	16	

TBI, traumatic brain injury; DGH, district general hospital (secondary care center outside city).

Jinnah Postgraduate Medical Centre (JPMC); Karachi has an approximate population of 20 million, but only 4 major trauma receiving centers.<sup>23</sup> Similarly, there are only 4 major trauma centers in Lahore, which serve a population of 12–20 million.<sup>13</sup> In 1970, JPMC reported 600 patients with TBI, a figure that increased to 3008 cases in 2003.<sup>13</sup> Between these periods, RTA gradually overtook falls as the leading cause of TBI. In 2021, JPMC reported a total head injury volume of 5546 patients over 4 months (an estimated 16,638 over 1 year).<sup>13,24</sup> A similar pattern for TBI, in general, can be observed in Lahore, a city that rapidly began to urbanize and motorize in the 21st century. Insight can be gained from the largest of 2 of the 4 major trauma centers, the Punjab Institute of Neurosciences (PINS) (which was the first neurosurgery department in Punjab and has



3 independently operating neurosurgical units) and Jinnah Hospital Lahore. In 2014, PINS reported a total volume of 3851 head injury cases over 6 months, of which 70% ( $n = 2703$ ) were RTA, 70% of which ( $n = 1892$ ) were caused by motorcycles and the remainder by cars. This would make approximately 5676 motorcycle accidents over 1 year, with motorcycles responsible for approximately 50% of all TBI at the largest neurosurgery center (in terms of volume of patients seen) in Pakistan. Similarly, 48.2% of all TBIs in our series were caused by motorcycle-associated RTAs. In 2019, neurosurgery unit 1 from PINS reported 1600 cases of head injury from motorcycles alone over 5 months, which when approximated to the overall departmental volume, as on average, each unit receives the same amount of trauma; motorcycle-associated RTA may be 4800 cases over 5 months and 11,500 over 1 year.

Most series evaluating TBI in Pakistan state that 80%–100% of patients are men in motorcycle-associated RTAs.<sup>9,10,12,14,19</sup> This finding is also reflected in our study, in which >98% of patients were male. This finding is not surprising given the sociocultural landscape, in which women, especially adolescent girls, do not drive motorcycles. In Pakistan, most households operate on a single husband's income, which is often supplemented by young

male children as soon as they are able to earn.<sup>25</sup> In many families, male children are encouraged from a young age to drive a motorbike because it aids in domestic chores.<sup>9,11,25</sup> This situation is reflected in the cases where parents were both aware of and consented to their child driving; the principal reason for the journey was to complete domestic chores such as running errands or escorting female family members. This situation is shown in **Figure 2**, which captures an adolescent boy driving with passengers who are most likely his mother and younger siblings (5 passengers on a 2-person motorcycle), breaking the legal limit of maximum passengers allowed on a motorcycle (2), the legal requirement for the driver to wear a protective helmet, and the minimum age to be licensed to drive. This image was captured by the first author at midday on a major carriageway road with a speed limit of 60 km/hour.

Just less than 50% of our cohort had mild TBI. This figure closely reflects that of other series in Pakistan studying motorcycle-associated TBI.<sup>9,14</sup> Similarly, the mortality in patients with sTBI in our study was 57.7%, which is close to that in other motorcycle-associated TBI series from Pakistan, where mortality has generally been highest in the youngest age-groups.<sup>9,14,20</sup> Equally, helmet use has been as low as 0.87% or as



**Figure 2.** An underage adolescent boy is carrying 4 passengers, which exceeds the total capacity of 2 for a single motorcycle. The individual at the back is presumably a female relative, such as an older sister, mother or aunt, and the young children, likely

cousins, or siblings. No helmet is being used. Captured in August 2021 by the first author on their daily commute to the hospital on a dual-carriageway road of 3 lanes with a speed limit of 60 km/hour (37 mph).

high as 23.3% of patients involved in motorcycle RTA in Pakistan, but generally at the lower end of this range.<sup>9,10,14,17,19</sup> For our study, this figure was 17%. In Pakistan, helmet laws are mandated but not enforced. The benefits of helmets in motorcycle RTA are clear. They significantly reduce the severity of injury, morbidity, and mortality.<sup>26</sup> Helmet enforcement is important in our demographic because the predominant group of patients involved in motorcycle RTA in Pakistan are men in their second and third decade. These men disproportionately tend to be from economically deprived families of Pakistani society in which men are the breadwinners and women do not work; thus, men's disability or death further worsens the poverty affecting numerous families.<sup>9-12,14,17-20,24</sup>

Although developed economies/HICs have trialed graduate drivers' licenses, helmet laws, and well-structured approaches to allow new drivers to develop driving skills and transition to safe

independent drivers,<sup>8</sup> the problem in Pakistan is systemic, including sociocultural and corruption issues.<sup>11</sup> In Pakistan, we find a proportion of motorcycle-associated TBI in underage drivers, many of whom have parental consent, and virtually none face legal repercussions. In instances where parents had not explicitly consented, they were arguably apathetic about their child's engagement in underage driving. All parents reported expressing disapproval but admitted to not taking any real steps to stop their children from driving the household motorcycle. This attitude has been previously studied to be widespread in Pakistan and a leading cause of underage driving.<sup>11</sup> In addition to a lack of law enforcement, government indifference to underage driving to schools/colleges has been reported to offset poor public transport systems.<sup>11</sup> We believe that this theory is true given the socioeconomic demographic of children and families who present to public sector hospitals, because for these families,



motorcycles are the only affordable transportation for their family's needs and often a requirement for employment and to sustain a lower-middle-income lifestyle.<sup>11,27</sup> Public transport is not to the standard required for intercity transport for families and has concerns of safety for women,<sup>11</sup> which may have contributed to underage driving for children of these lower-income families because their parents may allow them to drive for their required activities or transport of female family members; however, the obvious consequence is that these young children are not properly trained and arguably lack judgment and maturity, which predisposes them to risk-taking behavior and, hence, risk of head injury.<sup>11,27</sup>

Laws mandating helmet use for motorcycle drivers and the requirement for a driving license are well known, but these laws are not enforced, like in many other LMICs.<sup>8</sup> In Karachi, approximately 50% of drivers (older than the legal age of 18 years) sampled do not have a valid driver's license.<sup>11</sup> Thus, on a broader scale, the legal system is ridiculed from 2 fronts: complacency of the authorities and general attitudes of the public.<sup>11</sup> Financial bribery of traffic police is common and often actively pursued by the traffic police<sup>28</sup>; so is bribing testing centers to obtain a driver's license.<sup>11</sup> Complacency of the authorities can be observed at most traffic signals, where despite the presence of law officers, many motorcycles with more than 2 passengers (the maximum who should be on a motorcycle) can be observed, with many drivers ignoring the red

light signal if they see a gap in traffic from the oncoming lane (**Figure 3**).<sup>11</sup> Thus, the prevalence of underage driving in children as young as 10 years and a near-complete disregard for helmet use in Pakistan are arguably manifestations of broader poor sociocultural attitudes and absent legal enforcement.<sup>11,27</sup>

An interesting aspect of **Figure 3** is that it shows the disregard for obeying laws that are not enforced and following those that are. Captured on the first author's commute to the hospital, **Figure 3** shows a father driving a 2-person motorcycle with 6 other family members, including small children. Not only is the total number of passengers over the legal limit and the driver is not wearing helmet but is also attempting to drive into the oncoming traffic, ignoring a red light. The motorcycle driver made an effort to wear a face mask because traffic wardens were actively fining those without face masks because mask wearing laws were being tightly enforced in Pakistan because of increasing cases of COVID19. This is a typical lower-middle income family who are dependent on motorcycles for their livelihood and commuting. Along with **Figure 2**, the behavior shown is seen nationally daily so much that it has become a social norm/stereotype of motorcycle drivers.<sup>11</sup>

In the case of underage motorcycle driving, enforcing laws with a zero-tolerance policy has an important role. When directed by the authorities, the Sindh police fined 1400 underage drivers and their parents a cumulative (U.S. \$11,500) in 3 days alone. Within 3 months, 30,529 juvenile drivers and 17,126 parents/vehicle owners

were issued tickets totaling U.S. \$184,325 with an affidavit signed by parents to promise that their children would not be allowed to drive until legally eligible.<sup>29-32</sup> This situation reflects the power of enforcement in bringing offenders in line with the rule of law, and to do so requires the urgent involvement of senior policymakers. We argue that although legal actions curb the acute problem, awareness campaigns are needed to bring the much-needed sea change in the blasé attitude of both the children and the parents. These campaigns have worked in HICs but must be adapted to the socio-cultural context of Pakistan.<sup>4,8,33</sup> We argue that although TBI is commonly referred to as the silent pandemic, in Pakistan, certainly for these children, it is an **apathy pandemic**: apathy from individuals, society, and law and policy makers.

Although prehospital transport to a neurotrauma center has been a major impediment in many LMICs,<sup>4,8</sup> the 1122 service in Punjab delivers a commendable service. Investigators from Karachi have reported constraints in prehospital transport, with a minimum time of 2 hours from first responders.<sup>17</sup> In contrast, our provincial first responders transported our patients quickly and efficiently (mean 12.8 minutes). Neurosurgical departments in Lahore receive referrals from peripheral villages and districts because of a lack of local neurosurgery departments or ill-equipped neurosurgical departments in the vicinity.<sup>34,35</sup> The 26.8% of underage drivers whom we saw came from DGHs without a neurosurgical department/cover; thus, their transport took an average of 4.8 hours. It is believed that head trauma in these areas, on the outskirts of major cities, is just as high but undocumented and neglected.<sup>21</sup> In addition, there are not enough neurosurgeons in Pakistan per population, and the specialty is mostly centralized to teaching hospitals in major cities; the few neurosurgical departments outside the major cities are lacking in even basic facilities to manage head injury and so often transport their patients to other centers.<sup>23</sup> We received 14.3% of our cases from private hospitals. Most private hospitals in Pakistan do not have the facility to provide the care necessary for neurosurgical trauma and are limited to elective cases for private practice.<sup>35</sup> These hospitals often accept patients with neurotrauma but are not equipped with appropriate neurosurgical cover, especially for those with sTBI. Patients transferred from private hospitals had more severe injury (baseline) and were associated with having a poor outcome (Table 3). In our experience, all patients with moderate TBI and patients with sTBI came from private hospitals that lacked neurosurgical cover; these patients should not have been taken to these hospitals, nor should these hospitals manage such patients after delivering emergency treatment.

The private hospitals that do have the required standard of neurosurgical trauma services are unaffordable to most of the Pakistani population, many of whom are socioeconomically poor and underprivileged and cannot afford the costs of the intensive care unit after head injury because more than two thirds of the population are estimated to earn less than U.S. \$2/day/head.<sup>35,36</sup> A well-equipped private neurosurgical department in Karachi reported a total volume of 1378 patients with head injury from any cause over 2 years (2009–2011),<sup>17</sup> a number seen in mere months at the adjacent public sector neurosurgery department of JPMC in Karachi.<sup>24</sup> Comprehensive neurosurgery and neurosurgical trauma

are still provided for the masses in Pakistan by government-funded hospitals, free at the point of care.<sup>35</sup>

Unfortunately for the TBI landscape, the well-equipped neurosurgical departments that should be managing head trauma are in major developed cities, despite surrounding areas having the volume of sTBI and trauma burden necessitating local neurosurgical departments.<sup>20</sup> We receive referrals from them, because local neurosurgical departments have poor infrastructure. This situation has contributed to a perception among referring institutes and patients that head injury is best managed at neurosurgical departments in major cities at established government hospitals. This perception occurs because there is a lack of standardization of public sector neurosurgical departments, and those outside major cities have not been developed to a high enough standard.<sup>23,35</sup> This is an issue that the Pakistan Society of Neurological Surgeons has recognized and pledged to lobby the government to invest in neurosurgical centers in underserved areas where there are large populations who have to travel to distant cities for adequate neurosurgical care because a local neurosurgical unit is absent or severely underdeveloped. We argue that prevention is almost always better, and there is an urgent need to invest in public trauma prevention policies. The usefulness of such policies in Pakistan is evident from the commendable work of our colleagues in Peshawar when they introduced the first ThinkFirst (national injury prevention) chapter in our country to great success regarding head injury prevention.<sup>33</sup> Although concurrently, there is a need for better neurosurgical service in underserved areas, the neurotrauma community in our country needs to actively study appropriate public trauma prevention policies and invest in their implementation.

Several limitations need to be acknowledged. Our work and work from other neurosurgical departments treating TBI in Pakistan underestimate volume because all trauma presenting to the emergency department is referred to neurosurgery only if a head injury needs to be evaluated. The general surgery departments of hospitals in Pakistan have reported a substantial volume of trauma in motorcycle drivers who were potentially not seen by neurosurgery.<sup>10,12</sup> These reports did not analyze or discuss the underage drivers in their cohorts, did not report severity of injury by GCS score, and excluded patients who died, so a direct comparison is difficult. The need for registries is essential to appreciate the true scope of TBI in Pakistan, which is grossly underestimated.<sup>21</sup> Second, although there is no documented evidence, we argue that at least as many underage drivers have minor accidents that are brushed off as minimum injury and thus did not warrant a hospital visit, so they are not reported. There is no follow-up of our surviving patients and whether they were involved in subsequent accidents. It would be interesting to see if parents who were not aware of their children's driving had subsequently actively stopped them from driving. Many parents, when asked, were not recriminative, and a reprise is of no consequence because they consider their underage children's driving to be a solution to their commuting trouble.<sup>11</sup> Another limitation is that in 2021, there were lockdowns due to COVID-19 cases in Pakistan. However, the total number of underage motorcycle drivers in 2021 was approximately the same, at our



department, compared with pre-pandemic years. This finding may mean that the lockdown restrictions did not affect the total number of underage motorcyclists because children still went on recreational drives. However, lockdown did affect the reason for the journey. No patient reported traveling to educational institutes during their journey, which is a common reason that our department has previously seen in adolescent motorcyclists.<sup>9</sup> This situation is likely caused by the multiple short-term and long-term closures of schools and colleges in Pakistan resulting from lockdown restrictions. Arguably, there is a devil-may-care and recreational attitude and mindset as well as irresponsible parenting regarding civic responsibilities.

As we advance, options to address underage driving should evaluate the role of policy makers in introducing major reforms to Pakistan's road traffic systems, including implementing helmet use laws, and developing an infrastructure to teach teenagers to drive in a safe and supervised fashion. Commitment from government and nongovernment organizations and the neurosurgical community is necessary to catalyze a cultural change in the attitudes of institutions, parents, and youth. This strategy requires education, awareness, and involvement of many stakeholders for long-term changes, and legal action can serve in the immediate short-term as a major preventative barrier to underage TBI.

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## CONCLUSIONS

In Pakistan, underage motorcyclists are exclusively male and drive without helmet use. The principal reasons for underage driving are recreational enjoyment and enforced domestic responsibility. The prevalence of such activity is contributed to by poor law enforcement, parental and societal attitudes, a generally poor motor legal system, and absent public trauma prevention systems. There is an urgent need to improve public head injury prevention systems in LMICs, including evaluating options for changing political will, law enforcement, education, and sociocultural attitudes.

## CRedit AUTHORSHIP CONTRIBUTION STATEMENT

**Mohammad Ashraf:** Conceptualization, Methodology, Data curation, Formal analysis, Visualization, Writing - original draft, Writing - review & editing. **Usman Ahmad Kamboh:** Supervision. **Syed Shahzad Hussain:** Data curation, Project administration, Resources. **Muhammad Asif Raza:** Data curation, Project administration, Resources. **Mehreen Mehboob:** Data curation, Project administration, Resources. **Mohammad Zubair:** Data curation, Project administration, Resources. **Manzoor Ahmad:** Data curation, Project administration, Resources. **Naveed Ashraf:** Supervision.

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