Annals of King Edward Medical University

Research Article

Changing Presentation of Traumatic Brain Injuries in a Tertiary Hospital Lahore Following Enforcement of Motorcycle Helmet Laws - A Mixed-Method Study

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Abstract

Objectives: To observe change in traumatic brain injury (TBI) presentation after enforcement of a motorcycle helmet law and to explore perspectives of stakeholders on road safety measures.

Methods: A cross-sectional study was undertaken based on retrospective record review of traffic-related TBI patients, supplemented by a qualitative component. Patient data in periods before and after helmet-law enforcement were stratified by TBI grade. Stakeholders as doctors, motorcyclists, and policemen were interviewed to explore perceptions regarding the observed changes in neurotrauma, helmet-use behaviour and effectiveness of helmet-law enforcement.

Setting: Neurosurgery department, public-sector tertiary hospital in Lahore.

Results: After the law's enforcement, significant improvement in mean Glasgow Coma Scale (GCS) scores were seen on patient-admission (from 11.15 ± 3.51 to 12.24 ± 3.30). The severity of TBI, proportion of intracranial haemorrhages and other associated head injuries all reduced significantly ($p < 0.05$). Patient-survival rate increased (74.7% to 82%) and the operative rate reduced from 13.3% to 10.8%. After interviewing stakeholders, the main theme identified was "Enforcement of road safety measures remains partial and inconsistent". Changes in healthcare burden and challenges in implementing legislature were noted.

Conclusion: An association between the enforcement of a motorcycle helmet law and a decrease in the severity of traffic-related TBI hospital admissions was observed. Nonetheless, sustained helmet law enforcement remains a challenge in a temperate climate, and children, females and pillion riders are poorly-protected by current road policies.

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Key Words: Traumatic Brain Injury, Motorcycles, Helmet, Injuries, Prevention, Transportation, Epidemiology

Introduction

Traumatic brain injury (TBI), long on the rise in low and middle-income countries (LMICs), is largely attributable to road traffic incidents (RTI)[1]. Though LMICs have only 60% of the world's vehicles, 93% of the world's road fatalities occur in these regions[1]. The United Nations Decade of Action for Road Safety (2011–2020) ambitiously aimed to halve the 1.3 million traffic-related deaths that occur each year by 2020 through improved road-safety management, enhanced road and vehicle safety, better-informed road users, and an improved post-crash response[2]. Implementation of effective interventions, prompted by national actions and supported by a

conducive environment is the sole path to avoiding the staggering amount of national burden brought by these largely preventable 'accidents'[3]. However, the global incidence of TBI continues to rise, with limited progress being made[4], particularly in LMICs[3].

It is firmly established that enforced helmet use by all passengers is effective in reducing the severity of presentation of TBI[1,5,6]. Helmet use can reduce approximately three-fourths of serious brain injuries and death in 97% of motorcycle crashes[7]. In 1997, change in legislation increased motorcycle helmet use in Taiwan[8]. The result: a 33% drop in number of hospitalized patients with motorcycle-related head injuries. In addition, reduced severity of injuries on presentation, a decline in the neurosurgical operative rate and a significantly improved patient outcome were seen. In 2003, a similar observation was made in Italy[9] showing a 31.4% decline in the RTI-TBI admissions to neurosurgery after introduction of a revised motor-cycle helmet law.

In Pakistan, achieving universal helmet use remains a challenge. In 2016, the WHO estimated[1] 10% of motorcycle riders wear helmets. Pakistan's enforcement of the national motorcycle helmet law has been given a score of 3 out of 10, with a higher score indicating better-perceived law enforcement[1]. With annual road traffic fatalities numbering 27,582, and 73.76% of registered vehicles being motorcycles[1], legislature promoting helmet use can profoundly impact the clinical picture of brain injuries in the country. Lack of government commitment to road-safety declarations[10], poor civic engagement[3], increased motorization, inadequate traffic education and slow implementation of traffic safety regulations are the main reasons for the increasing incidence of TBI in LMICs[4].

In late September 2018, enactment of helmet laws in Lahore[11] provided the opportunity to evaluate the impact of local enforcement of unrestricted helmet laws on neurotrauma, and to explore the roadblocks to achieving Global Road Safety Target 7 (by 2030, increase the proportion of motorcycle riders correctly using standard helmets to close to 100%), to which Pakistan is committed[12].

The objective of the study was to compare TBI characteristics, in periods before and after implementtation of a helmet-law enforcement, in a public sector tertiary care setting which caters services to densely populated areas of Lahore. The study also explored stakeholder perspectives for changes in neurotrauma, helmet-use behaviour and the effectiveness of helmet law enforcement.

Methods

A cross-sectional study was undertaken based on retrospective record review of RTI-TBI patients presenting to a government tertiary hospital in Lahore, supplemented by a qualitative component. Record data of RTI-TBI patients admitted from 1/10/17 to 1/3/18 (pre-law enforcement) and from 1/10/18 to 1/3/19(post-law enforcement) was extracted from patient records using a structured checklist.

Ethical clearance was granted by the Institutional Review Board of the University (no.759/RC/KEMU, 8/5/2019). Head of Neurosurgical department provided administrative approval to extract data from patient files. Confidentiality of the patients was ensured. Additionally, verbal consent was taken prior to interviewing the participants of the qualitative component of the study.

All admitted patients presenting acutely to the Emergency wing of the Neurosurgery Department of a tertiary hospital with TBI and a history of RTI were included in the study. Non-admitted patients and those reported expired upon arrival were excluded. The wing had 35 beds available throughout the prelaw period, increasing to 69 beds thoughout the postlaw period.

The structured checklist used for extracting information from patient records included patient name (given a unique ID number for confidentiality), gender, age, survival status, duration of hospital stay, GCS scores on admission and upon discharge, any neurosurgical intervention, and, if present, a description of intracranial haemorrhage (epidural, subdural, subarachnoid, etc.) and other associated head injuries (detected either clinically; ENT bleed, rhinorrhoea, or radiographically; cerebral oedema, fracture, etc.). As

part of data preparation, ages were grouped into 10 year intervals, and all patients were stratified according to TBI status in accordance with commonly-used grading criteria[13, 14] (***Table I***).

Table I: *Stratification Criterion for Traumatic Brain Injuries*

Grade of TBI	Clinical (GCS score)	Radiographic (significant CT Scan Findings)
Uncomplicated Mild TBI	13–15	Negative
Complicated Mild TB	13–15	Positive
Moderate TBI	9-12	Not Considered
Severe TBI	3–8	Not Considered

The GCS score has 3 components, testing a patient's verbal responses (5 points), eye movements (4 points) and body movements (6 points). Total score of 15 (5 + 4 + 6 respectively) is the best possible score, where 3 is the poorest score, in a comatose patient, for example. If patient has an endotracheal tube inserted, speech cannot be assessed and the score has a total of 10 (4 + 6). In the score 2t, 't' represents intubation, and '2' represents sum of eye movement and body movement scores. Since intubated patients have poor outcomes, we imputed 't' to represent 1(lowest speech score). Thus, an intubated, sedate and paralyzed patient of 2t/10 was considered as 3/15.

SPSS software version 23 was used in comparing patient-survival rate, patient-operative rate, and frequency of suboptimal GCS on discharge (below 15 score) in the pre-helmet law-enforcement period and the post-helmet law-enforcement period. Comparison of means (t-test) was undertaken to test for significant differences in mean GCS scores on admission, on discharge and in duration of hospital-stay. The associations between grade of TBI and the law-enforcement periods; haemorrhages, other associated injuries, operative rate and survival rate with gender and age-groups were analysed using χ^2-test.

The record review was followed by qualitative component of the study. Structured interviews using field guides were conducted with 4 traffic police officers, 4 neurosurgeons and 4 motorcyclists of the general public. The perceived effect of helmet law-enforcement on the healthcare system, road safety concerns, and barriers to its enforcement were explored.

Participants, particularly policemen, were asked to explain any patterns and problems encountered in helmet-law enforcement and public attitude towards helmet-use. Motorcycle riders were approached in the vicinity of the hospital and interviewed to understand their perspectives on helmet ownership and the effectiveness of the helmet policy, license-exam, and poster-campaigns in promoting helmet use. Interview notes were transcribed manually within 24 hours. Content analysis was undertaken for qualitative data. Transcripts were coded, categorized from which themes were drawn.

Results

Record review found 462 patient files eligible for the study. Due to incomplete records, 6 files were discarded. The male-to-female ratio was 3.75. Mean age was 31.8 ± 17.47, and median age 27 years (IQR = 13.5 - 40.5). During the pre-enforcement period (2017 - 18), 150 patients were admitted, with patient-beds ratio of 4.28. In the post-law enforcement period (2018 - 19) 306 patients were admitted; with the similar patient-beds ratio of 4.43.

Operative rate of RTI-TBI patients presenting to the Neurosurgery department reduced from 13.3% in 2017-18 to 10.8% in 2018-19 (p = 0.425). The operative rate amongst moderate TBI patients decreased the most, from 14.5% to 9.21%, i.e. by 57%. In both pre and post-law-enforcement periods the operative rate was highest in those of 21-30 years age, at 20%. A significant lower operative rate was seen in females (5.2% of females to 13.3% of males, p = 0.02).

Following the law-enforcement, mean GCS scores on admission (see ***Table II***) improved significantly from 11.15 ± 3.51, to 12.24 ± 3.30 (p = 0.001, mean difference 1.09, 95% CI = 0.425 - 1.75), with similar improvement in GCS scores on discharge from 11.95 ± 5.18 to 12.80 ± 4.65. However, this difference was not statistically significant (p = 0.08). The mean GCS scores on admission in post-law period showed sig-

nificant improvements among 11 - 20 year-olds and 21-30 year-olds.

Table II: *Mean GCS Scores on Admission and on Discharge in the pre-law Enforcement and post-law Enforcement Periods – Stratified by Age-Group*

Age-groups n(%)	Period	Patients n(%)	Mean GCS scores on admission	Difference in means
All ages	pre	150(100)	11.15*	+1.09
456(100)	post	306(100)	12.24*	
0-10 years	pre	11(7.38)	10.73	+0.65
37(8.1)	post	26(8.52)	11.38	
11-20 years	pre	39(26.17)	11.46*	+1.32
108(23.7)	post	69(22.62)	12.78*	
21-30 years	pre	38(25.50)	10.53*	+1.55
115(25.2)	post	77(25.52)	12.08*	
31-40 years	pre	19(12.75)	13.16	-0.71
66(14.5)	post	47(15.41)	12.45	
41-50 years	pre	26(17.45)	11.35	+1.06
60(13.2)	post	34(11.15)	12.41	
51-60 years	pre	12(8.05)	8.92	+2.24
44(9.6)	post	32(10.49)	11.16	
60+ years	pre	5(2.68)	11.00	+1.95
26(5.7)	post	21(6.56)	12.95	

**significant with p<0.05*

After law-enforcement, frequency of intracranial bleeds reduced from 75 (50%) to 110 (37%) of patients (p = 0.002). The frequency of epidural haemorrhages fell by 5.9%, subdural by 4.2%, and subarachnoid haemorrhages by 3.6% ***(Figure1)***. 10 (6.6%) of patients in the pre-law enforcement period presented with more than one type of hemorrhage, against 6 (1.98%) in the post-law enforcement period (p = 0.01). Fatility was observed most in intraventricular hemorrhages 3 (100%), followed by intracerebral 3 (33%) and subdural hemorrhages 11 (31.4%). In post-enforcement period, the percent of patients with any non-haemorrhagic associated head injuries dropped from 90 (60%) to 99 (32.4%) (p = 0.00). The proportion of cerebral oedema decreased by 13.6%, cerebral contusion by 3.5%, and simple skull fractures by 5.1%. The frequency of patients presenting with more than one type of non-hemorrhagic head injuries was 11 (7.3%) in the pre and 11(3.6%) in the post-law enforcement period.

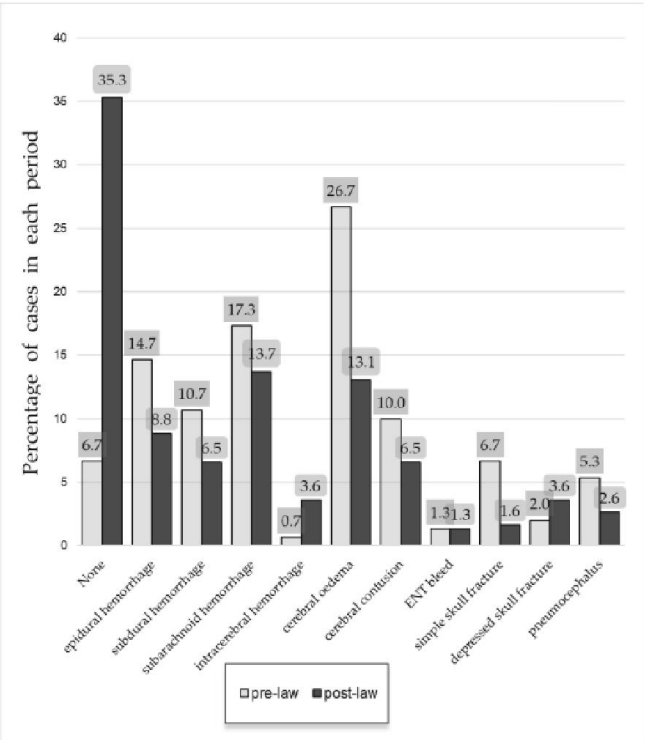

Figure 1: *Comparison of associated head injuries in the pre-law enforcement and post-law enforcement periods*

Following helmet law-enforcement, decrease in the severity of TBI, to less fatal grades, was seen on admission (p = 0.00), as shown by ***Table III***. Frequency of uncomplicated mild TBI presentation increased after law-enforcement, while those of complicated mild TBI, and moderate TBI decreased. Reduction in severe TBI was minimal, from 28 (18.7%) to 44 (14.4%). A decrease in TBI severity was also seen on discharge (p = 0.03).

Table III: Severity of TBI on admission in the pre-law enforcement and post-law enforcement periods – stratified by age-group

Age-groups n(%)	Period	Patients n(%)	Grade of TBI							
			uncomplicated mild	Δ	complicated mild	Δ	moderate	Δ	severe	Δ
All ages 456(100)	**Pre**	**150(100)**	**6*(4.0)**	**(+22.5)**	**61*(40.7)**	**(-6.4)**	**55*(36.7)**	**(-11.9)**	**28*(18.7)**	**(-4.3)**
	Post	**306(100)**	**81*(26.5)**		**105*(34.3)**		**76*(24.8)**		**44*(14.4)**	
0-10 years 37(8.1)	Pre	11(7.33)	0(0.0)	(+1.6)	5(3.3)	(+0.3)	4(2.7)	(-0.4)	2(1.3)	(-0.3)
	Post	26(8.50)	5(1.6)		11(3.6)		7(2.3)		3(1.0)	
11-20 years 108(23.7)	Pre	39(26.00)	2(1.3)	(+4.3)	16(10.7)	(-2.5)	14(9.3)	(-4.1)	7(4.7)	(-1.1)
	Post	69(22.55)	17(5.6)		25(8.2)		16(5.2)		11(3.6)	
21-30 years 115(25.2)	Pre	38(25.33)	1(0.7)*	(+6.2)	14(9.3)*	(-1.8)	17(11.3)*	(-3.5)	6(4.0)*	(-1.1)
	Post	77(25.16)	21(6.9)*		23(7.5)*		24(7.8)*		9(2.9)*	
31-40 years 66(14.5)	Pre	19(12.67)	2(1.3)	(+3.9)	9(6.0)	(-0.1)	3(2.0)	(+0.3)	5(3.3)	(-1.3)
	Post	47(15.36)	16(5.2)		18(5.9)		7(2.3)		6(2.0)	
41-50 years 60(13.2)	Pre	26(17.33)	1(0.7)*	(+2.9)	7(4.7)*	(-1.4)	13(8.7)*	(-5.8)	5(3.3)*	(-2.0)
	Post	34(11.11)	11(3.6)*		10(3.3)*		9(2.9)*		4(1.3)*	
51-60 years 44(9.6)	Pre	12(8.00)	0(0.0)	(+2.9)	7(4.7)	(-2.8)	3(2.0)	(0)	2(1.3)	(+1.3)
	Post	32(10.46)	9(2.9)		9(2.9)		6(2.0)		8(2.6)	
60+ years 26(5.7)	Pre	5(4.00)	0(0.0)	(+0.7)	3(2.0)	(+0.9)	1(0.7)	(+1.6)	1(0.7)	(+0.3)
	Post	21(6.54)	2(0.7)		9(2.9)		7(2.3)		3(1.0)	

**significant with p<0.05*

In both pre-law enforcement and post-law enforcement periods 51-60 year-old RTI-TBI patients had the highest proportion of intracranial haemorrhage (54.5%). Proportion of subarachnoid haemorrhage was greatest in 51 – 60 - year-olds (41.6%). Proportion of epidural haemorrhage was greatest in 21 – 30 - year-olds (40%). Proportion of subdural haemorrhage was most in 41-50-year-olds (32%). Non-haemorrhagic head injuries were presented most in patients over 60 years, i.e. 14(58.3%), with high rates of brain oedema 7(50%) and contusion 5(35%). Children under 10 years of age presented with highest proportion of simple skull fractures 8(36.3%) and depressed skull fractures 3(13.7%).

Subdural haemorrhage and brain oedema-associated TBI were observed more in female patients as compared to males (p = 0.302 and p = 0.515 respectively). Higher frequency of cerebral contusions was seen in females as compared to males (12.5% to 6.4%, p = 0.04). Male patients complicated more

frequently with epidural haemorrhage (11.9% to 6.3%), skull fracture (simple and depressed) and pneumoc-ephalus. Subarachnoid haemorrhage was present in about 15% of each gender. The proportion of patients without any associated head injuries were about 26% in each gender.

Patient-survival outcomes were not statisfically significant in the pre and post-law enforcement period; patient-survival rate improved from 74.7% to 82% (p = 0.081). Discharged patients with GCS of below 15 dropped from 4(2.7%) of patients to 0. Within respective age-groups, expiry rate was greatest in patients over 50 years old (40.9%), followed by children under 10 (22%). Improvements in GCS scores on discharge were statistically significant (p = 0.002). The difference in duration of hospital stay of the pre and post-law-enforcement periods was not significant (p = 0.89).

Themes identified

Altogether, 12 in-depth interviews were conducted with 4 traffic police officers, 4 neurosurgeons and 4 motorcycle riders of the general public. The analysis process of moving from categories to themes is detailed in ***Table IV***. Main theme identified was *"Enforcement of road safety measures remains partial and inconsistent"*. The subthemes are *'Enforcement of legislation challenging'* and *'Changing burden on the health system'*.

Table IV: *Analysis process for moving categories to themes*

Theme	
Enforcement of road safety measures remains partial and inconsistent	
Sub-theme	
Enforcement of legislation challenging	Changing burden on the health system
Categories	
1. Partial/ inconsistent helmet-law enforcement 2. Vehicle speed-limit and roadworthiness checks 3. Driving license inadequacies 4. Risky road-user behaviour with poor driver-education 5. Changes in type/quality of helmet used 6. Poor public awareness	1. Patients presenting to hospital with less severe injuries 2. Differences in injuries among women pillion riders 3. Less intensive interventions/ healthcare services

Enforcement of legislation challenging

This first subtheme encompasses enforced-legislature to mitigate high-risk behaviours of helmetless driving, speeding, overcrowding and reckless driving, other supplementary road safety policies being practiced and common road safety concerns.

Partial/ inconsistent helmet-law enforcement. Partial, unobjective, and inconsistent enforcement of the helmet law is reported. Enforcement is suggested to vary with the time of day and weather. Though police officers acknowledged universal helmet laws to be in the books, doctors suggest that strictness of enforcement waxed and waned, as evinced by prolonged peaks in admissions. We observed sharp peaks in admissions in Nov '18 and Jan '19. They stated,

'Traffic-related head injury has, on the whole, fallen, though there were sometimes peaks (in incidence) after the law's enforcement... TBI from other reasons, fall from height mainly, remains high.'-Neurosurgeon

Admissions have been observed to be mostly in the night, likely the result of limited police presence coupled with poor traffic visibility, especially on unilluminated roads. Doctors stated,

'In my experience night-time admissions (of RTI-TBI) have increased... Perhaps it is because of decreased traffic police presence at night.' –Neurosurgeon

A motorcycle rider suggests law-enforcement is neither impartial nor objective.

'If you have some connections, you can easily get away with not wearing a helmet. The law should be absolute, nobody should be able to escape it.' –Motorcyclist

Police officers concede their enforcement of helmet use is flexible; exemptions are made for women and pillion riders, particularly in the summer.

'...enforcement is happening but sometimes women and passengers(pillion) are exempt, especially in hot weather.'-Traffic Police Officer

In the words of a rider, there is a need for, '*...imposing fines on pillions. Pillions should have their own helmets; the driver isn't responsible for them.'*-Motorcyclist

Police presence is limited to predictable cross-roads on main roads. A police officer comments on inadequate police capacity,

'They (riders) often remove helmets when driving on smaller roads and the police cannot be everywhere.' -Traffic Police Officer

This allows motorcyclists to deceive officers by simulating helmet-use.

'So, what motorcyclists do is that they hang their helmets on the steering bar or side mirror, and as soon as they approach a crossroad, or see a policeman, they don their helmets, while driving.' -Motorcyclist

When questioned if less predictable police presence would increase helmet use, riders responded positively.

'Yes! Definitely! But the best-case would be inspection at every crossroad...That's the only solution.' -Motorcyclist

Vehicle speed-limit and roadworthiness checks. Supporting changes in enforced-legislature include a firm policy against motorcycle overcrowding, strict enforcement speed-limits, and the inspection of vehicles for their roadworthiness, all on certain major roads of the city. However, these initiatives are largely localized and, as one rider notes, their effect on vehicles is not yet apparent.

'Motorcyclists (still) do not keep side mirrors. Since helmets impair your (field of) vision a bit, if you don't have side mirrors, it would become more dangerous to drive a bike, especially when taking a turn.'-Motorcyclist

Riders state traffic cameras are not being employed to fine helmetless riders.

Driving license inadequacies. Riders judge their licensing examinations to be inadequate in testing sufficient knowledge and competence required for responsible driving.

'There is no real exam for motorcyclists. There is an exam for (driving) cars, but even that doesn't test adequately.' -Motorcyclist

Reports of frequency of license-inspection show non-uniformity; inspection remains the opinion of the police officer, not standard-procedure.

'They only check (my license) when I'm seen committing a (traffic) violation'. -Motorcyclist

Risky road-user behaviour with poor driver-education. Policing though driver education is neglected, riders opine. Unsafe behaviour of road-users is the primary concern of motorcyclists interviewed, with accidents more common when road-direction and speed-limits are ignored. As one motorcyclist comments,

'People don't follow the rules, putting others and themselves at risk.' -Motorcyclist

Changes in type/quality of helmet used. Regarding helmet quality, riders complain helmet theft and lack of safe storage places for helmets discourage purchase of high-quality helmets. While excuses given by riders to police officers are primarily climatic and financial, a rider comments availability of helmets is not a concern. However, an officer observes,

'Police inspection of helmets post-law has brought a transition towards those of acceptable (full-face type) quality.' -Traffic Police Officer

Poor public awareness. Public awareness of injuries avoided through helmet use is judged to be adequate by police officers. With minor accidents a common occurrence, most riders have experienced RTI personally, or have close contacts suffering the effects. Riders are seldom reported to give fatalistic reasons for non-compliance to the helmet policy to a questioning police officer. Riders report regular poster-campaigns promoting helmet use and road safety are ineffectual and largely ignored,

'Nobody pays any attention to them.' -Motorcyclist

Changing burden on the health system

This second subtheme covers changes observed by doctors after the road safety intervention.

Patients presenting to hospital with less severe injuries. All doctor respondents agreed that RTI-TBI patents had less severe injuries on presentation.

'In Emergency (dept.) almost all our TBI patients, barring fall patients, are motorcycle-riders with brain injuries… Since the law('s enforcement) these have become less serious(ly injured) patients. Haemorrhages are fewer now, as are limb fractures.' -Neurosurgeon

Differences in injuries among women pillion riders. Doctors opine that women, being pillion riders, face less impact in RTI;

'Generally, they are managed conservatively. Being passenger riders, they suffer less impact injuries… to the head and limbs. Males more often come with complications of limb fracture.' -Neurosurgeon

Less intensive interventions/ healthcare services. Doctors report RTI-TBI patients to be a less concerning burden to healthcare services post-enforcement.

'Nowadays we operate less on these (RTI-TBI) patients. Conservative management is usually done. Severe cases still do come, but the majority (of cases) are less (severe).' -Neurosurgeon

Exchanges with neurosurgeons revealed no major change in emergency TBI patient management guidelines within the duration under observation.

In late September, 2018, fines were introduced to enforce helmet laws in Lahore[11]. To know where we currently stand with regards road safety[15], it is important to assess the situation by determining the effectiveness of such interventions, the efficiency of responsible institutions, understanding barriers to their effective implementation and measuring their clinical impact.

Our quantitative data describes milder traumatic brain injuries after the policy change. Admissions showed significantly less morbidity in grade of TBI, and significantly better mean GCS scores, all comparable observations in larger population-based studies in Taiwan[8] and Italy[9]. Neurosurgeons related a better clinical picture, with less complicated injuries of the head and extremities, and a more conservative patient management. We observed a drop in intracranial bleeds from 50% to 37% of patients and a drop in other head complications from 60% to 32.4%, each with a significant relationship with the law's enforcement ($p < 0.05$).

Generally, patient outcomes improved after the law's enforcement, with a decreased patient-fatality rate and suboptimal GCS on discharge, similar to findings of other studies[8, 9]. Further similarities include the drop in specific TBI-related diagnoses like intracranial bleeds, and the law's effect being most profound in the same age bracket; 18-30-year-olds[9]. Amongst intracranial haemorrhages, epidural haemorrhages reduced by the greatest degree post-law; 5.8%. Larger studies' data[8, 9] also noted helmets being most effective in preventing TBI from impact

forces; epidural haemorrhage, but least effective against the high-velocity-related subarachnoid bleeds. Concurrent with another study[17], patients of greater than 60 years age had the poorest outcome throughout, likely due to their comorbidities and use of anti-platelet agents and oral anticoagulants[4].

In contrast to larger studies[8,9], both of which observed dramatic reductions in patient incidence, we observed a similar patient-bed ratio, both pre-law enforcement and post-law enforcement, suggesting that while a helmet-use policy is in place, its localized or inefficient implementation prevents it from influencing the entire patient population.

Amongst haemorrhages, subdural, intracerebral and intraventricular haemorrhages had the greatest fatality rates, in agreement with a local study[18]. Epidural (impact-related) haemorrhages were more prevalent in young adult males; this age-group has a decreased perception of risk of RTI[19]. Subdural and subarachnoid haemorrhages were more in the elderly and in female pillion riders, suggesting TBI of deceleration-shear etiology, not of direct impact. It has been shown helmetless pillion riders to be more likely to suffer subdural bleeds[20]. Policemen report laxity in enforcement of helmet use amongst pillion riders. Pillion riders are less likely to wear helmets[5] and face fewer head and neck injuries than drivers[21], as doctors report, and our data regarding female patients, who are almost entirely pillion riders, suggests. Females comprised 21.1 % of RTI-TBI-patients; far exceeding their proportion of motorcyclist population, estimated to be below 10% by interviewees, likely due to increased risk of injury of helmetless pillion riders.

Overall, we found the incidence of paediatric RTI-TBI patients 13.81%, similar to a Karachi-based study[22]. We observed children under 10 years being the second most likely age-group to expire of RTI-TBI, after those over 50 years. It is important that measures be taken to discourage having children as passengers on motorcycles. A legal minimum age for passengers should be established.

Post-law the neurosurgical operative rate decreased from 13.3%, to 10.8%; a rate similar to a Florida-based study[6] but far above that observed in Taiwan[7], with enforcement, their rate dropped by 41.8%, to 7.9%. Doctors reported surgical management being less common post-law, though severe RTI-TBI patients remain similarly incident as before and have greater healthcare demands. Helmet use is best documented as reducing mild and moderate TBI patients[7]; a multi-sectoral review of our road safety enforcement and post-crash services is required if severe TBI is to be prevented. That our enforcement of universal helmet laws, amongst other road safety interventions, is incomplete is clear.

Helmet laws are only as effective as their enforcement. Exchanges with riders revealed reckless riding, police leniency in enforcement, limited police presence, rider deception of officers, and use of cheap or convenient helmets in the post-law period, similar to observations made in an Iranian study[23]. Partially enforced helmet laws are found to be of little difference from areas without helmet laws[10,24]. If safe roads are to be a reality, the perceived likelihood of apprehendsion and penalization needs to be increased[25], by allocating police resources to areas of maximum deterence potential. Motorcyclist interviews suggest strategic, unpredictable and widespread police presence, either in person or through the introduction of automated detection-and-enforcement devices, would sharply increase helmet use. Motorcyclists viewed poster -campaigns as ineffective in promoting road safety. In Bangladesh, similar low-cost policies have been viewed as government circumventing commitments to funding real road safety interventions[10]. Further-more, policing through the road-user education has been largely neglected and demands attention.

There are some limitations of the study. Data was collected from only a single public-sector tertiary hospital. Information on vehicle type and description of accident was not recorded uniformly and information on helmet use was not recorded. Furthermore, proportion of helmeted motorcyclists in the post-law time period is unavailable with police. As Glasgow Outcome Scale scores of patients and long-term patient data describing years of life lost (YLL) is not recorded, information regarding patient outcome is

incomplete. Possible confounders include concomitant road-safety interventions. A need for exploration into the causes of helmet-non-compliance and reasons for cognitive dissonance remains; helmet laws demand civic engagement. Further research is needed regarding implementation gaps of the national road-safety policy so that informed national road-safety targets may be prepared and acted upon.

Conclusion

An association between the enforcement of a motorcycle helmet law and a decrease in the severity of RTI-TBI hospital admissions was observed. This decrease in severity was found most significant in adolescents and young to middle-aged adults, and was accompanied by a reduction in the operative rate. Nonetheless, sustained helmet law enforcement remains a challenge in a temperate climate, and children, females and pillion riders are poorly protected by current road policies. These are roadblocks to Pakistan's achieving Global Road Safety Target 7. Only by adoption, enforcement and continuation of contextualized proven road safety measures, can safe roads be realized.

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