The Effect of Delta-V on Traumatic Brain Injury sustained by Vehicle Occupants in Great Britain

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I. INTRODUCTION

Each year 1.2 million people die in Road Traffic Collisions (RTCs) globally (2.1% of global mortality) with a further 50 million casualties [1]. Head and brain injuries in particular cause life-altering injuries and increase the odds of being fatally injured by 6.3 times compared to non-head injuries. Traumatic Brain Injury (TBI) is frequently severe and leads to significant morbidity and reductions in quality of life [2-3]. Delta-V has been used as a collision severity metric for many years [4]. It has also been used to indicate overall injury severity as well as body-region specific injury severity [5]. Notably, in motorsport and real-world collision data, higher delta-V has been related to higher Abbreviated Injury Scale (AIS) head injuries [6-7]. While powerful, AIS is not used by Emergency Medical Services (EMS). To best position this research to inform EMS response we therefore adopted the more clinically used Mayo TBI classification system [8]. In this study we assess the ability of delta-V to predict TBI severity and specific pathologies in Great Britain (2013-2019) using Road Accident In-Depth Studies data (RAIDS) [9].

II. METHODS

Data Source and Inclusion Criteria

RAIDS is a UK Government Department for Transport initiative to collect in-depth RTC data across Great Britain [9]. Data about the collision scene, environmental factors, vehicles and injuries sustained is collected and entered by trained collision investigators to ensure high accuracy. Clinical information is from hospital notes, radiology reports and post-mortem reports where applicable. When accessed on 4 April 2019, RAIDS contained 1,856 accidents involving 3,521 vehicles including vulnerable road users, car occupants, goods vehicle occupants and other vehicles. Of 2,516 casualties, 78% are 16-60 years, 14% are >60 years and 5.5% are children <16 years old.

Traumatic Brain Injury Classification

We classify the TBI severity of casualties within RAIDS using the Mayo Classification system. The Mayo system combines a number of TBI indicators including the Glasgow Coma Scale (GCS), loss of consciousness (LOC) and the presence of specific pathology including brain haemorrhages, contusions and skull fracture. As solo indicators including GCS and LOC are only known for approximately 60% of the RAIDS population, a combined system was needed. We developed a free-text search algorithm to classify casualties based on TBI-related terms and treatments present in their clinical and post-mortem information. The casualties were classified into four groups: no TBI, symptomatic-possible TBI, mild-probable TBI and moderate-severe TBI. TBI pathology was also recorded. We chose Mayo over AIS severity because it is used widely in neurotrauma care, increasing this study's relevance.

Delta-V Analysis

We first selected collisions with only one impact phase. We additionally included collisions with multiple impact phases only if one phase was labelled as the clear injury-causing event. We investigate delta-V because it is known to relate to overall injury severity [5-7]. Delta-V was calculated using the CRASH3 programme [10]. CRASH3 calculates physical energy-based parameters from the collision based on the crush profiles of the vehicles involved. CRASH3 calculates longitudinal and lateral delta-V components. We produced normalised cumulative frequency curves to show variation in longitudinal, lateral and total delta-V for different TBI severity populations. We repeated this analysis for specific TBI pathologies compared to casualties who sustained no TBI. We conduct Kolmogorov-Smirnov (KS) tests to determine if the delta-V distributions differ for the TBI and No TBI groups.

III. INITIAL FINDINGS

We investigated 4,957 people involved in RTCs, with approximately half sustaining an injury (2,516 casualties). Of those injured, 1,171 (46.5%) sustained a head or neck injury. TBI was seen in 488 (19.4%) casualties. Of these, 277 (57%) were classified as moderate-severe, 90 (18%) were mild-probable and 121 (25%) were symptomatic-possible. The subsequent delta-V analysis was conducted on 1,247 car and van occupants with longitudinal, lateral and total delta-V calculated using CRASH3. 65 casualties sustained a moderate-severe TBI, 27 sustained a mild TBI, 40 sustained a symptomatic TBI, 714 casualties who sustained no TBI and 401 uninjured subjects.

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Fig. 1a

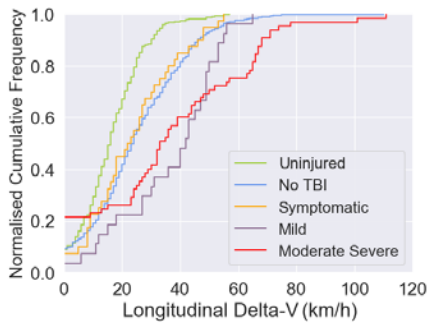

Fig. 1b

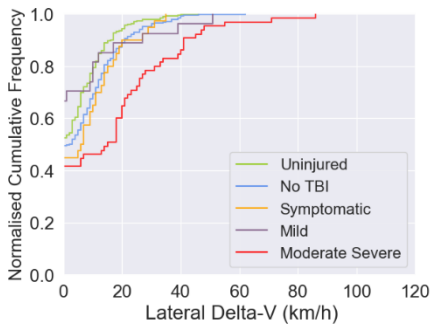

Fig. 1c

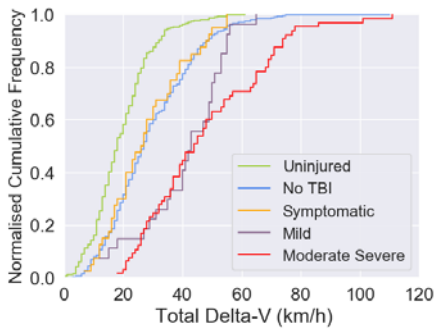

Fig. 1. The normalised cumulative frequency of (a) longitudinal, (b) lateral and (c) total delta-V in kph is shown for uninjured subjects, casualties with no TBI, symptomatic TBI, mild TBI and moderate severe TBI.

In general, the delta-V distributions drawn from the No TBI, Symptomatic TBI, Mild TBI and Moderate Severe TBI cohorts illustrate that, as delta-V increases, so does TBI severity (Fig. 1). All Symptomatic delta-V distributions do not differ from the No TBI cohort. Fig 1b. shows the lateral delta-V distribution of the Moderate Severe TBI cohort clearly separated from the other cohorts (p=3.0e-9). We performed KS tests on all groups. The delta-V distribution for Symptomatic TBI casualties did not statistically differ from that of the No TBI casualty cohort. The Mild cohort was statistically different for longitudinal and total delta-V ($p<0.005$), but not for lateral delta-V (p=0.28). All three Moderate Severe delta-V distributions differ significantly from the No TBI casualty cohort ($p<0.0001$). We repeated this analysis for skull fracture, subdural haemorrhage and subarachnoid haemorrhage. All delta-V distributions for the skull fracture cohort (n=27) differed significantly from the No TBI casualty cohort ($p\leq0.01$). There were fewer subjects with subdural (n=11) and subarachnoid haemorrhage (n=8), however the same trend of total delta-V being differentiable for both haemorrhage pathologies was seen ($p<0.02$).

IV. DISCUSSION

Delta-V distributions of mild and moderate severe Mayo TBI severity groups are distinguishable from uninjured subjects and casualties with no TBI. Findings shown in Fig. 1b support other studies which also found greater risk of serious head injury in lateral collisions. This may possibly be due to reduced restraint system protection and less protective material in the lateral direction [7]. High lateral delta-V is common in side impacts. 294 casualties were involved in side impacts (24%). The rate of side impact involvements was higher in moderate-severe TBI casualties (43%) than other groups (23%). Total delta-V distributions differed between the no TBI casualty (and uninjured) group and the mild TBI, moderate-severe TBI, skull fracture, subarachnoid and subdural haemorrhage groups. In these comparisons, the total delta-V p-values ranged from p=1.0e-9 (moderate-severe TBI compared to no TBI) to p=0.01 (subarachnoid haemorrhage compared to no TBI casualties). Further work with greater sample sizes is required to draw robust conclusions on a range of pathologies.

CRASH3 was developed for the American vehicle fleet. Both lateral and longitudinal delta-V have been shown to be underestimated when calculated by CRASH3 compared to in-vehicle sensor recorded data [8]. To combat this, our future work will include the analysis of collisions with Event Data Recorder information available. The ability to differentiate between delta-V distributions by TBI severity and pathology has important engineering and medical implications. Understanding how delta-V relates to TBI outcome gives scope to develop an automated, real-time TBI-specific early warning system to improve EMS response. This study also provides evidence for road safety policies and technology development to mitigate the impact of TBIs in future road traffic collisions.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

[1] Peden, M., et al., Inj Prev, 2004.
[2] Wu, X., et al., J Trauma Acute Care, 2008
[3] Zeckhauser, R and Shepard, D., Law Contemp Probl, 1976.
[4] Marsh, J. C., et al., 1977.
[5] Viano, D. C. and Parenteau, C. S., Traffic Inj Prev, 2010.
[6] Weaver, C. S. et al., 2004.
[7] Yoganandan, N., et al., AAAM Conference, 2011
[8] Lenerd, J. et al., ESV Conference, 1998.
[9] Transport Research Laboratory Ltd, accessed 2020.
[10] NHTSA, DOT-HS-805732, 1981.