Visual estimates of crash severity and child occupant injury: The ambulance record as a potential data source in crash injury surveillance

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Abstract
Crash severity is an important predictor of injury outcome for vehicle occupants involved in crashes. The best measures of crash severity are Δv or equivalent barrier speed. Both these measures require detailed inspection and measurement of the vehicles involved in the crash. These methods are resource intensive and limit the ability to include crash severity as a variable in mass crash data bases. This paper presents the results of a multivariate analysis of factors predicting injury outcome in restrained child occupants. The analysis is based on a sample of 152 children aged between 2 and 8 years collected through retrospective review of medical records at a children's hospital over a 30 month period. The crash severity measure used was based on the rating of ambulance officers attending the scene of the crash. Ambulance officers rated the crash as minor, moderate or severe based on visual assessment of the damage to the vehicle, and reported impact speeds. The analysis demonstrates a significant association between crash severity measured in this manner and injury severity, before and after adjustment for other potential confounders. This association reveals the potential for more widespread use of this relatively simple measure to obtain a de facto estimate of crash severity. Together with a previously reported validation exercise, these results indicate that a visual estimation of crash severity made by on-scene emergency personnel may be an under-utilized source of data. This issue warrants further investigation by those interested in collecting and analyzing mass crash data.

Keywords
Crash investigation methods, child occupants, crash severity, mass crash data

Introduction
Crashes are complex events and there are many factors that will influence whether or not injury occurs, and when injury occurs, the severity of that injury. To examine the influence of any one factor, all other potential influences must be controlled. For example most recent studies reporting an association between inappropriate restraint use and serious injury among child occupants have used statistical methods that allow for the control of potential confounders [1-4]. Intuitively one of the most important confounders is crash severity, yet few studies have controlled for this factor. Furthermore, while many studies have reported crash severity to have a major influence on injury outcome for adult occupants [5-10], only one has examined the influence of crash severity among child occupants [11].

Crash severity is a difficult variable to measure, and this might be why this factor is sometimes neglected. For example Durbin et al [12] in their study of the influence of seating position and restraint appropriateness on injury outcome did not control for crash severity. Even among those studies that attempt to control for severity, different measures have been used. Often these are based on de facto measures of severity such as driver survivability, fatality versus non fatality crash, speed limit of crash location, or estimated travelling speed. For example Zaloshnja et al [13] in their study of the effectives of dedicated child restraint use for young children used the costs associated with driver injury as a surrogate crash severity measure. Other studies have used measures based on self reported intrusion into the occupant compartment [2,3,4]. In many analyses of population-based surveillance data, estimated travelling speed or prevailing speed limits are typically used. For example Braver et al [14] used speed limit as a proxy for crash severity in their analysis of seating positions and children's risk of dying in motor vehicle crashes. The assumption is that these de facto measures, by acting as surrogates for crash severity, have some relationship with injury outcome, however this assumption is rarely tested

The most direct measures of crash severity are based on an estimation of the change in velocity experienced by the vehicle during the impact. This is referred to as Δv and is usually calculated from the mass, stiffness and deformation of the vehicles involved. Other associated measures include estimated crash test or barrier speeds. These estimate Δv by comparing the amount of vehicle deformation seen in the case vehicle with the amount of deformation seen in the same model of vehicle during laboratory testing (where Δv, or impact speed is measured). There have been many studies that have demonstrated a relationship between Δv and injury outcome. For child occupants, Nance et al [11] used in-depth investigation of crashes involving children to examine the relationship between Δv and injury outcome. They reported that Δv was a strong predictor of injury risk for child occupants in frontal crashes.

Measures based on Δv would be the ideal way to control for crash severity, since this measure has been closely correlated with injury risk. This makes Δv an ideal candidate for inclusion in mass crash data bases. However, as it requires in-depth crash investigation, it is time consuming and expensive to obtain. There are also limitations in the calculation of Δv from residual crash damage in some crash orientations. Therefore there are substantial problems associated with using Δv in large samples and explains why de facto measures are often used in analyses of population-based surveillance data.

In this study we have used a novel, readily available de facto measure of crash severity largely based on a visual estimation of vehicle damage made by NSW ambulance officers attending the crash. The objective of this analysis was to examine the influence of this de facto measure on injury severity among restrained child occupants.

Methods

This analysis is based on data collected during a retrospective medical record review of all child occupants aged 2 - 8 years attending the emergency department of the Children's Hospital at Westmead , Sydney, Australia over a 30 month period and reported elsewhere [15-17]. The methodology used was approved by the Human Ethics Committees at both the Children's Hospital Westmead and the University of NSW.

<u>Data collection and coding</u>

Full medical records were reviewed, and injury and crash details were extracted from the medical record. The primary source of information for restraint, seating position, vehicle damage and crash scene details was the ambulance record included in the medical notes. In cases where the ambulance report was missing, this data was extracted from elsewhere in the medical notes if possible. Data was then coded and entered into a customised database in SPSS 14.0

Data collected, and the coding schemes used are shown in **Error! Reference source not found.**. Codes were constructed for age, restraint type, appropriateness and correctness of restraint use (hereafter called quality of restraint use), seating position, crash type, object struck, impact direction and crash severity.

Age was calculated using date of birth and date of hospital attendance and rounded to the nearest whole year. Children were grouped into those aged 2- 4 years and those aged 5-8 years. These groupings reflect those used in previously published studies [1-4,15-17], and loosely correspond to transition between forward facing child restraints and booster seats.

Restraint type was coded as 'adult belt' if a lap sash or lap only belt was used, and 'child restraint system' if any type of dedicated child restraint was used. Three further variables related to the quality of restraint use were examined: - correct/incorrect use of restraint, appropriate/inappropriate choice of restraint, and optimal/suboptimal restraint use. Incorrect use was defined as any use contrary to the manufacturer's instructions as noted on the ambulance sheet and/or medical record, or obvious from injuries (e.g. belt contact marks etc.). Correct restraint use was assumed in all other cases. The type of restraint used, together with information on the child's age, weight, and size were combined to assess the appropriateness of restraint choice. Restraint appropriateness classifications were based on whether or not the child was using the restraint designed for that size of child. This determination was based on a combination of the weight ranges for Australian restraints designated by the Australian Standard for child restraints and the most commonly used guideline for appropriate use of adult seat belts (see Table 1). The definitions of appropriateness used are the same as we have used previously [15-17]. In approximately 40% of cases, accurate height and weight data were not available, and the 50th percentile weight and height for the child's age and gender were used. . Optimal restraint was defined as restraint use that was correct and appropriate. Suboptimal restraint use was therefore incorrect, inappropriate, or both. We have previously demonstrated that optimal restraint is associated with a reduced likelihood of injury in a crash [15]. Unrestrained children were excluded from statistical analyses.

Age	*Height/weight*	*Optimal Restraint*
2-4	Up to 18kg	Forward facing child restraint with 6 point internal harness
4-8	Height less than 145cm, weight above 18kg	Belt-positioning booster seat with lap-sash seatbelt.
6-8	Height above 145cm, weight above 32kg	Adult seatbelt

Table 1: Appropriate use classification guidelines

Seating position was initially coded as 'front' if the left or middle front passenger seat was occupied, 'left rear', 'centre rear', 'right rear' and 'rear unknown'. For analysis these were condensed into 'front' and 'other'. Due to the young age of the sample, there were no driver seat occupants.

Crash type was defined as the number of vehicles involved in the crash. Cases were coded as 'single' when only one vehicle was involved and 'other' when two or more vehicles were involved.

The object struck by the case vehicle was coded as a 'car', 'heavy vehicle', 'tree', 'pole', 'wall or fence', and 'none or unknown'. This was later condensed to 'tree/pole' and 'other'.

Impact direction was defined using a diagram depicting location of damage to the vehicle routinely recorded on the ambulance record by ambulance officers attending the crash. Impact direction codes were condensed into 'front', 'side' and 'other'. The 'side' category included both side impacts and rollovers. These were grouped into one category because of small cell sizes on the basis that these crash types involve non longitudinal directions of force, and are also impact types where intrusion is most likely to occur. Notably rollover crashes were relatively rare. The 'other' category included both rear impacts and unknown impact types.

The crash severity codes used were 'minor', 'moderate', or 'severe' based on descriptions routinely reported by ambulance officers attending the scene. The criteria used by ambulance officers in making the ratings is subjective, based both on vehicle deformation and likely impact speeds. No attempt was made to code for intrusion. In cases where the ambulance record was missing, data for this analysis was extracted from medical notes. Cases where there was no mention of crash severity in either the medical record or the ambulance report were coded as 'unknown' severity. A breakdown of crash severity by data source is shown in Table 2.

	Ambulance Report	Medical Record	Total
High	34	11	35
Moderate	28	12	40
Severe	12	3	15
Total (Known)	74	26	100
Unknown	6		6

Table 2**:** Crash severity categories by data source

For the logistic regression analysis, crash severity was condensed into 'high' and 'other'. 'Other' included moderate, minor and unknown severity crashes.

The condensed codes described above were necessary for the purposes of logistic regression analysis since without them there were a number of coded categories with low frequencies (less than 10). Small numbers in any coded category can reduce the stability of logistic regression modelling. In particular, there is a greater possibility that the estimates of the regression coefficients and the confidence intervals might be unreliable [18].

The outcome variable used in this analysis was injury severity. Injury details from the medical record were coded according to AIS 1990 [19]. Only children with at least one recorded injury were included in the statistical analysis. The overall highest AIS (Abbreviated Injury Score) were used to determine the MAIS (Maximum Abbreviated Injury Score). The AIS is classification system that scores injuries from 1 to 6 in terms of threat to life. An AIS 1 denotes a minor injury, and AIS 6 denotes an injury almost certain to cause death. The MAIS is the highest AIS score a child received. Cases were therefore initially coded MAIS 1 to MAIS 6 and then grouped into those with minor injury (MAIS 1) and those with moderate to severe injury (MAIS 2+).

Data analysis

The association between each potential variable and injury severity was initially examined using bivariate logistic regression. The significance of any observed association was then explored while controlling for potentially confounding factors using multivariate logistic regression modelling. The logistic modelling process allows for the estimation of the odds ratio and associated confidence interval for each variable of interest adjusted for the potential confounders. The differences were judged to be significant when the 95% confidence interval (C.I.) did not include 1. If the odds ratio (O.R.) was less than 1 the variable of interest was judged to have a protective effect and if it was greater than 1 it was judged to increase the likelihood of the outcome being investigated.

The primary goal of the modelling process was to construct a model with the minimum number of variables while still including all potentially important confounders [20-21]. Variables to be included in the model were selected using a manual backwards stepwise procedure. Two-way interaction terms were also examined. An appropriate model was selected based on the likelihood ratio test with a significance level of $p \leq 0.05$ [21].

Results

Throughout the 30 month study period, 153 children aged 2-8 were identified as occupants of a motor vehicle following presentation at the Emergency Department of the Children's Hospital, Westmead. There were five children not using any form of restraint, and restraint use could not be determined for a further six children. The majority of children sustained some injury. There were seven children who were fatally injured, and 104 who sustained non fatal injuries. Only injured (including those fatally injured) children who were identified as being restrained were included in the analysis. This resulted in a sample size of 106.

Sample Characteristics

Almost two thirds (65%) of the sample being analysed had MAIS 1 injury and 35% had MAIS2+ injury. There were slightly more males (60%) than females (40%), and the average and median age of the children was 5.2 years and 5.0 years respectively. The majority of children were rear seated and 78% of children who occupied front seat positions were aged 5 years or older. There was an approximately equal distribution of children under and over 4 in the rear seats. 65% of children were using adult belts and 27% using some form of dedicated child restraint system. This included 13% using booster seats; 12% using forward facing restraints and 3% using a child safety harness (alone). Dedicated child restraint systems were used most often by children aged between 2 – 4 years and adult seat belts most often by children aged between 5 and 8 years. 16% of children were correctly using the most appropriate restraint for their size. All other children were sub-optimally restrained. This includes 72% inappropriately but correctly using their restraint; 2% using an inappropriate restraint incorrectly; and 2% using an appropriate restraint incorrectly. Therefore the number of children identified as incorrectly using a restraint was small (seven).

33% of crashes were categorised as high severity and 44% medium severity. Low severity crashes made up 17% of the sample and crashes where severity could not be determined accounted for 6%. Crashes involving multiple vehicles accounted for approximately 80% of cases. Car to car (69%) and car to truck (10%) crashes were the most frequent crash types, 6% involved no other object and 13% of crashes involved impacts with fixed roadside objects. There was a strong association between single vehicle crashes and impacts with roadside objects (Spearman's correlation coefficient $p < 0.05$) and theoretically one might be a de facto measure of the other. Therefore only the variable object struck was investigated using logistic regression modelling. Half of the children were involved in primarily frontal impacts, and almost a third in side impacts. A further 10% were in rear impacts, and 5% in vehicles that rolled over. Impact direction was unknown for 5% of the children.

Variable		Frequency (%)		Unadjusted		Adjusted for factors+	
		MAIS 1	MAIS 2+	Odds ratio	95% CI	Odds ratio	95% CI
Gender	Female	30 (68.2)	14 (31.8)	0.8	0.3-1.8	-	-
	Male	39 (62.9)	23 (37.1)	Reference		-	-
Age	2 - 4	29 (70.7)	12 (29.3)	0.7	0.3-1.5	-	-
	5 - 8	40 (61.5)	25 (38.5)	Reference		Reference	
Restraint Type	CRS	22 (75.9)	7 (24.1)	Reference		Reference	
	Adult Belt	47 (61.0)	30 (39.0)	2.0	0.8-5.3	-	-
Restraint	Sub-optimal	54 (59.3)	37 (40.7)	-	-	-	-
	Optimal	15 (100)	0 (0.0)	Reference		Reference	
Restraint (i)	Inappropriate	53 (60.9)	34 (39.1)	3.4	0.9-12.6	9.8	1.1-83.8*
	Appropriate	16 (84.2)	3 (15.8)	Reference		-	-
Restraint (ii)	Incorrect	2 (28.6)	5 (71.4)	5.2	1.0-28.4	19.8	1.7-236.2*
	Correct	67 (67.7)	32 (32.3)	Reference		-	-
Crash Severity	High	23 (51.1)	22 (48.9)	2.9	1.3-6.7	3.3	1.3-8.4*
	Other	46 (75.4)	15 (24.6)	Reference		Reference	
Crash Direction	Front	44 (68.8)	20 (31.3)	Reference		Reference	
	Side	18 (56.3)	14 (43.8)	1.7	0.7-4.1	-	-
	Other	7 (70.0)	3 (30.0)	0.9	0.2-4.0	-	-
Crash Type	Single Veh	13 (52.0)	12 (48.0)	2.1	0.8-5.2	-	-
	Other	56 (69.1)	25 (30.9)	Reference		-	-
Object Struck	Other	62 (69.7)	27 (30.3)	Reference		Reference	
	Object	7 (41.2)	10 (58.8)	3.3	1.1-9.5	3.7	1.2-11.6*
Seating Position	Front	14 (53.8)	12 (46.2)	1.9	0.8-4.7	-	-
	Rear	55 (68.8)	25 (31.3)	Reference		-	-
Total children		**69**	**37**				

Table 3: Raw data and unadjusted and adjusted results from logistic regression modeling (* denotes factor significant in final model; +- reported in the adjusted table for factors that did not make it into the final model;. CRS = child restraint system, veh = vehicle))

Statistical Analysis
All results, including raw data, and results from logistic regression modelling are presented in **Error! Reference source not found.**.

Results from the bivariate analysis (or the unadjusted results, Table 3) demonstrate significant associations between injury severity and correctness of restraint use, crash severity and object struck. These variables were included in the final multivariate model. There was also a non significant trend towards an association between restraint appropriateness and injury outcome. This factor has also been widely reported to have a significant influence on injury outcome for child occupants. For this reason this factor was also included in the model.

The adjusted results (i.e. results from the final multivariate modelling) are shown in Table 3. These indicate that after adjustment for potential confounding all of the factors included in the final model have a significant influence on injury outcome.

Regardless of the quality of restraint use or object struck, a restrained child in a high severity crash, as measured here, was 3.3 times more likely to sustain an AIS2+ injury than a child in a crash of a lower severity (O.R. 3.3 95% C.I. 1.3 – 8.4).

Inappropriate restraint choice and incorrect restraint use were also more likely to result in AIS 2+ injury. However, the odds ratio estimations had large confidence intervals, particularly for correctness of use (inappropriate use O.R. 9.8, 95% C.I. 1.1-83.8; correctness of use O.R. 19.8, 95% C.I. 1.7-236.2). The absolute value of the odds ratio estimations should therefore be viewed with caution.

Being a restrained child occupant involved in an impact with a tree or a pole was also more likely to result in an AIS 2+ injury (O.R. 3.7, 95% 1.2-11.6). Since there was no significant correlation between high severity crashes and impacts with roadside objects (Spearman's correlation coefficient p=0.5), this is an additional risk over and above crash severity.

Discussion
The inclusion of a crash severity variable in databases used for widespread crash injury surveillance would greatly increase the utility of these data bases. Measures of crash severity that directly describe the energy involved in a crash are the ideal, but the problems associated with collecting such data often limit their use in large databases. A future solution might be to download velocity history from data recorders (similar to black boxes in an aeroplane) installed in many late model vehicles. While their have been a number of overseas studies and pilot projects initiated to explore this potential data source, there has been limited investigation of this issue in Australia. It is likely that many newer vehicles within the current Australian fleet have the capacity for obtaining this data post crash. However there are a number of issues that would require resolution before such data could be collected in a systematic way. Not the least of these involve privacy, data ownership, access to the stored data, and matching vehicle data with injury data. Nevertheless this alternative could be a source of extremely high quality data and it would be prudent for investigations in this area to be initiated in Australia.

In the interim, de facto measures of crash severity are the only real option for controlling crash severity on large sets of Australian data. For such a de facto measure to be useful it is imperative it demonstrates a similar relationship with injury risk as Δv. This work has shown there is a robust association between high severity crashes as defined by a simple visual estimation of the post-crash vehicle by onsite emergency personnel and severity of injury. While this measure is not strictly based on a theoretical link with the energy that might be involved in the impact, the fact that this relationship exists indicates its potential as a measure useful for controlling for crash severity. With further validation, this suggests that this novel method of measuring crash severity may have some future use in crash investigation and injury outcome studies, particularly those involving mass crash data or medical record reviews. This is particularly of interest given the relative ease with which this information may be collected, and the possibility that this de facto measure comes closer to describing the real crash severity than other de facto measures such as prevailing speed limit, or estimated speed limit currently being used in large data set analyses.

However, it is important to highlight the inherent limitations in this variable as it currently exists. The first of these are concerns regarding the accuracy of data collected from the ambulance record. Recently we published the results of a validation exercise comparing information in ambulance and medical records with data collected through in-depth crash investigation using a subset of the cases included in this analysis [22]. We found a reasonable degree of accuracy in the impact severity information. Although this was less accurate than other types of information in the ambulance and/or medical record, this was largely due to missing information. Impact severity estimates in the ambulance record matched the estimate made from in-depth crash investigation in 33% of cases and were within one category of the in-depth investigation estimate in a further 17% of cases. The ambulance record was therefore reasonably accurate in 50% of cases. However, when those cases where the ambulance record was missing were excluded, the impact severity estimations matched in 60% of cases and where within one category in a further 35% of cases. Neglecting the missing ambulance records, the information was therefore reasonably accurate in 95% of cases. The findings from our validation exercise [22] partly ease concerns that an ambulance officer might be more likely to call a crash ‘high severity’ when the child being transferred is clearly injured and a lower severity when there is less evidence of injury. There is also likely to be inherent individual differences in ambulance officer’s perceptions of severity, depending on experience and training.

Accuracy of crash severity information and bias control in the ambulance record could be improved through uniform training and/or modifications to the pro forma used by ambulance officers to describe severity. The substantial amount of missing ambulance records within individual medical records noted previously [22] would also need to be addressed. This might require improved processes in emergency departments, or novel means of access to the ambulance record. However, based on the findings of our current study, and the results of the validation exercise [22], addressing these issues could be beneficial in providing an easily accessible de facto severity measure for mass crash and/or injury surveillance purposes.

This current analysis, like our validation exercise [22], also demonstrates the potential of the ambulance record as a source of other crash related information. In particular, information about crash direction, restraint status and type, and seating positions is noticeably absent in hospital based injury data bases. The inclusion of this level of detail (and a crash severity measure) would greatly enhance opportunities for meaningful interrogation of these data sources for road safety related purposes.

An important point to make is that whatever problems there may be with the data currently in the ambulance record, it is likely that this data may be more meaningful than some other measures currently being used. For example prevailing speed limit, while accurately recorded, is less likely to have a bearing on the crash severity because it is not necessarily reflective of the actual travelling or impact speed of the vehicle.

The criteria used by ambulance officers in making the high, moderate and minor ratings is currently subjective, based both on vehicle deformation and likely impact speeds. There are no definitive protocols for making these estimations. It is almost certain that if some objective protocols were developed, the quality and accuracy of the data in the ambulance record could be improved.

In addition to the implications for injury surveillance, the association between high severity crashes and more serious injury among child occupants has implications for child occupant protection. On its own, the crash severity measure used here does not directly tell you anything about the velocities involved. However, our validation study found reasonable correspondence between the ‘high’ severity measure used here and crashes estimated to have a Δv over 60km/h [22]. Our findings are therefore in agreement with Nance et al [11] who found Δv to be associated with the odds of both AIS 2+ and AIS 3+ injury. They reported that at a Δv of 37km/h 50% of child occupants would be expected to sustain an AIS 2+ injury and at 63km/h, 50% of child occupants would be expected to sustain an AIS 3+ injury. Together with Nance et al’s findings our results suggest attention should be given to the protection currently being provided to child occupants in higher severity impacts. For example, in the past, test severities used in regulatory and consumer based laboratory testing of child restraints have been based on the most common crash severities, rather than on the severities where the most severe injuries occur. The best reductions in child occupant casualties might be achieved by concentrating assessment focus on higher severity crashes.

The Australian consumer based child restraint evaluation program CREP currently assesses the comparative protection provided by child restraints in frontal impact at 54km/h [23]. This is more severe than the current frontal test requirements for AS 1754 (48km/h) [23]. Recent CREP results have indicated that there are substantial variations in the performance of restraints currently available on the Australian market when tested at this severity. This is particularly true for head excursion in forward facing restraint and dynamic seat belt fit in booster seats [23]. At the very least it might be useful to include additional tests at higher severities in regulatory assessments.

Limitations

In addition to the limitations noted above, there are a number of other issues to be kept in mind. In cases where the ambulance record was missing (30% of cases), data for this analysis was extracted from medical notes. An assumption was made that in most cases the emergency physicians would have sighted the ambulance record prior to making notes regarding the severity (and other details) of the crash. The validity of this assumption is untested.

This sample was drawn on a convenience basis and is therefore not necessarily representative of either the entire population of children in crashes or the population of all children travelling in cars. Furthermore, children who die at the crash scene will be missed in this type of sampling. Conversely children who are uninjured or only have minor injuries may not attend hospital. This sample is therefore likely to be biased toward the more serious but survivable injuries.

Although this analysis was not focussed on the correctness of restraint use and appropriateness of restraint choice, these variables were included in the final model. There are a number of potential errors with restraint use classifications. Where possible, height and weight as recorded in the medical data were used to categorise children into those appropriately and inappropriately using their restraints. This information was not available in the majority of cases. In these cases, growth charts [25] were used to estimate height and weight based on age. It is therefore likely that there may have been some incorrectly categorized children, particularly among those aged close to appropriate transition times. Children were categorized as incorrectly using their restraints when the incorrect use was described by the attending ambulance officer. It is likely that some cases of incorrect use may have been missed. This is particularly true for those types of incorrect use involving improper installation of the restraint within the vehicle. In one or two cases, incorrect use was identified using the pattern of external injury. This is a sub-optimal way in which to classify incorrect use because of the potential for researcher bias and/or the potential for misinterpreting the relationship between injury position and the pre-impact position of the restraint systems. For these reasons classifications based on the injury pattern were only made when confidence in this relationship was high. Moreover, it is possible that incorrect use was more likely to be noted in cases where children were more seriously injured. The implication of these potential errors may be that the influence of incorrect use on serious injury may have been over estimated. Therefore, because of this and the fact that the confidence intervals are extremely wide, the absolute value of the odds ratio reported should be viewed with some caution.

Details of the vehicle (i.e. make, model and year of manufacture) in which the children were traveling, nor any similar details of other vehicles involved in the crash, were routinely recorded in the ambulance or hospital record. This meant that vehicle type and year of manufacturer could not be included in the analysis. It is possible that in-vehicle factors, particularly of newer vehicles with enhanced safety features, may also have some influence on the injury outcome of restrained children. Similarly, compatibility issues, such as differences in geometry and mass between the striking and struck vehicles could also have some influence on injury outcome. These potential confounders were not examined in this analysis.

Finally this sample was relatively small, and the necessarily complex analytical approach taken using logistic regression analysis to control for potential confounding can be affected if too many variables are included in any one model. For this reason great care was undertaken to ensure stability of models while still controlling for those variables that were potential confounders of the primary variables of interest. Small numbers in some groups are reflected by wide confidence intervals, and the values of the odds ratios should be viewed with caution.

Concluding Remarks

This analysis has demonstrated that crash severity, measured using ambulance officer reported severity, is associated with an increased likelihood of AIS 2+ injury among restrained child occupants. This finding has a number of potentially important implications, both from a child occupant protection perspective and a more broad crash injury surveillance perspective. For child occupants the results indicate there may be a need for greater attention to the protection provided in higher severity crashes. More broadly, the results indicate that there may be potential for using a visual estimate of crash severity made by ambulance officers in mass crash and/or injury data bases. Although this would require further validation and collaborative efforts between injury surveillance data managers, ambulance services and hospital emergency department personnel, the relative ease with which this data could be captured would make these efforts worthwhile. The ambulance record made by on-scene emergency personnel appears to be an under-utilised potential data source.

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