A STUDY OF IMPAIRING INJURIES IN REAL WORLD CRASHES USING THE INJURY IMPAIRMENT SCALE (IIS) AND THE PREDICTED FUNCTIONAL CAPACITY INDEX (PFCI-AIS)

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ABSTRACT – The ability to predict impairment outcomes in large databases using a simplified technique allows researchers to focus attention on preventing costly impairing injuries. The dilemma that exists for researchers is to determine which method is the most reliable and valid. This study examines available methods to predict impairment and explores the differences between the IIS and pFCI applied to real world crash injury data. Occupant injury data from the UK Co-operative Crash Injury Study (CCIS) database have been coded using AIS 1990 and AIS 2005. The data have subsequently been recoded using the associated impairment scales namely the Injury Impairment Scale (IIS) and the predicted Functional Capacity Index (pFCI) to determine the predicted impairment levels of injuries at one year post crash. Comparisons between the levels of impairment were made and any differences further explored. Injury data for the period February 2006 to September 2008 from the CCIS database were used in the analysis which involved a dataset of 2,437 occcupants who sustained over 8000 injuries.

This study found some differences between the impairment scales for injuries coded to the AIS 1990 and AIS 2005 coding dictionaries. The pFCI predicts 31.5% of injuries to be impairing in AIS 2005, less than the IIS (38.5%) using AIS 1990. Using CCIS data the pFCI predicted that only 6% of the occupants with a coded injury would have an impairing injury compared to 24% of occupants using the IIS. The main body regions identified as having the major differences between the two impairment scales for car occupants were the head and spine. Follow up data were then used for a small number of cases (n=31, lower extremity and whiplash injuries) to examine any differences in predicted impairment versus perceived impairment. These data were selected from a previous study conducted between 2003 and 2006 and identified the discrepancy between predicted impairment and actual perceived impairment as defined by the participant. Overall the work highlights the variaton between the pFCI and IIS and emphasises the importance and need for a single validated impairment scale that can be universally applied. This would allow emphasis to be directed towards preventing injuries that are associated with the most significant impairment outcomes.

INTRODUCTION

Recently a focus of the UK Governments' Road Safety Strategy has been to reduce the number of fatalities [DfT 2000] with little emphasis on the survivors of road traffic injury who may be left with impairing injury. The true level of impairment in the survivors of road trauma is not usually known but it is assumed to be high particularly in cases of lower extremity, spinal cord and brain injuries. Despite the lack of resources to follow up survivors of road trauma a need still exists to quantify such impairments based on the available injury data so that road safety researchers can establish the true socio-economic consequences of crashes and recommend targeted countermeasures.

There are two potential predictors of impairment available to road safety researchers both of which are based on the Abbreviated Injury Scale (AIS). The earliest formal predictor of impairment following injury was developed by the Association for the Advancement of Automotive Medicine (AAAM) in response to various previous attempts by researchers to examine the long term outcomes of injury [Bull 1985, Mackenzie, Shapiro, Moody 1985, Hirsch 1983]. The Injury Impairment Scale (IIS) was developed in collaboration with a number of medical specialists and researchers in North America and Europe [AAAM 1994]. It defined impairment as 'the loss of function or abnormal function of an organ, tissue or organ system resulting after healing has occurred'. Disability was also defined by this group as 'the effect or consequences of impairment or multiple impairments on the whole person that

restricts an individual from performing at, or near the pre-injury capability'.
The IIS framework is based on the 6 health dimensions of mobility, cognitive, cosmetic interfering with function, sensory, sexual /reproduction and pain. An overall 6 point impairment code was developed and assigned to every injury code in the AIS 1990 [AAAM 1990];

0 - Normal function: No impairment
1 - Impairment detectable but does not limit function
2 - Impairment level compatible with most but not all function
3 - Impairment level compatible with some normal function
4 - Impairment level significantly impedes some normal functions
5 - Impairment precludes most useful function
6 - Impairment precludes any useful function

The impairment score relates to the whole body, not organ or system dysfunction at one year post 'single' injury. States and Viano (1990) provide a more detailed description for all of the above states. The IIS has not been widely adopted by the road safety research community and to date, it remains invalidated [Yates, Woodford, Campbell, 1994, Waller, Skelly, Davis, 1995, von Koch, Nygren, Tingvall, 1994, Bradford, Thomas, Chambers 1994]. The ease of use of this scale is apparent. However the simplicity of assigning one single score to every injury does not take into account the fact that some individuals will recover without impairment. Furthermore the scale does not consider the effect that cumulative injuries may have on residual impairment.

In the similar time period that the IIS was being developed, work had commenced on developing the Functional Capacity Index (FCI). This was in response to a request by the National Highway Traffic Safety Administration in the U.S to develop a measure to evaluate the consequences of road traffic injury [MacKenzie, Damiano, Miller, 1996]. The FCI was designed to predict the outcome of the injury at 1 year post injury based on a single AIS 1990 injury. The work was first published in 1994 and is based on the assessment of 10 health dimensions. The 10 dimensions are excretion, eating, sexual function, ambulation, hand/arm movement, bending/lifting, visual function, auditory function speech and cognitive function. Its development was in 3 stages with the initial stage identifying the 10 health dimensions via medical specialists and the published literature. Secondly a group of raters from varying backgrounds categorized the items within the dimensions on a 0-100 scale. Then, using a multiplicative model, weights were assigned to these dimensions and items. The AIS 1990 codes were subsequently assigned an item level for each of the dimensions; for example the bending and lifting dimension has 4 items ranging from 'A' - 'no limitations' to 'D' - 'cannot bend or lift'. This stage resulted in the AIS 1990 codes having a profile consisting of 10 letters, 1 for each domain thus AAAAAAAAAA represents no problems at all. From these profiles a 'look up table' can be used to obtain the FCI weight which ranges between 0.0 and 1.0. However the FCI has not been validated at length and according to some studies, there is only moderate correlation between the FCI and impairment at 1 year post-injury [Schluter, Neale, Scott,. 2005, McCarthy, Mackenzie, 2001, Mackenzie, Shapiro, Moody 1986]. However the actual FCI has not been released widely for use but related work has continued which has recently been adapted and published in the AIS 2005 update dictionary as the pFCI which is a predictive ordinal score ranging from 1 (maximum impairment) to 5 (no impairment) [AAAM 2008]. What is not offered to the AIS user community is a description of the 'impairment' for pFCI 2 through 4. It is difficult to establish how this scale was derived from the original 0-100 weighting scales, now apparently redundant in use in preference of the AIS 2005 - pFCI. With the advancement in medical technology it is only right to update the injury scaling methods and alongside that there exists the need to update impairment scales to reflect these advances.

Most large crash injury databases such as those assembled as part of the Co-operative Crash Injury Study (in the UK) and the National Automotive Sampling System (in the US) have been using the AIS 1990 to code injuries for many years such that any subsequent impairment prediction can be based on the IIS. However the revision of the AIS dictionary to the AIS 2005 update has necessitated a review of the effect that this update has on such large databases. It is expected that there maybe some changes in impairment between the IIS and pFCI but it is important to consider the implications especially in respect of the overall effect on directing injury prevention measures.

This paper reviews available data to establish differences between the two impairment scales based on two versions of the Abbreviated Injury Scale (AIS 1990 and AIS 2005 update). It was postulated that any differences found to exist would potentially impact upon the road safety research community when examining burden of injury.

The aims and objectives were therefore considered to be as follows;

- Evaluation of the current available impairment scales to look at the inconsistencies between them; where they exist and to what extent;
- Evaluation of the impairment scales applied to a large injury database;
- Re-analysis of data from a previous research study (Barnes 2006, which collected data on impairment using a follow up methodology) to look at the potential use and validity of the scales with available relevant data.

METHODS

The AIS 1990 and AIS 2005 update dictionaries were used for an initial review of how the two coding methodologies considered impairment. Thus all injuries in the AIS 1990 dictionary were matched to the relevant IIS 1994 score and all injuries in the AIS 2005 update were matched to the relevant associated pFCI score. This enabled an overview of the distribution of the impairment for all injuries contained in both AIS dictionaries. Secondly a comparison of impairment in equivalent injuries in both dictionaries for the lower extremity was also undertaken. The AIS 1990 and AIS 2005 lower extremity chapters were reviewed for injuries that matched in description to identify these comparable injuries. Their associated impairment was recorded and any differences between the impairment scores reviewed.

In-depth crash injury data from the UK Co-operative Crash Injury Study (CCIS) were the basis of the study. The CCIS selects cases for investigation using a stratified sampling procedure based on car occupants' injury severity. Whilst this results in a sample which is biased towards fatal and seriously injured casualties, the injury data are representative of serious injuries in modern passenger vehicles. In this study, cases from February 2006 to September 2008 were selected from the database. All injuries were coded to both AIS 1990 and the AIS 2005 update from medical notes or post mortem reports where appropriate. AAAM trained coders were used to code all of the injuries. This double coding allowed for the application of both the pFCI and IIS to the sample population for the same detailed injury descriptions. The Functional Capacity Index (pFCI) score was assigned to all of the AIS 2005 injuries where available and the Injury Impairment Scores (IIS) were assigned to all of the AIS 1990 injuries where available. The injury descriptions were matched accordingly and where new injury codes were evident (such as 'bilateral' vessel injuries, or pan-facial fractures which may have a higher impairment in AIS 2005 compared to AIS 1990) they were not included in the analysis. Thus only injuries which were present in both dictionaries or could be matched in description were included in the analysis. Further data that had been gathered previously as part of a small follow up study were then reviewed to establish the potential of the two impairment methods for predicting impairing injuries. The follow up study was conducted by the first author to establish the physical and psychological outcomes of road trauma in survivors [Barnes, Thomas 2006]. Thus the study examined numerous factors relating to road traffic injury including the impact it had on finances, general health and quality of life as well as impairment and depression. A total of 120 participants were recruited into this study. In this study, 50 participants, who sustained injuries in a road crash, were followed up over a 1 year period. Follow up interviews were conducted which consisted of the application of two quality of life measures (SF-36v2, EQ-5D) using telephone interviews. Interviews were conducted at the study baseline and at 3, 6 and 12 months post injury. A further 70 participants were also recruited by post from the CCIS study and were also followed up for a 1 year period using the same protocol. Impairment was considered to have occurred if the injury prevented the participant from undertaking normal everyday activities at 12 months as determined by the individual.

RESULTS

Predicted Impairment – AIS 1990 and AIS 2005-update Dictionaries.

The IIS and pFCI using the relevant AIS 1990 and AIS 2005 update dictionaries found a similar general distribution of impairing injuries across the AIS body regions for all injuries (Figure 1).

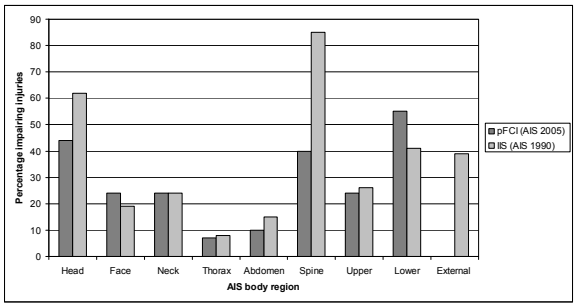

Figure 1 - Distribution of impairing injuries in the AIS 1990 and AIS 2005 dictionaries.

Overall it appeared that the head, spine and external injuries in AIS 1990 had a greater number of impairing injuries than their AIS 2005 counterpart. In contrast the AIS 2005 considers over 50% of lower extremity injuries to be impairing compared to the AIS 1990 (41%) and also more facial injuries. The 'external and other' chapter is not represented by the pFCI as this is incomplete with only 23% of the injuries having a pFCI score assigned all of which are non-impairing. The injuries contained within the 'external' chapter include burns, hypothermia and electrical injury.

The distribution of impairment was also reviewed for each body region and is shown in tables 1 and 2. There appears to be a similar pattern of impairment for most body regions particularly at the IIS 0 and pFCI 5 levels (61% IIS and 64% pFCI). However there were notable variations for the head, spine and lower extremities. There were fewer injuries with the maximum impairment in the IIS (2%) compared to the pFCI (8%). The IIS has more injuries (36.5%) across the 'mid-range' of impairment 1 through 5 for each body region compared to the pFCI (23.5%) 4 through 2. There were higher unknown pFCI impairments compared to the IIS of which most were from the 'External and Other Injury' chapter where the pFCI is not complete.

Table 1 - Percentage distribution of IIS for each AIS body region chapter

	IIS							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**9**
Head (n=239)	37	19	14	10	12	3	4	<1
Face (n=85)	81	13	6	-	-	-	-	-
Neck (n=78)	76	5	4	3	11	-	1	-
Thorax (n=172)	92	6	<1	1	<1	-	-	<1
Abdomen (n=226)	86	8	3	2	-	-	<1	<1
Spine (n=199)	15	24	14	17	19	6	5	-
Upper extremity (n=119)	76	15	8	2	-	-	-	-
Lower extremity (n=160)	59	23	10	6	<1	-	-	3
External /other (n=34)	62	9	18	6	-	3	3	-
Total %	**61**	**15**	**8**	**6**	**6**	**1.5**	**2**	**0.5**

Table 2 - Percentage distribution of pFCI for each AIS body region chapter

	pFCI					
	5	**4**	**3**	**2**	**1**	**9**
Head (n=280)	49	<1	10	11	22	7
Face (n=175)	74	1	16	6	<1	2
Neck (n=111)	73	<1	3	9	12	3
Thorax (n=191)	89	2	1	<1	4	4
Abdomen (n=250)	89	<1	4	4	2	1
Spine (n=216)	56	2	<1	10	27	4
Upper extremity (n=325)	73	17	4	2	2	2
Lower extremity (n=402)	42	31	13	10	2	3
External /other (n=48)	23	-	-	-	-	77
Total %	**64**	**10**	**7**	**6.5**	**8**	**5**

Distribution of head injuries and impairment – AIS 2005 and AIS 1990

Head injuries and their associated impairment were reviewed in the AIS 1990 and AIS 2005 dictionaries to examine the apparent impairment discrepancy. Overall 49% of head injuries in the AIS 2005 dictionary are considered not to be impairing at 1 year post injury with 22% incurring the maximum impairment on the pFCI. In contrast, the IIS considers 37% of head injuries to have no residual impairment at 1 year and only 4% of all head injuries incurring maximum impairment.

The distribution of impairment associated with all head injuries in the AIS 1990 and AIS 2005 update dictionaries for each AIS severity is seen in figures 2 & 3).

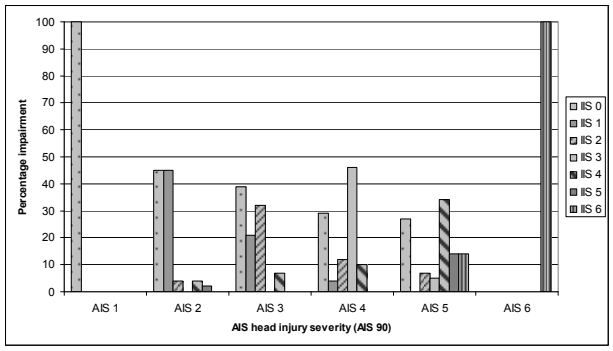

Figure 2 - Head injury AIS 90 severity and IIS

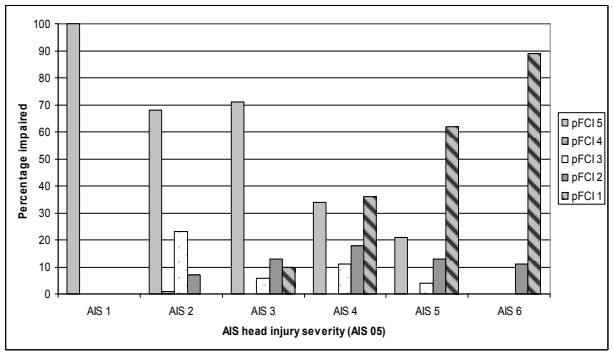

Figure 3 - Head injury AIS 2005 severity and pFCI

For the pFCI and the IIS there appears to be a similar pattern for non-impairing injuries (IIS 0 and pFCI 5) although higher percentages are noted in the AIS 2005 severity distributions. The AIS 2, AIS 3 and AIS 5 showed the most variation in impairment between IIS and pFCI. Also of note is the increase of maximum impairment for pFCI 1 as the AIS severity increases in AIS 2005. It is shown that all AIS 1 injuries are considered non-impairing in both AIS 90 and AIS 2005. All AIS 6 injuries score maximum impairment for the IIS and for the pFCI it is a similar, picture. However one new injury (bilateral sigmoid sinus laceration) at the AIS 6 severity is rated as having pFCI 2 impairment score.

The IIS distribution for head injuries by AIS severity reveals a wider range of impairment between IIS 0 and IIS 6 with some 58% of all head injuries scoring between IIS 1 and IIS 5.

Further examination of the AIS 1990 and AIS 2005 dictionaries identified the discrepancy in predicted impairment in some injuries which are usually associated with poor outcomes. In the IIS, diffuse axonal injury (DAI) in the cerebrum incurs an IIS of 5 indicative of 'impairment precluding most useful function'. However in AIS 2005 DAI can be coded in 2 separate sections and a DAI in the cerebrum with coma between 6 and 24 hours incurs an impairment of 1 (the maximum) but in the 'concussive injury' section DAI even with coma more than 24 hours only has a pFCI of 5 (no impairment at 1 year). This suggests that a patient with a DAI and associated prolonged coma of more than 24 hours will be fully recovered at 1 year post injury with no residual impairment. Therefore such assignment of pFCI codes appears to be inconsistent for similar injuries in some instances. Similarly severe fractures to the base of skull, which have an AIS 4 and can relate to loss of brain tissue, also have no impairment predicted at 1 year on the pFCI but the same injury will incur an IIS of 2. Even for severe vault fractures to the skull with loss of brain tissue the pFCI predicts no impairment compared to the IIS which incurs an IIS of 3; for the massively depressed vault fractures an IIS 4 is assigned. A further large discrepancy is evident with the injury pneumocephalus; the pFCI assigns the maximum impairment for this injury but the IIS assigns a 1.

Lower extremity injuries – impairment in comparable injuries

The lower extremity chapters were selected to illustrate potential changes in impairment between the AIS 1990 and AIS 2005 update dictionaries. Where injury descriptors were directly compatible between the two AIS dictionaries the impairment level was reviewed for the lower extremities. Overall some 118 injuries were matched of which 59 (50%) were considered non-impairing (IIS 0 and pFCI 5). A further 15 (13%) were non-impairing on the IIS but had some impairment on the pFCI. Seven injuries (6%) were considered impairing on the IIS but non-impairing on the pFCI. Thus overall the IIS considered 74 (63%) of these injuries to be non-impairing compared to the pFCI (56%, n=66). The remaining 37 injuries (31%) were considered impairing on both the IIS and pFCI. These findings are in contrast to the overall higher level of impairment found for lower extremity injuries (tables 1 & 2).

Real World CCIS Data - Predicted Impairment

The CCIS data from all occupants with a recorded injury between AIS 1 and AIS 6 were included in the following analysis. All injury descriptions were matched to their appropriate AIS severity and impairment score. Exclusions were made for 'new' injuries in AIS 2005. A total of 10,314 injuries were coded in AIS 2005 and the pFCI was recorded where applicable from the updated AIS 2005 dictionary (Table 3). Using this analysis, only 5% of these

injuries were predicted to be impairing at 1 year post injury.

Table 3 - Abbreviated Injury Score (2005) and corresponding pFCI

	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5	AIS 6	%
pFCI 5	7316	1465	678	135	52	0	95%
pFCI 4	18	265	62	0	2	0	3%
pFCI 3	22	44	22	4	2	0	
pFCI 2	1	33	17	18	4	0	
pFCI 1	0	0	12	13	30	48	2%
pFCI 9	42	0	3	1	2	3	

Using the AIS 1990 data a total of 10,230 injuries between AIS 1 and AIS 6 were recorded and in comparison for the same injuries the IIS predicts 24% to be impairing at 1 year (Table 4).

Table 4 - Abbreviated Injury Score (AIS 1990) and corresponding IIS

	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5	AIS 6	%
IIS 0	6175	991	434	125	42	22	76%
IIS 1	1157	434	290	69	30	0	19%
IIS 2	0	31	120	49	1	0	2%
IIS 3	0	6	7	51	9	0	1%
IIS 4	0	0	1	22	11	0	
IIS 5	0	0	0	0	16	3	1%
IIS 6	0	0	0	0	14	26	
IIS 9	11	44	39	0	0	0	1%

Body Region and Impairment

Impairing injuries were considered by body region with the head and spine considered to have the most impairing injuries using the IIS. The pFCI had a more even spread with the head and extremities having higher proportions of impairing injuries than other body regions (Figure 4).

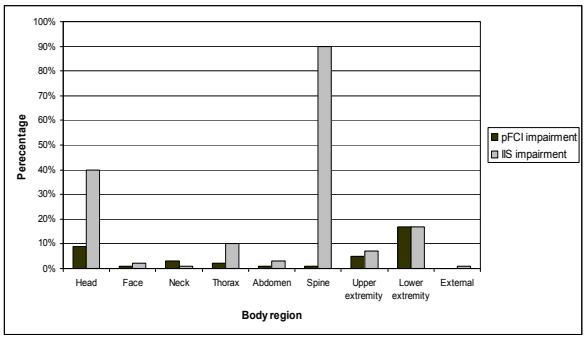

Figure 4 - Body region and corresponding IIS and pFCI

There were a total of 1,007 head injuries coded according to AIS 2005 of which 91% (n=914) were predicted not to have any impairment at one year with 6% predicted as having maximum impairment (n=61). There were 1,038 head injuries coded according to AIS 1990 of which 60% (n=619) were considered not to be impairing injuries; 17% (n=171) were at IIS 1 and 3% (n=30) were considered to be maximally impairing. There was a 21% distribution of injuries between IIS 2 and IIS 5 and less than 1% involved no IIS score. This compares to the pFCI whereby only 2% of the injuries were classified between pFCI 2 and pFCI 4 (n=23) with 1% (n=9) not having a pFCI score.

All AIS 1 head injuries in both impairment scales were considered 'non-impairing' and all AIS 6 injuries were 'maximally impairing'. The distribution in the other AIS severities particularly between AIS 3 and AIS 5 shows great variation between the predicted impairment scales with the pFCI predicting more injuries to be 'non-impairing' compared to the IIS (Figures 5 & 6).

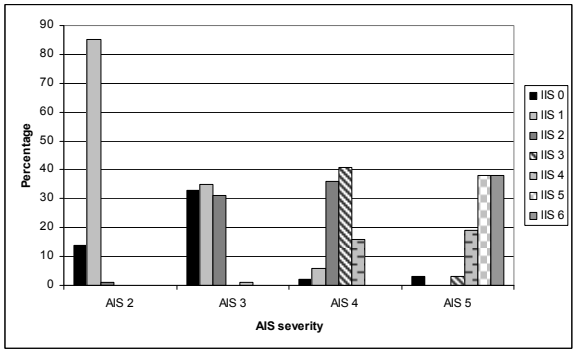

Figure 5 - Distribution of IIS for head injuries in CCIS data AIS 2 – AIS 5

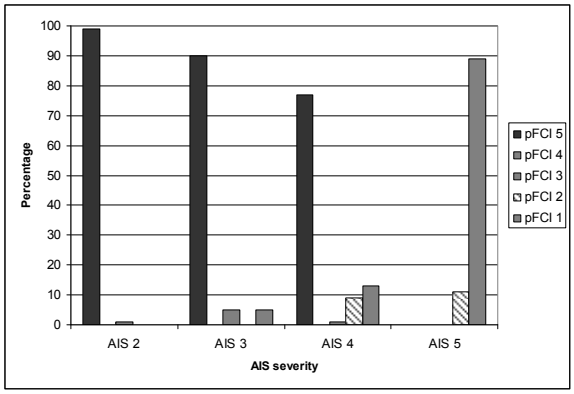

Figure 6 - Distribution of pFCI for head injuries in CCIS data AIS 2 – AIS 5

Spinal Injuries

The other area where a large discrepancy between the 2 impairment methods exists involves spinal injuries. Using the IIS, 90% of spinal injuries in the CCIS database were impairing injuries which is in contrast to the pFCI. Review of the data revealed the explanation in the issue of 'neck strain' which is considered to have an IIS of 1 (impairment detectable but does not limit function) but is recorded as having a pFCI of 5 (no impairment). The other main discrepancy is that 'burst vertebral body fractures' are considered not to be impairing using the pFCI but this injury is classified as involving an IIS of 1.

Follow up Studies

Data from two follow up studies were used to explore the outcomes for some specific injuries using both IIS and pFCI. The original data were coded to AIS 1990 and were then recoded to AIS 2005 using the original injury descriptions. The IIS and pFCI were then assigned to the injuries and impairment was considered using the patients' self-reported levels of impairment at 12 months.

Both the pFCI and IIS impairment scores are assigned on the assumption that the person has sustained a single injury. The two follow up studies had noticeable 'single' main injury types namely lower extremity injury and 'neck strain'. A total of seventeen participants in the follow up studies sustained their main injury or injuries to the lower extremity (most participants had additional AIS 1 skin injuries but these were disregarded). Table 5 (appendix 1) summarizes the data in terms of injury type, AIS severity, IIS, pFCI predicted impairment scores and subjective impairment at 3, 6, and 12 months as reported by the patients. Of those with lower extremity injuries it can be seen that there was a variety of type and severity of lower extremity injury in this small follow up sample. Of three participants predicted to have no impairment (IIS 0 / pFCI 5) one stated they had some impairment at 12 months. Of fourteen participants predicted to have some impairment at 12 months (IIS >0 / pFCI <5) seven stated they had some form of impairment, five had no impairment and two had unknown impairment at 12 months post injury. Four of the participants had impairment at the 6 month follow up but not at 12 months of which three were expected to have impairment based on the IIS and pFCI.

The issue of pain was a major factor for the participants at all stages of follow up and even at 12 months, eleven out of the seventeen participants still experienced pain which prevented them from undertaking certain activities. Pain as a factor in impairment is considered in the IIS as one of the components but not for the pFCI in its original development.

In a further follow up study there were 14 participants who had 'neck strain' as the main injury following a crash with follow up data available at 12 months. Of these participants six (43%), stated they had problems at 12 months relating to pain and restriction in activities as a result of the injury. Only five stated they had fully recovered with five stating they had almost recovered and four had not recovered at 12 months. These studies are small but show that neck strain is a problem injury as are lower extremity injury.

There was an expectation that head injuries would also be an area of concern. In the follow up studies there were only three people with head injury all of whom had problems at 12 months (Table 6). The IIS considers the impairment following a small cerebral contusion to be compatible with most but not all normal function (IIS 2) unlike the pFCI which considers this injury to involve no impairment at 12 months. This is also a small sample but highlights the differences in considered impairment for 'serious AIS 3' brain injuries. The first participant worked as a receptionist and was required to make written notes during phone calls or conversations otherwise she would immediately forget the details of the conversation. The last patient required residential rehabilitation for anger management as he was considered to be too unstable to continue with his current position in the armed forces.

Table 6 - Head injury and impairment

Head injury	AIS 90	IIS	AIS 05	pFCI	Impairment
Small cerebral contusion	3	2	3	5	Short term memory loss
vault #	2	0	2	5	
Amnesia	2	1	-	-	Depression
Small cerebral contusion	3	2	3	5	Mood swings / anger

DISCUSSION

Impairment is and will remain an important area for assessing the impact of injuries in the future. The ability to follow up patients post crash is dependent on access to these patients and is often limited to hospital centered data collection teams. For outside research institutes the ethical implications to conduct this type of research is limiting. Thus there is a dependency on the accessible data that is published relating to best methods for assessing impairment at 12 months to help focus attentions on preventing impairing injuries. This paper reviewed the two predictive impairment methods available for use.

The Abbreviated Injury Scale (AIS) has been used by road safety researchers to study the severity of injury in vehicle crashes for decades. It therefore follows that the assessment of injury impairment should have its basis in the Abbreviated Injury Scale and both the IIS and pFCI have therefore been developed accordingly. Despite both impairment methods being based on the AIS with both benefiting from expert opinion, there are areas of discrepancy between the two impairment scales. Using the IIS as a measure of impairment would possibly lead researchers to concentrate their efforts on preventing spine and head injury. In contrast the pFCI would point researchers in the direction of lower extremity and head injuries. So how can the researcher be sure to use the best method when there is such an apparent inconsistency between the IIS and pFCI assignment of impairment codes? Do we embrace the pFCI as it is available to researchers through the AIS 2005 dictionary? The AIS 2005 dictionary has incorporated advances in medicine and more importantly for researchers has enhanced the specificity of injury descriptions permitting more in-depth injury analysis in the future, but is impairment scaling at this same advanced stage? It has been suggested that the original FCI would have better predictive power if lower extremity fractures were better described (as in the current AIS 2005) than what exists in AIS 1990 {McCarthy, MacKenzie 2001]. Repeat studies for predicting impairment in lower extremity injuries would be welcomed in light of the amendments made to both the AIS 2005 and pFCI.

The general review of the actual dictionaries identified some apparent inconsistencies in the pattern of impairment as well as the assignment of some individual impairment scores. These apparent inconsistencies can be partly explained by the addition of 'new' injuries and an overall higher number of actual injuries in the AIS 2005 compared to the AIS 1990 dictionary. The increased numbers of injuries were found in the head and more particularly the extremity chapters. Of note in the lower extremity chapters, 6 injuries receive the maximum pFCI of 1 including bilateral amputations, crush injuries and sciatic nerve injuries. The highest impairment for the lower extremity injuries in IIS is 4 for above knee amputation. There were also added injuries in the 'head' including the introduction of 'bilateral' vessel injury which have a higher impairment than a unilateral vessel injury. One other factor in the head injury chapter is the removal of 2 pages of injury codes in the AIS 1990 dictionary relating to the 'Level of Consciousness'. A small proportion of these codes can be matched into the 'Concussive Injury' section in the AIS 2005 dictionary, but the remaining injuries would be obsolete if electronically converting AIS 1990 to AIS 2005 with a knock on effect on impairment scores between comparative databases. There were also particular head injuries in the AIS 2005 dictionary which showed no consistency within the same descriptor of injury as found for DAI and similarly between 'moderate' brain swelling and 'moderate' brain oedema a term that is often used interchangeably but with different levels of pFCI. The former is considered maximally impairing and the other less impairing (pFCI 2). Both of these injuries on the IIS are assigned an IIS 2 and therefore considered less impairing.

When comparative injuries were reviewed in this study it showed some diversity between the 2 methods - either car crashes in the CCIS sample cause only 5% of impairing injuries (pFCI) or 24% (IIS) - which is to be believed? Even removing neck strain injuries and assigning an IIS 0 to these injuries leaves some 16% of injuries which are considered impairing in the IIS. The assignment of the actual IIS score for whiplash was a dilemma for the original IIS experts in respect of assigning IIS 0 or IIS 1. This issue has not really been solved considering the number of insurance claims for perceived loss of 'quality of life' that this injury incurs. One would

question the assignment 'no impairment, pFCI 5' as being the true reflection for this injury as 'pain' seems to be the major issue under debate and interestingly, pain was not considered in the development of the original FCI. However pain is a very real problem following neck strain even at 12 months (as found in the follow up study) with 43% of participants restricted in everyday activity due to pain. This 'neck strain' dilemma and its associated impairment need to be redressed prior to adopting either impairment scale. The compensation paid out by insurance companies for whiplash injury (usually 12 months or more post injury) shows that it is a real problem. The question here remains whether 'pain' is an impairment and if not then the pFCI would be indicative of the method to adopt or if it is a factor in impairment then the IIS would be the method to use. So despite the differences in impairment scores and greater specification of injuries we are none the nearer to knowing the 'real impairment' of injured individuals.

The IIS would appear to distribute a range of impairments within an injury category whereas the pFCI often made a jump from no impairment to maximum impairment within the same injury description category, with no allowance for levels of impairment. This was particularly noticeable for head injuries and how they are treated in the AIS 1990 and AIS 2005 dictionaries. The agreement for AIS 6 injuries was apparent between the impairment scales however the pFCI assigns the maximum impairment score for a further 31 injuries whereas the IIS distribution for these injuries ranged between IIS 1 to IIS 5. The small sample of head injuries from the follow up studies showed a discrepancy between the impairment scales but even in the small sample all three persons injured had some form of 'impairment' at 12 months relating to their head injury despite the pFCI predicting no impairment. The IIS appears to have a wider variation for assessing the impairment of head injuries for this sample group compared to the pFCI which predicted maximum or no impairment as the outcome with very little variation between these two extremes.

Lower extremity injuries were found to be problematic particularly when examining occupants who sustained more than one leg injury. The follow up studies acted to highlight the impairing nature of lower extremity injury and again pain was a major factor in the participants' level of impairment. Despite the pFCI predicting more lower extremity injuries to be impairing in the AIS 2005 dictionary the IIS predicted more impairment for all of the injuries sustained by the follow up participants (72% compared to 58%). This overall increase in predicted impairing lower extremity injuries for the AIS 2005 dictionary injuries may be a product of the dictionary having doubled the number of actual injuries in each chapter compared to AIS 1990. This is a result of enhancing the specificity of extremity injuries as many fracture descriptions in the AIS 1990 dictionary are assigned to one AIS code (open, comminuted, displaced) and therefore one IIS score compared to the AIS 2005 which has separated these injuries out. However, it was found that even comparable lower extremity injuries showed discrepancies in impairment level between the IIS and pFCI.

The follow up sample itself was obviously small and could not be considered as representative as such. However use of this type of data and the methodology used is exactly what is needed in order to validate and further develop the evolution of impairment scales per se. A logical step is to explore the possibility of examining a much larger sample in order to derive a more accurate assessment of the validity of both scales. This would help to determine which scale is better too. Indeed given inaccuracies in both scales there appears to be a significant need for longitudinal follow-up studies to derive accurate profiles of injury impairment across the board. There also needs to be a decision regards pain and whether it is an 'impairment' or not.

The FCI has its roots in multi-attribute theory and therefore is presumably more scientific than the IIS which was developed by arbitrary assignment of scores by an expert panel. However there is a question as to how the multi-attribute theory has been adapted using 'an expert panel' to provide an ordinal scale of impairment in the current AIS 2005 update dictionary. It is suggested that both the IIS and the pFCI are indeed arbitrarily assigned ordinal scales based on expert opinion. As researchers we would welcome a definitive impairment scale from which to base injury and cost evaluations in future work but the lack of convincing data regards the performance of these impairment scales is disappointing.

CONCLUSION

There is a need for a simplistic assessment of impairment following traumatic injury but with two methods available to the road safety researcher should one select IIS over pFCI or vice versa? The variation between these two methods needs further exploration. Long term impairment studies are seen by some to be a requirement for prioritizing injury prevention interventions in traffic crashes, particularly for secondary (passive) safety developments. Thus it is evident that large

longitudinal follow up studies are necessary to contrast both of these predictive methods at one year post injury before any decision can be made on the preferred choice of impairment scaling. Further studies using follow-up data (existing and to be collected in due course) will be conducted to examine the validity of both scales with a view to identifying aspects of both scales especially in terms of accuracy and to establish specific instances where further consideration may be necessary.

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Further information on CCIS can be found at http://www.ukccis.org

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APPENDIX

Table 5 - Leg injuries and predicted impairment

Injury	AIS 90	IIS	AIS 05	pFCI	Impairment type	Pain	Impairment 12mth
Femur shaft #	3	0	3	5	Limp	Yes	Yes
Pelvis #	3	2	2	4	Limp, leg shorter	Yes	Yes
Open medial malleolus #	2	1	3	2	None	No	No
Pelvis #	2	1	2	4	Unknown	u/k	u/k
Penetrating injury	1	0	1	5	None	No	No
Tibial plateau #	2	1	3	2	None	Yes	No
Tibial plateau #	2	1	3	2	Kneeling	Yes	Yes
Tibial plateau #	2	1	3	2	Kneeling	Yes	Yes
Femur shaft #	3	0	3	5	None	Yes	No
Pelvis # Tibial plateau # Talus #	5 2 2	2 2 2	5 2 2	2 2 3	Cannot weight bear	Yes	Yes
Open tibia shaft # Femur shaft #	3 3	1 0	3 3	4 5	None	No	No
Open tibia # Open lateral malleolus # Fibula #	3 2 2	1 1 0	3 2 2	4 5 5	Limp	Yes	Yes
Femur shaft # Open tibia #	3 3	0 2	3 3	5 4	Limp	Yes	Yes
Open tibial plateau # Bilateral knee dislocation Disrupted cruciates Peroneal nerve transection Peroneal artery transection	3 2 3 2 3	1 3 1 3 3	3 2 2 2 2	2 2 3 5 5	Unknown	u/k	u/k
Bilateral open tibial plateau # Femur # Open fibula # Cruciate ligament disruption Cruciate ligament tear	3 3 2 3 2	1 0 0 3 2	3 3 2 2 2	2 5 5 5 5	Limp	Yes	Yes
Medial malleolus # Cruciate ligament tear	2 2	2 2	2 2	2 5	None	Yes	No
Tibial shaft # Fibula head #	3 2	1 0	2 2	4 4	None	No	No