Comparison of Tables that Map the Abbreviated Injury Scale 1998 Version to the 2008 Version.

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Abstract Two modified mapping tables that convert Abbreviated Injury Scale (AIS) 98 codes to AIS 2008 codes have been separately developed by Palmer et al. (P-map) and Tohira et al. (T-map). We aimed to determine which map gives the most accurate code conversion. We computed the intraclass correlation coefficients for the Injury Severity Score (ISS), the New ISS (NISS) and the Maximum AIS (MAIS) of six body regions using the mapped AIS 2008 codes and the manually determined AIS 2008 codes (gold standard). We also applied post-hoc severity adjustment to the mapped AIS 2008 codes. The ISS and NISS based on the two maps showed substantial agreement with the gold standard. The chest region MAIS of the P-map and the extremities region MAIS of both maps demonstrated moderate agreement with the gold standard, while the MAISs of the other regions displayed substantial agreement. The post-hoc severity adjustment for the P-map significantly improved the agreement for the chest region MAIS. The injury severity scores based on the two maps displayed similar agreement with the gold standard. The post-hoc severity adjustment provided by the P-map might be better at adjusting for severity levels than that provided by the T-map.

Keywords Abbreviated Injury Scale, Injury Severity Score, New Injury Severity Score, MAIS, Intraclass Correlation Coefficient

I. INTRODUCTION

The Abbreviated Injury Scale (AIS), issued by the Association for the Advancement of Automotive Medicine, is the best-known injury coding system. The AIS was revised in 2005 (AIS 2005) and updated in 2008 (AIS 2008) [1]. These two AIS versions similarly estimate injury severity and can be used interchangeably in most cases [2]. The principal previous version of the AIS is the AIS 98, which is still used in injury research. Because injury severity scores based on the AIS 2005 (i.e., the Injury Severity Score [ISS] and New ISS [NISS]) have been reported to be significantly lower than AIS 98 derived scores, it is inappropriate to use ISS/NISS based on AIS 98 and AIS 2008 (2005)interchangeably [2-4].

An AIS 2008 dictionary includes a mapping table that converts AIS 98 codes to AIS 2008 codes (hereafter refer to as the original mapping table)[1]. This table can be used to integrate AIS codes from AIS 98 to AIS 2008 compatible codes allowing comparisons and integration. However, this original mapping table has a drawback: it cannot map 153 AIS 98 codes to the equivalent AIS 2008 codes [5]. These unmappable codes represent injuries that are common in major trauma patients (e.g. pelvic fractures and rib fractures with pneumothorax). If a patient sustains an injury that has an unmappable AIS 98 code, an ISS based on mapped AIS 2008 codes cannot be computed, probably excluding that case from a study population, potentially introducing significant bias or inaccuracies. The proportion of excluded cases was reported as up to 30% in studies using regional trauma registry data [5, 6].

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Palmer et al. developed an enhanced mapping table that converts AIS 98 codes to AIS 2008 codes (P-map)[7]. Palmer et al. added new links that convert all of the AIS 98 codes that were unmappable by the original mapping table to equivalent AIS 2008 codes. These researchers also provided a post-hoc severity adjustment method. This post-hoc severity adjustment includes detailed directions for using free-text injury descriptions in a trauma registry to select the most appropriate AIS 2008 code when multiple candidate AIS 2008 codes exist. Moreover, they reported that the agreement between P-map and manually determined injury severity codes was excellent (weighted kappa statistic=0.97 for the ISS and the NISS)[7].

Tohira et al. also developed a modified mapping table to integrate AIS codes into AIS 2008 codes (T-map)[8]. Their approach was similar to that of P-map in that the researchers assigned the unmappable AIS 98 codes to equivalent AIS 2008 codes. A post-hoc severity adjustment method is also available for the T-map. Unlike Palmer et al., Tohira et al. did not utilize free-text descriptions associated with the AIS 98 codes. Instead, they used the frequency that the codes occurred in a trauma registry to adjust the AIS 2008 injury severity levels in cases where multiple candidate AIS 2008 codes existed for a given AIS 98 code. Tohira et al. reported substantial agreement between the injury severity scores created using T-map AIS 2008 codes and manually determined AIS 2008 codes (intraclass correlation coefficient [ICC] = 0.94 for ISS and NISS). They also studied the agreement between the maximum AISs (MAISs), which are the maximum severity levels for the six ISS body regions (head/neck, face, chest, abdominal, extremities and external). Among the six MAISs, only the Chest region had less than substantial agreement (moderate) against manually determined codes (ICC=0.79). Applying adjusted severities, Tohira et al. found the NISS and chest MAIS agreement improved significantly (ICC=0.96 for the NISS and ICC=0.89 for the chest MAIS)[8].

Both P-map and T-map have demonstrated considerable injury severity score agreement between mapped codes and manually determined codes. However, the within-subject accuracy of these two maps has not yet been compared. We therefore conducted this study to answer the following questions. 1. How do the AIS 2008 codes assigned to the unmappable AIS 98 codes differ between the P-map and T-map? 2. Is there any difference between the severity scores based on the P-map vs. T-map? 3. Is there any difference in injury severity scores (i.e., ISS, NISS and MAIS) agreement between the P-map and T-map?

To address these questions, we aimed to investigate the difference in code mapping and injury severity scores between the P-map and T-map and to determine which mapping table produced a more accurate code conversion.

II. METHODS

Comparison of the P-map and the T-map

We compared the newly assigned AIS 2008 codes in the P-map with those in the T-map. We investigated the number of unmappable AIS 98 codes whose assigned AIS 2008 codes differed between the P-map and the T-map. We further analyzed the number of these divergent codes where severity levels differed between the two maps. When multiple codes were assigned a given unmappable code, we used the highest severity level among the codes to determine the divergence of mapped codes between two maps because the highest severity level is the most relevant to the ISS, NISS and MAIS. For example, an AIS 98 code for one rib fracture with pneumothorax is 450214.3. This code will be mapped to 450201.1 (one rib fracture, severity level=1) and 442202.2 (pneumothorax, severity level=2) by the T-map (multiple codes), and 450201.1 by the P-map (single code). When we determined if the severity levels of mapped codes differed between the two maps, we used 442202.2 for the T-map and concluded that the severity levels of the mapped AIS 2008 codes were different between the two maps. We also analyzed these numbers according to the six ISS body regions.

Comparison of injury severity scores and agreements

Subjects

We used the trauma registry data of the Sir Charles Gairdner Hospital (SCGH), Western Australia, between 1998 and 2008. The SCGH trauma registry data contain three different versions of AIS codes: AIS 90 (1998-2005), AIS 98 (2006) and AIS2005 (2007-8). All AIS codes in the registry were manually determined by qualified coders from the hospital by chart review without using computer software which converts ICD codes to AIS codes. We included cases that were assigned at least one AIS 98 code whose compatible AIS 2008 code has a severity level that differs between the T-map and the P-map. We excluded drowned or suffocated patients because the codes for these types of injury were not available in the AIS 98.

Creation of the AIS 98 and AIS 2008 code sets

First, we created a set of manually determined AIS 98 and AIS 2008 codes for each subject. Manually determined AIS codes were created by two ways: extraction from the hospital trauma registry and chart review. To generate manually determined AIS 98 codes, we extracted the data registered between 1998 and 2006 from the SCGH trauma registry, which include AIS 90 and AIS 98 codes (Figure 1). Although the AIS 90 is compatible to the AIS 98 in terms of the injury severity assessment, there are some differences (51 codes were newly added to the AIS 98, 24 codes in the AIS 90 were removed, and the seven-digit identifiers of 26 codes were changed) [9]. AIS 90 codes that did not exist in the AIS 98 were manually converted to the equivalent AIS 98 codes. Because there were no AIS 98 codes for subjects registered in 2007 and 2008 in the SCGH registry, AIS 98 codes were manually determined by reviewing a chart (Figure 1). Free-text injury descriptions in the trauma registry data were used if a chart was not available or missing. This AIS 98 coding was conducted by another qualified coder without using an ICD-AIS mapping software. AIS 98 codes manually converted from AIS 90 codes, those extracted from the registry and those manually determined by chart review comprise the manually determined AIS 98 codes (Figure 1).

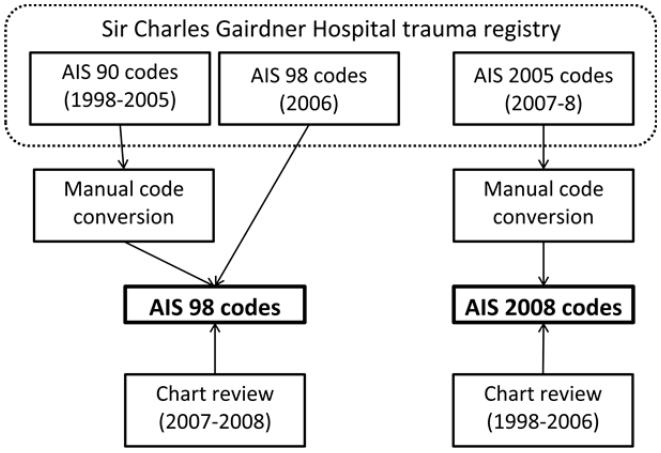

Figure 1. Schematic flow chart of the creation of manually determined AIS 98 and AIS 2008 codes.

The manually determined AIS 2008 codes were created in a similar manner to the AIS 98 codes. For subjects between 1998 and 2006, AIS 2008 codes were manually determined by chart review (Figure 1). For the data registered between 2007 and 2008, we extracted the manually determined AIS 2005 codes from the SCGH trauma registry (Figure 1). Because there are minor differences between the AIS 2005 and the AIS 2008 [10, 11], AIS 2005 codes that had a different severity level in the AIS 2008 were manually converted to the equivalent AIS 2008 codes. The AIS 2008 codes manually determined by chart review and those manually converted from AIS 2005 codes comprise the manually determined AIS 2008 codes (Figure 1).

Second, we converted the manually determined AIS 98 codes into AIS 2008 codes using the original mapping table, the P-map and the T-map. To convert the AIS 98 codes to the equivalent AIS 2008 codes, we simply matched an AIS 98 code in the dataset with an AIS 98 code in the mapping tables and identified an equivalent AIS 2008 code using statistical software. When we converted the AIS 98 codes to AIS 2008 codes using the P-map or T-map, we repeated this matching process until all of the equivalent AIS 2008 codes were matched with a given AIS 98 code because both the P-map and T-map allow the allocation of a single AIS 98 code to multiple AIS 2008 codes. At this stage, each patient had the following four sets of AIS 2008 codes: manually determined AIS 2008 codes (MAN), AIS 2008 codes that were mapped from the AIS 98 codes using the P-map

(P-codes), AIS 2008 codes that were mapped from the AIS 98 codes using the T-map (T-codes), and AIS 2008 codes that were mapped using the original mapping table (ORG).

Lastly, we performed a post-hoc severity adjustment. We modified the severity levels of the T-codes and P-codes using methods proposed by Tohira et al. [8] and Palmer et al. [7], respectively. Tohira et al. proposed the use of adjusted severities, which are the weighted averages of the AIS 2008 severity levels for a given AIS 98 code. The prevalence of each candidate code in a trauma registry was used as the weight. The adjusted severity levels of the AIS 2008 codes were computed when multiple candidate AIS 2008 codes existed for a given AIS 98 code and the severity levels of the candidate codes were not consistent. The details of this adjustment can be found elsewhere [8]. Palmer et al. proposed the use of free-text injury descriptions in trauma registry data. They provided a list of AIS 98 codes that can be mapped to more appropriate AIS 2008 codes using free-text injury descriptions compared to the P-codes. We used this list to identify AIS 98 codes that may benefit from free text and assigned appropriate AIS 2008 codes to these AIS 98 codes.

Comparisons of the injury severity scores

We derived the ISSs, NISSs and MAISs using the MAN, P-codes, adjusted P-codes, T-codes and adjusted T-codes. We selected the ISS and NISS for this comparison because they frequently appear in injury research articles. We analyzed the MAISs because they were closely related to the ISS and because they provide information about the differences in injury severity score agreement among the six body regions. We did not compute injury severity scores for the ORG because the scores were incomputable due to unmappable AIS 98 codes in all cases. We considered the scores that were derived from the MAN to be the gold standard.

Comparisons of the agreement of injury severity scores

We compared the injury severity score agreements between the MAN and the P-codes, adjusted P-codes, T-codes and adjusted T-codes. We measured the agreements with the intraclass correlation coefficient (ICC). The ICC represents the degree of homogeneity for pairs of measurements [12]. The ICC value ranges from 0 to 1. We described the ICC ranges as proposed by Shrout: 0-0.1, virtually none; 0.1-0.4, slight; 0.4-0.6, fair; 0.6-0.8, moderate; and 0.8-1.0, substantial [13].

We computed each injury severity score ICC for the following pairs of datasets: P-codes and MAN (ICCp), adjusted P-codes and MAN (ICCp-adj), T-codes and MAN (ICCt) and adjusted T-codes and MAN (ICCt-adj). We performed multiple comparisons for all pairs of these ICCs to determine which map produced the most accurate code conversion.

Statistical analysis

We compared the ISSs and NISSs using the Friedman analysis of variance for the overall comparison and the Wilcoxon signed-rank test for pairwise comparisons. We used the Fisher Z test to compare the ICCs [14]. We applied the Bonferroni correction when necessary[15]. We used SPSS version 20 (Chicago, Illinois) software for the code conversion and statistical analysis.

Ethics

This study was approved by the ethics committees of the University of Western Australia and the SCGH.

III. RESULTS

Comparison of maps

Of the 153 unmappable AIS 98 codes in the original mapping table, 66 codes (43%) were assigned a different AIS 2008 code by either the P-map or the T-map (Table 1) with 45 of these codes (29%) having different severity levels (Table 1). The unmappable AIS 98 codes were mainly injuries to the head, chest and extremities. All head region codes that differed between the maps also had different severity levels. The details of the differing codes for the two maps can be found in the table in the Appendix.

Table 1. Code assignments that differ between Tohira et al. and Palmer et al.

Regions	Unmappable codes	Different codes	Different codes with different severity levels
Head/neck	39	26	26
Face	8	3	1
Chest	35	13	4
Abdomen	8	2	1
Extremities	59	21	12
External	4	1	1
Total	153	66	45

We identified 106 major trauma cases with at least one AIS 98 incompatible code that had a different severity level between the two maps. We collected 879 and 874 manually determined AIS 98 and AIS 2008 codes for these cases, respectively (Figure 2). All AIS 98 codes were mapped to AIS 2008 codes using the P-map and T-map, and 710 codes (81%) using the original map. The numbers of AIS 2008 codes mapped by the P-map and T-map were 883 and 916, respectively (Figure 2). We were able to calculate the ISS/NISS for all of the cases using the P-codes and T-codes and were unable to calculate those for all of the cases using the ORG.

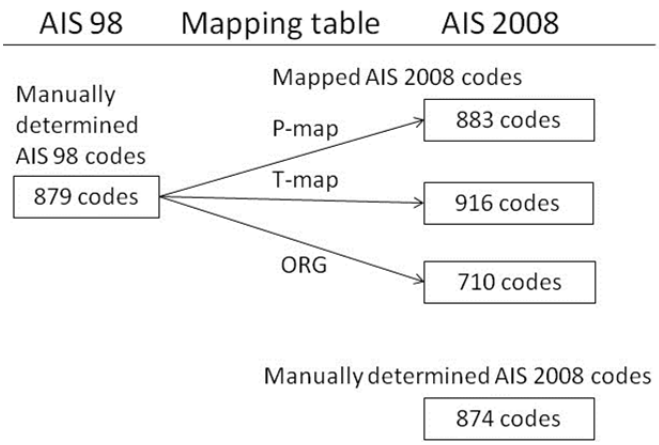

Figure 2. Results of converting AIS 98 codes to AIS 2008 codes using three different mapping tables. P-map, a mapping table developed by Palmer et al; T-map, a mapping table by Tohira et al; ORG, the original mapping table in an AIS 2008 dictionary.

Comparisons of scores

The median ISSs based on the MAN, P-codes, adjusted P-codes, T-codes and adjusted T-codes were 21, 18.5, 20, 20 and 20.7, respectively (Table 2). The rank distributions of the four ISSs were significantly different, $\chi^2(4)=46$, $p<0.001$. We used the Wilcoxon rank-sum test to further explore this finding. We applied the Bonferroni correction and reported all of the effects at the 0.005 significance level. None of the ISSs based on the four sets of mapped AIS 2008 codes were significantly different from the ISSs based on MAN. The ISSs based on the P-codes and T-codes were significantly different from the ISSs based on the adjusted P-codes and adjusted T-codes ($p=0.0046$ and <0.001, respectively) (Table 2).

Table 2. ISSs and NISSs based on the manually determined and mapped codes.

Codes	Severity adjustment	ISS (median [range])	p-value	NISS (median [range])	p-value
Manual		21 (6-59)		26 (6-75)	
P-codes	Unadjusted	18.5 (5-59)		22 (6-75)	
	Adjusted	20 (6-59)	0.0046	25.5 (6-75)	0.003
T-codes	Unadjusted	20 (4-59)		27 (4-75)	
	Adjusted	20.7 (4-62.5)	<0.001	27 (4-75)	<0.001

Manual: AIS 2008 codes manually selected by qualified coders; P-codes: AIS 2008 codes mapped using Palmer's map; T-codes: AIS 2008 codes mapped using Tohira's map.

The median NISSs based on the MAN, P-codes, adjusted P-codes, T-codes and adjusted T-codes were 26.0, 22.0, 25.5, 27 and 27, respectively (Table 2). These five NISSs were significantly different $\chi^2(4)=34$, $p<0.001$. The post-hoc comparisons demonstrated that no NISSs based on mapped AIS 2008 codes were significantly different from the NISSs based on MAN at the 0.005 level. The NISSs based on the P-codes and T-codes were significantly different from the NISSs based on the adjusted P-codes and adjusted T-codes (p=0.003 and <0.001, respectively) (Table 2).

Comparisons of agreements

The agreements between ISSs derived from MAN and those derived from P-codes, adjusted P-codes, T-codes and adjusted T-codes were all substantial (Figure 3). The NISSs showed the same figures as the ISSs, indicating good agreement. All ICCs for the ISSs were not significantly different at the 0.0083 significance level, as indicated by the Bonferroni correction. All ICCs for the NISSs were also not significantly different at the 0.0083 significance level.

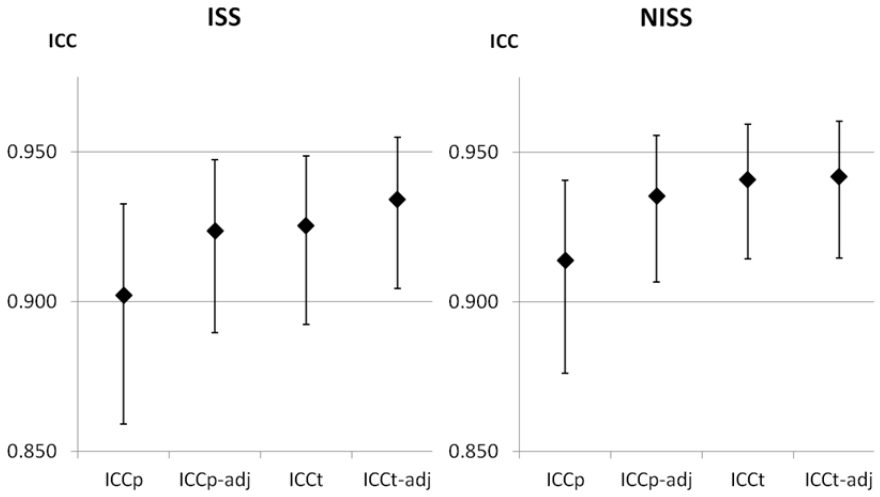

Figure 3. Comparing the Injury Severity Score (ISS) and New Injury Severity Score (NISS) intraclass correlation coefficients (ICCs) derived from the manually determined AIS 2008 codes with those derived from four different AIS 2008 code mappings.
ICCp, ICC of P-codes vs. MAN; ICCp-adj, ICC of adjusted P-codes vs. MAN; ICCt, T-codes vs. MAN; ICCt-adj, ICC of adjusted T-codes vs. MAN.

Regarding the MAISs, most of the ICCs of the head and chest region were substantial (ICC>0.8), while all ICCs of the extremities region were modest (0.6<ICC<0.8) (Figure 4). The ICCp-adj of the head region was

significantly greater than ICCt and ICCt-adj at the 0.0083 significance level (Figure 4). The ICCp-adj of the chest region was significantly greater than any other ICCs in the region, while the ICCt-adj was significantly greater than ICCp (Figure 4). There was no significant difference between any pair of ICCs of the extremities region (Figure 4). The ICCp, ICCp-adj, ICCt-unadj and ICCt-adj of the external region were all 0.96 (95% confidence interval, 0.94-0.97). All four ICCs of the face and abdominal region were 1.0 because all of the mapped AIS 2008 codes for facial and abdominal injuries had the same severity levels as those of the manually determined AIS 2008 codes.

Note that the ICC estimates were derived using the same subjects; therefore, overlapping 95% confidence intervals do not always indicate that there is no significant difference.

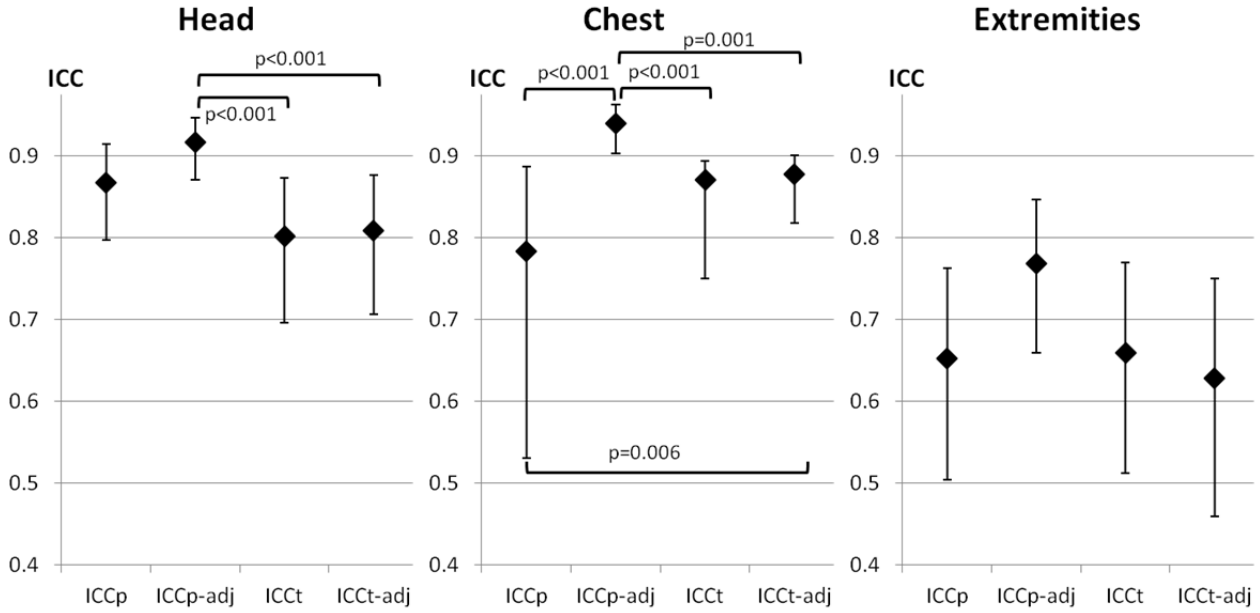

Figure 4. Comparisons of the intraclass correlation coefficients (ICCs) between the Maximum AISs of each head, chest and extremities region derived from MAN and those derived from P-codes, adjusted P-codes, T-codes and adjusted T-codes.
ICCp, ICC of P-codes vs. MAN; ICCp-adj, ICC of adjusted P-codes vs. MAN; ICCt, T-codes vs. MAN; ICCt-adj, ICC of adiusted T-codes vs. MAN.

IV. DISCUSSION

We have managed to compare two modified mapping tables that convert AIS 98 codes to AIS 2008 codes. We found that 43% of the unmappable AIS 98 codes were assigned different AIS 2008 codes and that 68% of differing AIS 2008 codes had different severity levels between the P-map and the T-map. However, the ISSs and NISSs based on the P-codes, adjusted P-codes, T-codes and adjusted T-codes were similar. The injury severity score agreement was substantial, except for the agreement of the extremities region MAISs. There were no significant differences in agreement of the ISSs and the NISSs between mapped AIS 2008 codes and the gold standard. For the head region MAISs, adjusted P-codes agreed with the MAN better than T-codes and adjusted T-codes. For the chest region MAISs, adjusted P-codes agreed with the MAN best among the other mapped code sets. There was no significant difference in the agreement of the extremities region MAISs among the four mapped AIS 2008 code sets. The face and abdominal region MAISs showed complete agreement between MAN and all mapped AIS 2008 codes, and the external abdominal region MAISs showed substantial agreement (ICC=0.96).

We found that 45 unmappable AIS 98 codes were assigned different AIS 2008 codes with different severity levels between the T-map and P-map. The majority of these differing AIS 2008 codes with different severity levels were found in the head region. The T-map assigned AIS 98 codes for loss of consciousness (LOC) codes to AIS-9 codes, which cannot be used to calculate injury severity scores. Tohira et al. concluded that these LOC codes did not have enough information to allow assigning a code with a specific severity level. In contrast, the P-map assigned these LOC codes a cerebral concussion code with a specific severity level. The issue underlying this difference is the accuracy of the severity levels of the mapped codes. If a specific brain injury that can cause unconsciousness is identified, an LOC code should not be selected [16]. If such an injury is identified, then the mapping from the LOC code to a cerebral concussion code may be inadequate, resulting in an inaccurate conversion regarding the severity level. We will discuss this issue in more detail later.

This study showed that there was no statistically significant difference in either the ISS or NISS between the four mapped AIS 2008 code sets and the gold standard, while both the ISSs and NISSs derived from the adjusted P-codes and T-codes were significantly different from those derived from the unadjusted P-codes and T-codes. Because the difference between the ISS (or NISS) based on the unadjusted and adjusted P-codes was apparent compared to that of the T-codes, the post-hoc severity adjustment method provided by the P-map might be more powerful than the one provided by the T-codes. Note that we detected a significant difference between ISSs and NISSs based on unadjusted and adjusted mapped codes despite the small differences in the median ISSs (or NISSs). This is because our sample size was large enough to detect small differences in the ISS (or NISS). We used a nonparametric test to detect differences in the ISSs (or NISSs). In general, a nonparametric test requires an approximately 15% greater sample size to achieve the same power as the equivalent t-test [17]. Based on this approximation, our sample size achieved almost 100% of the power required to detect a difference of 1 in the ISS by the equivalent t-test.

All of the mapped AIS 2008 codes could be used to compute the ISS and the NISS with substantial agreement with the gold standard. This finding is meaningful for injury researchers when analyzing longitudinal data that contain AIS 98 codes. As described earlier, the AIS 98 and the AIS 2008 cannot be concurrently used when computing the ISS or the NISS because of the incompatibility between the two AISs. However, using the P-map or the T-map, injury severity scores based on the AIS 98 could be made compatible to those based on the AIS 2008. For instance, the National Trauma Registry in Canada and state trauma registries of New South Wales, Queensland and Victoria in Australia had been using the AIS 90 or AIS 98 and recently started to use the AIS 2008 [18]. It is impossible to make a longitudinal comparison of injury severity profiles between data that were registered using the AIS 98 and those registered using the AIS 2008. Both the P-map and T-map enable this comparison without manually re-coding all injuries that were initially coded using AIS 98 codes.

The agreements of the head region MAISs of the T-codes and adjusted T-codes were inferior to those of the P-codes. The inferiority of the T-codes might be due to the existence of the LOC patient without brain injury in our dataset. As described earlier, the T-map converts most codes for LOC to AIS-9 codes, which do not have a severity level, while the P-map converts such codes to one of the codes for concussion. We identified 34 cases that had one of the LOC codes of the AIS 98. Of those, 15 cases also had one of the LOC codes of the AIS 2008. This discrepancy in the number of cases with an LOC code between the AIS 98 and the AIS 2008 may be due to the inability to select an LOC code in the AIS 2008 when a brain injury (e.g., brain contusion, subdural hematoma) that was associated with loss of consciousness existed, while the AIS 98 does not have this rule [11]. Because these 15 cases with a LOC code did not sustain any other head injury, their head region MAISs were one or two for the P-codes, while the head region MAISs of such codes were zero for the T-codes. Therefore, if a given dataset includes many cases with a code for LOC without any other head injury, the P-map may produce better agreement for the head region MAISs than the T-map.

The chest region MAISs of the unadjusted P-codes exhibited less agreement with the gold standard than the other three mapped codes. This is because the coding rule for rib fractures with pneumothorax and/or hemothorax is different between the AIS 98 and the AIS 2008. Rib fractures with pneumothorax/hemothorax can be coded using one code in the AIS 98, whereas rib fractures, pneumothorax and hemothorax have to be

coded using separate codes in the AIS 2008. For instance, an AIS 98 code for two rib fractures with hemothorax is 450220.2, while the codes for these injuries in the AIS 2008 were 450202.2 (two rib fractures) and 442200.3 (hemothorax). The P-map converted the codes for rib fractures with hemothorax to codes only for rib fractures, and did not consider hemothorax, i.e., AIS 98 code 450202.2 will be mapped to only 450202.2 of the AIS 2008. The chest region MAISs of the P-codes, therefore, could be less than those of the gold standard, particularly when the severity level of hemothorax is greater than that of rib fractures. The use of the post-hoc severity adjustment provided by the P-map significantly improved the chest region MAIS agreement because it enables one to capture the missed hemothorax.

The agreement of the extremities region MAISs was inferior to that of the other regions. This inferiority appeared to be due to the difference in codes for pelvic factures between the AIS 98 and the AIS 2008. In the AIS 98, the codes for pelvic fracture were determined based on anatomical characteristics (e.g., open, comminuted), and a sacroiliac fracture and symphysis pubis separation had separate codes. In the AIS 2008, the pelvis ring was considered as a single anatomical structure, and the severity levels of pelvic fractures were determined based on the instability of the pelvic ring, which is the major change from the AIS 98. Therefore, code-by-code mapping of pelvic injury is limited. The effect of this limitation can be found in our data. Of 78 patients who sustained at least one extremity injury in our dataset, 42 sustained a pelvic injury. The ICCs of the extremities region MAISs of the P-codes and the T-codes against the MAN were 0.398 and 0.305, respectively, for those who sustained a pelvic injury. The ICCs of the extremities region MAISs of the P-codes and the T-codes against the MAN were 0.883 and 0.798, respectively, for those who did not sustain a pelvic injury. The post-hoc severity adjustment improved the ICC of the MAIS from 0.398 to 0.584 for those who sustained a pelvic injury. Pelvic injuries may need to be manually re-coded for accurate code conversion.

Another limitation of automatic code mapping can be observed in the chest region. Many codes for chest injuries were subdivided into more specific codes in the AIS 2008. Some of these subdivided codes were assigned different severity levels. This subdivision of chest injuries can cause over- or under-estimation. For example, two rib fractures and three rib fractures share the same code, 450220.2 (severity level=2), in the AIS 98. In the AIS 2008, two rib fractures and three rib fractures were assigned separate codes: 450202.2 (severity level=2) and 450203.3 (severity level=3), respectively. All three mapping tables included in this study convert an AIS 98 code for two or three rib fractures into an AIS 2008 code for two rib fractures. Thus, the severity level of three rib fractures will be reduced to two for mapped AIS 2008 codes, while the severity level of the fractures will be three for manually determined codes. The post-hoc severity adjustment for the T-map can partially overcome this limitation by adjusting severity using the weighted averages of severity levels. The post-hoc severity adjustment for the P-map can also identify an appropriate code if the number of rib fractures was described in a free-text injury description.

The post-hoc severity adjustment of the P-map appeared to be better method than that of the T-map; however, there are a few limitations [19], including the existence of a trauma registry without free-text injury descriptions [20]. The post-hoc severity adjustment for the P-map is not applicable to such a trauma registry. Additionally, a free-text injury description does not always contain sufficient information to determine an appropriate AIS 2008 code. For instance, the thickness of a hematoma is required to determine an appropriate AIS 2008 code for a subdural and epidural hematoma of the brain. If the thickness is not provided in free text, it is impossible to apply the post-hoc severity adjustment.

Based on our findings, we recommend using the P-map with the post-hoc severity adjustment if an injury database has free-text injury descriptions. This method requires manual process to re-code injuries by reading free-text injury descriptions. Therefore, it may not be feasible if a number of codes have to be re-coded [19]. If free-text descriptions are not available and/or re-coding is not feasible, the T-map with or without the post-hoc severity adjustment is the second alternative because all the scores except the MAIS of the head region agreed better with the gold standard than those derived from the P-map without the post-hoc adjustment.

V. CONCLUSIONS

Despite the differing code assignments in the P-map and T-map, the two maps can derive similar overall injury severity scores and achieve substantial agreement with the gold standard. Either the P-map or T-map can be used to convert AIS 98 codes to AIS 2008 codes with satisfactory agreement. However, the use of the MAIS for the specific body region, particularly the extremities, based on the P-map and the T-map was limited. The use of the post-hoc severity adjustment with the P-map and the T-map may further improve the injury severity measurement agreement with the gold standard.

VI. REFERENCES

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VII. APPENDIX

A list of AIS 98 codes which are mapped to AIS 2008 codes with different severity levels between the two maps.

AIS 98		**AIS 2008**			
		Tohira et al.		**Palmer et al.**	
140206.5	Brain stem DAI	161007.4	DAI NFS	140299.5	Brain stem NFS
140406.5	Cerebellum DAI	161007.4	DAI NFS	140499.3	Cerebellum NFS
160404.2	Awake (GCS=15), no prior unconsciousness, with neurological deficit	100099.9	Injuries to the Head NFS	161000.1	Cerebral concussion
160406.2	Awake (GCS=15), prior unconsciousness, length of time NFS	100099.9	Injuries to the Head NFS	161000.1	Cerebral concussion
160408.3	Awake (GCS=15), prior unconsciousness, length of time NFS, with neurological deficit	161002.2	Cerebral concussion, brief loss of consciousness NFS	161000.1	Cerebral concussion
160410.2	Awake (GCS=15), amnesia	100099.9	Injuries to the Head NFS	161000.1	Cerebral concussion
160412.3	Awake (GCS=15), amnesia, with neurological deficit	100099.9	Injuries to the Head NFS	161000.1	Cerebral concussion
160414.2	Awake (GCS=15), unconsciousness<1h	100099.9	Injuries to the Head NFS	161003.2	Cerebral concussion, loss of consciousness<1h
160416.3	Awake (GCS=15), unconsciousness<1h, with neurological deficit	100099.9	Injuries to the Head NFS	161003.2	Cerebral concussion, loss of consciousness<1h
160499.1	Awake (GCS=15), NFS	100099.9	Injuries to the Head NFS	161000.1	Cerebral concussion
160602.2	Lethargic (GCS=9-14), no prior unconsciousness	100099.9	Injuries to the Head NFS	161001.1	Cerebral concussion, mild
160604.3	Lethargic (GCS=9-14), no prior unconsciousness, with neurological deficit	100099.9	Injuries to the Head NFS	161001.1	Cerebral concussion, mild
160606.2	Lethargic (GCS=9-14), prior unconsciousness, length of time NFS	100099.9	Injuries to the Head NFS	161000.1	Cerebral concussion

AIS 98		AIS 2008			
		Tohira et al.		Palmer et al.	
160608.3	Lethargic (GCS=9-14), prior unconsciousness, length of time NFS, with neurological deficit	100099.9	Injuries to the Head NFS	161000.1	Cerebral concussion
160610.2	Lethargic (GCS=9-14), unconsciousness<1h	100099.9	Injuries to the Head NFS	161003.2	Cerebral concussion, loss of consciousness<1h
160612.3	Lethargic (GCS=9-14), unconsciousness<1h, with neurological deficit	100099.9	Injuries to the Head NFS	161003.2	Cerebral concussion, loss of consciousness<1h
160614.3	Lethargic (GCS=9-14), unconsciousness=1-6hs	100099.9	Injuries to the Head NFS	161006.3	Cerebral concussion, loss of consciousness 1-6h
160616.4	Lethargic (GCS=9-14), unconsciousness=1-6hs, with neurological deficit	100099.9	Injuries to the Head NFS	161006.3	Cerebral concussion, loss of consciousness 1-6h
160699.2	Lethargic (GCS=9-14), NFS	100099.9	Injuries to the Head NFS	161000.1	Cerebral concussion
160802.2	Unconscious (GCS≤8), length of unconsciousness NFS	100099.9	Injuries to the Head NFS	161000.1	Cerebral concussion
160804.3	Unconscious (GCS≤8), length of unconsciousness NFS, with neurological deficit	100099.9	Injuries to the Head NFS	161000.1	Cerebral concussion
160806.3	Unconscious (GCS≤8), unconsciousness<1h	100099.9	Injuries to the Head NFS	161003.2	Cerebral concussion, loss of consciousness<1h
160808.4	Unconscious (GCS≤8), unconsciousness<1h, with neurological deficit	100099.9	Injuries to the Head NFS	161003.2	Cerebral concussion, loss of consciousness<1h
160810.3	Unconscious (GCS≤8), unconsciousness=1-6hrs	100099.9	Injuries to the Head NFS	161006.3	Cerebral concussion, loss of consciousness 1-6h
160812.4	Unconscious (GCS≤8), unconsciousness=1-6hrs, with neurological deficit	100099.9	Injuries to the Head NFS	161006.3	Cerebral concussion, loss of consciousness 1-6h
160899.3	Unconscious (GCS≤8), NFS	100099.9	Injuries to the Head NFS	161000.1	Cerebral concussion
250616.2	Mandible fracture, open, subcondylar	250608.1	Mandible fracture, closed, ramus	250610.2	Mandible fracture, open, NFS as to site
416008.3	Penetrating injury on chest with hemo/pneumothorax except tension pneumothorax	416002.1 442202.2	Penetrating injury, superficial Pneumothorax, NFS	416000.1	Penetrating injury NFS
441424.5	Lung laceration with parenchymal laceration with massive air leak, unknown laterality	441414.3 442204.5	Lung laceration, NFS Pneumothorax, massive air leak	441414.3	Lung laceration, NFS
441440.5	Unilateral lung laceration with parenchymal laceration with massive air leak	441432.4 442204.5	Lung laceration, unilateral, major Pneumothorax, massive air leak	441432.4	Lung laceration, unilateral, major
450214.3	One rib fracture with hemo/pneumothorax	450201.1 442202.2	One rib fracture Pneumothorax NFS	450201.1	One rib fracture
450252.4	open/displaced/comminuted rib fractures with hemo/pneumothorax	450200.1 442202.2	rib fractures NFS Pneumothorax NFS	450200.1	rib fractures NFS
543400.3	Placenta abruption NFS	545224.3	Uterus laceration, placental abruption	545220.2	Uterus laceration NFS
730430.2	Median, radial or ulnar nerve laceration, single nerve	730404.2	Median nerve laceration	730099.9	Nerve injury in upper extremity NFS
730440.2	Median, radial or ulnar nerve laceration, multiple nerves	730404.2 730604.2	Median nerve laceration Radial nerve laceration	730099.9	Nerve injury in upper extremity NFS
750642.2	Elbow joint laceration with ligament involvement	772089.1	Elbow joint injury, open	772089.1 740099.9	Elbow joint injury, open Ligament injury, NFS
750644.2	Elbow joint laceration with single nerve laceration	772089.1 730404.2	Elbow joint injury, open Median nerve laceration	772089.1 730099.9	Elbow joint injury, open Nerve injury in upper

AIS 98		AIS 2008			
		Tohira et al.		Palmer et al.	
					extremity NFS
750646.2	Elbow joint laceration with multiple nerve lacerations	772089.1 730404.2 730604.2	Elbow joint injury, open Median nerve laceration Radial nerve laceration	772089.1 730099.9	Elbow joint injury, open Nerve injury in upper extremity NFS
830606.2	Femoral, tibial, peroneal nerve, single nerve laceration	830304.2	Femoral nerve laceration	830099.9	Nerve injury in lower extremity NFS
830608.2	Femoral, tibial, peroneal nerve, multiple nerve lacerations	830304.2 830504.2	Femoral nerve laceration Peroneal nerve laceration	830099.9	Nerve injury in lower extremity NFS
840804.2	Multiple tendon lacerations	840800.2	Tendon tear	840099.9	Tendon injury NFS
852800.3	Sacroilium fracture	856161.3	Pelvic ring fracture, incomplete disruption	856100.2	Pelvic ring fracture NFS
853414.2	Tibia fracture, medial malleolus, open	854352.3	Tibia shaft fracture, simple, open	854331.2	Distal Tibia fracture, NFS
853418.3	Tibia fracture, posterior malleolus, open	854332.3	Distal tibia fracture, open	854331.2	Distal Tibia fracture, NFS
853699.1	Toe NFS	800099.9	Injuries to the whole lower extremities NFS	810099.1	Skin/subcutaneous/muscle injury NFS