Is the Charlson Comorbidity Index Useful for Predicting Trauma Outcomes?

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Abstract

Background: Inclusion of a measure of comorbidity in trauma scoring has been suggested due to the potential for preexisting conditions to impact on patient outcomes, but studies have reported varied results. The Charlson Comorbidity Index (CCI) includes 19 diseases weighted on the basis of their association with mortality, and can be extrapolated from International Classification of Diseases, Ninth Revision (ICD-9) codes for administrative databases. **Objectives:** To evaluate the CCI as a predictor of trauma outcome. **Methods:** Major trauma patient data from the Victorian State Trauma Registry (VSTR) were used to evaluate the CCI (n = 2,819). The CCI was scored from ICD-10 codes through modification of a previous method of mapping ICD-9 codes to the CCI. Logistic regression was used to determine the association between the CCI and mortality, the effect of adding the CCI to the Trauma and Injury Severity Score (TRISS) methodology, and the impact of adding the CCI to a modification of the TRISS methodology. Model performance was assessed through discrimination and calibration. **Results:** The CCI was associated with death ($p < 0.001$), but adding the CCI to TRISS [area under the receiver-operating characteristic curve (AUC) 0.86; 95% CI = 0.84 to 0.88] did not result in improved discrimination over TRISS alone (AUC 0.83; 95% CI = 0.81 to 0.86). Modifying TRISS methodology, with age left as a continuous variable, performed better than the original TRISS (AUC 0.91; 95% CI = 0.89 to 0.92), but the addition of the CCI did not further improve this model (AUC 0.91; 95% CI = 0.89 to 0.92). **Conclusions:** While the CCI can be extrapolated from ICD codes and provides a measure of comorbid condition severity and was associated with mortality, addition of the CCI to prediction models did not result in a substantial improvement in performance. **Key words:** major trauma; Charlson Comorbidity Index; comorbidity; TRISS; prediction; mortality. ACADEMIC EMERGENCY MEDICINE 2005; 12:318–321.

Validated trauma scores for predicting outcome are becoming increasingly important for benchmarking patient outcomes and improving trauma care. The most extensively used score is the Trauma and Injury Severity Score (TRISS), which combines the Injury Severity Score (ISS), the Revised Trauma Score (RTS), and age to predict mortality in trauma populations. Despite its widespread use, the TRISS methodology has been widely criticized.[1,2]

Inclusion of a measure of comorbidity in trauma scoring has been suggested due to the potential for preexisting conditions to impact on patient outcomes.[1,2] A recent study assessed the effect of adding comorbidity to a modified version of the TRISS methodology and found a small, nonsignificant improvement in the predictive validity of TRISS following this change.[2] However, only the presence or absence of any of eight comorbidities was assessed, and the severity of comorbidities was not considered.

The Charlson Comorbidity Index (CCI) includes 19 diseases weighted on the basis of their association with mortality.[3] The index score is constructed by awarding weight to each comorbidity depending on the magnitude of the relative risk associated with each condition.[4] The CCI was derived using a population of medical patients,[3] and has been shown to be reliable and a valid predictor of mortality in a number of populations, including hospital inpatients and the critically ill.[5,6] While not validated in a trauma population, the CCI has been adapted for use on International Classification of Diseases, Ninth Revision (ICD-9) administrative databases[7] and has the potential to be useful for trauma registries.

The purpose of this study was to evaluate the use of the CCI as a predictor of trauma outcome.

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METHODS

Study Design. This was a retrospective analysis of patient data from the Victorian State Trauma Registry (VSTR) database to evaluate the performance of the CCI as a predictor of trauma outcome. Ethics approval was obtained from all participating hospitals and the Monash Standing Committee on Ethics in Research Involving Humans.

Study Setting and Population. The VSTR is a statewide trauma registry in Victoria, Australia, servicing a population of nearly 5 million (24% of the Australian population), of whom 73% live in metropolitan Melbourne. The VSTR captures information about all major trauma patients using the definition[8]:

1. Death after injury
2. Admission to an intensive care unit for more than 24 hours, requiring mechanical ventilation
3. Significant injury to two or more ISS body regions or an ISS > 15
4. Urgent (within 24 hours) surgery for intracranial, intrathoracic, or intra-abdominal injury, or fixation of pelvic or spinal fractures

All hospitals providing trauma care in the state of Victoria are included in the VSTR. Currently, 139 hospitals provide data to the registry, including all three major trauma services (two adult and one pediatric) and the supporting metropolitan and regional trauma services. One health service is still yet to contribute due to a delay in ethics approval. Blunt major trauma cases for patients older than 14 years (n = 3,670) from the first three years (July 2001 to June 2004) of the VSTR were used for this study.

Charlson Comorbidity Index (CCI). Deyo and colleagues adapted the CCI for use on ICD-9–Clinical Modification (ICD-9-CM) administrative data by identifying specific ICD-9-CM codes to represent each of the individual comorbid conditions in the original CCI.[7] However, ICD-10 codes are currently used in Australia. Using the mapping developed by Deyo and colleagues as a model, the ICD-10 codes collected by the VSTR registry were used to classify patients into the various weighting categories of the CCI (Table 1).

Data Analysis. Descriptive statistics were performed to categorize the VSTR population. The outcome of interest was in-hospital death. Binary logistic regression was used to determine the predictive ability of the CCI: in isolation; combined with TRISS; and combined with age (continuous variable), ISS, and RTS. These models were compared with: original TRISS; and a modified TRISS combined with age (continuous variable), ISS, and RTS.

Discrimination and calibration of the models were evaluated using the area under the receiver-operating characteristic curve (AUC) and the Hosmer-Lemeshow (H-L) statistic, respectively. For all odds ratios (ORs) and AUC analyses, 95% confidence intervals (95% CIs) were calculated. SPSS for Windows (Version 12.0, SPSS Inc., Chicago, IL) was used for all analyses and the 5% level of significance was used.

RESULTS

Of the 3,670 adult major blunt trauma patients registered on the VSTR (July 2001 to June 2004), 2,819 (76.8%) had all data items complete and were included in the analyses. The median (range) age of the patients was 39 (15–98) years, the median (range) ISS was 21 (1–75), and the majority of the patients (71.5%) were male. There were 324 deaths in this population (11.5%). A total of 1,882 (66.8%) patients did not have a comorbidity; 677 (24.0%) had a CCI weighting of 1; 227 (8.0%) had a weighting of 2; 13 (0.5%) had a weighting of 3; and 20 (0.7%) had the highest weighting of 6.

The CCI was significantly associated with death ($p < 0.001$), but performed relatively poorly with respect to discriminating between survivors and deaths (AUC 0.57; 95% CI = 0.54 to 0.61). Patients who had a CCI weighting of 2 (OR 3.5; 95% CI = 2.5 to 4.9) or 3 (OR 4.1; 95% CI = 1.2 to 13.4) were at an elevated risk of death compared with patients who did not have comorbidities. Those who had a CCI weighting of 1 (OR 1.1; 95% CI = 0.8 to 1.4) or 6 (OR 1.1; 95% CI = 0.2 to 4.4) were at an elevated, but nonsignificant, risk of death compared with patients who did not have comorbidities.

Adding the CCI to the original TRISS did not result in improved discrimination over the TRISS alone (AUC 0.86; 95% CI = 0.84 to 0.88; vs. 0.83; 95% CI = 0.81 to 0.86), and calibration of both models was poor [H-L statistic 70.3 ($p < 0.001$) and 75.9 ($p < 0.001$), respectively]. Modifying TRISS by maintaining age as a continuous variable resulted in an AUC of 0.91 (95% CI = 0.89 to 0.92; H-L statistic 32.1, $p < 0.001$). Addition of the CCI did not alter the AUC (0.91; 95% CI = 0.90 to 0.92) but resulted in a slight increase in model calibration (H-L statistic 25.3, $p = 0.001$).

DISCUSSION

This study evaluated the CCI, an established index for measuring comorbidity, as a predictor of mortality following trauma. The CCI was associated with mortality in blunt trauma patients, with those who had a CCI weighting of 2 or 3 at an elevated risk of death when compared with those who did not have a comorbidity. However, the addition of the CCI to either the original or the modified version of the

TABLE 1. Extrapolation of the Charlson Comorbidity Index from International Classification of Diseases, Tenth Revision (ICD-10) Codes

Weight	Conditions	ICD-9-CM* Codes	ICD-10 Codes (2nd Edition, July 2000)
1	Myocardial infarction	410–410.9, 412	I21–I24, I25.2, I25.8
	Congestive heart failure	428–428.9	I09, I11, I48, I49.0, I49.8, I50.0, I50.1, I50.1 + J81, I50.9, I51.5, I97.1
	Peripheral vascular disease	443.9, 441–441.9, 785.4, V43.4, Procedure 38.48	I70, I71.1–I71.6, I71.8–I71.9, I72, I73, I74, I77
	Dementia	290–290.9	F00–F04, F05.1, F10
	Cerebrovascular disease	430–438	I60–I63, I65–I68, G45
	Chronic pulmonary disease	490–496, 500–505, 506.4	J41–J47
	Connective tissue disease	710, 710.1, 710.4, 714.0–714.2, 714.81, 725	M05–M06, M08–M09, M12–M13, M30–M36
	Ulcer disease	531–534.9, 531.4–531.7, 532.4–532.7, 533.4–533.7, 534.4–534.7	K25–K28
	Mild liver disease	571.2, 571.5, 571.6, 571.4–571.49	K70.0–K70.3, K70.9, K73, K74, K75.2–K75.9, K76.0–K76.5, K76.8–K76.9, K77
	Diabetes	250–250.3, 250.7	E10, E10.1, E10.5–E10.9, E11, E11.1, E11.5–E11.9, E13, E13.1, E13.5–E13.9, E14, E14.1, E14.5–E14.9
2	Hemiplegia	344.1, 342–342.9	G81.0–G81.1, G81.9, I63, I66–I67
	Moderate or severe renal disease	582–582.9, 583–583.7, 585, 586, 588–588.9	I12–I13, N00–N05, N17–N19
	Diabetes with end-organ damage†	250.4–250.6	E10.2–E10.4, E11.2–E11.4, E13.2–E13.4, E14.2–E14.4
	Any tumor	140–172.9, 174–195.8	D00–D48
	Leukemia	200–208.9	C91–C95
	Lymphoma	200–208.9	C81–C85
3	Moderate or severe liver disease	572.2–572.8, 456.0–456.21	K70.4, K71.1, K71.7, K72, K75.0–K75.1, K76.6–K76.7
6	Metastatic solid tumor	196–199.1	C00–C26, C30–C34, C37–C41, C43–C58, C60–C80, C88, C90, C96
	AIDS	042–044.9	B20–B24

*ICD-9-CM = International Classification of Diseases, Ninth Revision, Clinical Modification.
†Diabetes with renal, ophthalmic, or neurologic complications; ICD-10 codes used to approximate diabetes with end-organ disease.

TRISS methodology did not result in a substantial improvement in prediction of outcome.

Bergeron and colleagues, in a study of 5,672 blunt trauma patients, found the predictive ability of a modified (age cutoff of 65 years and ISS categorized) version of TRISS was improved with the addition of a measure of comorbidity.[2] However, the improvement was small (AUC 0.90 vs. 0.92) and nonsignificant ($p = 0.086$).[2] The current study also found that modifying the TRISS methodology by leaving age as a continuous variable improved predictive performance, but the addition of the CCI did not add anything further, despite the fact that the CCI included all of the comorbid conditions considered by Bergeron et al. and the grading of comorbidity severity by the CCI. Other studies have investigated the relationship between comorbid conditions and trauma outcome, with similar results.[9,10] Milham and LaMorte found that the addition of information to prediction models such as TRISS did not improve their overall performance,[10] while a study of trauma patients aged 50 years and over showed that comorbid conditions were associated with death in the group with minor injuries (ISS < 16), but not in those with moderate to severe injuries (ISS > 15).[9]

Clinically, the hypothesis that injury against the backdrop of comorbid conditions would result in poorer outcome seems logical, and a number of studies, including the current one, have found a univariate association between comorbidity and trauma outcomes. However, there is an association between age and the presence of comorbid conditions. Therefore, it is not surprising that the addition of comorbid information to a prediction model that already includes age resulted in no improvement in predictive performance. It would appear that age provides a greater contribution to prediction of mortality than comorbidity in the major trauma population, which comprises predominantly younger patients, of whom relatively few have significant or severe comorbidities.

LIMITATIONS

Whilst the data presented here support the findings of previous studies, this retrospective study has

a number of limitations that must be acknowledged. Approximately 23% of the major trauma patients had incomplete coding due to data extraction problems during the implementation phase of this registry. In addition, only the internal validity of the prediction models could be tested due to a lack of an independent data set for evaluation of the performance of the developed models.

Only blunt trauma patients were included, because of the very low proportion (<8%) of penetrating trauma in Victoria, preventing meaningful analysis of the impact of the CCI on the group of penetrating trauma patients. The CCI itself was not developed specifically for trauma patients, which could explain the lack of significant findings in the current study. The median age of the major trauma patients is quite young (39 years). Therefore, it is not surprising that less than 40% of patients in the current study had a comorbidity as defined by the CCI and, despite the use of three years of data from a statewide trauma registry, there were only 33 cases with a CCI weighting at the more severe end (3 or 6). Nevertheless, this pattern is likely to be reflective of major trauma populations in general, and the purpose of this study was to assess the predictive impact of the CCI in this type of population. Whether other measures of comorbidity would predict outcome better in the major trauma population must also be considered. Finally, outcomes other than mortality should be considered, as it is possible that the presence of comorbid conditions could impact on measures of patient morbidity such as hospital length of stay, patient quality of life, and functional outcome.

CONCLUSION

Overall, a validated global comorbidity score in trauma care is yet to be established in the trauma literature. The CCI is a possible candidate because it can be extrapolated from ICD-9 or ICD-10 codes, provides an index of the severity of comorbid conditions, and was associated with mortality. However, the addition of the CCI to prediction models did not result in an improvement in performance, potentially due to a small proportion of major trauma patients who have significant or severe comorbidities.

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