

Performance of CT-Based Prognostic Models in Younger Versus Older Adults with Traumatic Brain Injury

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BACKGROUND:

Several CT scoring systems have been proposed for traumatic brain injury (TBI) grading and prognosis. Most were developed in younger patients, and little is known about their reliability in older adults, who represent a growing proportion of TBI cases. This study evaluated the performance of different CT-based scoring systems in predicting long-term outcomes in younger versus older adult patients (>65 years).

MATERIALS AND METHODS:

We retrospectively analyzed 1,935 consecutive TBI patients admitted between 2013 and 2024. Rotterdam and Helsinki CT scores were assessed as prognostic tools, alone and in combination with clinical variables from the IMPACT extended model (age, pupils, motor response, shock, hypoxia). Model performance was evaluated with discrimination, calibration, and overall fit. Published equations were applied when available. As Rotterdam +IMPACT required refitting, its internal validity was tested using optimism-corrected bootstrap resampling (1,000 iterations). Outcomes of interest were 6-month mortality and unfavorable neurological status (GOS 1–3).

RESULTS:

Long-term outcome was available in 1,824 patients: 1,255 younger and 569 older adults. The Helsinki CT score outperformed Rotterdam for imaging-only prediction of mortality (AUC 0.807 vs. 0.771, $p < 0.001$) and unfavorable outcome (0.806 vs. 0.756, $p < 0.001$). With clinical predictors, Rotterdam+IMPACT was superior to Helsinki CT-clinical (AUC 0.913 vs. 0.885 for mortality; 0.888 vs. 0.834 for unfavorable outcome, both $p < 0.001$). Except for CRASH CT (mortality) and Helsinki CT-clinical (unfavorable outcome), all models performed better in younger than in older adults. In older adults, Helsinki CT-clinical best predicted mortality, while both Rotterdam+IMPACT and Helsinki CT-clinical were superior for unfavorable outcome compared with Marshall-based models.

CONCLUSION:

CT-based prognostic models show reduced accuracy in older adults compared with younger patients. In the elderly, Helsinki CT-clinical best predicted mortality, while Helsinki CT-clinical and Rotterdam+IMPACT provided the most reliable estimates of unfavorable outcome.

Mortality 6mon		DeLong test
IMPACT extended vs	CRASH CT refitted	p=0.476
IMPACT extended vs	Rotterdam CT score	p<0.001
IMPACT extended vs	Rotterdam CT score+IMPACT clinical	p<0.001
IMPACT extended vs	Helsinki CT score	p<0.001
IMPACT extended vs	Helsinki CT score+Helsinki Clinical*	p=0.287
CRASH CT refitted vs	Rotterdam CT score	p<0.001
CRASH CT refitted vs	Rotterdam CT score+IMPACT clinical	p=0.017
CRASH CT refitted vs	Helsinki CT score	p<0.001
CRASH CT refitted vs	Helsinki CT score+Helsinki Clinical*	p=0.911
Rotterdam CT score vs	Rotterdam CT score+IMPACT clinical	p<0.001
Rotterdam CT score vs	Helsinki CT score	p<0.001
Rotterdam CT score vs	Helsinki CT score+Helsinki Clinical*	p<0.001
Rotterdam CT score+IMPACT clinical vs	Helsinki CT score	p<0.001
Rotterdam CT score+IMPACT clinical vs	Helsinki CT score+Helsinki Clinical*	p<0.001
Helsinki CT score vs	Helsinki CT score+Helsinki Clinical*	p<0.001

Unfavourable outcome (GOSE 1-3) 6 mon		DeLong test
IMPACT extended vs	CRASH CT refitted	p<0.001
IMPACT extended vs	Rotterdam CT score	p<0.001
IMPACT extended vs	Rotterdam CT score+IMPACT clinical	p<0.001
IMPACT extended vs	Helsinki CT score	p<0.001
IMPACT extended vs	Helsinki CT score+Helsinki Clinical*	p<0.001
CRASH CT refitted vs	Rotterdam CT score	p=0.009
CRASH CT refitted vs	Rotterdam CT score+IMPACT clinical	p<0.001
CRASH CT refitted vs	Helsinki CT score	p=0.263

CRASH CT refitted vs	Helsinki CT score+Helsinki Clinical*	p<0.001
Rotterdam CT score vs	Rotterdam CT score+IMPACT clinical	p<0.001
Rotterdam CT score vs	Helsinki CT score	p<0.001
Rotterdam CT score vs	Helsinki CT score+Helsinki Clinical*	p<0.001
Rotterdam CT score+IMPACT clinical vs	Helsinki CT score	p<0.001
Rotterdam CT score+IMPACT clinical vs	Helsinki CT score+Helsinki Clinical*	p<0.001
Helsinki CT score vs	Helsinki CT score+Helsinki Clinical*	p=0.007

	Mortality 6mon (14d for CRASH)				
	AUC	Intercept	Slope	Brier score	PseudoR2 Nagelkerke
IMPACT extended	0.893 (0.877-0.909)	-0.347 (-0.467- -0.227)	1.777 (1.599-1.954)	0.116	0.530
CRASH CT refitted	0.884 (0.864-0.903)	-2.074 (-2.204- -1.945)	1.542 (1.367-1.717)	0.584	0.456
Rotterdam CT score	0.771 (0.747-0.795)	0.332 (0.221-0.443)	1.644 (1.463-1.825)	0.126	0.303
Rotterdam CT score+IMPACT clinical*	0.910 (0.901-0.929)	0.017 (-0.131-0.165)	1.014 (0.908-1.121)	0.099 (0.0874-0.105)	0.441 (0.423-0.503)
Helsinki CT score	0.807 (0.784-0.831)	0.547 (0.432-0.662)	1.383 (1.236-1.529)	1.305	0.342
Helsinki CT score + Helsinki Clinical	0.885 (0.868-0.902)	0.718 (0.591-0.845)	1.281 (1.149-1.412)	1.294	0.499

*Internal validity of Rotterdam+IMPACT clinical model was assessed with an optimized, corrected, 1000-sample bootstrap technique

**Age, motor response and pupils

	Unfavourable outcome 6mon				
	AUC	Intercept	Slope	Brier score	PseudoR2 Nagelkerke
IMPACT extended	0.870 (0.853-0.886)	-0.312 (-0.419- -0.205)	1.659 (1.499-1.819)	1.036	0.513
CRASH CT refitted	0.792 (0.771-0.812)	-2.943 (-3.063- -2.824)	0.624 (0.558-0.693)	0.607	0.221
Rotterdam CT score	0.756 (0.736-0.777)	-0.062 (-0.161- 0.036)	1.972 (1.747-2.196)	1.162	0.327
Rotterdam CT score+IMPACT clinical*	0.886 (0.876-0.907)	0.004 (-0.124- 0.132)	1.014 (0.911-1.112)	0.129 (0.116-0.135)	0.399 (0.379-0.453)
Helsinki CT score	0.806 (0.786-0.827)	0.228 (0.123-0.332)	1.365 (1.226-1.503)	0.943	0.374
Helsinki CT score + Helsinki Clinical	0.834 (0.815-0.853)	0.377 (0.261-0.493)	0.946 (0.855-1.037)	0.945	0.421

*Internal validity of Rotterdam+IMPACT clinical model was assessed with an optimized, corrected, 1000-sample bootstrap technique

**Age, motor response and pupils

Mortality 6mon	Younger patients	Older adults (≥65y old)	DeLong test
IMPACT extended	0.913 (0.890-0.936)	0.785 (0.747-0.823)	p<0.001
CRASH CT refitted (14d-mortality)	0.881 (0.852-0.911)	0.840 (0.804-0.877)	p=0.084
Rotterdam CT score	0.834 (0.801-0.867)	0.700 (0.662-0.738)	p<0.001

Rotterdam CT score+IMPACT clinical	0.919 (0.914-0.959)	0.801 (0.792-0.856)	p<0.001
Helsinki CT score	0.840 (0.807-0.872)	0.762 (0.723-0.801)	p=0.003
Helsinki CT score + Helsinki Clinical*	0.892 (0.867-0.919)	0.804 (0.767-0.840)	p<0.001

*Internal validity of Rotterdam+IMPACT clinical model was assessed with an optimized, corrected, 1000-sample bootstrap technique

**Age, motor response and pupils

Unfavourable outcome (GOSE 1-3) 6 mon	Younger patients	Older adults (≥65y old)	DeLong test
IMPACT extended	0.872 (0.850-0.894)	0.785 (0.748-0.822)	p<0.001
CRASH CT refitted	0.755 (0.727-0.784)	0.788 (0.752-0.825)	p=0.160
Rotterdam CT score	0.787 (0.761-0.813)	0.688 (0.652-0.724)	p<0.001
Rotterdam CT score+IMPACT clinical	0.899 (0.870-0.912)	0.809 (0.774-0.844)	p<0.001
Helsinki CT score	0.821 (0.795-0.846)	0.763 (0.725-0.801)	p=0.013
Helsinki CT score + Helsinki Clinical*	0.828 (0.802-0.853)	0.801 (0.765-0.837)	p=0.241

*Internal validity of Rotterdam+IMPACT clinical model was assessed with an optimized, corrected, 1000-sample bootstrap technique

**Age, motor response and pupils