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2022-04

Sepponen , R , Saviluoto , A , Jäntti , H , Harve-Rytsälä , H , Lääperi , M & Nurmi , J 2022 , ' Validation of Score to Detect Intracranial Lesions in Unconscious Patients in Prehospital Setting ' , Journal of Stroke & Cerebrovascular Diseases , vol. 31 , no. 4 , 106319 . https://doi.org/10.1016/j.jstrokece

http://hdl.handle.net/10138/343425
https://doi.org/10.1016/j.jstrokecerebrovasdis.2022.106319

Validation of Score to Detect Intracranial Lesions in Unconscious Patients in Prehospital Setting

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Objectives: Recognizing stroke and other intracranial pathologies in prehospital phase facilitates prompt recanalization and other specific care. Recognizing these can be difficult in patients with decreased level of consciousness. We previously derived a scoring system combining systolic blood pressure, age and heart rate to recognize patients with intracranial pathology. In this study we aimed to validate the score in a larger, separate population. *Materials and methods:* We conducted a register based retrospective study on patients ≥16 years old and Glasgow Coma Score <15 encountered by helicopter emergency medical services. Diagnoses at the end of hospitalization were used to identify if patients had intracranial lesion or not. The performance of score was evaluated by area under the receiver operating characteristics curve (AUROC). *Results:* Of 9,309 patients included, 1,925 (20.7%) had an intracranial lesion including 1,211 cases of stroke. Older age, higher blood pressure and lower heart rate were predictors for an intracranial lesion (P<0.001 for all). The score distinguished patients with intracranial lesion with AUROC of 0.749 (95% CI 0.737 to 0.761). The performance slightly improved if only patients intubated in prehospital phase were included AUROC 0.780 (95% CI 0.770 to 0.806) or convulsion related diagnosis excluded AUROC of 0.788 (95% CI 0.768 to 0.792). *Conclusions:* A scoring of systolic blood pressure, heart rate and age help differentiate intracranial lesions in patients with decreased level of consciousness in prehospital care. This may facilitate direct transportation to stroke center and application of neuroprotective measures in prehospital critical care.

Key Words: Blood pressure—Heart rate—Age—Stroke—Emergency medical services—Intracranial pressure—Intubation

Introduction

Impaired level of consciousness is a common cause for emergency medical services (EMS) contacts, and may be caused by a variety of medical or surgical conditions i.e. intoxication, hypoglycemia, stroke, seizure or trauma.[1,2] While EMS personnel can recognize and treat some of these conditions in prehospital setting,[3] accurate diagnosis of other conditions, especially in case of intracranial lesions, usually requires advanced in-hospital investigations, i.e. computer tomography.[4-6] However, intracranial lesions should be recognized as early as possible to avoid delay in transport to an appropriate tertiary-care unit with recanalization and neurosurgical capabilities.[6,7] Patients with an intracranial lesion as a cause of impaired level of consciousness often require controlled ventilation and oxygenation.[7,8] As prehospital anesthesia and airway

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Received November 17, 2021; accepted January 9, 2022.

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1052-3057/$ - see front matter

https://doi.org/10.1016/j.jstrokecerebrovasdis.2022.106319

management delay transport, require special skills and include several risks, it would be important to identify the patients most benefitting from them.[9-11]

Mobile stroke units (MSU) and biomarkers for bedside testing have been proposed to fasten the recognition of intracranial lesions in prehospital setting,[12-14] but none of them are commonly available, and in future costs may limit their large-scale use especially in low- and middle-income countries and rural areas.[15-17] Several validated scoring systems exist for identifying ischemic stroke.[4,18] These scores rely on neurological findings that may be impossible to observe on a patient with an impaired level of consciousness.[4,18,19]

To overcome the challenge of early recognition of an intracranial lesion as a cause of impaired level of consciousness, we have previously described a new scoring tool, combining heart rate, systolic blood pressure and age to recognize intracranial lesions among patients with impaired level of consciousness.[20] The aim of the present study was to validate the scoring tool in larger population.METHODS

The data that support the findings of this study are available from the corresponding author upon reasonable request.

We conducted a retrospective case-control study, comparing initial prehospital systolic blood pressure, heart rate and age of patients with and without intracranial lesion. Study was register-based and did not affect treatment of the patients. The Ethical Committee of Helsinki University Hospital approved the study protocol (HUS/3115/2019 §194). The study was reported according to Transparent reporting of a multivariable prediction model for individual prognosis or diagnosis (TRIPOD) statement.

We analyzed data from national helicopter emergency medical services (HEMS) quality database.[21] In Finland HEMS-services are governmentally coordinated, owned and financed. HEMS units are dispatched by national emergency response center based on predefined criteria for critically ill or injured patients. These carry out virtually only primary mission and are dispatched in addition to ground ambulances to provide prehospital critical care. The dispatching criteria include unconsciousness of unknown etiology, when hypoglycemia is not suspected. Five out of six HEMS units are physician staffed. They are not dispatched to suspected stroke the patient is known to be conscious. The HEMS unit serving extremely sparsely populated northern parts of the country is not physician staffed and is dispatched to awake stroke patients to facilitate fast transportation to hospital.

Finnish institute for health and welfare upholds National Hospital Discharge registry (HILMO) where data on the activities of all health centers, hospitals and other institutions providing inpatient care is submitted, excluding data from HEMS services. Data includes information about admission and discharge, provided treatment and diagnosis and can be traced by personal identity number.[22,23] The data collection to this registry is mandatory by Finnish legislation. We used personal identity code to link the HEMS mission data with corresponding admission and discharge data. Time period between the arrival of the HEMS unit and corresponding admission to hospital was set to be within 24 hours.

Participants

The study population consisted of patients that were 16 years or older, whose Glasgow Coma Scale (GCS) score was <15 and were encountered by any HEMS unit in Finland between time period of from January 2012 until the 9th September 2019. The population included in the previous score conducting study[20] was excluded. The patients aged less than 16 years were excluded due to the normal age dependent variation of blood pressure.[24] Patients whose decreased level of consciousness was caused by out of hospital cardiac arrest or obvious trauma were excluded, as well as patients whose diagnosis at the time of discharge was not found, e.g. due to missing personal identification number.

Outcome

After exclusions patients included in the study were categorized into two groups depending on their final diagnosis at the end of the hospitalization: 1) patients with intracranial lesion 2) patients without intracranial lesion. The International Statistical Classification of Diseases and Related Health Problems (ICD-10) diagnoses defined as intracranial lesions included e.g. ischemic or hemorrhaging stroke and non-traumatic intracranial bleeding. The detailed list of diagnose codes is presented in online supplement 1. Diagnosis upon discharge was acquired from HILMO -database where it is submitted by the corresponding hospital.

Predictors according to scoring tool

We previously investigated the predictive ability of systolic blood pressure, age and heart rate to predict whether

Table 1. *Previously derived ISHA-scoring system.*[20]

Variable	ISHA-Score Points
Systolic blood pressure	
< 140 mmHg	0
140 - 170 mmHg	1
> 170 mmHg	2
Heart rate	
≥ 100 / min	0
< 100 / min	1
Age	
< 50 years	0
50 - 70 years	1
> 70 years	2

a patient would have an intracranial lesion.[20] All initial vitals were registered by HEMS -personnel on the scene and uploaded to FHDB after mission. Following the statistical analysis each variable was given specific cut off value and number of points accordingly (Table 1), higher points increased the probability of intracranial lesion.[20] We named the scoring tool ISHA-score after intracranial lesion, systolic blood pressure, heart rate and age.

Sample size

All available data in the databases was used to maximize the power and generalizability of the results. However, the patient data that was used in the derivation study of the scoring tool was excluded. [20]

Statistical analysis methods

The score was initially derived by analyzing the increase of odds for an intracranial lesion with increasing age or systolic blood pressure and decrease in heart rate. The variables where categorized and logarithms of odds ratios (OR) for each category where rounded to the nearest integer to be used as points in the scoring system.[20]

Similarly to the previous study we fitted logistic regression models to investigate the association between the variables and the outcome and furthermore, to validate the scoring system. Diagnostic accuracy of the scoring system to detect an intracranial lesion was evaluated by calculating the area under the receiver operating characteristics curve (AUROC), reported with 95% confidence intervals (CIs). This was done separately for the continuous and categorized variables in a multivariate model and finally using the scoring system itself.

To evaluate the change in accuracy of the score by recalibration, we tested the effect of conducting the score based on the current dataset in similar methods used in the original work.

As the previous study consisted of patients who were intubated on scene, we analyzed them also as their own subgroup to see if the results matched. Patients with seizures caused by epilepsy, status epilepticus, alcohol withdrawal or other unclassified convulsions (ICD-10 categories G40-G41, R58.8, F10.31) were categorized in the group without intracranial lesion. However, since these may require neurological specialist treatment, we carried out a separate sensitivity analysis in which these were grouped in intracranial lesion group.

P-values below 0.05 were considered significant and all analyses were done using R version 4.0.3 (R Foundation for Statistical Computing, Vienna, Austria) and the visualization were done with the ggplot2 package.

Results

During the study period 36,715 patients were encountered by HEMS and 9,309 of these fulfilled the inclusion criteria and were consequently included in the study (Fig. 1). Of the included patients, 1,925 (20.7%) had an intracranial lesion. Of these patients 1,211 (63%) suffered from a stroke, of which 509 were ischemic in nature (ICD-10 category I63), 533 were intracerebral hemorrhage (I61), 162 were subarachnoid hemorrhage (I60) and seven were not classified as ischemic nor hemorrhagic (I64). The rest of the intracranial lesions consisted of varying types of traumatic and non-traumatic hemorrhage, neoplasms, infections of the central nervous system etc.

Patients with an intracranial lesion were characterized by higher systolic blood pressure, lower heart rates and older age (Table 2). The score had an AUROC of 0.749 (95% CI 0.737 to 0.761) in discriminating patients with and without a lesion (Fig. 2). The performance of the score was slightly better in the subgroup of patients intubated during prehospital care (AUROC 0.780, 95% CI 0.770 to 0.806) or if patients with convulsions were excluded (AUROC 0.788, 95% CI 0.768 to 0.792).

Score properties and patient distribution along different cut-offs are shown in Table 3. Due to missing values of systolic blood pressure and/or heart rate final regression analysis with the scoring tool included 8554 patients, results are presented in Table 4.

Recalibrating the score improved the accuracy marginally. Readjusting the points awarded for age 50-70 and over 70 years to two and three, respectively, while similarly awarding two and four points for systolic blood pressures of 140-170 and over 170 mmHg, resulted in an AUROC of 0.761 (95% CI 0.749 to 0.773). Recalibration and patient distribution can be seen in Online supplement 2 and 3 respectively.

Discussion

Our study indicates that a scoring tool based on systolic blood pressure, heart rate and age can be used in prehospital setting to identify patients whose decreased level of consciousness is caused by an intracranial lesion, i.e. stroke in most cases, with moderate accuracy. To our knowledge this is the first validated scoring tool that does not rely on neurological findings and require patient's cooperation when predicting intracranial lesions in a prehospital setting. While recalibrating the score improved accuracy by a small amount, the point distribution became less practical from clinical point of view and thus the old point distribution was kept.

Clinical significance

We think that the scoring tool can be used by EMS personnel in the field to assist when deciding whether

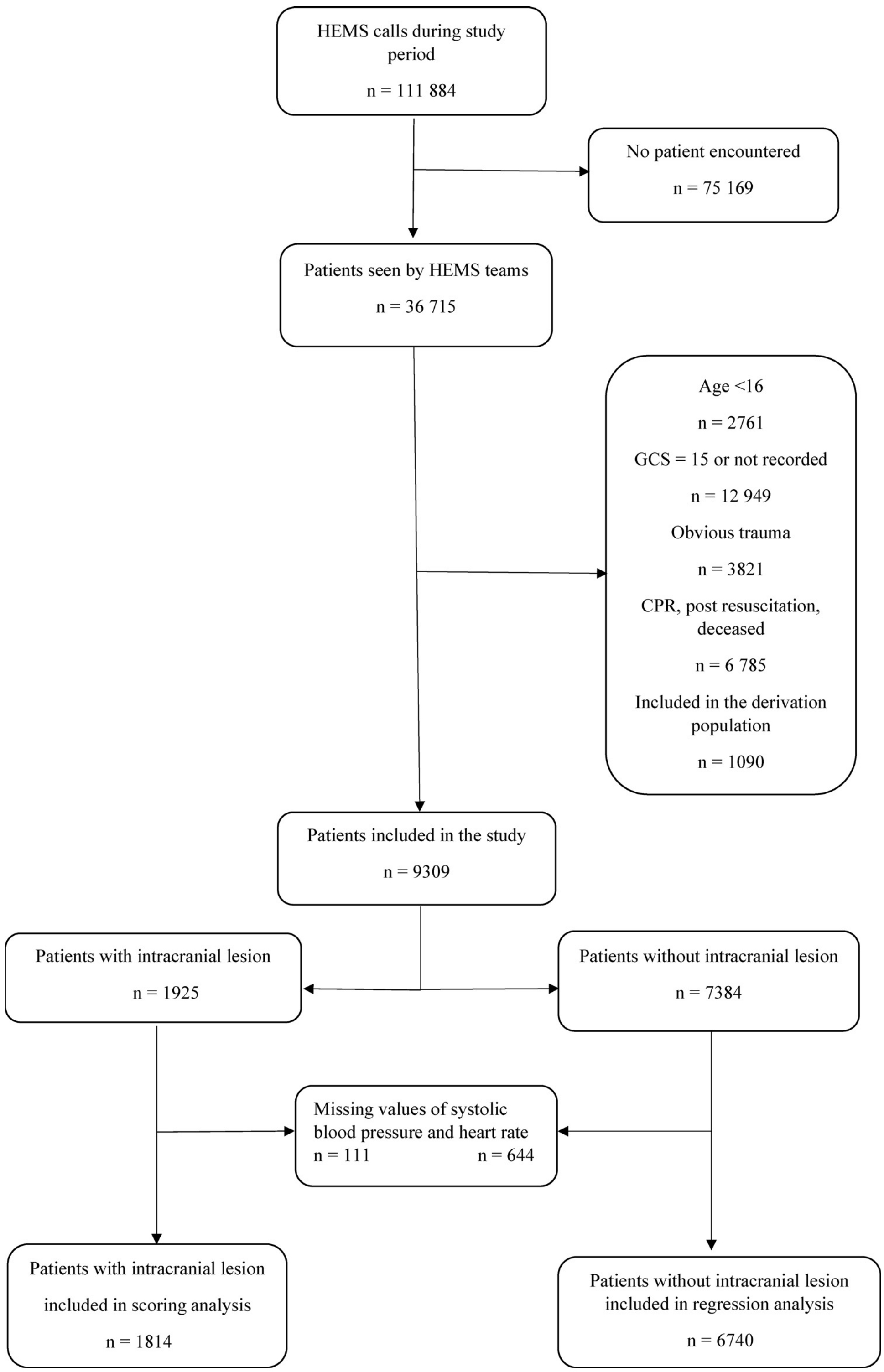

Fig. 1. *Patient selection flow chart.*

the patient needs direct transport to a tertiary neurological center. Even though several validated scoring systems exist to identify patients with stroke they are not designed nor applicable for patients with decreased level of consciousness or atypical stroke symptoms.[25-27] Delayed treatment of stroke and other intracranial emergencies are associated with worse outcome, i.e. increased invalidity, and total cost of treatment.[28-30] Thus, patient flow from prehospital setting to proper treatment center should be optimized even though some cases might still be misclassified.[31-33]

Physician provided prehospital critical care is available in many EMS systems worldwide. The patients with

Table 2. *Patient characteristics. Data are presented as median (Q1-Q3) or n (proportion).*

	Intracranial lesion n = 1925	No lesion n = 7384	P-value	Missing data n (%)
Age; years	71 (58 - 80)	57 (37-72)	< 0.001*	-
Sex; male %	52 (999)	57 (4233)	< 0.001†	32 (0.3)
Heart rate; beats per minute	87 (70 - 110)	90 (77 - 104)	< 0.001*	486 (5.2)
Systolic blood pressure; mmHg	157 (70 - 186)	126 (77 - 148)	< 0.001*	553 (5.9)
Glasgow coma scale; points	6 (4 - 10)	8 (4 - 13)	< 0.001*	39 (0.4)
Peripheral capillary oxygen saturation; %	96 (93 - 100)	96 (92 - 100)	0.07*	347 (3.7)
Respiratory rate; per minute	17 (14 - 22)	16 (13 - 22)	0.28*	2479 (27)

*Mann-Whitney U-test
†X^2 -test

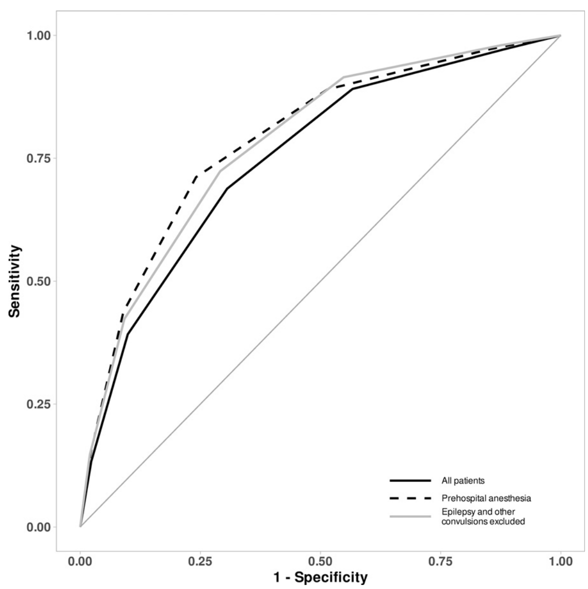

Fig. 2. *ISHA-Score performance detecting intracranial lesions presented as receiving operating curve for multivariate model with (a) full data (n = 8554), (b) patients intubated during prehospital care (n = 2691) and (c) all patients excluding those with epileptic seizures or other convulsions (n = 7636).*

potentially increased intracranial pressure, e.g. patients with traumatic brain injury or stroke, are likely to benefit from optimization of cerebral perfusion pressure, oxygenation and controlled ventilation.[34-36] On the other hand, intubation without proper precautions may be detrimental in the same patients.[34] We believe that this scoring tool will further help to identify the patients who benefit from a neuroprotective approach in prehospital anesthesia and intubation

Generalizability

Our study included only patients encountered by HEMS, which is dispatched on predetermined criteria.[20] During the study period, signs of stroke in a conscious patient were not among these criteria, limiting the generalizability of our results. However, HEMS was dispatched for all unconscious patients without a pain response and the operational area of HEMS covers almost the entire population.[20] Thus, the study population well represents the unresponsive patients seen by EMS, the patient group who the score was designed for. Furthermore, the predictive power of the factors in the score have been demonstrated in many studies[37,38] and we surmise the score to be useful in a variety of prehospital services.

Our tool was more accurate when patients with or other seizures were excluded. Thus, it should be further investigated whether it can be used when the patient is suspected to be suffering from these conditions.

Limitations & strengths

The current study has some limitation that must be considered when applying the results. Firstly, in the HEMS system in Finland, the physicians evaluate whether the patient benefits from HEMS involvement and cancel or deny a large proportion of missions. During the study period, there existed no uniform guidelines on which patients should be attended, therefore contributing to

Table 3. *Score properties and distribution among patients.*

	Score					
	0	1	2	3	4	5
Patients with lesion, n	52	146	368	537	469	242
Patients without lesion, n	801	2121	1758	1393	512	155
Sensitivity, %	100	97	89	69	39	13
Specificity, %	0	12	43	69	90	98
Positive predictive value, %	21	23	30	38	52	61
Negative predictive value, %	N/A	94	94	89	85	81

Table 4. *Regression model results showing the odds ratios (OR) of continuous, categorized variables and ISHA −score for intracranial lesion. Multivariate models include all the variables of the group, e.g. the multivariate model for the continuous variables includes age, heart rate and systolic blood pressure.*

			Univariate		Multivariate	
Group	Variable	Category	OR (95%CI)	P-value	OR (95%CI)	P-value
Continuous variables	Age		1.04 (1.03-1.04)	<0.001	1.03 (1.03-1.03)	<0.001
	Heart rate		0.99 (0.99-0.99)	<0.001	0.99 (0.99-0.99)	<0.001
	Systolic blood pressure		1.02 (1.02-1.03)	<0.001	1.02 (1.02-1.02)	<0.001
Categorical variables	Age	<50†	1		1	
		50-70	3.89 (3.33-4.56)	<0.001	2.96 (2.50-3.5)	<0.001
		>70	5.85 (5.03-6.83)	<0.001	4.09 (3.48-4.84)	<0.001
	Heart rate	≥100†	1		1	
		<100	1.45 (1.30-1.61)	<0.001	1.62 (1.44-1.83)	<0.001
	Systolic blood pressure	<140†	1		1	
		140-170	2.88 (2.53-3.28)	<0.001	2.65 (2.32-3.04)	<0.001
		>170	7.33 (6.41-8.38)	<0.001	5.96 (5.18-6.87)	<0.001
	ISHA-Score		2.11 (2.01-2.21)	<0.001		

†Reference

selection bias. Secondly, the data is not independently validated, hence recording errors are possible. However, these are most probably randomly distributed and unlikely to cause significant bias. Thirdly, the in-hospital diagnostic procedures were not controlled and for example, the patients did not undergo routine imaging of the head. Diagnoses were collected at the end of hospitalization and therefore it is possible that some intracranial lesions remained undiagnosed. However, as virtually all of the receiving hospitals have easy access to computed tomography, we assume missed lesions contributing to a decreased level of consciousness to be rare.

On the other hand, the study has several strengths. There is only one HEMS in the country covering almost the entire population. Furthermore, all missions are prospectively recorded into a uniform database with low levels of missing data. Moreover, the public hospital system and national registries enables data collection with little missing data. All these factors facilitate forming robust datasets for the study purposes.

Conclusions

A score combining systolic blood pressure, heart rate and age may help identify patients with an intracranial lesion in prehospital setting when level of consciousness is decreased. This can be utilized to recognize patients who should be transported directly to a tertiary neurological center and may benefit from neuroprotective approach in prehospital critical care.

Sources of funding

This work has been supported by Helsinki University Hospital (state funding, VTR TYH2019243) and FinnHEMS Research and Development Unit.

Declarations of Competing Interest

None.

Acknowledgments: None.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.jstrokecerebrovasdis.2022.106319.

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