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Research Article

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Glasgow Coma Scale (GCS): Multicenter Validation Study of Psychometric Properties of the Official Russian Version

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ABSTRACT Objective assessment of patients with impaired consciousness is a priority task in the department intensive care. The Glasgow Coma Scale (GCS), which includes assessment of motor, speech and ocular reactions, was the first scale developed for this purpose. The absence of versions of the GCS that passed validation research, reduces quality of its application in Russia and other Russian-speaking countries and limits the possibility of obtaining objective clinical results during evaluation patients with reduced level of wakefulness, significantly decreased availability of the scale for scientific and clinical use.

AIM OF STUDY Rating psychometric parameters of the Glasgow Coma Scale as part of the 2nd stage of the multicenter validation research.

MATERIAL AND METHODS In a group of 171 patients over 18 years old with different levels decreased wakefulness, as well as in clear consciousness, hospitalized in the department resuscitation and intensive care therapy performed assessment psychometric properties (reliability, validity, sensitivity).

RESULTS For the Russian version of the GCS received high levels of validity ($p<0.0001$, Spearman correlation coefficient $r=0.91$), reliability ($p<0.001$, coefficient correlations Spearman $r=0.88$; $p<0.0001$, Cronbach's alpha coefficient $\alpha=0.78$; $p<0.001$, Cohen's kappa coefficient $\kappa=0.74$) and sensitivity (Wilcoxon test $p=0.426$ in the main group and Wilcoxon test $p=0.782$ in the group "without speech function assessment").

CONCLUSION In the conducted research demonstrated a sufficient level psychometric properties of the Russian version of the Glasgow Coma Scale, which opens up the possibility of its application in Russia and Russian-speaking countries. The scale is available for downloading on the Validation Group website international scales and questionnaires of the Federal State Budgetary Scientific Institution Scientific Center of Neurology.

Keywords: GCS, Glasgow Coma Scale, coma, acute consciousness disturbance, validation, intensive care

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TBI - traumatic brain injury
GCS - Glasgow Coma Scale

INTRODUCTION

Coma is an acute life-threatening condition characterized primarily by decreased consciousness and requiring dynamic assessment and intensive care. In 1974, the Glasgow Coma Scale (GCS) became the first scale to offer an objective assessment of patients with impaired consciousness [1]. The idea behind its use was to assess motor, speech, and ocular reactions that characterize the level of consciousness in patients with traumatic brain injury (TBI). Its development also assumed that not only the physician, but also the medical staff as a whole would be able to effectively use this scale to assess the patient's condition.

And so it happened. The GCS has been widely used in clinical and research practice all over the world for 50 years [2]. Its protocol is characterized by the speed and simplicity of the modalities used. The GCS assesses the level of consciousness as a combination of three reactions: eye opening ("*E* "), verbal reaction ("*V* ") and motor reaction ("*M*") in response to a presented stimulus. The three components that make up the GCS can be assessed separately or combined into a total score in the range from 3 to 15. The total score is used as a general indicator of the degree of unconsciousness, since it denotes a complex of signs indicating the severity of damage to the human brain [1].

The GCS has been widely used in intensive care units around the world for many years, and its modalities are included in the assessment of patients with various life-threatening conditions, not just TBI. GCS modalities are used in the *APACHE* II scale, *the Traumatic Injury Scoring System* , *the Hunt Hess Scale* , and many other scales that assess brainstem reflexes [3–9]. Moreover, over time, prognostic

correlations have been identified linking GCS components and patient recovery [10].

At the same time, the GCS has a number of shortcomings. Thus, in intubated patients and in patients with aphasia, a reliable assessment of the speech response is impossible. In addition, there is no detailed assessment of brainstem reflexes. However, this does not detract from the advantages of the scale.

In 2021, the linguacultural adaptation of the Russian-language version of the GCS was successfully completed in Russia [11]. The emergence of the official Russian-language version increased the availability of the GCS for clinical and scientific use in Russia and other Russian-speaking countries.

This article presents an assessment of the psychometric parameters of the GCS within the framework of the second stage of a multicenter validation study.

MATERIAL AND METHODS

DESCRIPTION OF PATIENTS

Patients were recruited prospectively at the Federal State Budgetary Scientific Institution Research Center of Neurology (Moscow), State Budgetary Healthcare Institution S. P. Botkin City Clinical Hospital of the Moscow Health Department (Moscow), State Budgetary Healthcare Institution N. V. Sklifosovsky Research Institute for Emergency Medicine of the Moscow Health Department (Moscow), Federal State Budgetary Institution V. A. Almazov National Medical Research Center of the Ministry of Health of the Russian Federation (St. Petersburg) and ARO CPO Clinical Institute of the Brain, Yekaterinburg, Russia (Yekaterinburg).

In accordance with the inclusion and exclusion criteria (Table 1), 176 neurological patients over 18 years of age with varying levels of decreased wakefulness (coma, stupor, obtundation), as well as conscious patients, initially participated in the study.

Table 1

Criteria inclusion and non-inclusion in the validation Glasgow Coma Scale study

Inclusion Criteria	Non-inclusion criteria
– age 18 years and older; – patients in the intensive care unit with the following types of acute impairment of consciousness: stupor, stupor, coma, as well as patients in clear consciousness; – signed informed consent of the patient's representative; – diagnosed neurological nosologies: cerebrovascular accident of the ischemic/hemorrhagic type (including subarachnoid hemorrhage) in the acute period, traumatic brain injury, damage to the central nervous system of infectious etiology (meningitis, encephalitis, etc.), acute neuromuscular diseases (Guillain-Barré syndrome, myasthenic crisis), etc.	– the effect of sedatives or neuromuscular blockers at the time of the assessment on the scale. In this case, it is necessary to wait for one maximum half-life period (during the initial assessment and during the repeated assessment when the fact of taking these drugs is established during the three following days)

During the inter-assessment period, 5 patients were excluded from the study: three due to death, one due to sedation, and one patient was transferred to a multidisciplinary hospital due to the development of gastrointestinal bleeding.

The final group of 171 patients (87 men and 84 women) included 94 conscious, 20 stupefied, 26 stuporous, and 31 comatose patients. The degree of decreased alertness was assessed by two neurologists from the Department of Anesthesiology, Resuscitation, and Intensive Care with at least 3 years of experience on the first day of hospitalization (simultaneously with the first assessment using Full Outline for Unresponsiveness*,* *FOUR*) and repeated on the 2nd–3rd day.

According to the neurological type, the subjects can be divided into a group with cerebral damage (164/171) and damage to the peripheral nervous system (7/171). According to the etiology, the group with damage to the central nervous system (CNS) is presented as follows (Fig. 1): ischemic stroke (95/164); hemorrhagic stroke, including non-

traumatic subarachnoid hemorrhage (50/164); inflammatory diseases of the brain and membranes (encephalitis and meningitis) (3/164); closed TBI (3/164) and other causes (13/164). The group with damage to the PNS included patients with myasthenic crisis (1/7) and Guillain-Barré syndrome (6/7). The average age of patients in the entire sample was 63.0±16.8 years.

Другие причины:
– воспалительные заболевания головного мозга и оболочек (энцефалит и менингит) (3/171);
– закрытая черепно-мозговая травма (3/171);
– демиелинизирующие заболевания (3/171);
– патология сосудов головного мозга (2/171);
– эпилепсия (2/171);
– новообразования центральной нервной системы (2/171), последствия остановки сердечной деятельности (1/171);
– последствия аорто-коронарного шунтирования (1/171);
– оппортунистическая инфекция на фоне вируса иммунодефицита человека (1/171);
– токсическая энцефалопатия на фоне героиновой зависимости (1/171);
– миастенический криз (1/171);
– синдром Гийена-Барре (6/171).

Fig. 1. Quantitative distributions etiological factors

The most common cause of decreased alertness in this study was ischemic stroke (57.9%), less common was hemorrhagic stroke (30.5%) and other causes (11.6%), including damage to the peripheral nervous system.

In some patients (n = 52/171; 30.4%), due to tracheal intubation and other factors preventing an objective study of verbal abilities, the verbal function item was rated as "N" (not able to be checked). These patients were included in a separate group ("without verbal function assessment") and studied separately. Accordingly, the study considered two groups - the main one and "without verbal function assessment".

VALIDATION PROCEDURE

The second stage of validation of international scales in accordance with the established requirements is focused on determining psychometric indicators - reliability, validity and sensitivity. In the conducted study, these parameters of the GCS were assessed with the participation of two neurologists with experience in neuro-intensive care units. The assessments according to the questionnaire during the first, second and third examination by the first doctor were designated as "A_1", "A_2" and "A_3", during the first and only examination by the second doctor - "B_1", respectively.

Psychometric indicators

Taking into account the principles of validation of tests, questionnaires and scales, the following indicators were assessed in this study: test -*retest* and inter -*rater* reliability, internal consistency, criterion and content validity, as well as sensitivity [12]. Taking into account the characteristics of the obtained data, psychometric indicators were assessed in the main group, and sensitivity in both groups - the main group and the group "without speech function assessment".

The study of the scale sensitivity included a comparison of the data from the first and final examinations of patients (A_1–A_3), conducted on the first day of hospitalization in the intensive care unit and again on the 2nd–3rd day. In this case, the hypothesis was tested regarding the ability of the scale to effectively identify the dynamics of clinical indicators.

Statistical analysis of data

The calculation of the representativeness of the sample was carried out according to generally accepted recommendations [13]. The sample size of 171 people was sufficient to carry out all the necessary statistical calculations.

The following methods of statistical data analysis were used in the study of the psychometric parameters of the scale: criterion validity (with the Full Outline for Unresponsiveness, *FOUR*) and test-retest reliability were assessed using Spearman's correlation analysis, inter-rater reliability — by means of Cohen's kappa, internal consistency — using Cronbach's alpha coefficient; sensitivity — the Wilcoxon criterion. The threshold level of statistical significance corresponded to $p \leqslant 0.05$. Statistical data processing was performed using the *SPSS Statistics* 23 program (*IBM Corp.*, Chicago, USA).

RESULTS

According to the level of consciousness, the patients were distributed as follows: clear consciousness was determined in 82 patients (48.0%), moderate stupor — 3 patients (1.75%), profound stupor — 10 patients (5.85%), stupor — 15 patients (8.8%), coma — 9 patients (5.3%). The median and interquartile range (*Me* (*IQR*)) of the GCS score at the first visit in the main group was 15.0 (11.25–15.0) points, in the group "without speech function assessment" — 5.0 (3.0–9.25) points. The distribution of the sample by the level of decrease in wakefulness is presented in the diagram (Fig. 2).

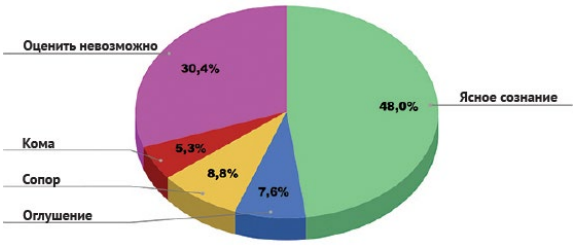

Fig. 2. Distribution diagram of the sample by the level of decreased wakefulness (stupor, sopor, coma) and the presence of clear consciousness

The study included 48% of patients in clear consciousness, 7.6% in stupor, 8.8% in sopor, and 5.3% in coma. In 30.4% of patients, the GCS was inapplicable.

PSYCHOMETRIC PROPERTIES OF THE RUSSIAN VERSION OF THE GCS

Reliability

The Spearman correlation coefficient between the results of repeated examinations in the study of test-retest reliability was $r = 0.88$ ($p < 0.001$), which corresponds to a high level of stability of the scale to errors associated with the time factor.

Cohen's kappa coefficient was $\kappa = 0.74$ ($p < 0.001$), confirming significant inter-rater agreement in independent assessment according to the GCS. When studying the discrepancy in the assessments of each of the scale items "eye opening", "verbal response" and "motor response", significant and balanced indicators were obtained (Table 2).

Table 2

Inter-rater agreement rates for each item of the Glasgow Coma Scale

Indicator Consistency of expert opinions	Glasgow Coma Scale			
	"Opening eyes"	"Speech response"	"Motor reaction"	Summary
Cohen's kappa (cutoff value ⩾0.7)	0.82	0.71	0.79	0.74
p -value	<0.001			

Independent assessment using the GCS confirmed significant inter-rater agreement ($\kappa = 0.74$; $p < 0.001$).

During the study of the internal consistency of the GCS, it was shown that the Cronbach's alpha coefficient is $\alpha = 0.78$ ($p < 0.0001$), which proves the high balance of the scale items.

When studying the criterion validity between the assessments on the GCS and *FOUR scale*, a significant correlation of $r = 0.91$ ($p < 0.0001$) was obtained.

Sensitivity of the Russian version of the GCS. When comparing the GCS scores of the main group at the first and final examinations, no significant differences were found. Thus, at the initial examination, the score was 15.0 (11.25–15.0) points, at the final one — 15.0 (11.0–15.0) points (Wilcoxon test, $p = 0.426$). In the group "without verbal function assessment", no significant differences were found either (Wilcoxon test, $p = 0.782$). The initial score in this group was 5.0 (3.0–9.25) points, the final one — 3.0 (4.0–10.5) points.

The results of the GCS assessment at the first and final visits in the main group and the group "without speech function assessment" are shown in Fig. 3.

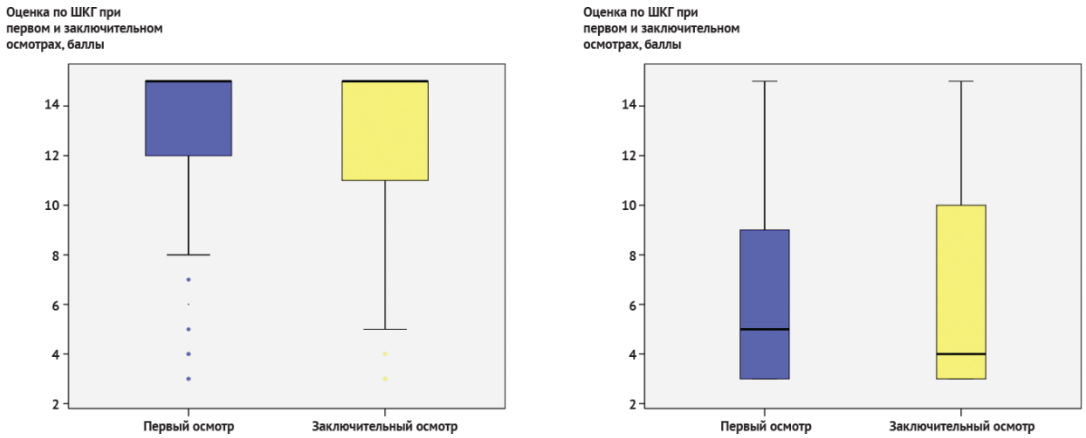

Fig. 3. Dynamics of the Glasgow Coma Scale (GCS) indices during the first and final examinations in the main group and the group "without verbal function assessment"

The sensitivity assessment at the first and final examination in the main group was 15.0 points (Wilcoxon test, p = 0.426), in the group "without speech function assessment" 5.0 and 3.0, respectively (Wilcoxon test, p = 0.782).

The reliability, validity and sensitivity indicators of the Russian version of the GCS are presented in Table 3.

Table 3

Psychometric indices of the Russian version of the Glasgow Coma Scale

Parameter	Parameter elements	Method of statistical analysis	Threshold value of the indicator	Result	
				indicator	*p* - value
Reliability	internal consistency (A_1)	Cronbach's alpha	0.8 and more	0.78	<0.0001
	inter-rater agreement	Cohen's kappa	0.7 and more	0.74	<0.001
	test-retest reliability ($A_1 - A_2$)	Spearman's correlation coefficient	0.7 and more	0.88	<0.001
Validity	criterion validity	Spearman's correlation coefficient	0.7 and more	0.91	<0.0001
Sensitivity	sensitivity ($A_1 - A_3$)	Wilcoxon test	*p* less than 0.05	<-0.3	>0.4

The official Russian version of the Glasgow Coma Scale has a high level of validity (p < 0.0001, Spearman correlation coefficient r = 0.91), reliability (p < 0.001, Spearman correlation coefficient r = 0.88; p < 0.0001, Cronbach's alpha coefficient α = 0.78; p < 0.001, Cohen's kappa coefficient κ = 0.74) and sensitivity.

DISCUSSION

The validation study of the GCS was conducted in two stages. As part of the linguacultural adaptation, the original scale was translated into Russian, an analysis was conducted, and a combined translation of the two versions was prepared. Based on the results of the first stage of validation, a preliminary version of the GCS was developed, translated back (from Russian to English) by a native English speaker with a medical education. The results of the first stage of validation were discussed at a meeting of the expert committee, whose decision approved the final Russian-language version of the GCS. This official version was used for the second stage of the validation study - an assessment of validity, reliability, and sensitivity in a multicenter study.

It should be noted that since its inception in 1974, the GCS has stood the test of time as one of the most sought-after clinical tools for assessing levels of consciousness worldwide. Among the advantages of this scale are its conciseness and the ability to assess levels of consciousness in a relatively short period of time, which expands the range of application of the GCS from scientific research to clinical practice.

On the other hand, it is obvious that after half a century of using the GCS, some researchers have

doubts and critical comments about its use [14–16]. However, it should not be forgotten that the GCS was developed before the widespread control of methods for quantitative measurement of clinical indicators. Multiple systematic analyses have yielded mostly confirmatory conclusions about the level of its validity and reliability [17–20].

As a result of the multicenter study, we obtained high levels of validity (p < 0.0001, Spearman correlation coefficient r = 0.91). In addition, we examined the reliability of the scale - this is of fundamental importance for the practical usefulness of the scale. The reliability of the GCS has been demonstrated in many studies [19, 20].

There are also inconsistencies in the assessment of the reliability of the scale, according to the accumulated literature [21]. In response to criticism, a systematic review *by FC Reith* [22] analyzed the literature from 1974 to 2015 describing the reliability, validity, and predictive value of the GCS. The authors recommended providing training for personnel using the GCS in their routine practice, as well as analyzing each of the three components of the GCS, rather than using only the sum of the scores [23].

Our study showed high reliability indices (p < 0.001, Spearman correlation coefficient r = 0.88; p < 0.0001, Cronbach's alpha coefficient α = 0.78; p < 0.001, Cohen's kappa coefficient κ = 0.74). In addition, we assessed the sensitivity of the GCS, which also demonstrated high indices (Wilcoxon criterion p = 0.426 in the main group and Wilcoxon criterion p = 0.782 in the group "without speech function assessment").

The developed version of the GCS in Russian is available on the website of the Group for the Validation of International Scales and Questionnaires of the Federal State Budgetary Scientific Institution Research Center of Neurology *https://neurology.ru/o-centre/struktura/institut-neyroreabilitatsii-i-vosstanovitelnykh tekhnologiy/gruppa-validatsii-mezhdunarodnykh-shkal-i oprosnikov/?ysclid=lo46dsgpr9826437705* and on the official website of *the Glasgow Coma Scale developers https:www.glasgowcomascale.org/downloads/GCS-Assessment-Aid-Russian.pdf.*

CONCLUSION

The conducted study demonstrated a sufficient level of psychometric properties of the Russian - language version of the Glasgow Coma Scale, which opens up the possibility of using the scale in Russia and Russian-speaking countries. The scale is available for downloading on the website of the Group for the Validation of International Scales and Questionnaires of the Federal State Budgetary Scientific Institution NCN.

CONCLUSIONS

1. The official Russian version of the Glasgow Coma Scale has a high level of validity (p <0.0001, Spearman correlation coefficient r =0.91)

2. The official Russian version of the Glasgow Coma Scale has a high level of reliability (p < 0.001, Spearman correlation coefficient r = 0.88; p < 0.0001, Cronbach's alpha coefficient α = 0.78; p < 0.001, Cohen's kappa coefficient κ = 0.74)

3. The official Russian-language version of the Glasgow Coma Scale has a high level of sensitivity (Wilcoxon test p = 0.426 in the main group and Wilcoxon test p = 0.782 in the group “without speech function assessment”).

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