Determining levels of linguistic deficit by applying cluster analysis to the aphasia quotient of Western Aphasia Battery in post-stroke aphasia

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Abstract

Background The aphasia quotient of Western Aphasia Battery (WAB-AQ) has been used as an inclusion criterion and as an outcome measure in clinical, research, or community settings. Although the WAB-AQ is commonly used to measure recovery, there was no quantitative relationship between WAB-AQ and severity classification. This study aimed to quantitatively determine levels of linguistic deficit by using a cluster analysis of the WAB-AQ in post-stroke aphasia (PSA). Methods 308 patients were extracted from the database. Cutoff scores defined by mean overlap WAB-AQ scores of clusters by systematic cluster analysis, the method of which is the farthest neighbor element, and the metrics are square Euclidean distance and Pearson correlation, performed on the full sample of WAB-AQ individual subitem scores. A 1-way analysis of variance, with post hoc comparisons conducted, was used to determine whether clusters had significantly difference. Results Three clusters were identified. The scores for severe, moderate and mild linguistic deficit levels ranged from 0 to 30, 30.1 to 50.3, and 50.4 to 93.7, respectively. Conclusions For PSA, the cluster analysis of WAB-AQ supports a 3-impairment level classification scheme.

Introduction

The number of stroke individuals worldwide is still increasing year by year[1]. Aphasia after stroke accounts for about one third of the total number of stroke survivors[2]. Stroke comprises a heterogeneous population with a wide range of linguistic deficit. To facilitate treatment planning and evaluation of progress in clinical, research, or community settings, stroke populations need to be comprehensively evaluated. Facing the increasing demand for stroke rehabilitation[3], although there is a lack of consensus on the measurement of the main results in both research and clinical guidelines[4], the WAB of linguistic deficit is the most widely used assessment to measure PSA in the research context[5, 6]. The WAB-AQ score has been used as an inclusion criterion and as an outcome measure for clinical trials[7, 8]. To determine the optimal method to evaluate poststroke linguistic deficit, previous articles[6, 9] studied related assessment tools, including the use of the WAB.

The WAB-AQ has 4 subsections[10, 11]: (1) spontaneous speech; (2) auditory comprehension; (3) repetition; and (4) naming designed to determine the presence of aphasia and judge the type of linguistic deficit and measure the severity of language impairment. The full score of spontaneous speech is 20, including fluency and content of information. The 200 points of auditory comprehension consists of 60 points of Yes-No questions, 60 points of auditory word recognition and 80 points of sequential commands. The total score of repetition is 100. A total of 100 points are given for naming, including 60 points for object naming, 20 points for fluency of word, 10 points for sentence completion and 10 points for responsive speech. The calculation formula of aphasia quotient is “AQ = (Spontaneous + Comprehension ÷ 20 + Repetition ÷ 10 + Naming ÷ 10) × 2”. All of the items result in a range of possible scores from 0 to 100. Combined with the clinical data of stroke patients, those whose aphasia quotient is less than 93.8 can be judged as aphasia, and the smaller the aphasia quotient, the more serious the aphasia[10]. Although the WAB-AQ is commonly used to measure recovery[12], there was no quantitative relationship between AQ and severity classification[13].

The current clinical reality is to use WAB-AQ to determine whether aphasia and its type. If you want to grade the severity of aphasia, you should re-conduct the Boston Diagnostic Aphasia Examination (BDAE). Compared with other common language clinical assessments (such as BDAE), WAB-AQ has the advantages of simple but quantifiable scoring system and relatively short execution time (approximately 1 hour), which disadvantage is the lack of hierarchical discussion of language impairment[11, 13]. Some studies[11, 14] have shown that the information content has a significant correlation with WAB-AQ scores in all sub-tests, but the characteristics of aphasia with various severity have not been analyzed, either perform an analysis of the items that constitute the WAB-AQ. We believe that the ratings of the individual WAB-AQ elements convey information that is lost when one considers only the WAB-AQ total score. The primary aims of our study were to use WAB-AQ individual items scores to (1) derive data-driven cutoff scores defining distinct levels of linguistic deficit; (2) determine the commonalities and differences of linguistic deficit within and between the severity levels.

Methods

The data used in this report were obtained through our retrospective screening of the baseline evaluation database during the course of 2 studies of PSA conducted between 2020 and 2022[15, 16]. The 2 studies used identical methodology for the collection of WAB-AQ data. A single physical therapist trained all 3 staff in the administration of the WAB-AQ. This study, which was conducted in accordance with relevant guidelines and regulations, was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Huashan Hospital, Fudan University. Patient consent was waived due to the retrospective nature of the study and the lack of patient interaction.

Statistical methods

We performed cluster analysis with SPSS 25.0 (IBM Corporation, Armonk, NY, USA). In the analyses, all sub-test items of WAB-AQ including spontaneous speech, auditory comprehension, repetition and naming were the independent variables. The method of systematic cluster analysis is the farthest neighbor element, and the metrics are square Euclidean distance and Pearson correlation. The optimal number of clusters was determined by selecting the largest, most discrete change in squared Euclidean distance or the minimum correlation coefficient between the adjacent number of clusters. A 1-way analysis of variance, with post hoc comparisons conducted using Tamhane T2 Test, was used to determine whether clusters had significantly different mean WAB-AQ scores.

WAB-AQ cutoff scores defining the optimal clusters were identified by using the following methods. The participants were ranked according to the WAB-AQ total score from high to low, and each cluster member was checked. When cluster overlap occurred, the first one in the overlapping area was defined as high score, and the last one was defined as low score. The cutoff score was defined as the mean of the high score and low score[17]. This process was repeated to determine the cutoff scores between each adjacent cluster, thereby defining groups with similar severity of linguistic deficit.

The characteristics of linguistic deficit within each cluster were defined by the aggregate scores of the WAB-AQ sub-tests. The mean subtest scores of each group were compared between groups.

Results

Characteristics of participants

Our study included 308 individuals with PSA (200 male, 108 female; 101 Broca, 73 Global, 69 Anomic, 16 Wernicke, 16 Conduction, 15 transcortical motor, 12 mix transcortical, 6 transcortical sensory). The participants' mean age was 60.5 ± 12.905 years, mean years of education was 10.89 ± 3.690, mean mouth of course was 7.56 ± 9.629, and mean WAB-AQ score was 44.309 ± 29.997. (Table 1)

Table 1
Baseline characteristics of participants. *SD* standard deviation, *WAB-AQ* aphasia quotient of Western Aphasia Battery

Items	
Number of individuals	308
Gender	
Female, *n* (%)	108 (35.1%)
Male, *n* (%)	200 (64.9%)
Age, years, mean ± SD (range)	60.5 ± 12.905 (18–89)
Course, months, mean ± SD (range)	7.56 ± 9.629 (0–42)
Education, years, mean ± SD (range)	10.89 ± 3.690 (0–18)
WAB-AQ scores, mean ± SD (range)	44.309 ± 29.997 (0-93.7)
Types of aphasia	
Broca’s aphasia, *n* (%)	101 (32.8%)
Global aphasia, *n* (%)	73 (23.7%)
Anomic aphasia, *n* (%)	69 (22.4%)
Wernicke’s aphasia, *n* (%)	16 (5.2%)
Conduction aphasia, *n* (%)	16 (5.2%)
Transcortical motor aphasia, *n* (%)	15(4.9%)
Mix transcortical aphasia, *n* (%)	12 (3.9%)
Transcortical sensory aphasia, *n* (%)	6 (1.9%)

Cluster analysis and range of WAB-AQ scores within each cluster

The analysis identified 3 clusters. After selecting cutoff scores by using the method of mean overlap score described above, the ranges of scores for the 3 clusters were 0 to 30, 30.1 to 50.3, and 50.4 to 93.7. The WAB-AQ scores within the 3 clusters correspond to severe, moderate, and mild impairment levels. (Table 2) (Fig. 1)

Table 2
Characteristics of the clusters. *SD* standard deviation, *WAB-AQ* aphasia quotient of Western Aphasia Battery. [a] 1-way analysis of variance

	Cluster1	**Cluster2**	**Cluster3**	***P* value**
Level of linguistic deficit	Severe	Moderate	Mild	
Number of participants	109	71	128	
WAB-AQ scores, mean ± SD (range)	13.100 ± 12.001 (0-44.6)	42.271 ± 16.918 (15.4–74.2)	72.017 ± 16.819 (26.3–93.7)	
Defined range of the WAB-AQ cutoff scores	0–30	30.1–50.3	50.4–93.7	
Group number of participants	123	55	130	
Group mean WAB-AQ score	13.058 ± 9.769	41.255 ± 5.816	75.235 ± 11.585	< 0.001[a]

Severe

Participants characterized as severe had poor verbal expression ability. Although some comprehension and repetition abilities are retained to some extent, it is still unlikely to participate in daily communication.

Moderate

Participants characterized as moderate had good auditory comprehension ability, relatively. However, due to the impairment of language expression ability, it is partially difficult to participate in daily communication independently.

Mild

Participants characterized as mild had retain relatively complete expression ability and auditory comprehension ability, who can participate in some daily communication activities independently.

Discussion

The original version of WAB was designed based on the BDAE, accompanying certain system continuity[10]. Subsequently, various versions of WAB appeared in the study for population with linguistic deficit in different countries, languages and diseases[18–20]. The severity of initial aphasia is closely related to the prognosis, which has been confirmed long ago[21]. In that case, why not directly correlate the severity stratification of linguistic deficit through WAB-AQ value? Considering the above situation, when solving the problem of severity classification of aphasia in clinic, we plan to conduct a secondary cluster analysis on those with WAB-AQ scores less than 93.8 based on the original score division of WAB, so as to further optimize the evaluation system of aphasia and facilitate the clinical application of aphasia evaluation.

In this study, we performed a division of linguistic deficit levels using cutoff scores. The benefit of using a cluster analysis to define impairment levels of the WAB-AQ assessment is that the cutoff points are derived using an objective quantitative method. In practical research, many scholars take WAB as an index to judge the type and severity of aphasia and evaluate the curative effect and outcome[22, 23]. However, up to now, we have not retrieved the relevant literature on the stratification of aphasia severity corresponding to WAB-AQ scores. The existing stratification of aphasia may be more based on the subjective impression of clinicians. As described in the BDAE, 0 indicates that the patient has no meaningful language or auditory comprehension ability and 5 indicates that there is almost no discernible language impairment[24]. Although in the clinical application of nervous system diseases, the diagnosis of language defects needs to be combined with more clinical data, such as imaging, biochemistry and pathophysiology, we hope to provide some convenience for language rehabilitation practitioners and patients through our research results.

In terms of the characteristics of linguistic deficit within each cluster, from the severe to the mild linguistic deficit group, there was an increase in WAB-AQ scores. In the WAB-AQ subtests, the scores of spontaneous speech, repetition and naming increased with the decrease of the severity of aphasia, while there was no significant statistical difference in auditory comprehension between the mild and moderate groups. According to the scores of all subitems, we tried to describe the characteristics of the groups at three linguistic deficit levels from three aspects: language output, language reception and communication, as shown in the research results. What we need to explain here is that the above characteristics are common features in the cluster and cannot represent the language characteristics of each individual in the cluster. Similar results were also obtained in this study: spontaneous speech was correlated with naming, which had the greatest impact on WAB-AQ score.

The limitation of the current study is to include individuals with post-stroke aphasia at various stages of the disease, which increases the heterogeneity of research objects. More than 65% of individuals had WAB-AQ scores lower than two-thirds of 93.7 within 6 months after onset. The number of patients within one month, one to six months, six months to one year and more than one year accounted for 29.2%, 36.4%, 13.6% and 20.8% respectively. There are significantly fewer individuals with moderate linguistic deficit level. Perhaps this phenomenon can be explained by the different number of individuals in different post onset periods.

In the future study, we can consider the stratification of samples according to the course of disease, or include language disorders caused by other diseases, such as primary progressive aphasia. There is no correlation analysis of aphasia types in this study, which can also be considered as a direction of future research.

Conclusions

For PSA, the systematic cluster analysis of the WAB-AQ revealed 1 set of classification schemes (severe, moderate, mild).

Declarations

Author contributions statement

Zhijie Yan and Jie Jia contributed to the study conception and design. Material preparation, data collection and analysis were performed by Zhijie Yan, Shuo Xu, Jingna Zhang, Chong Li, Yongli Zhang, Mengye Chen and Xiaofang Li. The first draft of the manuscript was written by Zhijie Yan and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability

The datasets generated during the current study are not publicly available due to privacy or ethical restrictions, but are available from the corresponding author on reasonable request.

Competing interests

The authors declare no competing interests.

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Figures

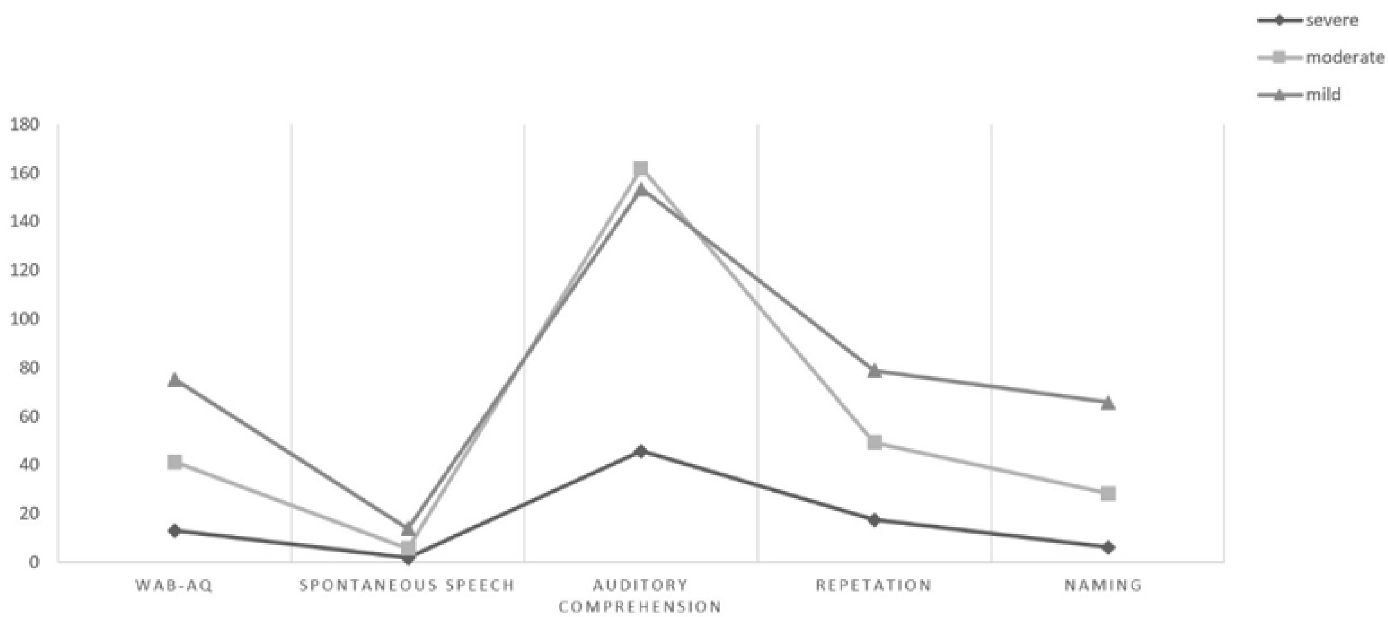

Figure 1

The characteristics of linguistic deficit within each cluster were defined by the aggregate scores of the WAB-AQ sub-tests. The mean subtest scores of each group were compared between groups.