Development and Assessment of a Computer Algorithm for Stroke Vascular Localization Using Components of the National Institutes of Health Stroke Scale

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Background: The National Institutes of Health Stroke Scale (NIHSS) was not intended to be used to determine the stroke's vascular distribution. The aim of this study was to develop, assess the reliability, and validate a computer algorithm based on the NIHSS for this purpose. *Methods:* Two cohorts of patients with ischemic stroke having similar distributions of Oxfordshire localizations (total anterior, partial anterior, lacunar, and posterior circulation) based on neuroimaging were identified. The first cohort (n = 40) was used to develop a computer algorithm for vascular localization using a modified version of the NIHSS (NIHSS-Localization [NIHSS-Loc]) that included the laterality of selected deficits; the second (n = 20) was used to assess the reliability of algorithm-based localizations compared to those of 2 vascular neurologists. The validity of the algorithm-based localizations was assessed in comparison to neuroimaging. Agreement was assessed using the unweighted kappa (κ) statistic. *Results:* Agreement between the 2 raters using the standard NIHSS was slight to moderate (κ = .36, 95% confidence interval [CI] .10-.61). Inter-rater agreement significantly improved to the substantial to almost perfect range using the NIHSS-Loc (κ = .88, 95% CI .73-1.00). Agreement was perfect when the 2 raters entered the data into the NIHSS-Loc computer algorithm (κ = 1.00, 95% CI 1.00-1.00). Agreement between the algorithm localization and neuroimaging results was fair to moderate (κ = .59, 95% CI .35-.84) and not significantly different from the localizations of either rater using the NIHSS-Loc. *Conclusion:* A computerized, modified version of the standard NIHSS can be used to reliably and validly assign the vascular distribution of an acute ischemic stroke. **Key Words:** Ischemic stroke—computer-based model—acute stroke—localization.

Introduction

Despite advancements in neuroimaging, the neurological examination and clinical localization remain an essential part of the evaluation of patients with an acute ischemic stroke. Clinical localization relies on signs and symptoms based on the history and examination to determine the site of neuroanatomical injury and to infer stroke vascular distribution. Understanding the localization and extent of infarction can provide information helpful for determining the potential etiology of the stroke and for guiding evaluation and treatment. Experienced clinicians are often able to quickly synthesize information at the

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bedside to formulate a clinical localization and hypothesis for stroke etiology, but this can be a daunting task for the nonexpert, particularly in the acute setting.

The National Institutes of Health Stroke Scale (NIHSS) was designed to be a rapid, highly reliable tool for assessing and quantifying stroke-related neurological impairments.[1,2] The NIHSS has good inter-rater reliability among neurologists, multiple types of non-neurologist physicians, and nurses.[2] The NIHSS has also been used as a measure of stroke severity and for distinguishing cortical from noncortical strokes.[3-5] The NIHSS was not designed to determine a stroke's vascular distribution with deficit laterality recorded only for arm and leg weakness. Clinical localization, however, relies on the laterality of other neurological examination findings including aphasia (based on the patient's handedness), ataxia, sensory deficits, spatial neglect, gaze preference, and visual field deficits.

Stroke systems of care have evolved in the United States with the designation of primary and comprehensive stroke centers. Nevertheless, a majority of patients present at hospitals without experienced stroke clinicians, where there is a need to make quick decisions regarding both early stroke management and secondary prevention.[6] Developing an algorithm to determine stroke vascular distribution using components of the NIHSS could help guide early management and triage decisions.

Methods

The study cohort was identified from patients discharged from Duke University Hospital between January 2011 and December 2013 who had a stroke discharge ICD-9 diagnosis (430-435). For inclusion, cases had to have documentation of 1, an initial NIHSS; 2, a complete neurological examination; and 3, radiographic evidence of a single, acute ischemic stroke. Patients with imaging evidence of hemorrhage, multiterritory infarctions, or other relevant central nervous system pathology were excluded.

Stroke vascular distribution was categorized using the Oxfordshire Community Stroke Project (OCSP) system as a total anterior circulation (TAC), partial anterior circulation, posterior circulation (POC), or lacunar (LAC) stroke.[7] The "gold standard" for determining the OCSP ischemic stroke vascular distribution was the results of magnetic resonance imaging in all cases except TAC infarcts that were evident on brain computerized tomography as reviewed by a study neurologist masked to clinical localization. All radiographic imaging was obtained within 48 hours of admission. The initial NIHSS score and detailed neurological examinations were collected by chart review. A total of 40 subject records (10 for each of OSCP category) were selected for model development and an additional set of 20 subject records (5 for each of OSCP category) was selected for model validation.

For model development, 2 attending vascular neurologists who were masked to the imaging results determined the OCSP classification and stroke laterality using the standard NIHSS for the first 40 records and then for the same 40 records using the NIHSS-Localization (NIHSS-Loc, Fig 1) that included the laterality of applicable deficits. NIHSS-Loc includes the side of deficit for gaze preference, visual field deficit, ataxia, sensory loss, neglect and aphasia only for right-handed patients with left-sided deficits. Through an iterative process, a predictive model was then developed that used combinations of typical neurological deficits to generate the OCSP localizations.

The NIHSS-Loc is similar to the standard NIHSS with the addition of the side of certain neurological deficits (Fig 1). For use in this study, the score was determined by using the standard NIHSS scoring and by evaluating the complete neurological examination to determine lateralization of findings. For example, the standard NIHSS has documentation of visual field deficit giving 1 point but no lateralization. In this case, the complete neurological examination documented a left inferior quadrantanopsia, which would then score on the NIHSS-Loc as 3a 1 and 3b 0.

This algorithm was written into Virtual Basic Applications Macro code in Microsoft Excel (Redwood, WA, USA). The code is a linear decision algorithm that determines OCSP based on constellations of signs. Figure 2 is a simplified version of the code using the results of individual items of the NIHSS-Loc. The program output is the side and vascular distribution of the subject's stroke.

After the development of the algorithm, each neurologist, masked to the imaging results and OCSP status, first independently determined the vascular distribution and lateralization of the stroke in each case in the validation cohort (i.e., the second group of 20 patients, 5 patients for each OSCP localization) using data from the standard NIHSS. After completing the assessments using the standard NIHSS and again without the imaging results or OCSP status, the same vascular neurologists independently determined the vascular distribution of each stroke using the NIHSS-Loc. They subsequently entered the data from the NIHSS-Loc into the computerized algorithm (Table 1).

The unweighted kappa statistic (κ) with 95% confidence intervals was used to assess the level of agreement (reliability) between the vascular neurologists using the standard NIHSS, the NIHSS-Loc, and the computer algorithm ($\kappa < 0$ poor, 0-.20 slight, .21-.40 fair, .41-.60 moderate, .61-.80 substantial, .81-1.00 almost perfect agreement).[8] The validity of the computer algorithm-generated localization was assessed based on the level of agreement with neuroimaging results as compared to the two vascular neurologists. The kappa statistic was determined using the calculator provided at http://vassarstats.net/kappa.html.