Epilepsy & Behavior 47 (2015) 45–54

Contents lists available at ScienceDirect

Epilepsy & Behavior

journal homepage: www.elsevier.com/locate/yebeh

Reliable change indices and standardized regression-based change score norms for evaluating neuropsychological change in children with epilepsy

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ARTICLE INFO

Article history:
Received 20 March 2015
Revised 20 April 2015
Accepted 21 April 2015
Available online 28 May 2015

Keywords:
Epilepsy
Reliable change indices
Standardized regression-based change score norms
Children
Neuropsychology

ABSTRACT

Reliable change indices (RCIs) and standardized regression-based (SRB) change score norms permit evaluation of meaningful changes in test scores following treatment interventions, like epilepsy surgery, while accounting for test–retest reliability, practice effects, score fluctuations due to error, and relevant clinical and demographic factors. Although these methods are frequently used to assess cognitive change after epilepsy surgery in adults, they have not been widely applied to examine cognitive change in children with epilepsy. The goal of the current study was to develop RCIs and SRB change score norms for use in children with epilepsy. Sixty-three children with epilepsy (age range: 6–16; M = 10.19, SD = 2.58) underwent comprehensive neuropsychological evaluations at two time points an average of 12 months apart. Practice effect-adjusted RCIs and SRB change score norms were calculated for all cognitive measures in the battery. Practice effects were quite variable across the neuropsychological measures, with the greatest differences observed among older children, particularly on the Children's Memory Scale and Wisconsin Card Sorting Test. There was also notable variability in test–retest reliabilities across measures in the battery, with coefficients ranging from 0.14 to 0.92. Reliable change indices and SRB change score norms for use in assessing meaningful cognitive change in children following epilepsy surgery are provided for measures with reliability coefficients above 0.50. This is the first study to provide RCIs and SRB change score norms for a comprehensive neuropsychological battery based on a large sample of children with epilepsy. Tables to aid in evaluating cognitive changes in children who have undergone epilepsy surgery are provided for clinical use. An Excel sheet to perform all relevant calculations is also available to interested clinicians or researchers.

1. Introduction

Neuropsychological assessment is an essential component of epilepsy surgery programs. These evaluations help determine the cognitive risks associated with epilepsy surgery and assess postsurgical neurobehavioral outcomes. Change in cognitive abilities across time or in response to interventions has historically been evaluated by 1) examining differences in cognitive outcome between groups of patients or 2) comparing change scores in individual patients to some predetermined, yet often arbitrary, difference believed to reflect actual change based on conventional practice (e.g., 10 or 15 standard score points). These procedures for assessing change are confounded by methodological artifacts (e.g., imperfect test-retest reliability, measurement error, practice effects, and regression toward the mean) that are likely to lead to erroneous conclusions regarding cognitive outcome.

Beginning in the 1990s, two methods for assessing postsurgical cognitive change while controlling these confounding factors emerged in the adult epilepsy literature: reliable change indices (RCIs) and standardized regression-based (SRB) change score norms [1–3]. These methods have been developed for a wide range of cognitive measures and are now routinely applied to assess cognitive outcome in adults following epilepsy surgery [1–4]. Despite the clear benefits, RCIs and SRB change score norms have not been developed to examine cognitive change in children after epilepsy surgery across a wide range of cognitive measures.

Our prospective, longitudinal study was designed to address this gap in the literature. Specifically, this study provides RCIs and SRB change score norms for children with epilepsy across a comprehensive neuropsychological battery using the same methods employed by Martin and colleagues [4] for adults with epilepsy. These data allow clinicians

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http://dx.doi.org/10.1016/j.yebeh.2015.04.052
1525-5050/

to objectively assess cognitive change after pediatric epilepsy surgery. Moreover, clinicians can use these RCIs and SRB change score norms to monitor the effect epilepsy has on the cognitive development of children who do not undergo surgery and to examine both the efficacy and potential side effects of nonsurgical medical treatments.

2. Materials and methods

2.1. Participants

This prospective study was approved by the Cleveland Clinic Institutional Review Board. Children who were being evaluated and/or treated for epilepsy within the Cleveland Clinic Epilepsy Center were approached regarding study participation during an outpatient appointment if they met the following inclusion criteria: 1) 6 to 16 years of age, 2) confirmed history of seizures as evidenced on EEG recordings, 3) history of seizures for at least one year, 4) maintained on a stable AED regimen, 5) fluent in English, 6) no past neurosurgical intervention, 7) no history of neurodegenerative disorder, and 8) no neuropsychological testing within the previous 6 months.

A total of 76 children met the inclusion criteria, agreed to participate, and completed the initial assessment. Caregivers provided written informed consent, and children over the age of 12 provided assent for the study. Repeat neuropsychological evaluations were scheduled approximately 9 months following the initial evaluation, whenever possible. This test–retest interval was selected to approximate the average interval between preoperative and postoperative neuropsychological assessments of children who undergo epilepsy surgery at our center. Participants received a $40 gift card after completing their first assessment and a $60 gift card at follow-up. A copy of the test results was also provided to interested caregivers. A total of 13 (17.1%) children did not complete the second neuropsychological assessment. This resulted in a final sample size of 63 children who were an average of ten years old and had completed approximately five years of education. The mean age at seizure onset was 6.5 years (SD = 3.1), and the average duration of epilepsy was 3.7 years (SD = 2.6). Eighty-four percent of the sample was Caucasian, and just over half of the participants were female (57.1%).

Given the wide age range of participants and age-specific differences in test items and developmental factors, participants were stratified into 2 age groups: 6–10 years old (younger group; n = 36) and 11–16 years old (older group; n = 27). Additional demographic and seizure information for the participants is presented in Table 1.

2.2. Measures

Participants completed a comprehensive neuropsychological evaluation that included measures of intelligence, memory, language, visuospatial skills, executive functioning, and academic achievement. The following instruments were administered on two separate occasions: Wechsler Intelligence Scale for Children — Fourth Edition [5], Children's Memory Scale [6], Expressive One-Word Picture Vocabulary Test — Revised [7], Beery–Buktenica Developmental Test of Visual–Motor Integration — Fourth Edition [8], Test of Visual–Perceptual Skills — Third Edition [9] (Visual Discrimination, Visual Memory, and Spatial Relationships subtests), Wisconsin Card Sorting Test [10], Delis–Kaplan Executive Function System [11] (Trail Making Test, Verbal Fluency Test, and Tower Test), and the Woodcock–Johnson III Tests of Achievement [12] (Letter–Word Identification, Reading Fluency, Calculation, Math Fluency, Spelling, Writing Fluency, Passage Comprehension, Applied Problems, Writing Samples, Word Attack, and Punctuation and Capitalization subtests). All measures were administered according to standardized instructions provided in the respective test manuals and scored using age-adjusted norms.

Table 1
Demographic and seizure data for study patients.

Variable		Younger group Ages 6–10 n = 36	Older group Ages 11–16 n = 27
		M (SD)	M (SD)
Age (years)		8.36 (1.38)	12.63 (1.60)
Education (years)		2.69 (1.31)	7.00 (1.66)
Full Scale IQ (standard score)		86.61 (17.27)	83.67 (16.06)
Age at seizure onset (years)		5.24 (2.24)	8.26 (3.18)
Duration of epilepsy (years)		3.12 (2.13)	4.48 (3.03)
Intertest interval (months)		13.03 (8.47)	10.93 (2.97)
Sex	Male	17 (47.2%)	10 (37.0%)
	Female	19 (52.8%)	17 (63.0%)
Race	Caucasian	32 (88.9%)	21 (77.8%)
	African-American	2 (5.6%)	3 (11.1%)
	Other	2 (5.6%)	3 (11.1%)
Handedness	Left	6 (16.7%)	4 (14.8%)
	Right	29 (80.6%)	23 (85.2%)
	Ambidextrous	1 (2.8%)	0 (0%)
Type of seizures	Generalized	16 (44.4%)	13 (48.1%)
	Focal	20 (55.6%; 9 left, 11 right)	14 (51.9%; 10 left, 4 right)
Seizure focus	Temporal	4	5
	Frontal	4	2
	Parietal	2	0
	Occipital	1	1
	Multilobar	9	6

M = mean and SD = standard deviation.

2.3. Analyses

2.3.1. Reliable change indices

Practice effect-adjusted RCI cutoff scores were calculated for each of the neuropsychological measures in the test battery according to the methods outlined by Jacobson and Truax [13]. First, test–retest reliability coefficients were computed for each of the neuropsychological measures. Then RCIs were developed for the two separate age ranges (i.e., 6–10 and 11–16). The standard error of measurement (SEM) was used to calculate the standard error of the difference (SE_{diff}), where $SE_{diff} = \sqrt{2(SEM)^2}$. As noted by Jacobson and Truax [13], the SE_{diff} describes "the spread of the distribution of change scores that would be expected if no actual change had occurred" (p. 14), that is, based solely on chance fluctuations in test scores across time. Next, confidence intervals were established at 80% and 90% by multiplying the SE_{diff} by ± 1.28 and ± 1.64, respectively. This provided two different distribution ranges of change scores, with the 90% confidence interval offering a more conservative estimate of test–retest change and the 80% confidence interval, a more liberal estimate. The resulting cutoff score ranges were then adjusted for practice effects [3,14]. Average practice effects were determined by calculating the mean change (i.e., Time 2 mean minus Time 1 mean) for each cognitive measure. Finally, these practice effects were added to the confidence interval in order to center the range of cutoff scores around the average test–retest practice effect. Score changes outside of these confidence intervals are considered uncommon in children with epilepsy who have not undergone surgery during the test–retest interval since they occur in less than 80% (80% CI) of these children or 90% (90% CI) of these children in the absence of surgical intervention.

2.3.2. Standardized regression-based change score norms

A series of multiple regression equations were used to predict retest scores for each neuropsychological measure using the baseline test score and potential modifying factors (e.g., age, age at seizure onset, and test–retest interval). Because age was included as a predictor in the regression equations, SRB change score norms were calculated using data from the full sample of nonsurgical children (N = 63). Linear regression analyses were conducted for each neuropsychological test