Research Article

Stroke Recurrence and Its Relationship With Language Abilities

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Purpose: Many factors influence poststroke language recovery, yet little is known about the influence of previous stroke(s) on language after left hemisphere stroke. In this prospective longitudinal study, we investigated the role of prior stroke on language abilities following an acute left hemisphere ischemic stroke, while controlling for demographic and stroke-related factors, and examined if earlier stroke impacted language recovery at a chronic time point.

Method: Participants ($n = 122$) with acute left hemisphere ischemic stroke completed language evaluation and clinical neuroimaging. They were divided into two groups: single stroke (SS; $n = 79$) or recurrent stroke (RS; $n = 43$). A subset of participants ($n = 31$) completed chronic-stage re-evaluation. Factors studied included age, education, diabetes and hypertension diagnoses, lesion volume and broad location, group status, aphasia prevalence, and language scores.

Results: Groups did not differ in language performance across time points. The only significant group differences were that participants with RS were older, had smaller acute lesions, and were less educated. Stroke group membership (SS vs. RS) was not associated with language performance at either time point. In patients with prior stroke, large acute lesion volumes were associated with acute language performance, whereas both large acute and chronic volumes influenced recovery.

Conclusions: History of prior stroke in itself may not significantly influence language impairment after an additional acute left hemisphere stroke, unless it contributes substantially to the total volume of infarcted brain tissue. Chronic and acute lesion volumes should be accounted for in studies investigating poststroke language performance and recovery.

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Stroke is a leading cause of disability worldwide, resulting in deficits that span physical, occupational, communication, and life participation domains, among others. Each year in the United States, approximately 795,000 acute stroke events occur (Benjamin et al., 2019). Of those events, an estimated 185,000 (21%) are recurrent strokes (RSs). Multiple modifiable and nonmodifiable risk factors contribute to overall stroke risk, including increased age,

hypertension, atrial fibrillation, diabetes mellitus (DM), hypercholesterolemia, and smoking (Andersen et al., 2009; Boehme et al., 2017; Sacco, 1998; Wolf et al., 1991). Additionally, greater first-time stroke prevalence and mortality have been recorded in racial minorities in the United States, which likely reflects disparate access to adequate health care (Benjamin et al., 2019; Morgenstern & Kissela, 2015). Regarding RS, Howard et al. (2016) compared rates of stroke recurrence in Black and White patients and reported no significant difference in incidence. Furthermore, Morgenstern and Kissela (2015) described that, while prevention of primary stroke events differs among racial and socioeconomic groups, stroke recurrence rates of the broader U.S. population have declined over the past several decades.

While risk factors that contribute to first-time stroke are known, those associated with stroke recurrence are less consistently reported (Zheng & Yao, 2019). Prior studies that have identified risk factors contributing to stroke recurrence have, unsurprisingly, yielded similar results compared to studies exploring first-time stroke risk. Overlapping factors include increased age, hypertension, atrial

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fibrillation, and DM (Alter et al., 1994; Leoo et al., 2008; Modrego et al., 2000; Zheng & Yao, 2019). Additional risk factors for RS include cardiovascular factors (e.g., coronary heart disease) and hyperlipidemia or dyslipidemia (Leoo et al., 2008; Modrego et al., 2000; Sacco et al., 1982; Zheng & Yao, 2019).

Multiple studies have indicated that risk of stroke recurrence is elevated following an ischemic stroke or transient ischemic attack (TIA; Hier et al., 1991; Moersch-Rasmussen et al., 2016; Wolf et al., 1991), particularly in the first year but also later (Burn et al., 1994; Hankey et al., 1998; Hier et al., 1991; Sacco, 1998). Following ischemic stroke, the cumulative risk of stroke recurrence after 2 years was 16.1% in a study by Hier et al. (1991). Hillen et al. (2003) reported that, 5 years following an initial stroke, cumulative risk of recurrence in their sample was 16.6%. A meta-analysis by Mohan et al. (2011) suggested that cumulative risk of stroke recurrence after 5 years was 26.4% and also extended their investigation to consider recurrence rates in the 10 years following an initial stroke, where cumulative risk continued to increase to 39.2%. Given variable findings in the RS literature, it is challenging to identify one accurate statistic regarding risk of recurrence over time. Nonetheless, a key point is that pervasive risk of recurrence exists in the years following an initial event.

In some cases, a prior stroke may have been asymptomatic and only detected via diagnostic imaging during hospitalization for a new acute lesion, meaning that some patients may be unknowingly susceptible to stroke recurrence (Kase et al., 1989). Erdur et al. (2015) retrospectively evaluated risk of recurrent ischemic stroke during hospitalization acutely following TIA or initial stroke. In their study of 5,106 participants, 40 experienced stroke recurrence within a median length hospital stay of 5 days. They also reported that frequency of stroke recurrence was elevated in participants with histories of prior TIAs, severe internal carotid artery, hospital-acquired pneumonia following initial ischemic stroke, or other certain causes of the initial stroke event, such as arterial dissection, angitis, and giant cell arteritis. Participants with RS, compared to single-event stroke, did not differ in age; sex; and presence of atrial fibrillation, DM, or hyperlipidemia (Erdur et al., 2015).

Acute symptom onset caused by TIA or “minor” stroke may also indicate the likelihood of stroke recurrence. For example, Johnston et al. (2000) reported that motor speech symptoms caused by TIA or minor stroke are indicative of greater likelihood of stroke recurrence in the future.

To our knowledge, no prior study investigating the nature of RS has identified relationships between stroke lesion characteristics; therefore, it is unclear if, for example, a relationship exists between size of initial stroke and RSs. A meta-analysis by Kauw et al. (2018) determined that magnetic resonance imaging (MRI) predictors of stroke recurrence include evidence of multiple ischemic changes and previous cortical lesions. However, they did not discuss size of chronic lesions compared to recurrent lesions. The relationship between hemisphere and stroke recurrence is also not clearly defined; Jørgensen et al. (1997) reported

that 131 of the 265 participants (49.4%) in their study sample who experienced RS exhibited ipsilateral recurrence to the initial stroke. Contralateral stroke recurrence occurred in 75 participants (28.3%), and 59 participants (22.3%) demonstrated recurrence in the brainstem or cerebellum.

Stroke and Language

For patients who present with stroke localized to the left hemisphere, language function is often impaired, as the left hemisphere is typically language dominant. Damage to specific left hemisphere regions can result in disorders such as aphasia and apraxia of speech. Aphasia, most commonly caused by stroke, is classified as disordered language, involving semantics, phonology, or syntax (Fridriksson et al., 2018; Jordan & Hillis, 2006). Patients with aphasia may exhibit deficits that span spoken/written output, auditory/reading comprehension, or a combination of these potentially affected domains, which can be devastating for patients and their families. Of the predicted 795,000 strokes that occur in the United States annually, roughly 225,000 result in poststroke aphasia (National Aphasia Association, 2016), and more than 2 million Americans currently live with aphasia (Simmons-Mackie, 2018).

Many studies that investigate the poststroke aphasia population characterize their study samples based on various demographic (e.g., sex, age) and language (e.g., impairment severity, domains affected) variables; however, a comprehensive report of this information in the U.S. poststroke aphasia population is generally limited. A review by Plowman et al. (2012) found that prevalence of aphasia is higher in women compared to men and in older populations compared to younger populations. Ellis et al. (2018) reported aphasia rates from eight states (Oregon, Arizona, Colorado, Florida, Kentucky, North Carolina, South Carolina, and Arkansas) over the span of 2 years using the Agency for Healthcare Research and Quality Healthcare Cost and Utilization Project State Inpatient Database. In their sample of 152,972 patients with stroke, aphasia occurred 18% of the time (Ellis et al., 2018), which was consistent with a previous report (Roger et al., 2012).

While some poststroke survivors make rapid language recovery, others are faced with more arduous rehabilitation processes. Clinicians and researchers are currently unable to predict individual recovery profiles. The first 3 months following stroke yield the greatest spontaneous language recovery, but improvements continue to be noted over the course of the first year following stroke and even beyond (Bakheit et al., 2007; Culton, 1969; Laska et al., 2001; Lendrem & Lincoln, 1985; Marsh & Hillis, 2006; Nicholas et al., 1993). Despite some amount of recovery, many patients are faced with chronic deficits.

Multiple factors are known to contribute to language recovery in individuals with aphasia. Lesion-related factors include lesion location and size (Goldenberg & Spatt, 1994; Hillis et al., 2018; Kertesz et al., 1979; Pedersen et al., 1995). Additionally, successful reperfusion and resolution

of edema in the acute stage positively influences rapid recovery of language function (Hillis & Heidler, 2002). Some studies report that demographic factors, such as age, sex, handedness, and education, influence language recovery (Basso, 1992; Basso et al., 1982; Laska et al., 2001). However, these results have been contested in the literature (Lazar & Antonello, 2008; Lazar et al., 2008; Pedersen et al., 1995; Shewan & Kertesz, 1984). Race and socioeconomic status also serve as possible contributors to poststroke aphasia language function and recovery (Ellis & Peach, 2017; González-Fernández et al., 2011). Others report the importance of “acute stroke severity” as measured by broad stroke scales (e.g., the National Institutes of Health Stroke Scale; Inatomi et al., 2008; Maas et al., 2012) or acute aphasia severity (Kernbach et al., 2018; Lazar & Antonello, 2008; Lazar et al., 2010; Lendrem & Lincoln, 1985; Shewan & Kertesz, 1984).

Variables that influence neural reorganization also affect language recovery following left hemisphere stroke. Reorganization is characterized by formation of new connections, which may rely on input from preserved brain regions and may be influenced by overall brain health (degree of atrophy, white matter hyperintensities), volume of undamaged tissue, and availability of crucial neurotransmitters (Kiran & Thompson, 2019; Marsh & Hillis, 2006). Furthermore, reorganization may involve the right hemisphere, perilesional left hemisphere regions, or both at different time points (Saur et al., 2006). One factor that could influence the process of neural reorganization, which has not previously been studied with a specialized focus on language recovery, is the presence of prior stroke(s).

Studies of poststroke aphasia often exclude patients with a history of prior stroke given the uncertainty surrounding the influence that prior brain damage has on language or other functions in the context of a new lesion (Lazar et al., 2008; Nys et al., 2005). The same exclusionary criterion is often seen in language treatment studies, which may substantially limit enrollment. Given this persistent exclusion, the influence of prior stroke on language function and recovery following a later left hemisphere stroke is currently unknown.

Stroke Recurrence Outcomes

Several cohort studies have reported stroke outcomes, including mortality, recovery, and stroke recurrence. Of those large cohort studies, a subset has focused specifically on the RS population, reporting incidence and implications of recurrence. Multiple studies suggest elevated mortality rates in participants who suffered stroke recurrence, both during and after hospitalization (Aarnio et al., 2014; Erdur et al., 2015). One study by Jørgensen et al. (1997), as part of the Copenhagen Stroke Study, compared stroke severity, risk factors, and overall prognosis for patients with RS to those who had experienced first-time stroke. The authors reported that initial stroke severity, measured by the Scandinavian Stroke Scale (Scandinavian Stroke Study Group, 1985), was higher in patients with RS compared to patients with single stroke (SS). Conversely, Erdur et al. (2015) found that participants with single-event stroke and those with RS

did not differ on initial National Institutes of Health Stroke Scale scores. The Scandinavian study reported that the extent and rate of recovery between the two groups following rehabilitation did not differ significantly (Jørgensen et al., 1997). Within the group of patients demonstrating RS, those who suffered RS in the hemisphere contralateral to the initial stroke demonstrated worse functional outcomes than those who experienced RS in the ipsilateral hemisphere.

Camden et al. (2014) monitored for symptom progression and stroke recurrence in a sample of patients with TIA or minor ischemic stroke. The authors were primarily interested in motor outcomes but also included a speech score as a part of the Historic Stroke Severity Score that coarsely classified severity of dysarthria or aphasia. The authors reported that neither symptom progression nor stroke recurrence was associated with speech Historic Stroke Severity Score. McHutchison et al. (2019) conducted a prospective study examining depression as well as, cognitive and physical deficits following TIA and minor stroke. They reported that 9% of their study sample ($n = 264$) experienced stroke recurrence and that, 3 years after the initial stroke, stroke recurrence did not contribute to cognitive deficits as measured by the Montreal Cognitive Assessment and Mini-Mental State Examination (McHutchison et al., 2019).

Regarding stroke recurrence and aphasia, Erdur et al. (2015) compared rates of poststroke aphasia in patients with RS to those with SS, finding no significant differences in aphasia prevalence. Another report from the Copenhagen Stroke Study (Pedersen et al., 1995) aimed to track aphasia recovery and identify factors predictive of positive language outcomes. The factors explored in the study included age, sex, handedness, side of stroke, mortality, comorbidity, Scandinavian Stroke Scale assignment on admission, aphasia severity rating, Barthel Index on admission, and history of prior stroke. The authors reported that, while history of previous stroke was associated with initial aphasia severity, prior stroke was not a significant predictor of language recovery.

To our knowledge, no study exists that compares patients with RS versus those with first-ever stroke while using objective language evaluation. Thus, little is known about the influence of prior stroke on language function and recovery in the left hemisphere stroke population.

Study Aims

The current study aimed to address the following research questions:

1. Do patients with single left-hemisphere stroke differ from patients with a history of previous strokes in demographic (age, education), language (overall language skills, aphasia status), or stroke risk (DM status, hypertension status, lesion volume) factors?
2. When controlling for demographic and stroke risk factors, does the presence of previous stroke(s) influence (a) acute language abilities or (b) recovery by the chronic poststroke stage?

3. Within the RS group, which lesion-related factors are associated with (a) acute language abilities and (b) language outcomes at the chronic poststroke stage?

We hypothesized that patients with prior stroke (RS group) would exhibit poorer language skills compared to patients with first-ever stroke (SS group), but not after controlling for total lesion volume. Additionally, we anticipated that, for the RS group, both acute and chronic lesion volumes would be associated with acute and follow-up language performance.

Method

The methods supporting data collection and analyses presented in this article received approval from the Johns Hopkins University Institutional Review Board. All participants or their legally authorized representatives provided written informed consent.

Participants

We enrolled 181 patients who were admitted to an inpatient stroke and brain unit for acute left hemisphere stroke in our longitudinal study of language and imaging, which investigates recovery over the first year after stroke. Inclusion criteria were as follows: left hemisphere ischemic stroke, premorbid proficiency in English, ability to provide informed consent or indicate a legally authorized representative to provide informed consent, and ability to begin testing within 48 hr of consent. We included both left- and right-hand-dominant participants. Exclusion criteria were as follows: history of neurological disease affecting the brain other than stroke, impaired level of consciousness or ongoing sedation, uncorrected hearing or visual deficits, contraindication for MRI, primary hemorrhage, and lesions isolated to the brainstem or cerebellum only. Some participants had cerebellar or right hemisphere involvement in addition to predominant left hemisphere ischemia; these patients were included in the study. Hearing was informally assessed, and for patients with uncorrected hearing impairments, investigators made accommodations (e.g., examiners raised their speaking volume). We ensured that participants with corrected vision wore their glasses and/or we increased the size of the visual stimuli as needed. Participants completed testing to determine presence of visual field cuts or neglect. In instances where hearing or vision was not adequate for participation, the evaluation was discontinued, and data were excluded from the study. Additionally, participants who consented to the study but did not complete study procedures or did not have acute clinical brain MRI were excluded from the study due to incomplete data. The final sample consisted of 122 participants; mean demographic information for the entire sample is provided in Table 1.

Participants included 79 in the SS group and 43 in the RS group. For this study, RS was defined as an entirely new focal neurological deficit associated with new MRI lesions, rather than an extension of the index stroke, as

determined by a cerebrovascular neurologist (A. E. H.). An additional broad classification process was completed for all participants, despite group status, based on general location of the acute lesion. This broad acute lesion location classification system included two subgroups: “left hemisphere only” ($n = 106$) and “other” ($n = 16$). The “Other” subgroup included those participants with cerebellar involvement in addition to acute left hemisphere ischemia ($n = 4$), acute bilateral lesions ($n = 8$) for whom the left hemisphere involvement was greater than that of the right, or a combination of bilateral (left > right) involvement and acute cerebellar lesions ($n = 4$).

For participants with RS, an additional broad classification was assigned based on the general location of the chronic stroke, which included three subgroups: (a) left hemisphere ($n = 9$), (b) right hemisphere ($n = 6$), and (c) other ($n = 28$). Prior strokes that were classified as “other” included chronic lesions located in both hemispheres ($n = 10$) or prior strokes located in either the cerebellum or the brainstem, often with additional cerebral involvement ($n = 18$). The participants with RS enrolled in the study at the time of their second stroke; therefore, retrospective information regarding the type and consequences of the initial stroke was unknown, including the number of individuals who presented with aphasia following their initial stroke. Note that most participants in the RS group had very small chronic lesions, many of which we suspect were asymptomatic.

Language Assessment and Aphasia Status Determination

The primary outcome was global language abilities, measured by standardized behavioral language assessments. Participants completed either the Boston Diagnostic Aphasia Examination (BDAE; Goodglass et al., 2000) or the Western Aphasia Battery-Revised (WAB-R; Kertesz, 2006) approximately 3.3 ± 2.6 days following acute left hemisphere stroke onset. Testing was completed by trained lab members or licensed speech-language pathologists. Fifty participants completed the BDAE, while 72 participants completed the WAB-R. To equate language skills on these two measures, a language summary z score was derived for each participant using comparable subtests from the BDAE and WAB-R. A z score for each individual for each time point was generated relative to language task performance of the other participants in the present sample. Specifically, z scores were calculated by subtracting each participant’s performance on specific subtests (listed below) from the overall patient group mean performance on that subtest and then dividing this value by the patient group standard deviation. This method was used given the wide range of language deficit severity of the study sample, ranging from minimal to severe. Subtests included from both assessments focused on auditory comprehension and spoken output abilities. Auditory comprehension was measured by the following subtests from the BDAE, namely, Word Comprehension, Complex Ideational Material, and Commands, and the following subtests from

Table 1. Mean demographic factor information for entire sample, single stroke (SS), and recurrent stroke (RS) groups.

Factor	Total sample	SS	RS
<i>n</i>	122	79	43
Age (in years)	59.2 ± 13.0	56.6 ± 13.4	64.1 ± 10.9
Education (in years)	13.3 ± 2.8	13.8 ± 2.7	12.6 ± 2.9
Sex	Female: 52 Male: 70	Female: 35 Male: 44	Female: 17 Male: 26
Race/ethnicity	White: 54 Black: 64 Hispanic/Latinx: 3 Asian: 1	White: 39 Black: 37 Hispanic/Latinx: 2 Asian: 1	White: 15 Black: 27 Hispanic/Latinx: 1 Asian: 0
Handedness	Right: 112 Left: 6 Unknown: 4	Right: 74 Left: 4 Unknown: 1	Right: 38 Left: 2 Unknown: 3

the WAB-R, namely, Auditory Verbal Comprehension, Auditory Word Recognition, and Sequential Commands. Spoken output was measured using the following subtests from the BDAE, namely, Word Repetition, Sentence Repetition, Responsive Naming, and Confrontation Naming, and the following subtests from the WAB-R, namely, Repetition, Object Naming, Word Fluency, Sentence Completion, and Responsive Speech. After *z* scores were calculated for each subtest, they were averaged to generate an overall language summary *z* score for each participant.

A subset of the sample (*n* = 31; SS: *n* = 21, RS: *n* = 10) completed follow-up language evaluation several months after their acute left hemisphere ischemic event, ranging from 4.6 months (128 days) to 26.0 months (748 days) post stroke onset ($M_{\text{time}} = 11.22$ months or 314.25 days), which allowed for a longitudinal comparison of performance on language assessments. Follow-up language scores were calculated identically to the acute scores, using a language summary score *z* score derived from select subtests of either the BDAE or the WAB-R, depending on which assessment was completed with the patient initially.

We identified patients within the cohort who presented with aphasia following their acute stroke by conducting an in-depth chart review of their medical record. A total of 55 participants presented with acute-onset aphasia (SS: *n* = 39; RS: *n* = 16). Of the sample that completed follow-up testing (*n* = 31), 15 presented with aphasia at the acute time point.

Neuroimaging and Volume Extraction

All lesion tracings were completed by trained lab members (E. B. G., E. L. M., and S. M. S.). Diffusion-weighted imaging (DWI) is an optimal method for detecting acute ischemic stroke (Baird & Warach, 1998; Bammer, 2003; Drake-Pérez et al., 2018; Merino & Warach, 2010; Moseley et al., 1990; Wessels et al., 2005). Therefore, to capture acute lesion size, we manually traced hyperintense areas in every slice of the acute DWI trace (*b* = 1000) map for every participant.

Unlike DWI, fluid-attenuated inversion recovery (FLAIR) images are useful for detecting intracranial abnormalities other than stroke and detecting chronic strokes

(Alexander et al., 1996; Ashikaga et al., 1997). As such, to capture chronic lesion volume, we manually delineated hyperintense regions, slice by slice on FLAIR images for participants within the RS group. In extremely rare cases, if the acute stroke resulted in tissue damage that surrounded the previous stroke, we ensured that we were not accounting for the same damaged voxels in both the acute and chronic lesion maps.¹ Upon completion of lesion tracings on DWIs and FLAIR images, study researchers (E. B. G., E. L. M., S. M. S., and B. L. B.) reached consensus regarding the lesion tracings with input from a cerebrovascular neurologist (A. E. H.).

Next, lesion maps representing the stroke volume and the corresponding images used for lesion tracing were warped to Montreal Neurological Institute (MNI) space (Brett et al., 2001). For acute lesion maps, we used a bespoke pipeline optimized for DWIs using segmentation, bias correction, and normalization routines from SPM8 (Ashburner et al., 2013). Chronic volume tracings were normalized using the MR-Segment Normalize function of the Clinical Toolbox (Rorden et al., 2012). Within this procedure, the pathological scans (i.e., FLAIR images in the current study) and lesion maps were registered to T1-weighted images; the lesion was masked out; and segmentation, bias correction, normalization, and smoothing routines from SPM8 were applied to the anatomical images. Two trained researchers (E. L. M. and E. B. G.) reviewed the accuracy of normalized images. Once images were normalized, lesion volumes were extracted using NiiStat software (<https://github.com/neurolabusc/NiiStat>). Lesion overlap maps depicting only acute lesion volumes were constructed for the SS group (see Figure 1A) and the RS group (see Figure 1B). Additionally, a separate lesion overlay map was derived for the RS group displaying only the chronic stroke volumes (see Figure 1C).

Hereafter, “acute lesion volume” refers to volumes traced on DWIs. Given that all of the participants presented with acute ischemic stroke, acute lesion volumes were extracted and analyzed for all participants in both the

¹High spatial overlap between the acute and prior stroke lesions occurred in only one participant.

Figure 1. Lesion overlay maps displaying acute lesion volume of the single-stroke group (A), acute lesion volume of the recurrent stroke (RS) group (B), and chronic lesion volume of the RS group (C). Note this image is displayed in radiologic convention, such that the left hemisphere is presented on the right side of the screen. The scale presented in Part C of this image reaches 1, suggesting that there was no lesion volume overlap in this specific map.

SS and RS groups. The term “chronic lesion volume” refers to the lesion volume traced on FLAIR images for the RS group only. “Total lesion volume” is the sum of acute lesion and chronic lesion volume in RS or equal to acute lesion volume in SS.

Statistical Analyses

We conducted all analyses in R (R Core Team, 2019). To address the first study aim, we used Wilcoxon or chi-square tests to determine between-group (SS–RS) differences in demographic (age, years of education), stroke (acute and total lesion volumes, diabetes, and hypertension), and language (e.g., acute language summary z scores, follow-up language summary z scores) variables. Note that we used nonparametric tests for continuous variables to account for the uneven group sizes and the nonnormal distribution of data. We also corrected for multiple comparisons at a false discovery rate of $q < .05$. To address the second aim, we then conducted linear regression analyses to determine if group status (SS vs. RS) was associated with acute and follow-up language summary z scores while controlling for demographic (age and years of education) and stroke/medical (diabetes, hypertension, total lesion volume, and broad acute lesion classification) factors.

Finally, to address the third aim, we conducted hierarchical regression analyses by running three separate regression models using data from the RS group only. The first regression model included only acute lesion volume as a predictor of acute language scores. The second model included both acute lesion and chronic lesion volumes, and the third included acute lesion volume, chronic lesion volume, and chronic lesion classification. The first two nested regression models were replicated for those patients in the RS group who completed follow-up testing. We were unable to replicate the third model including lesion location due to inadequate power for this analysis.

Results

Between-Group Comparisons in Demographic, Stroke, and Language Factors

Table 2 shows all between-group statistical comparisons of demographic and stroke variables. Figure 2 presents visual comparisons of group comparisons of language factors, including number of cases of aphasia per group (see Figure 2A) and language summary z scores at the acute and chronic follow-up stages (see Figures 2B and 2C, respectively). The SS and RS groups did not differ in total lesion volume, $W = 1712$, $p = .945$, $q = .945$; frequency of DM, $\chi^2 = 2.806$, $p = .093$, $q = .150$; or frequency of aphasia at the acute time point, $\chi^2 = 1.208$, $p = .272$, $q = .311$. Most notably, they did not differ in acute language summary z score, $W = 1477$, $p = .236$, $q = .311$, or follow-up language summary z score, $W = 64$, $p = .087$. There were some differences between groups such that participants in the RS group tended to be older, $W = 2255.5$, $p = .003$, $q = .023$; have smaller acute

lesion volumes, $W = 1306$, $p = .036$, $q = .094$; have fewer years of education, $W = 1134.5$, $p = .030$, $q = .094$; and have more diagnosed cases of hypertension, $\chi^2 = 3.837$, $p = .050$, $q = .100$, as compared to the SS group; although, only age survived correction for multiple comparisons.

The primary outcome measure, the language summary z score, represents global language skills and was calculated using comparable subtests of the BDAE and WAB-R. The breakdown of performance across specific language functions, represented by the subtests of the BDAE and WAB-R that were used to calculate the language summary score, can be found in Supplemental Materials S1–S4. Averages are grouped by SS, RS, and Total Group. Specifically, acute and follow-up average performances for BDAE subtests are presented in Tables 1 and 2, respectively. Acute and follow-up average performances for WAB-R subtests can be found in Tables 3 and 4, respectively.

Across the sample and subsamples, auditory comprehension and spoken production were worse at the acute time point relative to greatly improved performance at the follow-up testing session, with the exception of some WAB-R subtests for participants with RS (see Supplemental Materials S1–S4). At the acute time point, deficits were distributed across auditory comprehension and spoken language subtests, such that there was not one subtest or group of subtests where ceiling performance was reached. At follow-up, however, ceiling performance was achieved for the Commands and Responsive Naming subtests of the BDAE. At the acute time point, naming abilities appeared to be a relative weakness for both participants with SS and those with RS as measured by the Confrontation Naming subtest of the BDAE and the Object Naming subtest of the WAB-R.

Group Status and Other Predictors of Acute and Follow-Up Language Skills

The multivariable linear regression model investigating whether group status predicted acute language summary z score, while controlling for total lesion volume, age, education, diabetes status, hypertension, and acute infarct classification (left hemisphere [LH] or other), was significant, $F(7, 114) = 18.42$, $p < .001$, adjusted $R^2 = .502$. Controlling for other variables in the model, factors that significantly predicted acute language z scores included total lesion volume, $t = -10.957$, $p < .001$; age, $t = -2.398$, $p = .018$; and acute infarct classification, $t = -2.310$, $p = .023$. These findings suggested that better performance was seen in patients who presented with smaller total lesion volumes, were younger, and presented with acute infarct classified as “other.” See Table 3 for comprehensive results of this linear regression model. Note that the factor of interest, group status, was not a significant predictor of acute language score even when controlling for relevant demographic and stroke factors.

We replicated the multivariable linear regression model for patients with follow-up behavioral data, to determine if group status predicted follow-up language

Table 2. Results of between-group comparisons of demographic and stroke variables.

Variable	Statistic	<i>p</i> value	Correction for multiple tests	<i>M</i> ± <i>SD</i>
Age (in years)	<i>W</i> = 2255.5	<i>p</i> = .003**	<i>q</i> = .023*	SS: 56.6 ± 13.4 RS: 64.1 ± 10.9
Education (in years)	<i>W</i> = 1134.5	<i>p</i> = .030*	<i>q</i> = .094	SS: 13.8 ± 2.7 RS: 12.6 ± 2.9
Acute lesion volume (mm ³)	<i>W</i> = 1306	<i>p</i> = .035*	<i>q</i> = .094	SS: 2,793.892 ± 5,747.91 RS: 1,510.75 ± 3,762.70
Total lesion volume (mm ³)	<i>W</i> = 1712	<i>p</i> = .945 (<i>ns</i>)	<i>q</i> = .945	SS: 2,793.89 ± 5,747.91 RS: 1,972.32 ± 4,083.63
Acute language summary <i>z</i> score	<i>W</i> = 1477	<i>p</i> = .236 (<i>ns</i>)	<i>q</i> = .311	SS: 0.0018 ± 0.6554 RS: -0.0033 ± 0.5331
Follow-up language summary <i>z</i> score	<i>W</i> = 64	<i>p</i> = .087 (<i>ns</i>)	—	SS: 0.0541 ± 0.4869 RS: -0.1138 ± 0.4836
Number of positive cases of diabetes	χ^2 = 2.806	<i>p</i> = .093 (<i>ns</i>)	<i>q</i> = .150	SS: 32/79 RS: 25/43
Number of positive cases of hypertension	χ^2 = 3.84	<i>p</i> = .050	<i>q</i> = .100	SS: 61/79 RS: 40/43
Number of patients with acute aphasia	χ^2 = 1.21	<i>p</i> = .272 (<i>ns</i>)	<i>q</i> = .311	SS: 39/79 RS: 15/43

Note. SS = single stroke; RS = recurrent stroke; *ns* = not significant.

*p/*q* < .05. **p/*q* < .01.

abilities while controlling for demographic (age, education) and stroke (DM and hypertension statuses, total lesion volume, and acute lesion classification) variables. It is worth mentioning that participants who completed follow-up testing in the SS and RS groups did not have significantly different acute lesion volumes, *W* = 92, *p* = .603.

The model was significant, $F(7, 23) = 72.36$, $p < .001$, adjusted $R^2 = .943$, and both smaller total lesion volume, $t = -18.787$, $p < .001$, and higher education, $t = 5.181$, $p < .001$, significantly predicted better follow-up language abilities. The primary factor of interest, group, did not significantly predict language recovery, $t = -1.079$, $p = .292$.

Figure 2. Language outcomes data. Part A presents the number of participants in the recurrent stroke (RS) and single stroke (SS) groups who presented with aphasia following their acute left hemisphere stroke. The two density plots display visual comparisons of acute language summary *z* score (B) and follow-up language summary *z* score (C) between the SS and RS groups.

Table 3. Results of multivariate linear regression predicting acute language scores from demographic and stroke variables.

Coefficient	Estimate	Standard error	t value	p value
Group	−0.005	0.044	−0.122	.903 (<i>ns</i>)
Total lesion volume	−0.008	0.001	−10.957	< .0001***
Age	−0.008	0.003	−2.398	.018*
Education	−0.013	0.015	−0.870	.386 (<i>ns</i>)
Diabetes status	0.003	0.040	0.064	.949 (<i>ns</i>)
Hypertension status	0.002	0.055	0.045	.965 (<i>ns</i>)
Acute lesion classification	−0.135	0.058	−2.310	.023*

Note. *ns* = not significant.

* $p < .05$. *** $p < .001$.

Comprehensive results of this multivariable linear regression can be found in Table 4.

Lesion Predictors of Language Skills in RS

We conducted hierarchical regression analyses of only RS participant data to determine the role of acute versus prior stroke on acute language function. The first model predicting acute language summary z scores from acute lesion volume alone was significant, $F(1, 41) = 28.00$, $p < .001$, $R^2 = .406$, such that patients who presented with larger acute lesion volumes had lower language scores. Chronic lesion volume was then added to the regression model, and the model remained significant, $F(2, 40) = 13.67$, $p < .001$, adjusted $R^2 = .376$. However, while acute lesion volume was significantly associated with acute language summary z scores, $t = -5.048$, $p < .001$, chronic lesion volume was not, $t = 0.141$, $p = .889$. There was no significant difference in the predictive power of these two models, $p = .889$. Finally, chronic lesion location (LH, right hemisphere [RH], or other) was added to the previous model. Again, the model remained significant, $F(4, 38) = 7.407$, $p < .001$, adjusted $R^2 = .379$, and acute lesion volume remained the only significant predictor of acute language summary z score, $t = -5.195$, $p < .001$. Chronic lesion volume, $t = 0.514$, $p = .610$, and chronic lesion classification, with LH as the referent (other: $t = 1.254$, $p = .218$; RH: $t = 1.349$, $p = .185$), were not found to be significant. Predictive power of the first

and third models, $p = .541$, and the second and third models, $p = .349$, were not significantly different.

Hierarchical regression analysis was used again to determine if acute and/or chronic lesion volumes predicted follow-up language z scores within the participants with RS who completed follow-up testing. The model predicting follow-up language performance from acute lesion volume was significant, $F(1, 8) = 98.47$, $p < .001$, $R^2 = .925$. The model remained significant when chronic lesion volume was added, $F(2, 7) = 95.79$, $p < .001$, adjusted $R^2 = .955$, and both acute lesion volume, $t = -2.570$, $p = .037$, and chronic lesion volume, $t = -2.814$, $p = .026$, significantly predicted follow-up language summary z scores. When comparing predictive power of these two models, the model including both acute and chronic lesion volumes was stronger compared to the model including only acute lesion volume, $p = .026$.

For all regression models, we checked model assumptions using the “car” (Fox & Weisberg, 2011), “MASS” (Venables & Ripley, 2002), and “gvlma” (Pena & Slate, 2014) packages in R. We found that outliers significantly affected model residuals, $p < .001$, in the regression addressing acute language scores and that skewness was an issue across all models addressing aims involving the acute language data. As such, we reran the aforementioned analyses using robust regression with Huber weights, which de-weights outliers. The main findings were unchanged; acute and total lesion volumes continued to be significantly associated with language scores. Complete results from the robust regression

Table 4. Results of multivariate linear regression predicting follow-up language scores from demographic and stroke variables.

Coefficient	Estimate	Standard error	t value	p value
Group	−0.029	0.027	−1.079	.292 (<i>ns</i>)
Total lesion volume	−0.007	0.000	−18.787	< .0001***
Age	0.001	0.002	0.437	.666 (<i>ns</i>)
Education	0.040	0.008	5.181	< .0001***
Diabetes status	−0.016	0.023	−0.686	.499 (<i>ns</i>)
Hypertension status	−0.006	0.031	−0.179	.859 (<i>ns</i>)
Acute lesion classification	0.057	0.037	1.542	.137 (<i>ns</i>)

Note. *ns* = not significant.

*** $p < .001$.

analyses can be found in Supplemental Materials S5–S8. Of note, we found no violations in model assumptions for any models addressing aims surrounding follow-up language data.

Discussion

Stroke Recurrence's Influence on Language

In this study, we aimed to determine if (a) patients with SS and those with RS differ in demographic, language, or stroke variables; (b) stroke group membership (i.e., SS vs. RS) is associated with acute language function and/or recovery, controlling for a variety of factors; and (c) lesion-related factors are associated with acute and chronic language abilities within the RS group. At the acute and follow-up (chronic stage recovery) time points, language scores did not differ between the patients in the SS group versus those in the RS group. Furthermore, history of prior stroke defined by SS or RS group status was not a significant predictor of language abilities, even when controlling for a variety of demographic and stroke variables. From these findings, the presence of previous stroke alone, based on a binary yes/no classification, does not appear to influence acute language abilities or future recovery in patients following an acute left hemisphere stroke.

We acknowledge that this finding may not be true for all individuals with histories of previous stroke. In fact, as discussed below, chronic lesion volume proves to be important when considering language recovery in our small cohort of participants with RS at the follow-up testing time point. Given what is known about neural reorganization, it is reasonable to expect that previous damage to areas within the language network could hinder functional reorganization following an additional LH stroke. For example, if a participant had a sizeable previous lesion in the left posterior superior temporal gyrus, their recovery process following an additional LH stroke could look very different compared to an individual with a history of an asymptomatic stroke sustained to the left striatum. Recovery during the subacute into chronic poststroke phases relies heavily on the formation of connections between areas that are spared from damage, including regions in the contralesional hemisphere. Thus, in the event an individual suffered a previous stroke that resulted in either (a) extensive brain damage, (b) focal brain damage to critical structures within the left hemisphere language network, or (c) focal brain damage to right hemisphere homologues of crucial left hemisphere regions, we might expect functional reorganization would be less robust due to restricted functional tissue to build on, compared to an individual with RS whose chronic stroke was small and asymptomatic.

Jørgensen et al. (1997) reported that patients who presented with RS in the cerebral hemisphere contralateral to the initial stroke exhibited reduced acute stroke severity (using a global stroke scale measure) compared to patients with RS in the ipsilateral hemisphere; however, both groups recovered similarly and as well as patients with only one

stroke. The authors concluded that RS survivors should receive similar rehabilitation as SS survivors (Jørgensen et al., 1997). Critically, this conclusion was based on the use of a broad stroke scale and not fine-tuned language evaluation. Additionally, only lesion size of the new stroke was considered. In this study, we did not have enough participants in the RS group who completed follow-up testing to add chronic lesion location to the regression model; future studies with larger longitudinal sample sizes should include chronic lesion location as a factor in analyses.

It is worth noting that, although the comparison was not significant, there was a trend of lower language summary z scores for the participants with RS at follow-up. This effect was likely driven by the relatively small sample (10 participants in the RS group completed follow-up testing) and was primarily influenced by one participant who scored -1.42 at the follow-up time point (see Figure 2C) compared to -1.63 at the acute phase. Thus, if the prior stroke substantially contributes to the total volume of damaged tissue, poorer language outcomes are likely, consistent with our speculation above and which is described in more detail in the next section.

Results from both linear regression models predicting language scores (at the acute and chronic follow-up time points) demonstrated that total lesion volume served as the strongest predictor, whereas the factor of interest—group status—did not approach significance in predicting language abilities. Furthermore, the linear regression model predicting acute language summary scores for just the RS group, which included acute lesion volumes and chronic lesion volumes as separate predictors, revealed that acute lesion volume was a significant predictor and chronic lesion volume was not. Taken collectively, findings pertaining to acute language performance suggest that, for our sample, total volume of damaged tissue was driven primarily by acute lesions. These findings highlight the critical contribution that acute lesion volume has on immediate language abilities. The same conclusion cannot be said for the RS group when considering follow-up performance, which we will address in the following section.

Other studies that have investigated language function following stroke have also cited volume of damaged brain tissue as a key factor in determining language impairment and recovery (Kertesz et al., 1987, 1979; Laska et al., 2001; Watila & Balarabe, 2015). Clinicians and scientists may see “recurrent stroke” listed in a patient’s medical history and assume that a history of prior stroke in and of itself implies a greater extent of brain damage and therefore more severe deficits, yet this may not be the case. Rather than immediately concluding that a patient with a new LH stroke and a history of prior infarct will present with more severe deficits, clinicians and researchers should consider lesion factors, such as how much tissue has been damaged and the locations of the lesions. Speech-language pathologists and other clinicians are encouraged to review neuroimages or imaging reports, as these documents can provide insight into suspected deficits prior to evaluation. Given the critical role that total lesion volume has on

language function, it is worth remarking that a history of prior stroke does not itself indicate that total volume of brain damage in the RS population is larger than that of those presenting with a first-time event. In fact, in our sample, total lesion volume was smaller in the RS group.

At the acute time point, other factors (in addition to total lesion volume) predicted language scores, including age and acute lesion location classification. As age increased, language summary z score decreased, which aligns with previous studies (Holland et al., 1989; Laska et al., 2001). The location of the acute lesion, when controlling for the other demographic and stroke variables, was also associated with acute language scores. Specifically, controlling for other variables in the model, patients with lesions limited to the left cerebral hemisphere had significantly poorer language skills than patients with lesions classified as “other.” Visual inspection of Figure 1 reveals that the RS lesion overlay map (see Figure 1B) has a patchier appearance compared to the SS group (see Figure 1A), which can be attributed to the small RS sample size as well as the relatively small lesions in many participants in this sample, including the RS subgroup.

In our study, we only assessed global language scores, which included performance across multiple auditory comprehension and verbal expression subtests from the BDAE and WAB-R; in this context, “poorer” skills suggest that this global language score was reduced relative to performance of other participants. Prior studies investigating poststroke language function have not focused on comparing pure LH stroke survivors to individuals who sustain LH injury in addition to other brain regions (i.e., the RH, cerebellum, or brainstem) since individuals with brain damage outside of the cortex are often excluded from language studies. Further investigation of the role of additional damage to the RH, cerebellum, and/or brainstem in the event of acute left hemisphere ischemia is warranted.

Although not a significant predictor acutely, education was associated with follow-up language performance, where individuals with greater number of years of education achieved higher language follow-up scores. Some studies have supported education as a factor that contributes to long-term poststroke language function (González-Fernández et al., 2011), although other studies refute the role of education on language recovery (Connor et al., 2001; Lazar et al., 2008; Plowman et al., 2012). In this study, we did not aim to thoroughly investigate the relationship between certain demographic variables and language outcomes, and therefore, patients were not asked to report socioeconomic information. Because of this fact, we did not include these variables in our planned comparisons. However, certain variables (i.e., sex, race/ethnicity, handedness) have been associated with stroke and aphasia outcomes. Thus, as a follow-up, we compared the SS and RS groups in additional available demographic factors; there was no difference in the distribution of Black versus White (and few Asian or Latinx) participants, $\chi^2 = 3.220$, $p = .359$; between men versus women, $\chi^2 = 0.101$, $p = .751$; or dextral versus sinistral participants, $\chi^2 = 2.865$, $p = .239$, between the SS and RS groups. Note that

these comparisons are uncorrected. Nonetheless, it is important to note that, in addition to racial disparities in first-time stroke prevalence, racial and ethnic minorities experience disparate access to quality care following a stroke event (Cruz-Flores et al., 2011). Factors such as education level and socioeconomic status have been associated with this observation (Skolarus et al., 2020). Future studies of language recovery in poststroke aphasia should explicitly set out to determine the influence of these factors, as they have the potential to impact patient outcomes.

Lesion Predictors of Language Function in RS

Another main aim of the study was to identify lesion factors that contribute to language abilities in RS. For the patients in the RS group, we deliberately separated the acute and chronic volumes so that we could determine their distinct impact on language abilities. At the acute time point, we found that only acute lesion volume (and not chronic lesion volume or location) was significantly associated with language scores in a group of participants with relatively small previous lesions, few of which were located in the left cerebral hemisphere. From these findings, we can infer that volume of the acute left hemisphere stroke alone is critical in predicting acute language function, when the size of the prior stroke was small.

The results differed for the follow-up language scores in that both acute and chronic lesion volumes influenced follow-up language function. At chronic follow-up, larger chronic lesion volumes resulted in weaker performance on language tasks. Of note, only 10 of the 31 participants who completed follow-up data were in the RS group; this limited sample may have influenced the findings. This is a limitation of the study, and additional investigation of the potential influence of prior stroke volume on language recovery is needed.

Based on the dichotomous (e.g., SS, RS) group classification system, one potential explanation for the lack of influence of prior stroke on language function is that the chronic lesions in our sample tended to be relatively small. No prior study investigating RS has reported lesion volumes of the chronic and new lesions; therefore, we are unsure if this observation is incidental or consistent with other clinical samples. Our sample represented a cohort of new LH stroke patients admitted to a large urban hospital system within a 12-year time span and is likely representative of the stroke population in our geographic location. The average chronic lesion volume for patients in the RS group was quite small compared to the acute lesion volumes in either group (see Table 2). On average, the chronic volumes were one third the size of the acute volumes. Most strokes (first or subsequent) are small (median reported across population studies is 2.5–8.8 cm³; Zakaria et al., 2008), and asymptomatic strokes often represent the smallest of these strokes. Furthermore, survival is lower for larger strokes, so it is unsurprising that most of the chronic lesions were small. Future studies should aim to include participants with a spectrum of chronic stroke lesion sizes. In such a study, if participants with larger prior strokes are enrolled, two

potential accounts for a finding that previous stroke would result in worse language recovery include the following: (a) RS patients with large prior lesions may have damage to brain areas that could otherwise have been used to assume the function of the acutely damaged areas, or (b) areas that would otherwise be available to compensate for damaged language network nodes have already been repurposed to compensate for the previous stroke.

Clinical and Research Implications

Our results can aid in better understanding aphasia prognosis after stroke. Unsurprisingly, accumulating more damage to the brain puts patients at a greater risk for worse outcomes, even though the presence of a prior stroke itself is not the critical prognostic factor.

Based on our findings, binary stroke group classification of SS or RS is not predictive of language function at acute and follow-up time points and therefore is not informative regarding language recovery. Instead, the total amount of brain damage is the most important factor for which to account. Location of prior and acute lesions may also contribute significantly and ought to be considered.

The conclusions of this study are drawn from a measure of global language function, and future studies should consider studying more specific language functions such as auditory comprehension, repetition, and naming. Supplemental Materials S1–S4 offer descriptive information regarding average performance of the SS, RS, and Total Group on the different subtests of the BDAE and WAB-R. The sample tended to present acutely with diffuse deficits, though accuracy for naming appears to have been notably impacted in both participants with SS and participants with RS. Comparison of Tables 3 and 4, which contain acute and follow-up WAB-R averages, shows that the RS group did not show the same recovery pattern as participants with SS who completed follow-up testing. The key message is that volume of accumulated (e.g., both chronic and acute lesions) brain damage is the most important determinant of later language outcomes.

Historically, patients with RS have been excluded from studies investigating poststroke language function in aphasia as well as in treatment studies targeting improved language outcomes in the poststroke aphasia population. Yet, RS is common (one in four annual strokes are recurrent in the United States) and deserves further attention in the context of language function and recovery. An additional study of a larger longitudinal sample to investigate effects of prior stroke on subsequent language outcomes is needed. Researchers should consider enrolling participants with a history of RS into clinical trials, because we must begin to understand how this sizeable population recovers language function following a new stroke, especially in response to evidence-based language treatments.

Study Limitations and Future Directions

Not all participants completed the same language assessment because procedures changed over the course of

this longitudinal study. Although the WAB-R and BDAE measure similar linguistic functions, the specific tasks are not identical. We attempted to minimize the influence of language battery on the language summary scores by generating within-assessment *z* scores using comparable subtests. Nonetheless, future studies should utilize the same language assessment protocol across all participants.

Furthermore, mostly due to attrition, only a subset of participants enrolled in the study completed follow-up testing, which resulted in a much smaller ($n = 31$; $SS = 21$, $RS = 10$) number of participants for whom we were able to make longitudinal comparisons. A larger sample of individuals with both acute and chronic testing would improve the strength of the findings.

Compared to the sample of individuals who completed acute testing, participants who completed follow-up testing did not differ in terms of acute lesion volume, $W = 1983.5$, $p = .676$; age, $W = 1617$, $p = .214$; sex, $\chi^2 = 0.02482$, $df = 1$, $p = .336$; years of education, $W = 2026$, $p = .114$; or acute language summary score, $W = 1981$, $p = .683$. Therefore, it is unlikely that demographic, stroke, or language factors contributed to attrition. Instead, attrition may have occurred due to failure to successfully reach participants, transportation issues, further health complications unknown to us, scheduling conflicts (e.g., in the setting of rehabilitation), or change in disposition, such as needing to transition to assisted living facilities following stroke.

Given the small number of participants studied at the follow-up time point, we were underpowered for the linear regression model that included all predictor variables. Indeed, there is some evidence for model overfit, given the high degree of explained variance in this model. Heterogeneity of stroke patients is also a limiting factor in identifying significant effects, especially as it relates to statistical power. We acknowledge this is a major limitation of the follow-up performance results, which should be interpreted with caution. However, this study is the first of its kind to specifically investigate the influence of prior stroke on language function, and these findings serve as preliminary work that should be replicated and expanded upon using a larger sample of individuals. In future, prospective work, researchers should conduct power analyses that account for attrition rates, especially given the inherent variability in poststroke samples that must be overcome.

Participants in the RS group enrolled in this study at the time of RS, and chronic symptom information was unavailable for review as some participants sought care at outside hospital systems, while others may have not pursued medical attention. Relative to acute volumes, chronic lesions were small, and we suspect that the majority of the participants with RS did not demonstrate symptoms following their chronic stroke. Most strokes (particularly asymptomatic ones) are small, and survival is higher for small strokes, so it is unsurprising that most of the chronic lesions were small.

The classification system that we used in this study to distinguish the location of lesions was very coarse. Based on the findings, it is clear that future work should investigate

lesion location in a more specific manner (e.g., using a voxel-based lesion symptom mapping approach) to identify specific regions associated with positive and negative outcomes. Additionally, we used a coarse language measure: The language summary z score was a global measurement of language abilities. Further work investigating how specific subdomains of language function in patients with RS compared to those with SS would be valuable in characterizing language deficits in these populations.

Finally, we did not control for any interventions that might have influenced language outcomes. For example, the amount of successful reperfusion at the acute time point has been shown to impact the degree of language recovery (Hillis et al., 2002; Marsh & Hillis, 2006). Evidence is also emerging supporting the influence of pharmaceutical interventions, such as selective serotonin reuptake inhibitors, on language function (Hillis et al., 2018). Moreover, frequency and quality of behavioral language interventions likely influenced language recovery (Bhagal et al., 2003; Doogan et al., 2018; Poeck et al., 1989), but these variables were not quantified in our prospective, longitudinal study that provided the data for these analyses.

Conclusions

We found that single-event stroke versus RS group membership was not associated with language performance at the acute or follow-up time point. However, we expect that patients with prior strokes that contribute substantially to total lesion volume (i.e., large previous strokes) may have poorer recovery. Clinicians should not assume that patients with RS will exhibit worse language than individuals with first-ever stroke. Clinical researchers should consider including participants with a history of prior stroke in their clinical trials so long as they account for volumes of brain tissue damaged from both previous and current strokes.

Author Contributions

Emily B. Goldberg: Conceptualization (Equal), Data curation (Lead), Formal analysis (Supporting), Methodology (Supporting), Project administration (Lead), Writing – original draft (Lead). **Erin L. Meier:** Conceptualization (Lead), Data curation (Supporting), Formal analysis (Lead), Methodology (Equal), Project administration (Equal), Resources (Lead), Supervision (Lead), Writing – review & editing (Lead). **Shannon M. Sheppard:** Conceptualization (Supporting), Data curation (Supporting), Methodology (Supporting), Supervision (Supporting), Writing – review & editing (Equal). **Bonnie L. Breining:** Conceptualization (Supporting), Methodology (Supporting), Project administration (Supporting), Supervision (Supporting), Writing – review & editing (Supporting). **Argye E. Hillis:** Conceptualization (Lead), Funding acquisition (Lead), Methodology (Lead), Project administration (Equal), Supervision (Equal), Writing – review & editing (Equal).

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