Original Article

Speech and Language Impairments After Childhood Arterial Ischemic Stroke: Does Hemisphere Matter?

Fréderique J. Liégeois, PhD [a], Cristina Mei, PhD [b], Lauren Pigdon [b], Katherine J. Lee, PhD [c, d], Belinda Stojanowski, BNurs [e], Mark Mackay, MBBS, PhD [d, e], Angela T. Morgan, PhD [b, f, *]

[a] UCL Great Ormond Street Institute of Child Health, London, United Kingdom
[b] Speech and Language Group, Murdoch Children's Research Institute, Melbourne, Australia
[c] Clinical Epidemiology and Biostatistics Unit, Murdoch Children's Research Institute, Melbourne, Australia
[d] Department of Paediatrics, University of Melbourne, Melbourne, Australia
[e] Department of Neurology, Royal Children's Hospital, Melbourne, Australia
[f] Department of Audiology and Speech Pathology, School of Health Sciences, University of Melbourne, Melbourne, Australia

ABSTRACT

Background: The association between left hemisphere stroke and acute speech and language impairment is well documented in adults. However, little is known about this association in childhood arterial ischemic stroke. Here we examined potential predictors of acute speech (dysarthria and apraxia) and language impairments after childhood arterial ischemic stroke, including site of lesion.
Methods: Children with radiologically confirmed acute arterial ischemic stroke, admitted to a tertiary pediatric hospital from 2004 to 2012, were identified from an institutional registry. We examined the prevalence of dysarthria, apraxia, and language impairment within two weeks of the stroke. Associations with age at stroke event, lesion side (left, right, or bilateral), and arterial territory affected (anterior, posterior, or both) were assessed using logistic regression.
Results: Sixty-two children with mean age eight years (range three to 17 years) were identified. Strokes were located in the left (32%), right (44%), or both hemispheres (24%). Dysarthria (74%) and language impairment (50%) were frequent. Verbal dyspraxia was less common (11%). There was little evidence that variables of interest, including site of lesion, were significantly associated with increased odds of dysarthria or language impairment (all $P > 0.49$).
Conclusions: Regardless of age, children are at high risk of communication disorders after stroke. Unlike adults, left hemisphere stroke was not associated with either speech or language impairment in our cohort, suggesting there may be bihemispheric contribution to language function. Future studies are needed to examine whether the predictors examined here determine long-term outcomes.

Introduction

Difficulties with speech and language are core stroke symptoms in adults. Speech disturbance is reported as a stroke symptom in 28% to 55% of children at initial presentation,[1-3] but there is very limited reporting of the spectrum of speech and language deficits at presentation or at long-term follow-up.[4-6] There is well-documented evidence in adults of an association between left hemisphere infarction and speech disorder (apraxia[7] and dysarthria[8]) and language impairment (aphasia).[9] It may not be appropriate to extrapolate these findings to children,[10] because of differences in stroke location, functional, organization, plasticity, and environmental factors between children and adults.[11-13] Furthermore, the influence of lesion characteristics and age at stroke are poorly characterized.

In this article, we present the largest study to date examining predictors of acute speech and language impairments in childhood arterial ischemic stroke (AIS). We hypothesized that left hemisphere strokes would be associated with higher odds of apraxia, dysarthria, and language impairment than right hemisphere strokes. In addition, we postulated that infarction in territories affecting the course of the corticobulbar tract[8,14] (as in capsular

infarcts) would be associated with dysarthria. We hypothesized that the perisylvian language networks (as in middle cerebral artery [MCA] infarcts) would be associated with apraxia and language impairment. Finally, we hypothesized that earlier age at stroke would be associated with better speech-language skills.

Methods

All children aged three to 17 years with radiologically confirmed acute AIS, admitted to the Royal Children's Hospital between January 2004 and January 2012, were retrospectively identified by institutional stroke registry and ICD-10 searches. Children aged less than three years were excluded because speech and language development is highly variable at this time and it would have been more challenging to determine linguistic pathology during the acute stage. Medical records were reviewed for documentation of acute speech disorder (apraxia and dysarthria) and language impairment (aphasia) within the first two weeks after stroke at a time when children were deemed medically stable. At this time, informal assessment by the attending speech pathologist or neurologist was recorded (see Results section for percentage of cases rated by speech pathologist versus neurologist).

Language impairment was classified as present when any language issue was reported affecting language comprehension, language production, or both. Language difficulties reported included difficulties with response initiation, understanding instructions, word finding, fluency, grammatical structure of sentences produced, and word association.

Dysarthria was classified as present when there were indications of hypernasality, "soft voice" as well as "unclear," "distorted," "mumbled," or "slurred speech." Apraxia was classified as difficulty with speech consistency, coarticulation, groping or repetition of sounds, or speech transposition errors. Data on age at the time of stroke and lesion side (left, right, or bilateral) and circulation territory (anterior, posterior, or both) of the stroke were also collected from medical records.

Statistical analysis

The prevalence of dysarthria, apraxia, and language impairment and summaries of age, lesion side, and affected circulation are reported. Left cerebral hemisphere and right cerebellar infarcts were both coded as "left" given the contralateral projections of cerebellar structures to the cortex. Age, lesion side, and affected circulation were assessed as predictors of dysarthria and language impairment using logistic regression, fitting separate univariable models for each predictor-outcome combination. Results are presented as odds ratios and 95% confidence intervals. Given the interaction effects that occur in this population,[15] we also examined whether there was evidence for an interaction between lesion side and age at the time of stroke in exploratory analyses, as our study did to have sufficient statistical power to examine these effects.

Ethics

This study was approved by the Royal Children's Hospital Human Research Ethics Committee (HREC #32031).

Results

Sixty-two children with mean age eight years (range three to 17 years) were identified (Table 1). Over three quarters had dysarthria, half had language impairment, and just over one in 10 had verbal apraxia (see Online Table). A speech pathologist diagnosed 56% (26 of 42) of the dysarthric group, 100% of the verbal apraxic

group, and all but one of the language cases. The remaining speech and language diagnoses were made by the treating neurologist. All assessments were conducted during the acute period, typically within two to five days of the stroke, although some patients were seen up to two weeks after stroke. Infarction affecting the right hemisphere and anterior circulation were most prevalent. Given the low prevalence of verbal apraxia, we were unable to analyze predictors of apraxia. Descriptively, however, only one of seven apraxic cases had a left anterior MCA that involved multiple cortical and subcortical structures. Three patients had a right infarct (two posterior cerebral arteries [PCAs] and one MCA), two of which involved cortical and subcortical structures and the third the cerebellum only. The remaining three individuals had bilateral involvement, one an MCA (subcortical), one an MCA and PCA (cortical and subcortical), and one a PCA (cortical and subcortical), all three involving multiple infarcts. A large proportion of the group had facial weakness (n = 35/62, n = 18 left-sided, n = 12 right-sided, and n = 3 bilateral or nonspecified, Table 1), and over half of all participants with dysarthria (26 of 46) had facial weakness.

Predictors of dysarthria

There was little evidence that age, lesion side, or arterial circulation were associated with dysarthria (Table 2, Figure A), and little evidence of an interaction between age and lesion side predicting dysarthria (interaction P value = 0.63), even when coding age as a binary variable (greater than 10 versus less than 10 years; P = 0.86).

TABLE 1.
Summary of Patient Characteristics

Characteristic	No. (%)
No of participants	62
Age (years), mean (S.D.)	8.5 (4.3)
Risk factors	
None specified	30 (48)
Congenital heart condition	12 (19)
Chicken pox/vasculitis	8 (13)
Moyamoya	4 (6)
Migraine history	2 (3)
Recent mild head injury	2 (3)
Genetic syndrome	2 (3)
Obesity	1 (1.5)
Lymphoblastic leukemia	1 (1.5)
Laterality, n (%)	
Left	20 (32)
Right	27 (44)
Bilateral	15 (24)
Circulation, n (%)	
Anterior	42 (68)
Posterior	17 (27)
Both	3 (5)
Topography, n (%)	
MCA	36 (58)
ACA + MCA	6 (10)
MCA + PCA	2 (3)
PCA	10 (16)
PCA + other (postcirculation)	2 (3)
Other (postcirculation)	6 (10)
Facial weakness	
Left	18 (29)
Right	14 (23)
Bilateral	3 (5)
Dysarthria, n (%)	46 (74)
Apraxia, n (%)	7 (11)
Language impairment, n (%)	31 (50)

Abbreviations:
ACA = anterior cerebral artery
MCA = middle cerebral artery
PCA = posterior cerebral artery

TABLE 2.
Predictors of Dysarthria (n = 62)

Predictor	Without Dysarthria (n = 16)	With Dysarthria (n = 46)	OR (95% CI)	P Value
Age (years), mean (S.D.)	7.8 (3.9)	8.7 (4.5)	1.05 (0.92, 1.20)	0.49
Age >10 years (vs ≤10 years)	3 (19%)	19 (41%)	3.05 (0.76, 12.19)	0.12
Laterality, n(%)				
Left	5 (31%)	15 (33%)	1	0.79
Right	8 (50%)	19 (41%)	0.79 (0.21, 2.92)	
Bilateral	3 (19%)	12 (26%)	1.33 (0.26, 6.74)	
Circulation, n(%)				
Anterior	12 (75%)	30 (65%)	1	0.69
Posterior	4 (25%)	13 (28%)	1.30 (0.35, 4.80)	
Both	0 (0%)	3 (7%)	*	

Abbreviations:
CI = confidence interval
OR = odds ratio from univariate (unadjusted) logistic regression
* n = 59 for circulation model because of categories with perfect prediction not being included in the model.
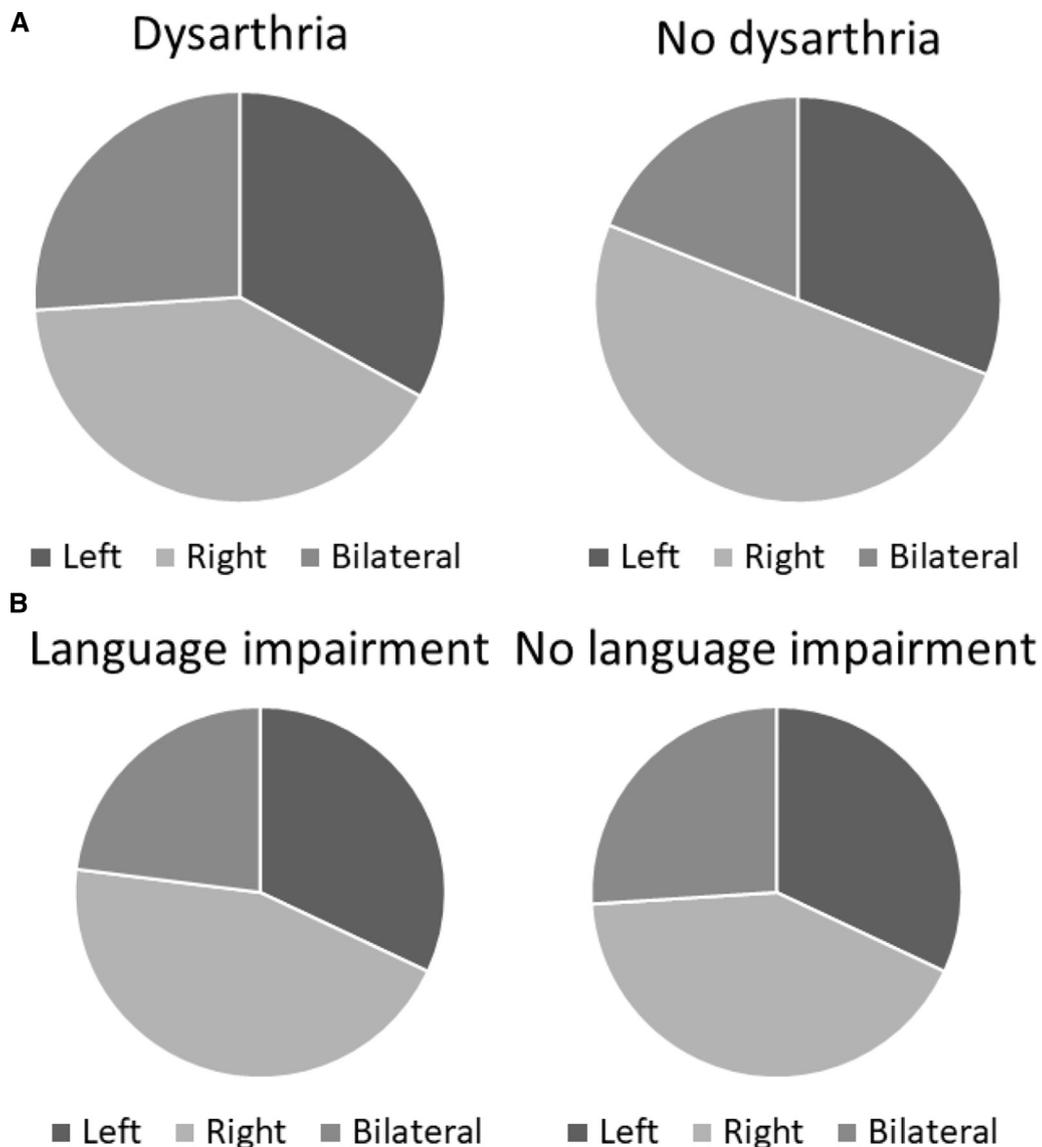

FIGURE. (A) Proportion of children who had a left, right, or bilateral stroke according to whether they did (left) or did not (right) suffer from dysarthria. (B) Proportion of children who had a left, right, or bilateral stroke according to whether they did (left) or did not (right) suffer a language impairment.

TABLE 3.
Predictors of Language Impairment (n = 62)

Predictor	Without Language Impairment (n = 31)	With Language Impairment (n = 31)	OR (95% CI)	P Value
Age (years), mean (S.D.)	8.1 (4.2)	8.8 (4.4)	1.04 (0.93, 1.17)	0.51
Age >10 years (vs ≤10 years)	9 (29%)	13 (42%)	1.77 (0.62, 5.06)	0.29
Laterality, n(%)				
Left	10 (32%)	10 (32%)	1	0.95
Right	13 (42%)	14 (45%)	1.08 (0.34, 3.42)	
Bilateral	8 (26%)	7 (23%)	0.88 (0.23, 3.34)	
Circulation, n(%)				
Anterior	20 (65%)	22 (71%)	1	0.79
Posterior	9 (29%)	8 (26%)	0.81 (0.26, 2.50)	
Both	2 (6%)	1 (3%)	0.45 (0.04, 5.40)	

Abbreviations:
CI = confidence interval
OR = odds ratio from univariable (unadjusted) logistic regression

Predictors of language impairment

There was little evidence that age, lesion side, or topography was associated with language impairment (Table 3, Figure B) and little evidence for an interaction between lesion side and age predicting language impairment ($P = 0.20$), even when coding age as a binary variable ($P = 0.36$).

Discussion

In this unselected sample of 62 children, three quarters had dysarthria, and half had language impairment in the acute phase after AIS. Despite our original hypotheses, these impairments were not significantly associated with age, lesion side, or arterial circulation.

In contrast to adults, we found little evidence that stroke lesion side is associated with dysarthria or apraxia of speech, consistent with previous pediatric findings.[10,11] As data were limited on apraxic cases, predictors could not be explored; therefore our discussion focuses on dysarthria. Functional magnetic resonance imaging (fMRI) data show that bilateral motor cortices are recruited for the speech[14] and nonspeech movements of the articulators.[16] We suggest that this bilateral representation puts children at risk for acute dysarthria after stroke, affecting either hemisphere. Given that 75% of our sample had dysarthria, an important clinical implication of our findings is that a change in speech production (such as slurred articulation) is more prevalent in childhood AIS than suggested by previous literature. Dysarthria should therefore be emphasized as an important indicator of potential childhood stroke in public awareness campaigns.

Arterial territory was not a predictor of dysarthria either. The fact that a wide range of stroke territories is associated with dysarthria indicates that the brain network involved in speech motor control is widely distributed in children. This finding is consistent with the widespread location of lesions associated with dysarthria in children previously indicated.[10]

The lack of evidence for a relationship between lesion side (left cortical and right cerebellar) and language impairment reported here is in agreement with data from the limited pediatric stroke literature.[6] As our data were collected within the first week after stroke, it is unlikely that there was time for functional reorganization of language functions. Instead, we suspect that both the left and right hemispheres are necessary for language function in childhood. This hypothesis is consistent with fMRI studies showing bilateral semantic networks and greater right hemisphere frontal involvement for language production in children than in adults.[17,18] One important clinical implication of this finding is that acute language impairment in a child should not be interpreted as a sign of left hemisphere infarct.

In our study, age at stroke was not found to be a predictor of acute speech or language outcome. In addition, there was no evidence that the relationship between age and outcome varied according to lesion side, as assessed using an interaction analysis. This negative finding had previously been reported for chronic language impairments affecting discourse skills, where earlier stroke was not associated with better outcome.[19] Furthermore, a recent study found no association between lesion side and language outcome in children and adolescents at three months to 10 years after stroke.[12] We interpret the lack of age effect in our sample as an indication that little change in speech and language lateralization occurs in the age range examined here (three to 17 years). This conclusion is in agreement with fMRI studies indicating limited changes in language lateralization in childhood.[18]

Our study was conducted during the acute period when formal speech and language tests are not appropriate to administer. In the acute stage, neurological assessments rarely include extensive speech and language evaluation. Children are unwell and disoriented at this time and lengthy standardized testing is not appropriate, nor necessary given the children typically display obvious anomalies at this time. The level of diagnostic detail reported here is, on the other hand, typical of acute pediatric centers, and therefore is clinically relevant. The impairments considered in this study were severe enough to be detected by medical officers who are not trained in speech and language pathology. It is possible that detailed evaluation would have identified further cases with less obvious speech and language impairments, and as a consequence, our data may underestimate prevalence levels. Although it is also possible that the cognitive limitations of some patients during acute presentation may have led to overestimation of language impairments, particularly in cases where formal language assessment was lacking. Another limitation of this study is the relatively small sample size that limits the statistical power to identify associations, although this is the largest study of its kind. Future work is required to evaluate speech and language outcomes into the longer-term (e.g., greater than six months after stroke) to determine whether persistent deficits in speech and language were related to lesion side, as cannot be determined by the present acute data.

Conclusions

Dysarthria is a common acute symptom of childhood AIS caused by injury to either hemisphere at any age. To a lesser extent, these children are also at high risk of acute language disorders. The results of this study suggest that both hemispheres may be necessary for language functions and speech motor control during childhood.

Author contributions: A.M., F.L., and M.M. designed the study. F.L. and A.M. wrote the manuscript. K.L. performed the statistical analysis. C.M. and L.P. performed the chart review under supervision by A.M., with recruitment support from M.M. and B.S. All authors revised the manuscript.

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pediatrneurol.2018.11.006.

References

1. Steinlin M, Pfister I, Pavlovic J, et al. The first three years of the Swiss neuro-paediatric stroke registry (SNPSR): a population-based study of incidence, symptoms and risk factors. Neuropediatrics. 2005;36:90—97.
2. Mackay MT, Wiznitzer M, Benedict SL, Lee KJ, Deveber GA, Ganesan V. Arterial ischemic stroke risk factors: the international pediatric stroke study. Ann Neurol. 2011;69:130—140.
3. Gabis LV, Yangala R, Lenn NJ. Time lag to diagnosis of stroke in children. Pediatrics. 2002;110:924—928.
4. Cnossen MH, Aarsen FK, Akker S, et al. Paediatric arterial ischaemic stroke: functional outcome and risk factors. Dev Med Child Neurol. 2010;52:394—399.
5. Gout A, Seibel N, Rouviere C, et al. Aphasia owing to subcortical brain infarcts in childhood. J Child Neurol. 2005;20:1003—1008.
6. Rowan A, Vargha-Khadem F, Calamante F, et al. Cortical abnormalities and language function in young patients with basal ganglia stroke. Neuroimage. 2007;36:431—440.
7. Hillis AE, Work M, Barker PB, Jacobs MA, Breese EL, Maurer K. Re-examining the brain regions crucial for orchestrating speech articulation. Brain. 2004;127: 1479—1487.
8. Urban PP, Rolke R, Wicht S, et al. Left-hemispheric dominance for articulation: a prospective study on acute ischaemic dysarthria at different localizations. Brain. 2006;129:767—777.
9. Flowers HL, Al Harbi MA, Mikulis D, et al. MRI-based neuroanatomical predictors of dysphagia, dysarthria and aphasia in patients with first acute ischemic stroke. Cerebrovasc Dis Extra. 2017;7:21—34.
10. Liegeois FJ, Morgan AT. Neural bases of childhood speech disorders: lateralization and plasticity for speech functions during development. Neurosci Biobehav Rev. 2012;36:439—458.
11. DeVeber G. Risk factors for childhood stroke: little folks have different strokes!. Ann Neurol. 2003;53:149—150.
12. Anderson V, Spencer-Smith M, Wood A. Do children really recover better? Neurobehavioural plasticity after early brain insult. Brain. 2011;134:2197—2221.
13. Bartha-Doering L, Novak A, Kollndorfer K, et al. Atypical language representation is unfavorable for language abilities following childhood stroke. Eur J Paediatric Neurol. 2019;23:102—116.
14. Liegeois FJ, Butler J, Morgan AT, Clayden JD, Clark CA. Anatomy and lateralization of the human corticobulbar tracts: an fMRI-guided tractography study. Brain Struct Funct. 2016;221:3337—3345.
15. Fuentes A, Deotto A, Desrocher M, deVeber G, Westmacott R. Determinants of cognitive outcomes of perinatal and childhood stroke: a review. Child Neuropsychol. 2016;22:1—38.
16. Takai O, Brown S, Liotti M. Representation of the speech effectors in the human motor cortex: somatotopy or overlap? Brain Lang. 2010;113:39—44.
17. Gaillard WD, Hertz-Pannier L, Mott SH, Barnett AS, LeBihan D, Theodore WH. Functional anatomy of cognitive development: fMRI of verbal fluency in children and adults. Neurology. 2000;54:180—185.
18. Weiss-Croft LJ, Baldeweg T. Maturation of language networks in children: a systematic review of 22 years of functional MRI. Neuroimage. 2015;123: 269—281.
19. Chapman SB, Max JE, Gamino JF, McGlothlin JH, Cliff SN. Discourse plasticity in children after stroke: age at injury and lesion effects. Pediatr Neurol. 2003;29: 34—41.