Speech and language impairments after childhood arterial ischemic stroke: does hemisphere matter?

Cover title: Child speech and language –does hemisphere matter?

A "Clinical Observation/Short Communication" manuscript submission

Frederique Liegeois PhD[1], Cristina Mei PhD[2], Lauren Pigdon[2], Katherine J Lee[3,5] PhD, Belinda Stojanowski BNurs[4], Mark Mackay MBBS PhD[4,5] Angela Morgan PhD[2,6]

1. UCL Great Ormond Street Institute of Child Health, London, United Kingdom

2. Speech and Language Group, Murdoch Children's Research Institute, Melbourne, Australia

3. Clinical Epidemiology and Biostatistics Unit, Murdoch Children's Research Institute, Melbourne, Australia

4. Department of Neurology, Royal Children's Hospital, Melbourne, Australia

5. Department of Paediatrics, University of Melbourne.

6. Department of Audiology and Speech Pathology, School of Health Sciences, University of Melbourne.

Address for correspondence:

Prof. Angela Morgan,

Speech & Language Group, Murdoch Children's Research Institute

30 Flemington Road, Parkville, 3052 Melbourne, Australia

e-mail: angela.morgan@mcri.edu.au

phone: + 61 3 8341 6458

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Abstract

Background and purpose: 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 (AIS). Here we examined potential predictors of acute speech (dysarthria, apraxia) and language impairments after childhood AIS, including site of lesion.

Methods: Children with radiologically confirmed acute AIS, admitted to a tertiary pediatric hospital from 2004 until 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, mean age 8 years (range 3-17 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 post stroke. Unlike adults, left hemisphere stroke was not associated with either speech or language impairment in our cohort, suggesting there may be bi-hemispheric 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 28-55% 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 not 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 characterised.

In this paper 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) and the perisylvian language networks (as in middle cerebral artery infarcts) would be associated with dysarthria and apraxia/language impairment, respectively. Finally, we hypothesized that earlier age at stroke would be associated with better speech-language skills.

METHODS

All children aged 3 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 3 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 post-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 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; 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, co-articulation, 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 are reported as well as summaries of age, lesion side and affected circulation. Left cerebral hemisphere and right cerebellar infracts 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 interaction effects are known in this population,[15] we also examined whether there was evidence for an interaction between lesion side and age at 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, mean age 8 years (range 3-17 years) were identified, see Table 1. Over three quarters had dysarthria while half had a language impairment, and just over 1 in 10 had verbal apraxia. A speech pathologist diagnosed 56% (26/42) 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 2-5 days of the stroke, although some patients were seen up to two weeks post-stroke. Infarction affecting the right hemisphere and anterior circulation were most prevalent. Given the low prevalence of verbal apraxia, we were unable to analyse predictors of apraxia. Descriptively however, only one of seven apraxic cases had a left anterior MCA that involved multiple cortical and subcortical structures. Three cases had a right infarct (2 PCA, 1 MCA), two of which involved cortical and subcortical structures and the third the cerebellum only. The remaining three cases 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 non-

specified, Table 1), and over half of all participants with dysarthria (26/46) had facial weakness.

Predictors of dysarthria

There was little evidence that age, lesion side or arterial circulation were associated with dysarthria (Table 2 and Figure 1A), 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 (over vs. under 10 years; p=0.86).

Predictors of language impairment

There was little evidence that age, lesion side or topography were associated with language impairment (Table 3 and Figure 1B), 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 following 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 MRI data show that bilateral motor cortices are recruited for the

speech[14] and non-speech movements of the articulators.[16] We suggest that this bilateral representation puts children at risk for acute dysarthria post-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 emphasised 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 been lesion side (left cortical/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 hemisphere 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] Further, a recent study found no association between lesion side and language outcome in children and adolescents at 3 months to 10 years post-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 (3 to 17 years). This conclusion is in agreement with functional MRI 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 standardised 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 centres, 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 over-estimation 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 evaluating speech and language outcomes into the longer-term (e.g., > 6

months post-stroke) to determine whether persistent deficits in speech and language were related to lesion side (or not), as cannot be determined by the present acute data.

Summary/conclusion

We conclude that 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.

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Author Contributions

AM, FL and MM designed the study. FL and AM wrote the manuscript. KL performed the statistical analysis. CM and LP performed the chart review under supervision by AM, with recruitment support from MM and BS. All authors revised the manuscript.

Conflicts of Interest

Nothing to report.

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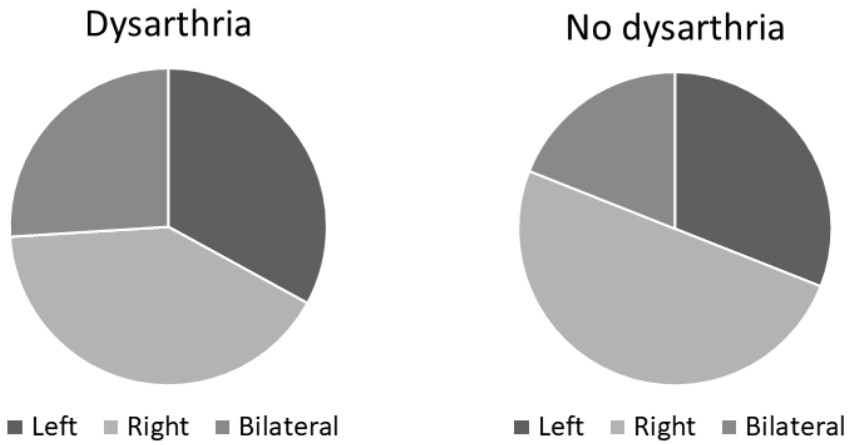
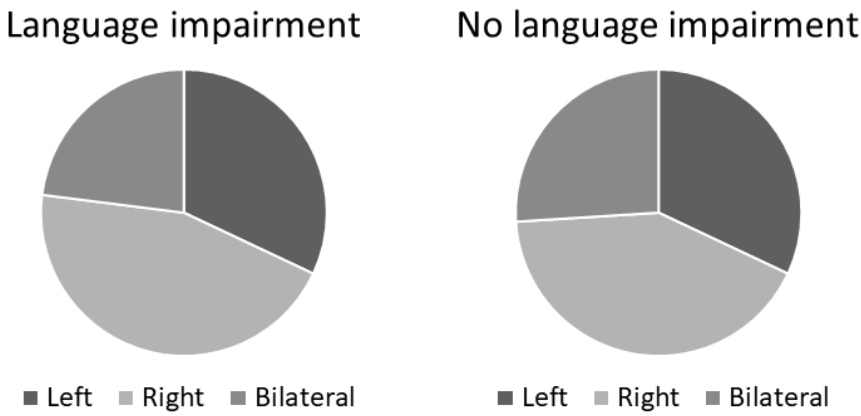


A. Proportion of children who had a left, right or bilateral stroke according to whether they did (left) or did not (right) suffer from dysarthria.



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 I. Summary of patient characteristics

Characteristic	**No. (%)**
No of participants	62
Age (years), mean (SD)	8.5 (4.3)
Risk factors	
- Nil 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 leukaemia	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 (post circ.)	2 (3)
- Other (Post-circ.)	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)

ACA: anterior cerebral artery, MCA: middle cerebral artery, PCA: posterior cerebral artery, Other (posterior circulation).

Table II. Predictors of Dysarthria (n=62)

Predictor		**Without dysarthria (n=16)**	**With dysarthria (n=46)**	**OR (95% CI)**	**p-value**
Age (years), mean(SD)		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%)	*	

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

Table III: 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(SD)		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)	

Note: CI = confidence interval; OR = odds ratio from univariable (unadjusted) logistic regression.

Supplementary Table 1. Language presentation of children (n=31) with language problems in the first two weeks after stroke

Case	Age	Formal test	Receptive language	Expressive language
1	10	Y	CELF-4 Receptive Language Index >1.5 SD below mean.	Unable to complete CELF-4 expressive subtests due to limited verbal output; BNT administered, child scored < 3SD below mean, using voice lightwriter device. Verbal dyspraxia.
2	17	N	Understanding basic 1 & 2 stage commands only.	Limited verbal production, 2-5 word phrases.
3	6	Y	CELF-P Receptive Language Index > 1 SD below mean.	CELF-P Expressive Language >1 SD below mean. Limited initiation & verbal output. Reduced vocabulary post-stroke, confirmed with pre-stroke kindergarten reports.
4	11	N	Unable to understand basic 1 & 2 stage commands.	Limited verbal output, restricted to single words or short phrases.
5	6	Y	CELF-P Receptive Language Index >1.5 SD below mean.	Could not complete CELF-4 Expressive Language Index due to limited verbal output.
6	11	N	Able to understand only basic instructions with visual cues– e.g., answer Yes/No to 'Want a drink'? Cannot accurately complete 2 step instructions.	Expressive output severely limited. Using short phrases. Significant word-finding difficulties. Using simple words to communicate - mainly responses in absence of initiation. Semantic & phonemic paraphasias. Also pointing and gesturing to communicate. Uses non-words, but self-corrects.
7	3	N	Receptive Language Impairment. Child had PLS-4 administered 5 months prior to stroke & was WNL. Able to follow simple 1 stage spoken & gestured commands. Recognised pictures, body parts, function of objects. Responded appropriately to questions using pointing or head nod/shake.	Severe expressive impairment. Largely non-verbal communication, using pointing, eye gaze, facial expression, varied pitch vocalisation. Verbal dyspraxia. Some recent use of automatic speech (e.g. mum) - mostly single words, infrequent short phrases.
8	12	N	Follows basic commands. Answers questions yes/no reliably and can produce interaction about a topic. Requires increased time to process language. Receptive vocab is borderline for age post-stroke but was WNL pre-morbidly. Facial expression: sometimes jumps to conclusions as he is watching a face rather than listening to /processing what is said.	First week post-stroke, unable to vocalize, largely gestural communication (head nod, pointing). Two weeks post-stroke: using lightwriter to communicate as has verbal dyspraxia as well as language impairment. Has several key words which he uses appropriately (i.e. mum, no, OK, home, TV). Gesture: Pointing & own single hand sign for everyday greetings, requests (give it to me), questions (where is it?). Expressive aphasia in writing compared to pre-morbid levels, but sentences (using lightwriter) include function words indicating at least partial access to grammar. Multimodal strategy depending on need. 1. Gesture/sign - for everyday routine requests, 2 - speech - for greetings and calling yes/no. 3. Lightwriter - for specific or novel requests/answer. Still using lightwriter 1 month post-stroke.
9	6	Y	CELF-4 Receptive Language Index > 1.5 SD below mean, particular difficulty with Sentence Structure subtest.	CELF-4 Expressive Language Index > 2 SD below mean, particular difficulty with Word Structure, Formulating Sentences subtests.

Supplementary Table 1. Language presentation of children (n=31) with language problems in the first two weeks after stroke

10	4	N	Unable to follow basic commands able to be followed pre-stroke. Evaluation of video from pre-stroke demonstrated advanced speech & language development with significant regression in abilities. Reliance on echolalia as a cue for responses to questions. Requires carrier phrases & forced choice questions to cue appropriate/accurate statements in response to questions.	Echolalia, word finding difficulties, grammatical & syntactical errors which were not present pre-stroke. Semantic paraphasias. Perseveration when labelling objects/pictures was also present early on (e.g. naming subsequent pictures with the name of a previous picture). Even up to 2 months post-stroke, child had ongoing complex language issues including fluctuating, but overall lower than pre-morbid expressive skills.
11	17	N	Generally able to follow instructions & understand information, memory issues impacting on comprehension of more complex language.	Higher level language issues present up to 2 weeks post-stroke including poor word finding, problem solving difficulties.
12	9	N	Ability to understand more preserved than expressive ability. Difficulty following more complex instructions, ok with direct simple instructions.	Using spelling board for first week, then progressed to use of single words & short phrases by end of second week but grammatically impaired content.
13	10	N	Able to follow basic instructions only. Severely impaired receptive language compared to pre-morbid levels, even up to 2 weeks post-stroke.	Limited 1-word commands in first week progressing to 2 to 5 word sentences with effort in second week. Word finding difficulties & semantic paraphasias.
14	9	N	Ability to understand more persevered than expressive ability but difficulty following 2 stage commands. Makes errors on second step of command or omits second step.	Limited verbal output. Grammatical errors & semantic paraphasias.
15	10	N	Following basic commands & able to use gesture appropriately (nod yes/no) to show understanding of basic concepts.	Limited verbal output. Word finding difficulties, 1-3 word phrases only.
16	16	N	Follows simple 1-2 step instructions only, significantly reduced for this age level. Can reason verbally when provided with visual cues, but comprehension markedly impaired.	Communicating in basic short sentences only. Significant difficulties with pragmatic language: participates in conversation, but perseverates on certain topics in contrast to previous language ability. Word finding problems & reduced vocabulary.
17	3	Y	Assessed with RAPT. Able to follow 1-2 step instructions without cues in context. Able to identify parts of an object (body parts and animal pictures). Difficulty naming familiar items and responding to questions. Could identify objects by function. Inconsistently able to identify mine & yours. Responded inconsistently to ‘no’ and ‘wait’. Receptive language impaired relative to pre-morbid ability. Delay in processing & response time.	RAPT revealed mostly 1-word utterances. Can produce 2-3-word utterances but had to be prompted to provide answers. Phonological errors. Difficult to understand in connected speech due to dysarthria & phonological errors (wue to blue) & consonant omissions (re for red, di for this).
18	15	N	Slowed information processing. Followed 3 stage commands, identified unrelated words from a series of 4 & demonstrated comprehension of comparative relationships & complex sentences. Able to read & follow 3 stage commands & read a short 2 sentence	Appropriate eye contact. Flat effect. Reduced spontaneous verbal communication. Limited initiation of topics & questions. Adequate naming of words within a category & verbal fluency age appropriate for words beginning with F & A. Adequately generating synonyms for

Supplementary Table 1. Language presentation of children (n=31) with language problems in the first two weeks after stroke

			paragraph & answer factual questions. More complex tasks too challenging. 3 months later CELF-4 Understanding Spoken Paragraphs > 2SD below mean.	abstract concepts & described sequence of making a sandwich, although required increased processing & response time relative to age.
19	3	Y	Reduced ability to sustain attention to 1 activity or task, easily distracted by auditory or visual stimuli. Assessed with PLS-4 and was able to identify parts of objects, but errors in response to verbal sentences/picture task.	Marked expressive dysphasia noted. Initially unable to talk. Verbal expression variable, predominantly single words but did produce some short sentences ("I want Einstein (game)"). Persistent moderate word finding difficulties. Perseverative output, jargon, grammatical errors & when struggling to recall word will use perseveration. Reduction in frequency & complexity of language.
20	8	N	Problems processing auditory information. Verbal memory/attention reduced for lengthy instructions & paragraph length information. Follows 2-stage instructions in quiet environment once attention gained. Difficulty distinguishing between angry, concerned & sad facial expressions during sessions & describes all as sad.	Poor pragmatic language, changes topics frequently, verbose, poor turn-taking. Dysfluency noted - repeating phrases. Parents have reported change in use of language including inappropriate remarks/swearing & reduced ability in switching topics/reading facial expressions of others.
21	11	N	Can follow 1 & 2 stage commands.	Limited verbal production, 2-4 word phrases, agrammatic, semantic paraphasias, word-finding difficulty.
22	11	Y	Parents reported premorbid performance in line with peers, but language skills affected post-stroke. In first week, showed task avoidance by switching topics. Difficulty with response generation, taking longer to process and formulate responses and using non-specific vocabulary. Attention span was short and she was easily fatigued. At 10 days post-stroke, was able to follow simple instructions but difficulty with increasing complexity of the task. Over 3 weeks post-stroke, reasoning & language processing remain affected, with increase in processing & response formulation time.	Semantic paraphasias on 100 word naming test. Poor word retrieval. Moderate difficulties with producing specific vocabulary. Prolonged response formulation times. Reduced fluency in conversation. Up to 2 weeks post-stroke inappropriate behaviours still noted (laughing, repeating erroneous answers). Still required prompts to retrieve familiar words from memory. Phonemic cues and binary choices helpful. Responses remain mildly off topic. Naming difficulties more evident at sentence level, with associated circumlocution. Ability to retrieve words from memory when given simple category names was mildly impaired.
23	9	Y	CELF-4, severe receptive and expressive language disorder. Core Language Score, 2.5 SD below mean (1st percentile). Receptive Language, 2SD below mean (2nd percentile).	CELF-4, Expressive Language Index, 2.5 SD below mean (1st percentile).
24	13	Y	K-BIT, Composite overall IQ, 3rd percentile; Non-verbal IQ, 12th percentile; PPVT-3, 14th percentile (moderately low range).	K-BIT, Verbal IQ, 2nd percentile. Word finding difficulty, semantic paraphasias, EOWPVT, 3rd percentile (moderately low range).
25	14	Y	No difficulty with auditory discrimination of single words. Errors in semantic relationships (receptive language).	Communicating in simple sentences. Word association & verbal reasoning adequate but poor verbal fluency & repeats items. Writing simple sentences spontaneously & to dictation but markedly reduced grammar up to 2 weeks post-stroke & not at pre-morbid levels. Expressive language effortful & speech unclear.

Supplementary Table 1. Language presentation of children (n=31) with language problems in the first two weeks after stroke

26	6	Y	Comprehension adequate for everyday interactive language use, however reduced precision noted on comprehension of grammar testing. Sentence Structure on CELF-P-2, 3 weeks post-stroke, > 1SD below mean, i.e. comprehension of grammar below average for age, as was vocabulary.	Marked word finding issues contributing to non-fluent expressive presentation. Parents describe a marked reduction in output (single words or short phrases only). Multiple false starts, hesitations & re-organisations. Confrontational naming problems for everyday objects. Issues in both English & German. Both German & English sentences containing omissions & grammatical simplifications for age. Word finding issues & reduced output persisted past acute-stage, as well as confusion with sequences such as counting. Expressive Vocabulary on CELF-4, 2 SD below mean.
27	7	N	Child unable to process simple instructions. Confused with inappropriate repetition of words.	Using few words, grammatically simplified phrases, inappropriate repetition of words, poor word recall, difficulty drawing & spelling. Persistent word finding difficulty.
28	5	N	Previously bright child. Slowed processing & unable to follow 2-stage commands. Apparent issues with recognising common objects & answering basic questions.	Limited verbal production, 1-3 word phrases, word-finding problems.
29	3	N	Able to identify & say simple body parts with verbal & visual prompting.	Speaking in simple sentences, i.e. "go away". Markedly reduced output, limited initiation & word-finding problems. Previously highly verbal & communicative. Father reports child's overall communication is 4/10 in comparison to pre-morbid skills.
30	14	N	By end of second week post-stroke, inconsistently following 1-step commands & non-verbal Y/N responses unreliable. Unable to follow 2 stage commands. Severe receptive dysphasia. Relies heavily on use of gestures & context to aid comprehension. Unable to answer forced choice questions. >1 month post-stroke: persistent global aphasic with co-morbid verbal dyspraxia.	Immediately post-stroke was either non-verbal or at other times using jargon, unable to imitate sounds or words. Use of non-verbal communication through head shaking/nodding unreliable. One week-post stroke could verbalise simple words inconsistently (e.g. hi, mum). Verbal dyspraxia present, speech difficulty to initiate and is inconsistent, unintelligible and groping behaviour present. Over 2 weeks post-stroke, significant difficulty with naming/word finding on command & conversation breakdowns. Speech is frequently unintelligible due to dyspraxic and phonemic paraphasic errors, especially in structured tasks. Difficulty producing sounds in isolation. Over a month post-stroke, dyspraxic errors remain and continued evidence of perseveration.
31	14	N	First week post-stroke, non-verbal, but can communicate if asked Y/N questions with head nodding, gestures & pointing but not always reliable responses, e.g., Head nodding often defaults to 'no', but can self-correct to a nod. At 2 weeks post-stroke was able to follow 1-stage commands, but only once instructed to wait until	Non-verbal immediately post-stroke but within first week was able to make some vocalisations with encouragement. No words or short phrases until second week post-stroke when some Yes, No, family names & basic needs could be verbalised. Expressive dysphasia with word finding difficulty and cannot type basic words such as "kite" and

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	question/instruction was given fully. Not able to follow 2-stage commands consistently. Follows simple questions but unable to process general conversation or more complex questions.	"cup" to picture cue, at odds with pre-morbid abilities of typical 14 year old who was performing in line with peers at school.

NB. All children were reported to have typical language commensurate with their peers pre-stroke; CELF-4: Clinical Evaluation of Language Fundamentals-4; SD: standard deviation; BNT: Boston Naming Test; CELF-P2: Clinical Evaluation of Language Fundamentals Preschool -2; PLS-4: Preschool Language Scales-4; WNL: Within Normal Limits; RAPT: Renfrew Action Picture Test; K-BIT: Kaufmann-Brief Intelligence Test; PPVT: Peabody Picture Vocabulary Test; 100 word naming test; EOWPVT: Expressive One Word Picture Vocabulary Test.