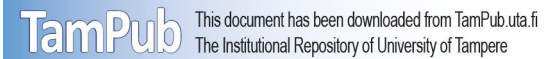


Speech deterioration in ALS after manifestation of bulbar symptoms



Keywords: Amyotrophic lateral sclerosis, ALS, bulbar symptoms, motor speech disorder

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The authors state that there are no conflicts of interest to disclose.

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Abstract

Background: The symptoms and their progression in amyotrophic lateral sclerosis (ALS) are typically studied after the diagnosis has been confirmed. However, many people with ALS already have severe dysarthria and loss of adequate speech at the time of diagnosis. Speech and language therapy interventions should be targeted timely based on communicative need in ALS.

Aims: The aim of this study was to investigate how long natural speech will remain functional and to identify the changes in the speech of persons with ALS.

Methods & Procedures: Altogether 30 consecutive participants were studied and divided into two groups based on the initial type of ALS, bulbar or spinal. Their speech disorder was evaluated on severity, articulation rate and intelligibility during the two-year follow-up.

Outcome & Results: The ability to speak deteriorated to poor and necessitated augmentative and alternative communication (AAC) methods with 60% of the participants. Their speech remained adequate on average for 18 months from the first bulbar symptom. Severity, articulation rate and intelligibility declined with nearly all participants during the study. To begin with speech deteriorated more in the bulbar group than in the spinal group and the difference remained during the whole follow-up with some exceptions.

Conclusions & Implications: The onset of bulbar symptoms indicated the time to loss of speech better than when assessed from ALS diagnosis or the first speech therapy evaluation. In clinical work, it is important to take the initial type of ALS into consideration when determining the urgency of AAC measures as people with bulbar-onset ALS are more susceptible to delayed evaluation and AAC intervention.

What this paper adds

1) What is already known on this subject.

The speech of people with ALS can range from normal to a need for augmentative communication at the time of diagnosis. The interval from diagnosis may not be the best indicator to predict the rate of speech deterioration.

2) What this study adds

On average, 60% of the participants lost their ability to speak 18 months from the first bulbar symptom. It would be preferable to focus more on the time when the first bulbar symptoms appear than when the ALS diagnosis is confirmed to predict the rate of speech deterioration.

3) Clinical implications of this study

More detailed knowledge on the progression of speech deterioration helps the SLTs to plan timely speech-therapy and communication-aid processes and to counsel people with ALS, their family members and health-care professionals.

Introduction

Amyotrophic lateral sclerosis (ALS) is a progressive neurodegenerative disorder that destroys motor neurons in the cerebral cortex, brainstem and spinal cord (Kiernan *et al.* 2011). The disease affects both upper and lower motor neurons. Upper motor neuron involvement leads to spasticity, weakness, and brisk deep tendon reflexes, while lower motor neuron manifestations include fasciculations, wasting, and weakness. The first symptoms can appear anywhere along the motor tract. In classical ALS muscle weakness spreads inevitably to encompass all voluntary muscles including respiratory muscles, leading to death within 2-5 years after the onset of symptoms (median survival time 3 years) (Couratier *et al.* 2016). In approximately one third of the persons with ALS, the disease starts with bulbar symptoms, and these people tend to have more severe type of motor speech disorder than those with initial spinal symptoms (Turner *et al.* 2010; Yorkston *et al.* 1993). Bulbar-onset disease and bulbar dysfunction overall is associated with poorer prognosis (Chio *et al.* 2009, Williams *et al.* 2013). Progressive loss of muscle control and strength, reduction in movement and increased duration of movements in the bulbar area lead to a gradual loss of speech function (Shellikeri *et al.* 2016, Yunusova *et al.* 2016).

Typically, the diagnostic process takes a long time from the onset of symptoms to a definitive diagnosis of ALS (Williams *et al.* 2013). The median delay from the initial symptoms to diagnosis is about 14 months and especially common in bulbar-onset disease (Kiernan *et al.* 2011; Turner *et al.* 2010). People with ALS demonstrate various speech symptoms at the time of diagnosis, ranging from normal speech to the use of augmentative communication (Yorkston *et al.* 1993). Particularly those with bulbar-onset ALS have obvious speech deterioration before a definitive diagnosis and the beginning of speech-therapy intervention (Makkonen *et al.* 2016). The speaking rate and

intelligibility was observed to be lower in bulbar-onset than spinal-onset participants after the diagnosis (Ball *et al.* 2002).

Speech difficulties occur in 80-95% of people with ALS at some point during the progression of the disease, which weakens the functionality of natural speech and indicates the need for augmentative and alternative communication (AAC) methods (Beukelman *et al.* 2011, Creer *et al.* 2016). The loss of effective communication may result in difficult psychological and social problems (Simmons 2005) and also deterioration in quality of life (Felgoise *et al.* 2015). In fact, persons with ALS often consider the potential loss of speech as one of the worst aspects of the disease (Hecht *et al.* 2002).

There is limited follow-up research on the progression of dysarthria in ALS, and most follow-up studies have the time of diagnosis as a starting point (Hanson *et al.* 2011). In Dworkin and Hartman's case study (1979) dysarthria progressed from mild to severe in about 1.5 years and similarly, anarthria appeared after 17 months in 49 bulbar-onset ALS patients in another longitudinal study by Turner *et al.* (2010). Sentence intelligibility declined from 96% to 10% in seven months in Watts and Vanryckeghem's case study (2001), and single-word intelligibility declined from high to low between 6-12 months in another multi-case study (Nishio and Niimi 2000). Average sentence intelligibility dropped from 95% to 75% in over a year (median 455 days) during a follow-up of 66 ALS patients (Rong *et al.* 2016). Slower motor-speech performance has been shown to precede the decline in intelligibility with persons suffering from ALS (Ball *et al.* 2002, Green *et al.* 2013, Kent *et al.* 1991, Nishio and Niimi 2000, Rong *et al.* 2016, Turner and Weismer 1993). Prior work has suggested that instrumental-based measuring of speech, such as that of articulation rate, can detect early-onset bulbar symptoms of ALS and can be used for monitoring disease progression (Allison *et al.* 2017, Green *et al.* 2013,

Yunusova *et al.* 2016).

In clinical work, more information about speech deterioration would be highly appreciated by people with ALS, their family members and health-care professionals. One of the most common questions patients with ALS have asked during clinical visits is how long will they be able to speak. The main objective of this study was to assess how long natural speech will meet the patients' communication needs studied at three different time points: time since 1) the first bulbar symptoms, 2) the diagnosis of ALS and 3) the first speech and language therapist (SLT) evaluation, and to study the differences between the initial type, bulbar or spinal, of ALS. Another objective has been to identify the changes and the effects of different variables on severity of speech disorders, intelligibility and articulation rate.

Methods

Forty-seven consecutive participants were referred to the SLT in the Department of Neurology and Rehabilitation from August 2007 to December 2009 because of suspected or diagnosed ALS and one or more clinical signs of bulbar symptoms. Of these 47 participants thirty met inclusion criteria: 1) native Finnish speaker and 2) no other diseases affecting speech, language or swallowing. Of the 17 excluded patients ten had another diagnosed disease or condition affecting speech, language or swallowing such as stroke or Alzheimer's disease, three were excluded because they died before the diagnosis of probable or definitive ALS, and four declined to participate. All participants had normal hearing and adequate vision without or with eye-glasses. Clinically obvious cognitive dysfunction due to ALS was evident in five participants (4 bulbar and 1 spinal-onset) as the disease progressed. All diagnoses were confirmed by a neurologist as probable or definitive ALS according to revised el Escorial criteria (Brooks *et al.* 2000) during the data collection by August 2011. The study protocol was approved by the Ethics

committee of Pirkanmaa Hospital District. All participants gave their written informed consent to participate in the study.

The 30 participants were divided into two groups based on the initial type of ALS: bulbar (n=13) and spinal (n=17). In four participants the initial type of ALS was originally determined as mixed, but as in two of them the major initial symptoms were bulbar and in the other two spinal, they were classified into these groups. The demographic and clinical features of the participants are presented in table 1. Females were more numerous in the bulbar group (11 female, 2 male), but no statistical differences in gender (Fisher's exact test) or age (Mann-Whitney U-test) between the groups were found. The participants were asked to determine the date (in months) when they first noticed bulbar symptoms (i.e. speech or voice changes, difficulty with tongue movement, nasal voice). Verification of onset of symptoms was requested from family or accompanying persons if possible. The time of adequate speech was counted in months from 1) bulbar symptoms, 2) diagnosis of probable or definitive ALS, and 3) the first SLT evaluation. Time from the first bulbar symptom to the last SLT evaluation was counted in months.

[Table 1 near here]

The changes in various aspects of speech were recorded at the first SLT visit and on average every three months according to the participants' clinical needs. The objective of the study was to monitor each participant for two years. Due to the nature of the disease, 21 participants died due to respiratory insufficiency during the follow-up (Table 2). Nine participants survived the whole two years; five in the spinal group, four in the bulbar group.

[Table 2. Near here]

The functional change of speech was evaluated using the ALS Severity Scale of Speech (Hillel *et al.* 1989, Yorkston *et al.* 2004). On this 10-point scale a speech score of

10 represents normal speech and speech score of 1 indicates loss of useful speech limited to occasional vocalizations. Speech scores 10 to 5 represent adequate speech, meaning that natural speech remains a functional means of communication despite possible deterioration in motor speech production. Score 4 or less signifies poor speech and the need for AAC to supplement or replace natural speech.

To estimate the speed of articulatory movements in spontaneous speech the participants were asked to generate a story based on a wordless cartoon strip. Articulation rate was measured as a spoken narrative in syllables per total narration time excluding silent or filled (e.g., “um”, “er”) pauses of 200 msec or longer (Nishio & Niimi, 2000, Turner & Weismer 1993) and reported as syllables per second. The stories were recorded with a headset microphone, saved as WAV files directly with Sound Forge software and transcribed orthographically for articulation rate analysis. The PRAAT-program was used to acoustically verify syllable boundary. If the participant was unable to speak clearly enough for syllable boundaries to be detected, the articulation rate was scored as 0.

The intelligibility of semi-spontaneous speech in the cartoon narrative task was evaluated perceptually by seven experienced SLTs on a 100 mm Visual Analogy Scale (VAS). VAS value 0 (0mm) equals non-intelligible and 100 (100mm) fully intelligible speech. The mean VAS value was reported in the evaluation. All seven SLT listeners rated every speech sample entirely in random order. The listeners had the possibility to listen to the samples as many times as required to be confident about their rating. The interjudge reliability between the listeners was good (intraclass correlation; ICC=.896). The median across-judge difference was 5.5 (Q₁=1 and Q₃=20.75, min= 0 and max= 84). If a person with ALS was unable to produce any speech in the narrative task, the intelligibility of spontaneous speech was scored as 0.

In the group comparison of the participants' demographic and clinical features at the first visit, the nonparametric Fisher's exact test was used for categorical variable (gender) and the Mann-Whitney U test was used for continuous and interval variables. These statistical analyses were performed using SPSS (Version 23, SPSS Inc).

The severity of symptoms and communication abilities differed between patients and the data was also unbalanced, i.e. there was a varying number of measurements for individual patients. Therefore, linear mixed-effects (LME) models with symptom or score value as a dependent variable were fitted using function LME in R (Software environment for statistical computing and graphics, version 3.3.0, The R Foundation for Statistical Computing). Time, age at the first evaluation, gender and initial type of ALS were used as independent variables. Additionally, the interaction effect of time and initial type of ALS was analysed. Likelihood ratio test was used to compare models. Random intercept was used together with independent random errors. A p-value of $<.05$ was considered significant.

A total of 157 communication assessments were performed in this study. LME model analysis of the data was carried out with actual information on evaluation dates for all 30 participants. The data collected on speech scale was organized into three-month intervals (\pm one month) to describe the changes in time. If there were two assessments during the same interval (as in 11 cases), the latter was included in the study.

Results

Speech deteriorated to poor, necessitating the use of AAC methods (score 4 or less) in 60% of the participants (18/30) during the study. The speech score was 4 or less in all bulbar-onset participants at the last evaluation. Speech was functional at the first visit with all spinal-onset participants and with 29 % (5/17) of them speech deteriorated to poor by the time of the last evaluation. With those 18 participants whose speech score

decreased to 4 or less, speech remained adequate on average for 18 months from the first bulbar symptoms and no statistical difference between the two groups was found (Table 3).

[Table 3. Near here] [Figure 1a-c. Near here]

Three bulbar-onset participants had no functional speech at the beginning of the follow-up, and after the first year only one participant was able to speak adequately. In contrast, the first participants in the spinal group to lose functional speech were identified after nine months of follow-up. At the end of the two-year follow-up, three spinal-onset ALS participants – out of the nine remaining – were still able to speak sufficiently.

Time and initial type of ALS were significant factors ($p = <.001$) in all LME models (articulation rate, intelligibility and speech score)(Table 4.). Overall, participants with spinal-onset ALS performed better in all these tasks than persons with bulbar-onset disease (figure 1a-c). Age or gender were not significant in LME model. Interaction effect between the time and initial type of ALS was significant only for speech intelligibility ($p = .0043$) (Table 4.).

[Table 4. Near here]

Discussion

This study has focused on the progression of motor speech symptoms in persons with ALS. The main finding was that the ability to speak was lost in 60% of the participants during the two-year follow-up. In these persons, speech remained adequate and communication functional on average for 18 months after the appearance of the first bulbar symptoms regardless of the initial symptom type, whether bulbar or spinal. A participant's speech varied from fully functional speech to the need for AAC measures when assessed at the time of ALS diagnosis or the first speech therapy evaluation. The beginning-point of bulbar symptoms reported by the participant appeared to indicate the

duration of adequate speech function better than the time-point of ALS-diagnosis or of the first SLT-evaluation.

In the present study, dysarthria progressed from mild to severe in a similar timeframe as in the previous studies in bulbar-onset participants (Dworkin and Hartman 1979, Turner *et al.* 2010). In their retrospective database study Yorkston *et al.* (1993) reviewed speech deterioration in 44 ALS participants post diagnosis and found variable changes in speech both in bulbar- and spinal-onset participants. These changes occurred earlier in bulbar-onset participants. Our study confirms the earlier results. In the present prospective study, we used similar methods such as speech score, speech intelligibility and articulation rate, but unlike in the previous studies we focused on the starting point of bulbar symptoms rather than confirmation of diagnosis.

While all bulbar-onset participants lost their ability to speak during the follow-up, only five (29%) in the spinal group had non-functional speech at the end of the follow-up. Speech performance at the first SLT visit was more decreased in the bulbar-onset than in the spinal-onset participants (figure 1a-c). The monitoring time from the first bulbar symptoms to the last SLT visit (either at the end of the two-year follow-up or before the patient passed away) was on average 10.5 months shorter in the spinal-onset group (Table 1.). It is possible that in some spinal-onset patients the disease progresses to encompass respiratory muscles and is fatal before the major decline in speech appears. This indicates that even though the progression of motor speech symptoms is a significant part of ALS, not all participants need AAC during the course of the disease.

The information on how fast speech will worsen is important in clinical work as it helps the SLT to plan timely speech therapy and communication aid processes and to counsel people with ALS and family members. The diagnosis of ALS is based on clinical criteria and an accurate diagnosis is typically delayed from the appearance of first

symptoms (Williams *et al.* 2013, Kiernan *et al.* 2011, Turner *et al.* 2010). According to the present data the people with bulbar-onset ALS lost their functional speech on average seven months after the first speech therapy intervention rendering mere seven months to organize individually appropriate AAC. People with spinal-onset ALS are referred to the speech therapist sooner than bulbar-onset patients because they are usually already being regularly monitored for their other symptoms. Thus, there is substantially more time (on average 14 months) to organize communication aid services for them.

Speech score, speech intelligibility and articulation rate declined in nearly all participants as expected (Ball *et al.* 2002, Green *et al.* 2013, Hillel *et al.* 1989, Kent *et al.* 1991, Nishio and Niimi 2000, Rong *et al.* 2016, Turner and Weismer 1993, Watts and Vanryckegehem 2001). Time and onset type of ALS were the most significant factors contributing to the motor speech functions. Our results are compatible with earlier results in that people with initial bulbar symptoms tend to have more severe motor speech disorders than those with initial spinal symptoms (Turner *et al.* 2010, Yorkston *et al.* 1993).

Neither age nor gender were significant in relation to the decline in speech functions. In earlier studies, female gender and higher age were associated with more severe bulbar dysfunction and with greater probability of progression to anarthria (Turner *et al.* 2010, Yorkston *et al.* 1993). Females were more numerous in the bulbar group. However, no reliable conclusions can be made based on gender in our study.

The interaction effect between time and initial type of ALS was not significant for speech score or articulation rate analysed by LME, suggesting that most speech symptoms progress similarly, once started, irrespective of the initial type of ALS. Speech intelligibility declined more in bulbar-onset participants during the follow-up as shown in figure 1c, although the level of speech intelligibility was lower at the first SLT visit. A

possible explanation is that nearly all bulbar-onset participants had unintelligible speech at the last evaluation against only four in the spinal-onset group. Another explanation might be that intelligibility decreases at a slow rate and intelligibility measurements, therefore, lack sensitivity in the early stages of speech disorders. During the later stages of the disease intelligibility declines rapidly and progresses to the loss of adequate speech in quite a short time (Ball *et al.* 2001, Green *et al.* 2013, Nishio & Niimi 2000, Rong *et al.* 2016, Yorkston *et al.* 1993). The progression of speech intelligibility declining after the first manifestation of bulbar symptoms has been reported in a limited number of studies (Nishio & Niimi 2000, Rong *et al.* 2016, Watts and Vanryckeghem 2001). Our results are similar, even though the language of our participants and the methods used for rating intelligibility were different, making comparisons with earlier studies difficult. We rated intelligibility from semi-spontaneous speech in the cartoon narrative task while in the earlier studies intelligibility has been rated from single word or sentence reading tasks.

Collecting clinically valid follow-up data from participants with ALS is challenging, owing to the progressive and fatal nature of the disease. Participants are unavoidably lost during a long follow-up, and their number varies between different observation points. Therefore, linear mixed-effects models were used to analyse longitudinal data in this study. The selection of the measurement tools is also challenging as there is a need to reach both the early and the longitudinal changes in motor speech production. The severity scale of speech is not sensitive enough to detect the early changes in motor speech function (Allison *et al.*, 2017), but the scale still indicates a need for AAC intervention (Yorkston *et al.*, 1993). Even a minor decline in intelligibility again indicates loss of adequate speech (Ball *et al.* 2001, Green *et al.* 2013, Nishio & Niimi 2000, Rong *et al.* 2016, Yorkston *et al.* 1993), and can no longer be measured due to the loss of spoken communication. Articulation rate is more sensitive for early changes

(Allison *et al.* 2017, Green *et al.* 2013, Yunusova *et al.* 2016), the syllable boundaries need to be extractable from spoken words to be measured and therefore become unmeasurable when speech is no longer functional. As in this study the challenging choice of measures may result in floor effect, because the variables related to speech cannot be assessed.

We observed speech deterioration prospectively from the first speech assessment, which is the earliest point in our health-care system where communication ability is evaluated. We collected information on speech and communication changes in people with symptoms of ALS but with yet uncertain diagnosis. To ensure the changes in speech and communication were due to ALS, only those participants whose ALS diagnosis was confirmed as probable or definitive during the data collection were included in the final analyses.

One of the limitation of this study is the low number of participants. In the spinal group, a relatively small number of participants (5) lost their ability to speak adequately. This might reflect on some statistical findings like the time to need for AAC. Other limitations were the bias in gender, the potential bias in the participant's recall of bulbar symptom onset point and the lack of formal cognitive assessment. Speech performance in the five participants with signs of cognitive dysfunction did not differ from the other participants. Intelligibility and articulation rate were determined from semi-spontaneous speech in the cartoon narrative task that does not require reading skills. The professional listeners were instructed to rate intelligibility solely based on the aspects of motor performance, as articulation rate without pauses measures bulbar motor symptoms well without the effect of possible cognitive or respiratory dysfunction (Green *et al.* 2013, Yunusova *et al.* 2016). A formal screening or assessment of cognitive abilities should be performed in future studies.

Conclusion

Motor speech function declined inevitably in most of the participants and they lost adequate speech on average in 18 months from the first bulbar symptoms. In clinical work when assessing the need for AAC procedures, it would be preferable to focus more on when the first bulbar symptoms appear than when the ALS diagnosis was confirmed or the first SLT evaluation was undertaken. The motor speech function of persons with bulbar-onset ALS is probably more deteriorated than that of those with spinal-onset at the first speech therapy assessment. This indicates a rapid need for speech evaluation and AAC services.

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Table 1. Demographic and clinical features of participants with ALS

Feature	All (N=30)	Bulbar group (n=13)	Spinal group (n=17)	Sig. between groups
Mean age at first SLT evaluation (min-max)	62.8 (31.1–83.0)	64.3 (44.3–76.6)	61.6 (31.1–83.0)	p=.536
Gender (males:females)	10:20	2:11	8:9	p=.119
Mean follow-up time, months (min-max)	15.3 (0–25)	16.7 (5–25)	14.3 (0–24)	p=.385
Mean time from bulbar symptoms to diagnosis, months (min-max)	10.6 (-5–50)	20.5 (8–50)	3.1 (-5–19)	p=.001
Mean time from bulbar symptoms to 1st SLT evaluation, months (min-max)	6.5 (-3–22)	11.2 (4–22)	3.0 (-3–13)	p=.001
Mean time from diagnosis to 1 st SLT evaluation, months (min-max)	-4.1 (-34–8)	-9.4 (-34–1)	-0.1 (-7–8]	p=.001
Mean time from bulbar symptoms to last SLT evaluation, months (min-max)	21.87 (0-44)	27.8 (15-44)	17.3 (0-34)	P=.007

SLT, speech and language therapist

Table 2. Cumulative mortality

	Cumulative mortality per cent every three months							
	3	6	9	12	15	18	21	24
Bulbar (n= 13)	0	0	7.7	30.8	38.5	53.8	61.5	69.2
Spinal (n=17)	5.9	11.8	29.4	35.3	47.1	52.9	58.8	70.6
All (N=30)	3.3	6.7	20.0	33.3	43.3	53.3	60.0	70.0

Table 3. The time of decrease of speech to score 4 or less

Initial type of ALS	The mean time to poor speech in months (range) from		
	bulbar symptoms	ALS dg	1 st SLT evaluation
Bulbar (n= 13)	18.0 (6-40)	-2.5 (-15-8)	6.8 (0-24)
Spinal (n=5)	19.6 (12-27)	11.4 (3-25)	14.2 (10-20)
All (n=18)	18.4 (6-40)	1.3 (-15-25)	8.9 (0-24)
Sig. between groups	p=.503	p=.003	p=.014

SLT, speech-language therapist

Table 4. Linear mixed-effects model(LME) estimates

		Estimates without interaction effect			Estimates with interaction effect between time and initial type of ALS		
		Beta	Std.Error	p-value	beta	Std.Error	p-value
Articulation rate	Intercept	3.49	1.12	0.0023	3.52	1.12	0.0021
	Time	-	0.00075	< . 001	-0.0054	0.0011	< . 001
	Gender (male)	0.77	0.43	0.084	0.78	0.43	0.083
	Age	-0.018	0.016	0.29	-0.018	0.016	0.30
	Initial type of ALS (spinal)	2.27	0.37	< . 001	2.18	0.41	< . 001
	Time*spinal				0.00075	0.0015	0.62
	Intelligibility	Intercept	70.76	23.51	0.0031	74.57	23.50
	Time	-0.11	0.019	< . 001	-0.16	0.023	< . 001
	Gender (male)	8.06	8.98	0.38	8.58	9.01	0.35
	Age	-0.063	0.34	0.86	-0.016	0.35	0.96
	Initial type of ALS (spinal)	40.42	7.79	< . 001	27.35	8.85	0.0047
	Time*spinal				0.095	0.03	0.0043
Speech score (ALSSS ¹ of speech)	Intercept	4.36	1.45	0.0032	4.39	1.46	0.0031
	Time	-	0.00090	< . 001	-0.0085	0.0013	< . 001
	Gender (male)	0.91	0.56	0.12	0.91	0.56	0.12
	Age	0.012	0.021	0.57	0.012	0.021	0.57
	Initial type of ALS (spinal)	2.89	0.49	< . 001	2.83	0.51	< . 001
	Time*spinal				0.00070	0.0018	0.70

¹ALSSS= ALS severity scale; 1-10

Figure 1a. Decline in speech scores of individuals in the bulbar (13) and spinal (17) groups

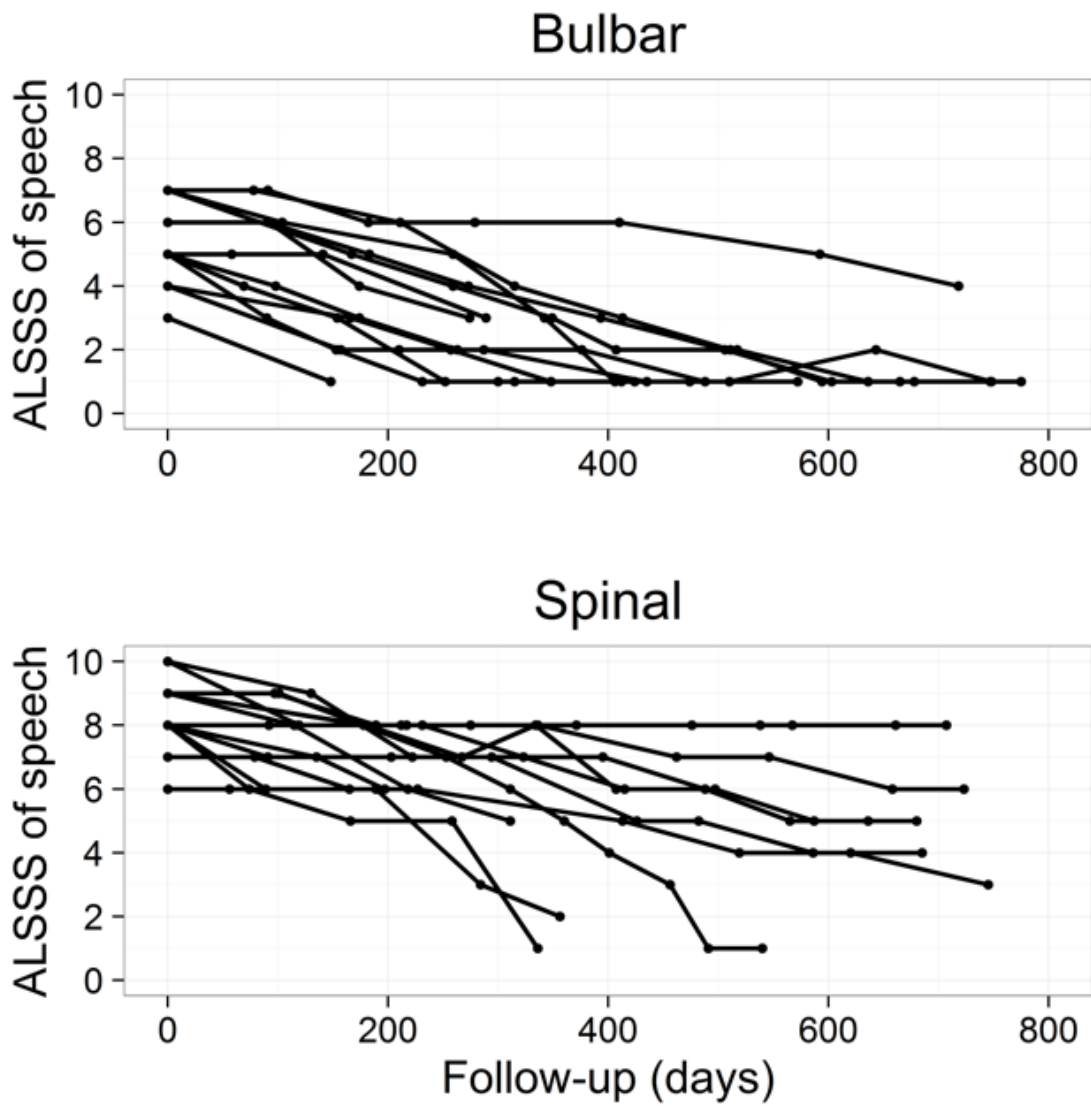


Figure 1b. Decline in articulation rate of individuals in the bulbar (n=13) and spinal (n=17) group.

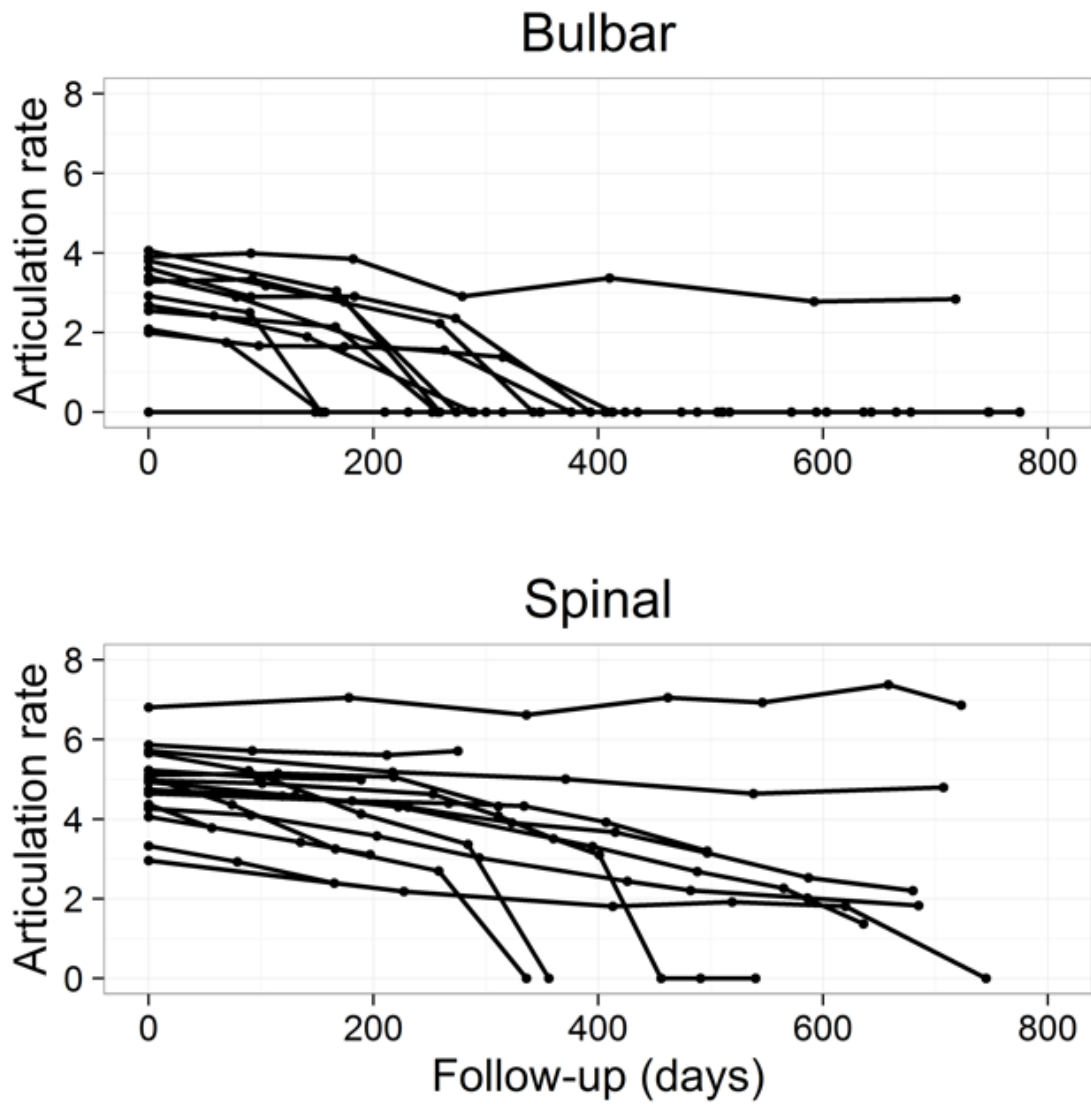
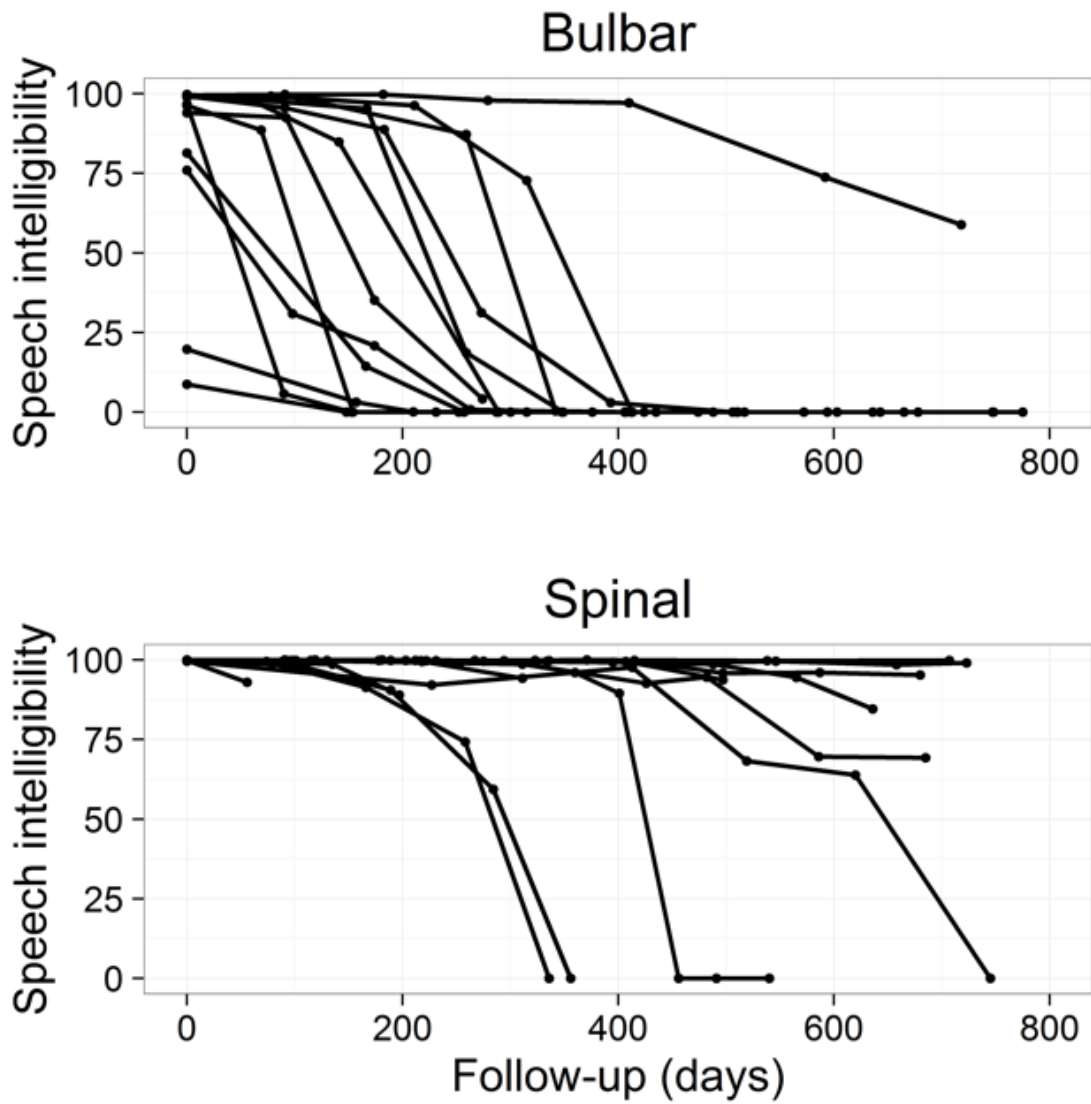


Figure 1c. Decline in intelligibility of narrative speech of individuals in the bulbar (13) and spinal (17) groups



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