Examining the Speech Intelligibility of Individuals With Oromandibular Dystonia Receiving Botulinum Toxin: A Series of Cases

Examiner l'intelligibilité de la parole des individus ayant une dystonie oromandibulaire et recevant des injections de toxine botulique : une série de cas

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KEYWORDS
SPEECH INTELLIGIBILITY
OROMANDIBULAR DYSTONIA
BOTULINUM TOXIN A
DYSARTHRIA

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Abstract

Oromandibular dystonia is a focal dystonia affecting the facial, lingual, and labial musculature. Oromandibular dystonia can result in a hyperkinetic dysarthria with associated reductions in speech intelligibility. Botulinum toxin A injections are the gold standard in the therapeutic management of oromandibular dystonia. Unfortunately, there is a sparse empirical literature that has examined changes to speech intelligibility in individuals receiving botulinum toxin A therapy. In this preliminary study, we measured the speech intelligibility of 10 individuals with oromandibular dystonia at two time points over the course of a therapeutic botulinum toxin A injection cycle. Intelligibility was assessed using the Sentence Intelligibility Test and a conversational speech task. Four listeners rated sentence intelligibility and conversational intelligibility via visual analogue scaling. Changes to speech intelligibility over the course of the botulinum toxin A treatment cycle were analyzed using a series of cases. The speech intelligibility of one individual with lingual oromandibular dystonia demonstrated significant increases to speech intelligibility over the course of the treatment cycle. The remaining nine participants demonstrated relative stability in speech intelligibility scores over the course of the treatment cycle. It appears that for jaw opening, jaw closing, and mixed presentations of oromandibular dystonia, botulinum toxin A injections did not significantly reduce or improve speech intelligibility. Our preliminary results provide a rationale for examining speech intelligibility and the response to botulinum toxin A based on the type and location of oromandibular dystonia in larger scale study.

Abrégé

La dystonie oromandibulaire est une dystonie focale affectant la musculature faciale, linguale et labiale. La dystonie oromandibulaire peut entraîner une dysarthrie hyperkinétique, celle-ci associée à une réduction de l'intelligibilité de la parole. Les injections de toxine botulique de type A sont considérées comme étant la prise en charge de référence pour la dystonie oromandibulaire. Malheureusement, il existe peu d'études empiriques qui ont examiné les changements dans l'intelligibilité de la parole des individus recevant des injections de toxine botulique de type A. Dans la présente étude préliminaire, nous avons mesuré l'intelligibilité de la parole de 10 individus ayant une dystonie oromandibulaire, et ce, à deux moments au cours d'un cycle d'injection de toxine botulique de type A. L'intelligibilité a été évaluée à l'aide du *Sentence Intelligibility Test* et d'une tâche conversationnelle. Quatre auditeurs ont évalué l'intelligibilité de la parole dans les échantillons de phrases et de conversation, et ce, grâce à une échelle visuelle analogique. Un devis de série de cas a été utilisé pour analyser les changements observés au niveau de l'intelligibilité de la parole. Une augmentation significative de l'intelligibilité de la parole au cours du cycle de traitement a été observée pour un individu ayant une dystonie oromandibulaire affectant la musculature linguale. L'intelligibilité de la parole des neuf autres participants est demeurée relativement stable au cours du cycle de traitement. Il semble que les injections de toxine botulique de type A n'augmentent pas ou ne diminuent pas l'intelligibilité de la parole des individus ayant une dystonie oromandibulaire affectant les muscles responsables de l'ouverture ou de la fermeture de la mâchoire, ou encore, affectant plusieurs muscles du bas du visage (p. ex. linguaux, labiaux et/ou faciaux). Les résultats de cette étude préliminaire supportent la réalisation d'études de plus grande envergure pour examiner l'effet de la toxine botulique de type A sur l'intelligibilité de la parole, et ce, en fonction du type et de la localisation de la dystonie oromandibulaire.

Oromandibular dystonia (OMD) is a focal dystonia affecting the mouth and facial regions (Tan, 2004). It consists primarily of forceful involuntary contractions of the facial and lingual musculature. These contractions may either be sustained or repetitive. Other terms for OMD are orofacial-buccal dystonia, jaw dystonia, lingual dystonia, cranial dystonia, and adult-onset facial dystonia (Schneider & Hoffman, 2011). In some cases, OMD occurs with blepharospasm or involuntary contractions of the eyelids. This condition is called Meige's syndrome (Lee, 2007). Although the exact cause of dystonia is unknown, it has been recognized as a disease involving basal ganglia (Kaji, 2003; Shanker & Bressman, 2012; Tsui, 2005). Additionally, the DYT1 gene has been noted to play a role in the onset of dystonia (Tagliati, Pourfar, & Bressman, 2005; Tsui, 2005).

The basal ganglia refer to a group of nuclei in the central nervous system that plan and execute motor movements (Mink, 2003). Lesions isolated to the putamen and globus pallidus of the basal ganglia are the most frequently associated with dystonia (Bhatia & Marsden, 1994). The extent of basal ganglia involvement in dystonia remains poorly understood; however, it has been hypothesized that dystonia results from reduced firing of neurons within the globus pallidus interna. This decreased activity of the globus pallidus interna neurons leads to incomplete inhibition of competing motor movement patterns. Reduced inhibition of these surrounding motor patterns can lead to the involuntary contraction of neighbouring muscles (Mink, 2003).

The DYT1 gene has been implicated in causing the greatest number of primary dystonias that have been genetically researched (Tagliati et al., 2005). A deletion of a GAG sequence in the DYT1 gene leads to dystonia (Tagliati et al., 2005). The DYT1 gene encodes torsinA, a protein that is involved in vesicle fusion and cytoskeletal dynamics (Tagliati et al., 2005).

Because OMD involves abnormal contraction of the facial muscles, it may produce difficulty in mastication and swallowing (Bhidayasiri, Cardoso, & Truong, 2006; Lee, 2007). It may also lead to difficulties in opening and closing the mandible and controlling the lingual and labial musculature. These difficulties can result in dysarthria, defined as

> a collective name for a group of speech disorders resulting from disturbances in muscular control over the speech mechanism due to damage of the central or peripheral nervous system. It designates problems in oral communication due to paralysis, weakness, or incoordination of the speech musculature (Darley, Aronson, & Brown, 1969a, p. 246).

The type of dysarthria most frequently associated with OMD is a slow hyperkinetic dysarthria in which the most affected aspects of speech production are articulatory in nature and include imprecise consonants, distorted vowels, and irregular articulatory breakdowns (Duffy, 2013).

OMD is among the most challenging types of dystonia to treat (Jankovic, 2004). Because of the various clinical presentations and severities of OMD, it has become a challenge among clinicians to properly diagnose this condition (Balasubramaniam, Rasmussen, Carlson, Van Sickels, & Okeson, 2008). There are many available clinical treatments for OMD. The most common and well-tolerated treatment for OMD is chemodenervation. This is achieved via localized injection of botulinum toxin into the affected muscles. In rare cases, neurosurgical surgical intervention, such as deep brain stimulation of the globus pallidus internus is also possible, but a less common approach (Capelle, Weigel, & Krauss, 2003). The most common oral medications for OMD are anticholinergic drugs such as trihexylphenidyl, dopaminergics, dopamine receptor blockers, carbamezapines, and baclofen (Tsui, 2005). Oral baclofen has been shown to be commonly used in OMD (Jankovic, 2005; Tan, 2004; Tsui, 2005), and has been reported to be effective in 20% of patients with OMD (Tsui, 2005). In general, treatment of OMD using pharmaceuticals has been reported to be unremarkable and reports of side effects have been high (Cultrara, Chitkara, & Blitzer, 2004; Jankovic, 2004; Tsui, 2005).

Botulinum toxin A (BoNT-A), known commercially as Botox ® (Allergan, Inc. Irvine, CA, USA) and Xeomin ® (Merz Pharmaceuticals, Germany), has been used in the treatment of OMD (Batla, Stamelou, & Bhatia, 2012; Bhattacharyya & Tarsy, 2001; Cultrara et al., 2004; Teemul, Patel, Kanatas, & Carter, 2016). Not only are BoNT-A injections effective in alleviating symptoms of dystonia, but research has also shown that use of BoNT-A can be effective in improving the quality of life with patients with OMD, including the subdomains of social support and physical health (Bhattacharyya & Tarsy, 2001). Similarly, it has also been found that BoNT-A injections can improve domains of activity and participation, as well as improving social, emotional, and vocational aspects of general well-being (Dykstra, Adams, & Jog, 2007).

In contrast, the effect of BoNT-A injections on speech intelligibility in OMD has a sparse empirical literature, and therefore, is poorly understood in comparison to more studied outcome measures such as quality of life (see Bhattacharyya & Tarsy, 2001; Teemul et al., 2016). This is unfortunate because dysarthria can be a disabling

consequence of OMD (Tan & Jankovic, 1999). Dykstra, Domingo, Adams, and Jog (2015) was one of the first groups of researchers to conduct a study that examined ratings of speech intelligibility and self-rated communicative effectiveness in individuals with OMD over the course of a BoNT-A injection cycle. The results of their study found no significant overall group differences in sentence intelligibility or self-rated communicative effectiveness over the course of a treatment cycle of 3 months (Dykstra et al., 2015). This 3-month re-injection schedule is the standard protocol for re-injection in OMD because BoNT-A has a wearing off cycle of approximately three months (Blitzer & Sulica, 2001). To our knowledge, there has been no report of permanent stabilization of symptoms or cumulative effects of BoNT-A over prolonged periods of treatment (Bakheit, Liptrot, Newton, & Pickett, 2012; Colosimo, Tiple, & Berardelli, 2012).

Although Dykstra et al. (2015) did not find significant group differences in speech intelligibility over the course of the BoNT-A treatment cycle in their participants with OMD, it is possible that individual differences may have been present based on the type and/or location of OMD that was not revealed through the analysis of aggregated intelligibility data.

Current Study

This preliminary study examined, on an individual, case-by-case basis, the speech intelligibility of 10 participants with various presentations of OMD over the course of a single BoNT-A treatment cycle. Using case reports, this study aimed to evaluate if therapeutic BoNT-A injections produced differential changes to speech intelligibility based on the type and/or location of OMD. Although this study is preliminary and exploratory in nature, it is hypothesized that those individuals with primarily lingual involvement will derive a greater benefit to speech intelligibility following BoNT-A therapy as compared to individuals with other presentations of OMD such as jaw-opening or jaw-closing. This hypothesis is driven by a case study that reported improved speech intelligibility following BoNT-A injections of an individual with lingual dystonia (Dykstra et al., 2007). Furthermore, previous literature suggests that tongue control is more strongly related to speech intelligibility than jaw or lip control in individuals with neuromotor disorders (Weismer, Yunusova, & Bunton, 2012). Finally, in previous work examining the efficacy of BoNT-A injections on OMD, it has been found that jaw-opening OMD was associated with less functional improvement and higher complication rates after BoNT-A injections than jaw-closing OMD (Tan & Jankovic, 1999; Teive et al., 2012). Taken together, these studies suggest possible differential effects of BoNT-A on speech intelligibility based on the articulator primarily affected by OMD.

The data from the current study and from Dykstra et al. (2015) come from a larger clinical study in which the same set of participants was asked to complete several intelligibility tests and questionnaires. The results of these tests are reported across the two articles, depending on the specific questions being addressed. Further, the current study uses a subset of the listeners recruited in Dykstra et al. (2015). The advantage of using the same raters is that the results of both studies are comparable. One participant was excluded in the current paper because that participant provided many outlier responses for the measures we reported. As such, it was difficult to ascertain whether these anomalous results were because of true perceptual differences or if that participant did not understand the visual analogue scaling (VAS) task or make an effort to give accurate responses.

In Dykstra et al. (2015), researchers sought to explore potential relationships between sentence intelligibility judged by transcription with patient-reported self-ratings of communicative effectiveness. Because the transcription-based intelligibility scores were quite high in the first published study, researchers sought to determine if VAS estimates of intelligibility would reveal more about the speech intelligibility of people with OMD over the course of their treatment cycle. The current study aims to address that question by examining VAS estimates of sentence intelligibility and conversational intelligibility, neither of which were explored in the 2015 paper.

Evaluating sentence intelligibility using VAS and comparing it with VAS-rated conversational intelligibility are novel and important contributions to the literature because daily communication is almost entirely composed of conversational, spontaneous speech. Furthermore, because we had a heterogeneous sample of OMD types, it was important to explore the potential differences in intelligibility outcomes on a case-by-case basis.

Method

Participants

Participants with OMD. Ten participants with OMD participated in this study. **Table 1** provides a summary of participant demographics. Participants were diagnosed with OMD by a neurologist specializing in movement disorders (M. J.). The same neurologist also administered therapeutic BoNT-A (Botox® or Xeomin®) injections to participants as part of their routine clinical care. Participants were tested just prior to their pre-scheduled therapeutic BoNT-A injections occurring on an ongoing 3-month schedule, when effects are believed to have worn off (Blitzer & Sulica, 2001).

Table 1

Demographic Information of Participants With Oromandibular Dystonia

Participant case	Sex	Age	OMD duration (years)	Years receiving BoNT-A	Frequency of injection (months)	Type of OMD	Injection site and type of BoNT-A
1	M	69	4	3	3	Meige's (labial)	Orbicularis oris: 10u total h/s (Xeomin®)
2	F	78	2	3 months	3	Jaw opening	R&L lateral pterygoid: 30u total, R&L digastric: 40u, f/s (Botox®)
3	F	60	10	8	3	Lingual	Genioglossus: 15u total, R&L digastric: 40u total, f/s (Botox®)
4	F	69	21	21	3	Lingual, labial, jaw closure	R&L pterygoid: 30u total, R&L digastric: 10u total, f/s (Xeomin®)
5	M	78	13	11	3	Labial, jaw closure	Orbicularis oris: 60u total, R&L masseter 40 units total, f/s (Botox®)
6	M	56	4	4	3	Jaw opening, jaw closure, lingual	R&L lateral pterygoid: 140u total, R&L digastric: 40u total, tongue: 30u total, f/s (Botox®)
7	M	80	23	22	3	Meige's (jaw opening, jaw closure)	R&L lateral pterygoid: 120u total, R&L digastric: 30u total, f/s (Xeomin®)
8	M	68	8	3	3	Jaw closure	R&L masseter: 30u total, medial pterygoid: 30u total, f/s (Botox®)
9	F	67	5	4	3	Meige's (labial)	R&L digastric: 10u total, R&L pterygoid: 20u total, f/s, Orbicularis oris: 5u, h/s (Botox®)
10	M	44	3	1	3	Meige's (labial, jaw closure)	R&L masseter: 40u total, medial pterygoid, 40u total, f/s (Botox®)

Note. BoNT-A = Botulinum toxin A; OMD = oromandibular dystonia; R = right; L = left; u = units; f/s = full strength; h/s = half strength.

A speech-language pathologist (A. P.) with over 15 years of experience with dysarthria determined that participants demonstrated hyperkinetic dysarthria associated with OMD. Participants were recruited if they were receiving BoNT-A injections to manage their symptoms of OMD, presented with dysarthria, and had no other speech impairments other than those resulting from OMD. Participants also reported that they were not receiving speech therapy and were not taking any other medications that could impact motor function. In total, there were 6 men and 4 women (age range = 44–80 years, *M* = 66.9) recruited to participate, with an average OMD onset of 13.8 years.

This study was approved by the Health Sciences Research Ethics Board at Western University (Research Ethics Board approval #101658) and occurred over two

testing sessions. The experimenter obtained informed consent before both testing sessions.

Listeners. Four naive individuals were recruited to participate in this study as listeners. These listeners were young adults, 20–23 years of age (*M* = 21 years). All listeners were native English speakers; had no known speech, hearing, or neurological impairments; and had no familiarity with dysarthric speech. All listeners passed a 30 dB HL hearing screening bilaterally at 500, 1000, 2000, and 4000 Hz before participating.

Procedure

The speech intelligibility of participants with OMD was assessed over two experimental sessions. The first experimental session, referred to as the *pre-BoNT-A* condition, occurred immediately before participants received their routinely scheduled BoNT-A injections. This also corresponded to approximately three months after participants' last BoNT-A injections, except for one participant who was de-novo. The second experimental session, referred to as the *post-BoNT-A* condition, occurred approximately four to six weeks after participants received their BoNT-A injections to correspond to peak therapeutic effectiveness (Blitzer & Sulica, 2001).

Speech intelligibility. All recordings were done in a quiet testing room. Each participant wore a headset microphone (AKG C520) that was placed 6 cm from his/her mouth and connected to a digital audio recorder (Zoom H4n) that recorded the participant's speech at a 16 bit and 44 kHz sampling rate. Each recording session lasted approximately 10 minutes.

Participants completed sentence and conversational intelligibility tasks during each experimental condition (pre- and post-BoNT-A). Sentence intelligibility data was obtained using stimuli from the Sentence Intelligibility Test (SIT; Yorkston, Beukelman, & Hakel, 1996), which has been found to be a valid and reliable tool for assessing speech intelligibility in dysarthric speakers (Yorkston, Strand, & Kennedy, 1996). The SIT is comprised of lists of 11 unique and randomly generated sentences ranging from 5–15 words in length. Each participant read aloud a different and randomly generated list of SIT sentences and he or she was audio recorded for later analysis of speech intelligibility.

Conversational speech samples were obtained by asking each participant to talk about a familiar topic while being audio recorded. Open-ended questions were used to elicit spontaneous responses. Example questions included "What do you do for a living?" "What are your hobbies?" and "Tell me about your last vacation." Participants were asked different questions in the pre-BoNT-A and post-BoNT-A conditions to ensure that their responses were unrehearsed.

After each session, SIT recordings from each participant with OMD were combined into a single excerpt using Praat (Boersma & Weenink, 2013). Each participant with OMD therefore had two SIT excerpts, corresponding to the two experimental conditions. Conversational intelligibility samples were created from a continuous segment of spontaneously generated speech lasting about 30–45 seconds in duration. Selection of conversational samples were not blinded to treatment condition, but in order to maintain consistent quality for all samples, the following criteria were applied: (a) segments had to have minimal to no filler words present, (b) segments needed to be 30–45 seconds in duration (i.e., splicing together several shorter segments to create a longer segment was not permitted), and (c) segments had to have no extraneous sounds (e.g., adjusting the chair or microphone, coughing, yawning) or further probing by the experimenter (e.g., "Can you tell me more about that?"). All SIT excerpts and conversational speech samples were then numbered and compiled into playlists generated by Windows Media Player (version 12). All playlists were counterbalanced and randomized so that each listener was presented with SIT and conversational recordings from each OMD participant in a different order. Each participant with OMD produced 11 SIT sentences in the pre-BoNT-A condition and another 11 SIT sentences in the post-BoNT-A condition, creating a total of 22 SIT sentences. Additionally, each participant produced 30–45 seconds of conversational speech pre- and post-BoNT-A, creating 60–90 seconds of conversational speech across both experimental conditions. Across both treatment conditions and both tasks, participants produced a total of approximately 3–3.5 minutes of speech.

After all speech samples were compiled and edited, each listener completed a single listening session lasting approximately 90 minutes in a quiet laboratory wherein free-field presentation of speech samples were played at a comfortable listening level via M-Audio speakers (AV 40) placed approximately 0.6 metres (24 inches) away. During this listening session, listeners used VAS to rate the speech intelligibility of the recorded sentences and conversational speech samples obtained from participants with OMD during pre- and post-BoNT-A experimental conditions.

Speech intelligibility was rated by listeners on a 100mm visual analogue scale with the anchors labeled *0% intelligible* on the left and *100% intelligible* on the right side of the VAS. Listeners were presented with SIT sentences and conversational speech samples and

they were required to indicate the level of intelligibility by drawing a hatch mark along the 100mm line corresponding to how intelligible they perceived the speech sample to be. Speech intelligibility was measured as the distance in millimetres from the left end of the scale to where the hatch was drawn and was expressed as a percentage (i.e., 83 mm = 83% perceived intelligibility).

To determine whether participants with OMD experienced significant changes in intelligibility, we followed the guidelines of the Assessment of Intelligibility of Dysarthric Speech (Yorkston & Beukelman, 1984), from which the SIT was derived, that stated that sentence intelligibility must change by a minimum of 8.6% to be considered a clinically significant difference.

Results

Reliability

Inter-rater and intra-rater estimates of reliability were calculated for both sentence and conversational intelligibility tasks. Scores from each listener for each intelligibility task were measured against each other to obtain inter-rater reliability values. All four listeners re-measured 10% of data to determine intra-rater reliability. **Table 2** summarizes the intra-class correlation and Cronbach's alpha values in obtaining inter-rater and intra-rater reliability values.

The intra-class correlation value obtained for overall inter-rater reliability was .910 with 95% confidence intervals between .854 and .948. This correlation coefficient demonstrates an excellent reliability measure among listeners for our sentence and conversational speech intelligibility measures. Furthermore, we found moderate intra-rater reliability within measurements of each listener. The intra-class correlation was .847 with 95% confidence intervals between .373 and .965.

Case Reports

A summary of sentence and conversational intelligibility scores and measured intelligibility change pre- and post-BoNT-A injections for each participant is presented in **Table 3**.

Applying the threshold of 8.6% change in intelligibility as a benchmark of clinical significance to both our sentence and conversational ratings, a significant increase to both sentence and conversational intelligibility over the course of a single BoNT-A treatment cycle was observed in only one (Case 3) of our nine participants. This was our only participant that presented with an isolated lingual dystonia. The other participants we studied presented with either jaw opening (Case 2), jaw closing (Case 8), labial (Cases 1 and 9), or mixed (Cases 4, 5, 6, 7, and 10) presentations of OMD. **Figure 1** shows percentage change between treatment conditions whereby participants are classified as having lingual dystonia only (Panel A), mixed case involving lingual dystonia (Panel B), or the absence of involvement (Panel C).

For most of our participants studied, relative stability was observed in speech intelligibility across the treatment cycle with the exception of Case 10 who demonstrated a relatively large increase in conversational intelligibility (+16.25%) from pre- to post-testing despite minimal changes to sentence intelligibility ratings (+2.88%).

Of the five participants (Cases 2, 4, 6, 8, and 9) who demonstrated decreased conversational intelligibility, four (Cases 2, 4, 6, and 8) presented with dystonic symptoms involving the jaw. While this is an interesting pattern of results, it is not conclusive evidence and we do not suggest that BoNT-A injections worsen conversational intelligibility because Cases 5 and 9 also presented with jaw involvement but did not demonstrate the same pattern. This result warrants careful consideration in a future study.

Across the 10 participants, both sentence and conversational estimates of intelligibility remained relatively stable over the course of a single BoNT-A injection cycle.

Table 2

Summary of Inter-Rater and Intra-Rater Estimates of Reliability for Sentence and Conversational Intelligibility Tasks

	Intra-rater reliability	Inter-rater reliability
Intraclass Coefficient Correlation	.847	.910
Cronbach's Alpha	.915	.910

Table 3

Mean Sentence and Conversational Intelligibility Scores of Participants with Oromandibular Dystonia and Their Corresponding Intelligibility Change Pre- and Post-BoNT-A.

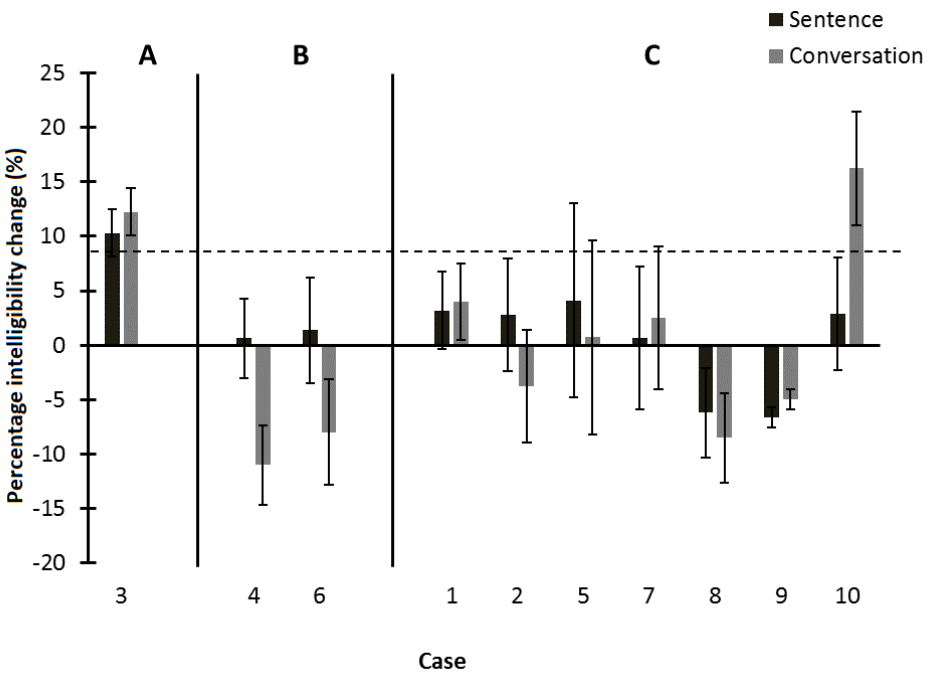
Case	Type of OMD	SIT – VAS		Direction and magnitude of change (%)	Conv		Direction and magnitude of change (%)
		M Pre (*SD*)	*M* Post (*SD*)		*M* Pre (*SD*)	*M* Post (*SD*)	
1	Meige's (labial)	89.31 (10.35)	92.50 (6.26)	+3.19	84.75 (9.57)	88.75 (11.93)	+4.00
2	Jaw opening	91.25 (6.97)	94.06 (5.17)	+2.81	93.25 (5.74)	89.50 (9.26)	-3.75
3	Lingual	82.81 (16.88)	93.13 (8.29)	+10.32	82.00 (9.42)	94.25 (5.19)	+12.25
4	Lingual, labial, jaw closure	77.75 (10.25)	80.63 (13.62)	+2.88	33.00 (19.51)	49.25 (21.09)	+16.25
5	Labial, jaw closure	76.25 (13.84)	76.88 (9.05)	+0.63	82.00 (7.39)	71.00 (13.49)	-11.00
6	Jaw opening, jaw closure, lingual	75.06 (5.20)	79.19 (9.49)	+4.13	79.13 (6.49)	79.88 (18.12)	+0.75
7	Meige's (jaw opening, jaw closure)	46.94 (21.25)	48.31 (20.77)	+1.37	55.63 (17.61)	47.63 (23.02)	-8.00
8	Jaw closure	78.63 (12.05)	79.31 (13.24)	+0.68	71.50 (17.46)	74.00 (15.06)	+2.50
9	Meige's (labial)	95.44 (3.70)	89.25 (11.44)	-6.19	88.50 (8.58)	80.00 (12.75)	-8.50
10	Meige's (labial, jaw closure)	87.88 (6.85)	81.25 (10.37)	-6.63	84.25 (8.66)	79.25 (7.46)	-5.00

Note. BoNT-A = Botulinum toxin A; OMD = oromandibular dystonia; SIT-VAS = Sentence Intelligibility Test measured using Visual Analog Scaling; Conv = Conversational intelligibility.

Mean VAS sentence intelligibility ratings increased post-BoNT-A by 1.31% (median = 2.09%, range = 16.94%) and conversational estimates of intelligibility decreased by 0.05% (median = -1.5%, range = 27.25%). Eight participants (Cases 1, 2, 3, 4, 5, 6, 7, and 10) demonstrated increased sentence intelligibility over the course of the injection cycle and five of these eight participants (Cases 1, 3, 5, 7, and 10) also demonstrated increased conversational intelligibility over the course of the injection cycle. Cases 2, 4, and 6 demonstrated decreased conversational intelligibility despite improved sentence intelligibility. The remaining two participants (Cases 8 and 9) who demonstrated decreased sentence intelligibility also demonstrated decreased conversational intelligibility over the course of a single injection cycle. None of the participants were rated to have increasing conversational intelligibility but decreasing sentence intelligibility scores.

A Pearson correlation analysis was conducted to determine if there was a relationship between change in intelligibility scores and the amount of BoNT-A injected, as well as change in intelligibility scores to each other. Only

Figure 1



Percentage of intelligibility change between treatment conditions in the sentence (black bars) or conversational (grey bars) task for each participant with oromandibular dystonia (Case) having lingual dystonia only (Panel A), mixed cases involving lingual dystonia (Panel B), and no lingual involvement (Panel C). Errors bars are 95% confidence intervals. The horizontal dashed line represents the threshold of clinically significant intelligibility change.

participants receiving full-strength BoNT-A were included in this analysis, therefore data from Case 1 was excluded. The correlation between SIT change and units of BoNT-A was not significant (r = .11, p = .78), neither was the correlation between conversational intelligibility change and units of BoNT-A (r = -.08, p = .84). There was also no significant correlation between the percentage of intelligibility change in SIT and conversational tasks (r = .62, p = .08).

Discussion

Oromandibular dystonia is a focal dystonia primarily affecting the muscles of the lips, jaw, and tongue. The motor speech disorder associated with OMD, a slow hyperkinetic dysarthria, is primarily characterized by imprecise consonant articulation, vowel distortion, and irregular articulatory breakdown (Darley, Aronson, & Brown, 1969b). Dysarthria is known to have global impacts on speech production affecting parameters such as intelligibility, prosody, voice quality, and speech rate (Kent, 2000).

In the current study, we presented a case series of 10 individuals with varying presentations of OMD and associated hyperkinetic dysarthria and we examined both sentence and conversational speech intelligibility at two time points over the course of a single BoNT-A injection treatment cycle. Nine out of 10 participants were experienced with BoNT-A injections since they had been receiving BoNT-A for several years prior to participating in the study, while one participant was de-novo. It remains unclear whether long-term use of BoNT-A results in stabilization of dystonic symptoms over time (Colosimo et al., 2012). Bakheit et al. (2012) investigated the possibility of developing neutralizing BoNT-A antibodies that block the action of BoNT-A. In this study, patients had a minimum of 10 consecutive treatment cycles spaced at least 3 months apart, and none of them developed antibodies. Importantly, over the course of the study BoNT-A treatment was found to be at least partially beneficial in 97% of cases, suggesting that the therapeutic effects of BoNT-A are present after prolonged periods of treatment.

Our rationale for examining intelligibility using a case series approach was not only to further our knowledge of intelligibility deficits in this under-studied clinical population, but it also served to provide preliminary data to justify, in a

larger scale study, the examination of the differential effects of BoNT-A on speech intelligibility based on type and/or location of OMD.

Task-specific changes in intelligibility were found in Case 10 in which there were large increases in conversational intelligibility but relative stability in sentence intelligibility. This result is somewhat puzzling, but the large standard deviation associated with this participant suggests a high degree of variability in how our listeners rated conversational intelligibility in this participant. Inspection of his sentence intelligibility scores versus conversational intelligibility scores also show a significant overall discrepancy in speech intelligibility ratings when reading sentences from the SIT (pre = 77.75%, post = 80.63%) versus his intelligibility in a conversational task (pre = 33.00%, post = 49.25%), regardless of BoNT-A injections. Anecdotally, this task effect difference was very prevalent during testing. One potential explanation is that reading tasks (i.e., sentence intelligibility) provide an external model or cue which serves to decrease demands placed on the basal ganglia with regard to the planning and the execution of motor speech movements and the additional demands involved in planning spontaneous speech movements (Kempler & Van Lancker, 2002). Kempler and Van Lancker (2002) demonstrated this task effect by showing that lower intelligibility scores are associated with spontaneous speech versus read speech in a participant with dysarthria associated with Parkinson's disease.

It is also possible that there is a task-specific dystonic response when reading that serves to disrupt dystonic movements during reading versus in spontaneously produced conversation. This mechanism can be considered similar to a *geste antagoniste*. A geste antagoniste, also referred to as a sensory trick, is a voluntary maneuver such as chewing or laughing, by which participants can temporarily decrease dystonic symptoms (Blitzer & Sulica, 2001). It has been suggested that the relief of dystonic symptoms occurs through the activation of different sensory pathways (Giladi, 1997). Perhaps relief of dystonic symptoms may also be achieved by activating different pathways involved in planning motor movements, such as those involved in reading as opposed to generating spontaneous speech. Case 10 is particularly intriguing and his task specific changes in intelligibility require more detailed examination in a future study.

We gathered anecdotal evidence that many of our participants felt a great deal of disablement due to their speech production difficulties associated with OMD that were not fully alleviated by their therapeutic BoNT-A injections. Despite these impressions our participants expressed, and in conjunction with our data, we do not consider our results to be an indicator that BoNT-A injections are not effective in our participant group. The pre-BoNT-A intelligibility scores of most of our participants were already quite high. Yorkston and Beukelman (1984) defined mild dysarthria as having intelligibility scores in the range of 95%. In our sample, four of our participants with OMD had intelligibility scores above 90%; therefore, it is possible that we are observing ceiling effects in intelligibility.

It has been suggested that dysarthrias caused by chronic conditions, as is the case in the current study, cannot be resolved solely by medical interventions alone (Kent, 2000). Therefore, relying on BoNT-A treatment exclusively to manage speech-related deficits caused by OMD may not be a realistic expectation. A recent systematic review that examined the use of BoNT-A as a treatment for OMD discussed the highly variable outcomes experienced by individuals with OMD pre- and post-BoNT-A treatment and emphasized the need for further research on use of BoNT-A treatment in OMD (Comella, 2018). The inconsistent effects of BoNT-A injections on speech intelligibility in the current paper support the conclusions of Comella (2018) and reinforce the importance of evaluating the suitability of BoNT-A in OMD.

The treatment of OMD with BoNT-A injections has focused on the improvement of dystonic muscle contractions, pain management (Cultrara et al., 2004; Esper, Freeman, & Factor, 2010; Teive et al., 2012), orofacial esthetics, chewing and mastication, and health-related quality of life (Bhattacharyya & Tarsy, 2001; Teemul et al., 2016). Speech-related outcomes appear to have a secondary priority to those factors listed above.

Although there is no cure for OMD, behavioural therapy in conjunction with BoNT-A therapy may be helpful in the management of dystonic symptoms that impair speech intelligibility (Yorkston et al., 1996). Common behavioural interventions for dysarthria include, but are not limited to, articulation exercises, breath control exercises, and rate control techniques such as the use of a pacing board (Yorkston et al., 1996). There is also a demand for a combination of both behavioural and medical interventions; however, the efficacy of combining interventions has not been empirically examined and is thus still poorly understood (Kent, 2000). Furthermore, by combining behavioural interventions with BoNT-A treatment, the management of dystonia and its related symptoms can be customized to individuals based on the subtype of OMD with which they present as well as the severity of symptoms.

Clinical Implications

Based on our preliminary results discussed above, it appears that speech intelligibility may show differential patterns of response to BoNT-A based on the location of the dystonia and the articulator(s) affected. More specifically, our results provide preliminary support to our hypothesis that those with lingual presentations of OMD may derive more benefit to intelligibility from BoNT-A injections than other presentations such as jaw-opening, jaw-closing, labial, or mixed OMD. These interpretations are evidenced by Case 3, the only participant in our sample to present with lingual dystonia only and who demonstrated improvements in both sentence and conversational intelligibility above the threshold of clinical significance. Our results may be explained by Weismer et al. (2012) who asserted that the tongue is the most influential articulator for intelligibility as compared to other articulators such as the jaw. It may be that muscles of the tongue are more responsive to BoNT-A injections than muscles with greater mass such as the masseter (i.e., jaw closure dystonia). Additionally, it appears that there are significant individual differences in changes to intelligibility evident in even our small sample of participants as shown by the range of improvement and decline in intelligibility scores across task (see range of y-axis values in **Figure 1**), which suggests an individualized approach to management.

Taken together, our results provide useful clinical implications for speech-language pathologists. First, we must be mindful of the potential differences to speech intelligibility in response to BoNT-A injections rather than viewing this medical intervention as a one-size-fits-all approach. Moreover, we must pair medical interventions (i.e., BoNT-A injections) with other strategies for supporting effective communication and tailor intervention to our clients' needs and potentially based on the type and location of OMD. By providing additional communication support, such as the provision of strategies that can be used to improve effectiveness of communication, we can ultimately ensure that the clients we serve have opportunities for meaningful communicative interactions and for participation in a variety of contexts and roles that involve communication.

Lastly, we must be cognizant of the impact of BoNT-A therapy on other aspects of an individual's functioning such as pain management, improvement to swallowing and mastication, facial esthetics, and overall impact on quality of life outcomes. Only by taking a multi-faceted approach will we gain a comprehensive understanding of the benefits of BoNT-A injections, despite observing relatively stable speech intelligibility over a single treatment cycle for many of the individuals with OMD we assessed.

Limitations

While this study provides preliminary data to support the hypothesis that subtypes of OMD may show differential benefits to speech intelligibility over the course of a BoNT-A treatment cycle, the findings of this study should be interpreted with caution due to some study limitations. The first limitation relates to our small sample size, which limits the generalizability of our results.

Second, nine of our 10 participants were already receiving ongoing BoNT-A injections before participating in the current study. Although it has been demonstrated that effects of BoNT-A wear off after approximately three months (Blitzer & Sulica, 2001), we were not able to determine with certainty if our participants had experienced the complete wearing off effects and had returned to their baseline intelligibility. Perhaps our participants would have demonstrated a greater change to their speech intelligibility scores over the course of a treatment cycle and perhaps even demonstrated greater improvements to their intelligibility scores if we were able to obtain a true return to baseline. This would have been possible if BoNT-A injections were delayed for a longer period. Future studies may wish to extend the injection cycle to ensure BoNT-A has completely worn off when obtaining baseline speech intelligibility measures.

Third, injections were not performed under electromyography guidance so there is a possibility that the precise location of dystonic activity may not have been injected. Future studies may wish to use electromyography-guided injections. Lastly, although the SIT is usually rated via orthographic transcription, we opted for visual analogue scaling to provide a more consistent measure between sentence and conversational speech samples. Conversational or spontaneously generated speech samples have higher face validity compared to sentence intelligibility measures because the majority of everyday communication occurs spontaneously; therefore, speech elicited in conversational tasks is the most naturalistic (Kent, Weismer, Kent, & Rosenbek, 1989). Future studies may want to include orthographic transcription and acoustic measures such as the second-formant slopes to provide a more detailed description of intelligibility in this clinical population. Second-formant slopes have been shown to correlate well with measures of intelligibility involving single-word identification (Kent, Kent et al., 1989) and

may be considered as a measure of motor involvement in speech (Kim, Weismer, Kent, & Duffy, 2009).

Future Directions

Due to our small sample size, this study has not yielded definitive conclusions of how BoNT-A may produce differential changes to speech intelligibility based on OMD subtypes. However, we believe the trends in our preliminary data present a clear direction for future work. A larger scale, multi-centre study is warranted to systematically assess how therapeutic BoNT-A injections impact speech production across various subtypes of OMD. In addition to measuring speech intelligibility from a perceptual approach, it would also be valuable to assess changes in acoustic and kinematic parameters in a pre- and post-injection paradigm.

Further, since BoNT-A injections are the "gold standard" of treatment for OMD (Tan & Jankovic, 1999), it would be of interest to evaluate and understand how BoNT-A impacts other aspects of functioning to get a comprehensive understanding of the benefits of BoNT-A. Ideally, this would include a detailed evaluation and assessment of the effects of BoNT-A injections on mastication and swallowing, speech intelligibility, and facial esthetics, as well as self-ratings of health-related quality of life, communication-related quality of life, and communicative participation. This information could help to provide much needed objective and patient-reported outcome data to determine the overall benefit of BoNT-A injections.

Further investigation of the relationship between severity of symptoms, location of dystonia, speech rate, and total number of words produced in the conversational task is also valuable to understand and characterize how location of dystonia affects speech production. Gathering this information in a larger scale study but also on an individual basis during clinical interactions could inform treatment planning and tailor the appropriate management of OMD. This can be achieved by examining the relative importance of each aspect of impaired functioning on an individual's life and if BoNT-A injections provide the desired benefit.

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Acknowledgments

This research was supported by a grant from the Academic Development Fund at Western University awarded to the second author.

Disclosures

No conflicts of interest, financial or otherwise, are declared by the authors.