Progressive Apraxia of Speech as a Sign of Motor Neuron Disease

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Purpose: To document and describe in detail the occurrence of apraxia of speech (AOS) in a group of individuals with a diagnosis of motor neuron disease (MND).

Method: Seven individuals with MND and AOS were identified from among 80 patients with a variety of neurodegenerative diseases and AOS (J. R. Duffy, 2006). The history, presenting complaints, neurological findings, and speech-language findings were documented for each case.

Results: Spastic or mixed spastic-flaccid dysarthria was present in all 7 cases. The AOS was judged as worse than the dysarthria in 4 cases. Nonverbal oral apraxia was eventually present in all cases. Aphasia was present in 2 cases and equivocally present in another 2. Dementia was present in 1 case and equivocally present in 2.

Conclusions: AOS can occur in MND, typically also with dysarthria, but not invariably with aphasia or other cognitive deficits. Thus, a diagnosis of MND does not preclude the presence of AOS. More importantly, MND should be a diagnostic consideration when AOS is a prominent sign of degenerative disease.

Key Words: apraxia of speech, motor neuron disease, amyotrophic lateral sclerosis

Motor neuron disease (MND), in which amyotrophic lateral sclerosis (ALS) is the most common form (Sorenson & Windebank, 2006), is a neurodegenerative disease that typically affects the upper motor neuron (UMN) and lower motor neuron (LMN) systems, with subsequent symptoms and signs of spasticity and flaccid weakness. It usually begins with limb involvement, but in about one quarter of cases, dysarthria is its first manifestation (Traynor et al., 2000). The prototypic motor speech disorder in ALS is progressive spastic-flaccid dysarthria (Duffy, 2006).

Apraxia of speech (AOS) is an impaired capacity to plan or program commands that direct speech movements. The primary clinical features of AOS include errors in speech sound production (e.g., distorted substitutions, vowel distortions, intrusive schwa, sound/syllable repetitions); reduced speech rate; increased time to transition between speech sounds, syllables, and words; and disordered prosody (Duffy, 2005; Wambaugh, Duffy, McNeil, Robin, & Rogers, 2006). AOS is rarely, if ever, considered a concomitant diagnosis in MND, but there are several reasons why it might occur. They derive from findings of language and other cognitive deficits in some people, thus establishing that manifestations of the disease can extend beyond the motor domain, and from structural and functional neuroimaging and autopsy studies that identify abnormalities beyond the UMN and LMN systems. Indirect support also comes from observations that AOS can occur in several neurodegenerative diseases. The following paragraphs provide support for these broad conclusions.

Cognitive and behavioral deficits are present in about 4%–6% of patients in retrospective epidemiological studies and in one third or more of patients in prospective studies of MND investigating cognitive and behavioral disorders (Gallassi et al., 1989; Lomen-Hoerth et al., 2003; Massman et al., 1996; Rakowicz & Hodges, 1998; Strong, Grace, Orange, & Leeper, 1996; Strong et al., 1999). Some of these studies suggest that people with bulbar onset ALS are more vulnerable...
to cognitive dysfunction. Deficits can affect problem solving, executive functions, and attention. Apathy, irritability, stereotypic behavior, and poor insight can be present.

There is evidence that ALS can include more than UMN and LMN pathways and that cognitive functioning can be affected (Strong et al., 1996). For example, in a study of 18 ALS patients with UMN and LMN signs (Ludolph et al., 1992), positron emission tomography found that regional glucose metabolism was reduced in the entire cortex (i.e., beyond the motor cortex) compared with controls, and that such abnormalities were associated with mild neuropsychological deficits.

It is now generally agreed that the association between MND and dementia is not coincidental, and that their co-occurrence may reflect a common underlying etiology. Some argue that the contemporary view of MND should be that motor neurons are selectively vulnerable but that nonmotor involvement, including cognitive deficits, can occur (Bak, O’Donovan, Xuereb, Boniface, & Hodges, 2001; Lomen-Hearth et al., 2003). The presence of dementia may be missed in some cases because people with frontal lobe dysfunction, lacking insight into their cognitive deficits, may not complain of them (Lomen-Hearth et al., 2003). In addition, speech and other motor problems may preclude or complicate neuropsychological testing.

An association between MND and dementia is also found in studies of people with a primary diagnosis of frontotemporal dementia (FTD; Neary, Snowden, & Mann, 2000). It is estimated that about 15% of patients with FTD will develop ALS (Vercelletto et al., 2003). The syndrome of MND/dementia tends to present initially with changes in behavior, personality, cognition, and language that are followed months to years later by features of MND (Neary et al., 2000; Toyoshima, Tan, Kozakai, Tanaka, & Takahashi, 2005; Vercelletto et al., 2003). The course of FTD associated with MND tends to be rapid, approximately 3 years to death (Vercelletto et al., 2003). Pathology is consistent with MND, but there are also widespread cortical changes in the frontal and temporal lobes, including the premotor and opercular areas (Bak & Hodges, 2001; Neary et al., 2000; Yoshida, 2004). The clinical and pathological overlap of ALS and FTD is also supported by genetic studies that have identified loci on Chromosome 9p and specific gene mutations in families with cosegregation of ALS and FTD (Vercelletto et al., 2003). Some people with MND have aphasia as the primary manifestation of an accompanying FTD. Several studies describe people in whom a progressive aphasia was a presenting and dominant feature that preceded or at least accompanied signs of MND (e.g., Bak et al., 2001; Caselli et al., 1993; Catani et al., 2004; Rakowicz & Hodges, 1998; Tsuchiya et al., 2000). In a study (Bak et al., 2001) postmortem findings for 3 such patients showed pronounced involvement in Brodmann’s areas 44 and 45. Another study demonstrated hypoperfusion in the left frontotemporal cortex (Catani et al., 2004). Such cases support conclusions that MND with dementia or aphasia should be considered a variant of ALS or a distinct syndrome within the group of FTDs (Catani et al., 2004; Tsuchiya et al., 2000).

The aphasia that infrequently occurs in people with MND is usually classified as “nonfluent” (e.g., Caselli et al., 1993). Although typically poorly described, terms such as “effortful” and “stuttering-like” in some reports raise the possibility that AOS was part of the clinical syndrome. More relevant, several case reports or case series provide fairly convincing evidence that AOS can occur in neurodegenerative disease, including FTD and primary progressive aphasia, and that it is sometimes the only or the predominant sign of disease (e.g., Boeve et al., 2003; Broussolle et al., 1996; Chapman, Rosenberg, Weiner, & Shobe, 1997; Didic, Cecaldi, & Poncet, 1998; Frattali & Sonies, 2000; Gorno-Tempini et al., 2004; Hart, Beach, & Taylor, 1997; Josephs et al., 2005; Lehman Blake, Duffy, Boeve, Ahlskog, & Maraganore, 2003; Rosenfield, Bogatka, Viswanath, Lang, & Jankovic, 1991).

Perhaps most convincing is a recent retrospective summary of 80 patients with a variety of degenerative diseases in whom AOS was a prominent communication disorder (Duffy, 2006). Among the 80 patients were 7 individuals with ALS or MND, but their specific clinical characteristics, as distinct from the entire group of 80 patients, were not explicitly addressed. In this article, these 7 cases will be described in detail to begin to establish salient clinical findings and the clinical context in which MND and AOS may co-occur. The intent is to alert clinicians and researchers to the possibility that speech problems in people with MND sometimes include AOS and that AOS may sometimes herald the clinical onset of ALS.

Method

Seven patients with a diagnosis of MND or ALS were identified from among the 80 patients described by Duffy (2006) who had an unselected variety of degenerative diseases and AOS. The remaining 73 patients had diagnoses other than MND or ALS (see Duffy, 2006, for demographic features and diagnoses for the entire group of 80 patients).

Five of the patients were seen on one occasion by the first author. One was seen by the first or third author on three separate occasions. One patient was first seen by the first author once and then subsequently on several occasions by the second author over a 9-month period. All patients were seen between 1995 and 2003.

With institutional review board approval, the neurology and speech-language pathology records for each patient were reviewed in detail. A number of demographic, neurological, and speech-language pathology variables were examined. The data first will be summarized for the group as a whole. A brief history and more detailed clinical description will then be provided for each of the 7 patients.

Results

Reliability

The retrospective nature of this study precluded systematic assessment of the reliability of speech-language diagnoses, the most important of which was the diagnosis of AOS. However, in Duffy’s (2006) report of the 80 cases from which the patients of this study were derived, crude estimates of intrajudge reliability (for 19% of the group) and interjudge reliability (for 16% of the group) for the diagnosis of AOS

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were 100%. In addition, for one patient in the current study (P2) who was seen on three occasions by two of the authors, both authors agreed on the diagnosis of AOS and on the presence of dysarthria. For another patient (P4), a videotape, made while he was being followed by the second author after his initial evaluation, was reviewed independently by all three authors; all agreed that the patient had AOS, spastic dysarthria, and aphasia. Each author has more than 30 years of clinical experience in the area of neuropathologies of speech and language.

**Basic Demographic Features**

Basic demographic features and presenting complaints and findings are summarized in Table 1. There were 6 men and 1 woman. Age ranged from 48 to 84 years with a median of 67 years ($M = 66.6$). Duration of speech symptoms at the time of initial evaluation ranged from 6 to 56 months, with a median of 10 months ($M = 16.6$).

**Presenting Complaints and Prominent Initial Findings**

For 5 patients, speech difficulty was the first symptom (one also had dysphagia as a first symptom). For the remaining 2 patients, one had personality changes that preceded speech difficulty by 14 months, and the other had toe paresthesias that preceded speech difficulty by 4 months. For both of them, speech difficulty was the second symptom to appear.

Speech was a primary complaint during initial neurological evaluation in all 7 patients and was the only unequivocal complaint in 4. Two patients also complained of swallowing problems, and an additional patient complained of weakness, gait difficulty, and falls. One patient had equivocal concerns about word retrieval difficulty.

Initial neurological examination (i.e., prior to other examinations and tests) confirmed the predominance of speech difficulty in all 7 patients. It also identified cognitive problems in 1 patient; fasciculations in various body parts in 4; weakness in the tongue, neck, and/or a varying number of limbs in 5; and hyperactive reflexes and spastic gait in 1.

**Table 1.** Demographic features, complaints, and primary neurological findings at the time of initial evaluation.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age</th>
<th>Hand</th>
<th>Initial symptoms</th>
<th>Speech symptom duration (months)</th>
<th>Presenting complaint</th>
<th>Primary initial neurological findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>55</td>
<td>R</td>
<td>Personality change; speech changes 14 months later</td>
<td>10</td>
<td>Speech</td>
<td>Speech; cognitive deficits; widespread fasciculations</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>67</td>
<td>?</td>
<td>Speech</td>
<td>7</td>
<td>Speech</td>
<td>Speech; scattered limb weakness and fasciculations</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>74</td>
<td>R</td>
<td>Speech</td>
<td>6</td>
<td>Speech</td>
<td>Speech; neck flexor weakness and upper extremity fasciculations</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>48</td>
<td>R</td>
<td>Speech</td>
<td>10</td>
<td>Speech (? language)</td>
<td>Speech; neck weakness; upper and lower extremity weakness and spasticity</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>65</td>
<td>R</td>
<td>Speech and swallowing</td>
<td>15</td>
<td>Speech and swallowing</td>
<td>Speech; hyperactive stretch reflexes; spastic gait; upper extremity weakness and fasciculations</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>73</td>
<td>R</td>
<td>Toe paresthesias; speech 4 months later</td>
<td>56</td>
<td>Speech, weakness, gait difficulty</td>
<td>Speech; hyperactive stretch reflexes; spastic gait; upper extremity weakness and fasciculations</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>84</td>
<td>R</td>
<td>Speech</td>
<td>12</td>
<td>Speech and swallowing</td>
<td>Speech; hyperactive stretch reflexes; spastic gait; upper extremity weakness and fasciculations</td>
</tr>
</tbody>
</table>

**Speech-Language and Related Findings**

Table 2 summarizes the speech-language and related findings for each patient. By study definition, all had AOS. The diagnosis of AOS was consistent with definitions of AOS and the auditory and visual perceptual characteristics that are currently considered compatible with the diagnosis, as provided by Wambaugh et al. (2006) and Duffy (2005).

Five patients had unequivocal nonverbal oral apraxia (NVOA) on initial examination; NVOA emerged in the remaining 2 patients on subsequent examination 5 months to 1 year later (the co-occurrence of NVOA in people with AOS is fairly common, but NVOA is uncommon in people with dysarthria and no AOS). The diagnosis of NVOA reflected off-target groping, vocalization, verbalization, or incorrect movements when imitating or following commands to cough, blow, smack the lips, or click the tongue. One patient (P7) reported lifelong mild stuttering but was not disfluent during examination.

**Dysarthria.** The diagnosis of dysarthria and its specific types was consistent with current definitions and descriptions (e.g., Duffy, 2005). All patients had dysarthria. Three had spastic dysarthria, without any obvious flaccid component. Two had mixed spastic-flaccid dysarthria; one of them (P4) retained the diagnosis during several examinations over the next 9 months. One (P1) had only equivocal evidence of dysarthria that was believed probably to reflect mixed spastic-flaccid dysarthria. Another (P2) had a dysarthria of undetermined type on initial examination that evolved to unequivocal spastic-flaccid dysarthria 1 year later.

The primary distinguishing characteristics of those with a spastic component to their dysarthria included one or more of the following features: strained-harsh voice quality; slow speech rate; slow-but-regular speech alternating motion rates (AMRs) during attempts at rapid repetition of /p/; /t/; and /k/; and hypernasality without any other features of flaccid dysarthria. The primary distinguishing characteristics of those with a flaccid component to their dysarthria included one or more of the following features: vocal flutter, hoarse and/or “wet” voice quality, and hypernasality and weak pressure consonants. All patients with an unambiguous flaccid...
component also had lingual fasciculations and, in some cases, chin fasciculations. The features of the dysarthria for each patient are summarized in Table 3.

**Aphasia.** The definition of aphasia was consistent with that provided by McNeil and Duffy (2001). Diagnosis was based on patient responses on multimodality language tasks that included subtests from the Minnesota Test for Differential Diagnosis of Aphasia (Schuell, 1972), the Token Test (DeRenzi & Vignolo, 1962), the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 2001), a letter word fluency task (Wertz, Keith, & Custer, 1971), and unstructured conversational interaction.

There was no evidence of aphasia in 3 patients. Two (P3 and P4) had mild-to-moderate “nonfluent” aphasia (see case descriptions for details) on initial evaluation; aphasia progression was documented during subsequent examinations for P4. Two (P1 and P7) performed abnormally on language tasks, but evidence of aphasia was considered equivocal, either because of probable lifelong language or learning problems (P1) or limited education (P7), thus reducing certainty about whether poor language performance could be attributed to their degenerative neurological disease.

**Dementia.** Judgments about dementia were based on mental status examination during neurological examination.

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**TABLE 2. Basic speech-language and related examination findings during initial assessment.**

<table>
<thead>
<tr>
<th>Patient</th>
<th>AOS</th>
<th>NVOA</th>
<th>Dysarthria</th>
<th>Aphasia</th>
<th>Dementia</th>
<th>Dysphagia</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+</td>
<td>+</td>
<td>Probable spastic-flaccid</td>
<td>?</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>+</td>
<td>–</td>
<td>Type undet. → Spastic-flaccid</td>
<td>–</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>+</td>
<td>+/-</td>
<td>Spastic-flaccid</td>
<td>Nonfluent</td>
<td>+/-</td>
<td>+/- → +</td>
</tr>
<tr>
<td>4</td>
<td>+</td>
<td>+/-</td>
<td>Spastic-flaccid</td>
<td>Nonfluent</td>
<td>+/-</td>
<td>+/- → +</td>
</tr>
<tr>
<td>5</td>
<td>+</td>
<td>+</td>
<td>Spastic</td>
<td>–</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td>+</td>
<td>+</td>
<td>Spastic</td>
<td>–</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>7</td>
<td>+</td>
<td>+</td>
<td>Spastic</td>
<td>?</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

*Note.* AOS = apraxia of speech; NVOA = nonverbal oral apraxia; + = present; – = absent; +/- = equivocally present.

**TABLE 3. Motor speech characteristics during initial speech-language evaluation.**

<table>
<thead>
<tr>
<th>Deviant speech features</th>
<th>Dysarthria</th>
<th>AOS and/or dysarthria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Distorted substitutions; vowel distortions; irregular articulatory breakdowns; syllable and word segregation</td>
<td>Strained voice quality; subtle vocal flutter; slow AMRs; slow rate AMRs</td>
</tr>
<tr>
<td>2</td>
<td>Distorted substitutions and irregular articulatory breakdowns; increasing with increased length; syllable segregation</td>
<td>Hoarseness; increased pitch; occasional pitch breaks</td>
</tr>
<tr>
<td>3</td>
<td>Distorted substitutions and additions within multisyllabic words and SMRs; vowel distortions; irregular articulatory breakdowns; difficulty initiating speech; effortfully produced SMRs</td>
<td>Strained voice quality; hoarseness; vocal flutter</td>
</tr>
<tr>
<td>4</td>
<td>Distorted substitutions, especially in multisyllabic words; irregular articulatory breakdowns; syllable segregation; intrusive schwa; poor sequencing (with distortions) of SMRs; decreased words per breath group in spite of adequate maximum vowel prolongation</td>
<td>Hoarseness; vocal flutter; hypernasality; slow speech AMRs; slow rate</td>
</tr>
<tr>
<td>5</td>
<td>Distorted substitutions; irregular articulatory breakdowns; subtle articulatory groping; decreased words per breath group in spite of adequate maximum vowel prolongation; subtle sequencing difficulty during SMRs</td>
<td>Strained-harsh voice quality; slow AMRs; Monopitch and monoloudness; imprecise articulation; slow rate</td>
</tr>
<tr>
<td>6</td>
<td>Distorted substitutions; sound/syllable repetitions; decreased words per breath group in spite of adequate maximum vowel prolongation; articulatory groping</td>
<td>Strained-harsh voice quality; equivocal vocal flutter; hypernasality and weak pressure consonants; slow speech AMRs</td>
</tr>
<tr>
<td>7</td>
<td>Syllable and word segregation; poor coordination of inspiration, phonation and articulation; inability to produce a sequence of sounds for speech AMRs</td>
<td>Strained voice quality; slow rate; markedly reduced intelligibility</td>
</tr>
</tbody>
</table>

*aAlthough irregular articulatory breakdowns are also a feature of ataxic dysarthria, in the context of the overall speech pattern, it was believed that they most likely reflected AOS (e.g., there were no other speech characteristics suggestive of ataxic dysarthria).

bAMRs = alternating motion rates, as in repetitions of /pʌpʌpʌ/; SMRs = sequential motion rates, as in repetitive repetitions of /pʌtʌkʌ/.
Specific Abnormal Speech Features

The abnormal speech features noted during initial speech examination for each patient are summarized in Table 3. All had three or more speech features consistent with AOS, based on current conceptions of the disorder (Duffy, 2005; Wambaugh et al., 2006). Those features, taken together, are not likely to reflect dysarthria, especially the spastic and flaccid dysarthrias associated with MND. All patients had one or more features consistent with dysarthria. All patients had at least one speech feature explainable by either AOS or dysarthria, or both in combination.

The features of dysarthria were consistent with spastic dysarthria or mixed spastic-flaccid dysarthria in 6 of the 7 patients. Only P2 had speech features during initial evaluation that might have represented flaccid dysarthria alone (hoarseness, pitch breaks), although her slow rate could have reflected a spastic component (and/or AOS). During follow-up examination 9 months later, features of a mixed spastic-flaccid dysarthria were unambiguously present.

The most commonly noted features of AOS (demonstrated by 2 or more patients) included distorted substitutions, irregular articulatory breakdowns, syllable or word segmentation, difficulty with speech sequential motion rates (SMRs; rapid repeated productions of /pAtAkA/), decreased words per breath group in spite of adequate sustained vowel duration (discussed subsequently), vowel distortions, and articulatory groping. Additional features, recorded for only single patients, included distorted sound additions, intrusive schwa, sound/syllable repetitions, difficulty initiating speech, inability to produce a series of sounds on speech AMR tasks (e.g., /pApApA/...), and apparent difficulty coordinating respiration, phonation, and articulation. We recognize that some of the features listed as reflecting AOS can also be noted in dysarthria, particularly ataxic dysarthria (e.g., irregular articulatory breakdowns, intrusive schwa, vowel distortions), but in the context in which they occurred in these patients (i.e., no other features of ataxic dysarthria, plus other features of AOS), they likely reflected AOS.

Three patients (P4, P5, and P6) had reduced words per breath group during sentence level utterances, in spite of adequate maximum vowel prolongation; P7 had apparent poor coordination of respiration, phonation, and articulation, perhaps reflecting similar difficulty. This phenomenon was typically characterized by the production of 2–4 syllables between brief, relatively rapid, and not deep inhalations; this did not appear explainable by phonatory or resoratory inadequacy. This feature is not commonly associated with dysarthria, and it has not been described as a feature of AOS resulting from nondegenerative disease (e.g., stroke). However, it has been noted in patients with AOS associated with degenerative disease (Duffy, 2006). The Discussion section will comment further on this.

Although ranking the severity of AOS and dysarthria in a given patient is often difficult, the clinical impressions during initial examination across patients were that the AOS was more prominent than the dysarthria in 4 patients (P1, P2, P3, and P4), that the dysarthria was more prominent than AOS in 1 patient (P5), and that the AOS and dysarthria were of about equivalent severity in 2 patients (P6 and P7).

Patient Descriptions

Patient 1

A 55-year-old right-handed man who worked as a welder presented to neurology, stating, “I’d like to talk better.” He had a 2-year history of personality changes; his wife noted his tendency to anger quickly and to be suspicious, distrustful, depressed, angry, and verbally abusive. Fourteen months later, he insidiously developed speech difficulty. He also tended to repeat himself and forget recent conversations. He remained independent in self-care and shopped and drove without difficulty.

Initial neurological examination was noteworthy for speech difficulty. Fasciculations were observed in the extremities and tongue. He had moderate weakness in the right arm, less significant weakness in the left upper arm, and mild weakness in the right leg. Reflexes were brisk bilaterally, but more so on the right.

Subsequent neuropsychological assessment estimated premorbid intelligence in the 80–85 range. His test performance suggested generalized dementia, although atypical for a primary cortical dementia because of preserved delayed free recall of verbal material. The examination was said to be complicated by “expressive aphasia.”

During speech-language assessment, he did not offer specific language complaints. He did report significant lifelong difficulty with reading, to a degree that led him to seek work without reading demands. His father and son were reportedly dyslexic. Language examination revealed mild verbal comprehension difficulty, moderately slow reading rate with mild comprehension difficulty, and gross misspellings during writing and oral spelling. He could not name 6 of the first 30 items on the Boston Naming Test and did not benefit from semantic or phonemic cues. It appeared that missed items may never have been in his vocabulary repertoire. He spoke slowly but was not agrammatic. He made no semantic or phonemic paraphasic errors during conversation or narratives, and had no obvious delays for word retrieval efforts. Word definitions were concrete.

Lingual fasciculations and fleeting fasciculations in the chin/perioral area were observed. Lingual strength (assessed in all patients by resistance to the clinician’s finger pressure when the tongue was lateraled into the cheeks, or resistance to inward pressure from a tongue depressor against the tip of the protruded tongue; Duffy, 2005) was grossly normal, and there was no obvious weakness of the jaw, lower face, or palate. Positive suck, snout, and palomental reflexes were present. He had a subtle NVOA, characterized by...
groping when performing oromotor movements on command. Conversational speech was characterized by moderately slow rate; segregated syllables and words; distorted substitutions and irregular articulatory breakdowns, particularly on multisyllabic words; vowel distortions; and mildly strained voice quality (it was unclear if this reflected true spasticity or increased volitional efforts at motor control). Speech AMRs were mild-to-moderately slow but regular. Vowel prolongation contained inconsistent vocal flutter. Speech intelligibility was normal.

The speech-language pathologist concluded that the patient had AOS and, possibly, a dysarthria that was difficult to characterize but very possibly spastic and perhaps also flaccid. Although his inadequate performance on several language tasks was recognized as possibly reflecting acquired aphasia, it was believed that it also could at least partially be explained by lifelong borderline intellectual abilities and perhaps a superimposed language-based learning disability and/or generalized dementia.

Subsequent electromyography (EMG) showed denervation with fibrillation and fasciculation potentials in the right upper extremity, right lower extremity, and bulbar muscles. Detailed medical genetics workup failed to identify a specific gene alteration. The final neurological diagnosis was ALS with an accompanying cognitive disorder and speech disturbances (AOS and perhaps dysarthria). The patient was not seen for further follow-up.

**Patient 2**

A 67-year-old woman presented to neurology with a primary complaint of speech difficulty that began with hoarseness and progressed to difficulty pronouncing words. Neurological examination was normal except for the speech problem. The neurologist stated that the dysarthria could reflect early MND. EMG and testing for myasthenia gravis were ordered, but the neurologist noted, “the most important initial test here will be speech pathology consultation.”

During the speech-language pathology examination, the patient said that her speech problem had progressed significantly in recent months and that she was developing swallowing difficulty. She denied language or cognitive problems. Oral mechanism examination was normal. Conversational speech was characterized by mild-to-moderately slowed rate, subtle syllable segmentation, mild-to-moderate hoarseness, high pitch with occasional pitch breaks, occasional distorted articulation and irregular articulatory breakdowns, and infrequent distorted substitutions. Speech AMRs were normal. She had difficulty rapidly repeating multisyllabic words or complex sentences containing multisyllabic words, characterized by irregular articulatory breakdowns and occasional distorted substitutions, of which she was aware. Although she said she was speaking slowly to compensate for her difficulty, she could not increase rate when pushed to speak rapidly. Her facial appearance during speech attempts reflected effort, and there was some overflow muscle tension in her upper extremities.

The speech-language pathologist concluded that the speech problem was unusual but best characterized as a mild AOS that seemed partly masked by compensatory efforts to slow rate and articulate carefully. Dysarthria was also suspected, primarily on the basis of her dysphonia. Dysarthria type was uncertain; her slow rate raised the possibility of a spastic component, but some of her voice characteristics were also suggestive of LMN flaccid weakness. The final speech diagnosis was AOS and dysarthria of undetermined type.

Magnetic resonance imaging (MRI) showed no evidence of lesions or specific atrophy. Single photon emission computed tomography (SPECT) scan was normal. EMG abnormalities were mild and not diagnostic but, given the clinical context, most consistent with ALS.

On reexamination 9 months later, SPECT scan showed bilateral abnormalities, somewhat worse in the left hemisphere. Pulmonary function testing revealed diaphragmatic weakness with reduced maximum inspiratory and expiratory pressures. EMG of several cranial and upper and lower extremity muscles demonstrated a long-standing, progressive, active, diffuse disorder of motor neurons or axons, sufficient to meet criteria for progressive MND.

Speech-language reexamination noted significant progression of the patient’s motor speech disorder. She was no longer easily understood and frequently communicated by writing. Speech AMRs were slow and imprecise, as were speech SMRs. Connected speech rate was slow and reduced in loudness, with monopitch and monoloudness. Voice quality was strained and harsh. Articulation reflected a combination of AOS and dysarthria. The AOS was primarily reflected in off-target articulatory movements, inconsistent voicing errors (distortions that crossed phoneme boundaries), and increased articulatory inaccuracy within utterances of increased length and complexity. Perioral muscles were weak, range of lingual motion was reduced, and lingual fasciculations and atrophy were evident. Pseudobulbar affect was present. The speech diagnosis was significant AOS, mild NVOA, and unambiguous spastic-flaccid dysarthria. Therapy was recommended to work on strategies for maintaining comprehensibility of speech and to address alternative and augmentative means of communication.

The final neurological diagnosis was MND (ALS) with AOS and dysarthria.

**Patient 3**

A 74-year-old right-handed farmer presented to neurology for evaluation of dysarthria and possible MND. He had a 6-month history of progressive speech difficulty and problems swallowing pills. Performance on brief mental status testing was abnormal, but neither the patient nor his family complained about his memory, thinking, or behavior. Neurological examination revealed dysarthria, lingual fasciculations, and lingual weakness, and scattered weakness in the limbs with diffuse fasciculations. ALS was suspected. Subsequent behavioral neurology consultation noted reduced mental status examination performance and suggested that the patient had cognitive impairment with MND.

Speech-language pathology assessment confirmed the history of progressive speech difficulty and drooling and occasional loss of food from the mouth when swallowing. Language examination showed quantitatively normal verbal comprehension but delayed responses and occasional self-corrected errors. Telegraphic/agrammatic speech was evident during repetition, conversation, and narratives. He was able to repeat only 4 of 10 sentences accurately, with errors characterized by function word omissions and loss of

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information. Word definitions were brief, unelaborated, and mildly concrete, as were proverb explanations. He scored only 36/60 on the Boston Naming Test. He occasionally substituted yes/no in response to conversational questions. Sentence and paragraph reading comprehension was mildly impaired. Some grammatical and spelling errors were evident in writing. Nonaphasic cognitive deficits were not noted.

Oral mechanism examination revealed equivocal chin fasciculations. Jaw strength was normal. The tongue was moderately weak bilaterally and deviated mildly to the right on protrusion; equivocal lingual fasciculations were noted on the right. NVOA was evident, characterized by off-target movements when he attempted to cough volitionally or click his tongue, with occasional vocalization during those attempts.

Speech was characterized by strained voice quality; monopitch and monoloudness; equivocal vocal flutter; irregular articulatory breakdowns and distorted substitutions, especially during multisyllabic words; imprecise articulation; vowel distortions; and occasional difficulty initiating speech. The patient seemed to have difficulty coordinating respiration with phonation and articulation. Vowel prolongation was characterized by vocal flutter and mild hoarseness. Speech AMRs were mildly slow and irregular. SMRs were produced with effort, and he occasionally added an additional syllable to the required three sound sequences. Intelligibility was moderately reduced.

The speech-language pathologist concluded that the patient had dysarthria and AOS. The AOS made determination of dysarthria type difficult, but it was believed that both spastic and flaccid components were present. AOS was judged the predominant motor speech disorder. Language examination was consistent with aphasia, nonfluent or Broca-like in character.

EMG of several upper and lower extremity muscles revealed a diffuse process affecting anterior horn cells or their axons, but absolute electrophysiological criteria for a diagnosis of ALS were not met. The neurologist concluded that the patient had probable ALS with motor speech, language, and other cognitive impairments.

**Patient 4**

A 48-year-old right-handed banker presented to neurology with a 10-month history of progressive speech difficulty. Neurological workup elsewhere was not diagnostic. MRI scan of the head had been normal.

Neurological examination noted dysarthria. Lingual atrophy, weakness, and fasciculations were apparent, as was mild neck flexor weakness. Limb strength was normal, but arm reflexes were brisk; diffuse fasciculations were evident. He seemed to have some word-finding problems. Progressive aphasia with MND, possibly reflecting FTD, was suspected. Subsequent neuropsychometric testing was normal with the exception of circumscribed language deficits, consistent with a diagnosis of primary progressive aphasia.

During speech-language pathology assessment, the patient’s primary complaint was “I can’t speak clearly” and that his speech was “slurred.” He admitted to occasional word-finding problems and errors but denied difficulty with auditory or reading comprehension or writing. He denied swallowing difficulty.

Oral mechanism examination noted mild weakness on lip rounding and mildly weak lingual strength, with fleeting fasciculations. NVOA was evident, reflected in awkward execution of movements, including on imitation. Conversational speech was characterized by mild-to-moderately slow rate, moderate monopitch and monoloudness, mild-to-moderate hypernasality, mild-to-moderate irregular articulatory breakdowns, occasional distorted substitutions, fairly frequent insertion of an intrusive schwa or “uh” between words and phrases, moderate syllable segregation on multisyllabic words, and short phrases, with a maximum of three to four syllables per breath group. Maximum vowel prolongation was characterized by subtle vocal flutter and nonspecific hoarseness; the patient could prolong it for 12 s. Speech AMRs were slow, and speech SMRs were moderately slow and deliberately produced, with occasional sequencing difficulties. Distorted substitutions were evident during multisyllabic word repetition.

Language examination revealed mild verbal and reading comprehension difficulty. Delays, occasional omission of function words, and agrammatic/paragrammatic errors were evident during sentence repetition and conversational and narrative speech (e.g., “I do the banker” for “I am a banker”), although not floridly. Some of his verbal responses were partly echolalic. Writing contained spelling and grammatical errors. Delays and semantic errors were evident on confrontation naming tasks. On open-ended and abstract language tasks, several responses were concrete or personalized, raising suspicions that the patient might have cognitive deficits beyond the language domain.

It was concluded that the patient had both AOS and mixed spastic-flaccid dysarthria, with the AOS probably predominating, plus an aphasic language impairment that was most evident in verbal output, which was classified as nonfluent.

EMG of several upper and lower extremity muscles showed patchy areas of denervation and fibrillation potentials and widespread fasciculations. The final neurological diagnosis was primary progressive aphasia with a motor neuron syndrome.

In subsequent months, during which the second author followed the patient, his speech and language deficits continued to dominate. When first seen about 1 month after the first examination, there was evidence of regression. He received an Aphasia Quotient (AQ) of 78.7 and a Cortical Quotient (CQ) of 81.5 on the Western Aphasia Battery (WAB; Kertesz, 1982); problems with grammar remained. His moderate aphasia was characterized by agrammatic language production and moderately impaired auditory comprehension, naming, reading, and writing. He had speech characteristics consistent with AOS and mixed spastic-flaccid dysarthria. During about 10 subsequent therapy sessions, he made some improvement in the use of compensatory strategies to maximize speech intelligibility.

During reassessment about 8 months later, the patient received a WAB AQ of 57.7 and CQ of 65.1. Aphasia severity was judged as moderate-to-marked. Speech intelligibility was poor, reflecting the combined effects of his motor speech disorders and aphasia. Nonetheless, he performed normally on the Raven’s Coloured Progressive Matrices (Raven, 1965). At about that time, however, his local neurologist
noted that he was refusing medical recommendations, leading to a recommendation that his power of decision making be removed because he was no longer able to make competent decisions about some aspects of his medical care and the care of his minor-aged child. His neurologist concluded that he had a progressive FTD versus primary progressive aphasia, with significant MND.

**Patient 5**

A 66-year-old right-handed semi-retired farmer presented with an 18-month history of progressive speech difficulty plus dysphagia for liquids. He also admitted to slowed movements, occasional muscle twitches, and slight memory decline. Neurological examination revealed a severe speech deficit. Cognitive function seemed normal. Scattered fasciculations were apparent in the tongue and upper extremities. Overall findings were suggestive of MND. Subsequent EMG of several upper and lower extremity muscles was consistent with a widespread process affecting anterior horn cells or their axons, with mild motor unit changes, a pattern seen in early MND.

During speech-language pathology examination, the patient complained of the gradual onset and progression of difficulty pronouncing words. He denied problems with word retrieval or language comprehension or formulation. He admitted to choking on liquids. Fleeting fasciculations were apparent in the chin. Lip rounding was mild-to-moderately reduced. Lingual strength was normal, and atrophy or fasciculations were not apparent. There was equivocal NVOA, reflected primarily in subtle grogging and a tendency to vocalize during task performance. Conversational speech was characterized by moderately slow rate, moderate-to-marked strained-harsh voice quality, moderate-to-marked monopitch and monoloudness, mildly imprecise articulation, irregular articulatory breakdowns, distorted substitutions, and subtle articulatory grogging. Words per breath group were mildly reduced. Speech AMRs were moderately slow but regular. He had subtle difficulty sequencing SMRs. Voice during vowel prolongation was markedly strained-harsh. Intelligibility was normal in the quiet setting. There was no evidence of aphasia. It was concluded that the patient had an unequivocal spastic dysarthria, but there was only equivocal evidence of an LMN/flaccid component. His short phrases per breath group, in spite of adequate maximum vowel prolongation, were noteworthy and suspicious for difficulty with articulatory/respiratory programming or coordination. In combination with the patient’s subtle articulatory grogging and off-target speech movements, AOS was considered present.

**Patient 6**

A 73-year-old right-handed man presented with complaints of speech difficulty, progressive weakness, and gait difficulty. His problems began about 4½ years earlier, initially as toe paresthesias. Three to 4 months later, he noted speech changes, and about 5 months later problems with gait and falling. Neurological examination elsewhere suspected myasthenia gravis. He was placed on Mestinon, without benefit.

Neurological examination noted speech difficulty, weak neck flexion, and weakness and trace evidence of spasticity in the upper and lower extremities. Mental status was normal. MND was suspected, although almost exclusively with UMN findings. Subsequent EMG showed evidence for a diffuse chronic process involving the motor neurons and their axons, consistent with chronic MND or a polyradiculopathy.

During speech-language pathology assessment, the patient said his speech problem initially sounded as if he had been drinking. He complained, “I have no breath when I talk,” but he had no complaints of shortness of breath for nonspeech activities. He denied difficulties with language. He admitted to difficulty swallowing liquids and to crying more frequently than in the past.

Jaw and face strength were normal. Lingual strength was reduced, but there was no atrophy or fasciculations. Cough and glottal coup were mildly weak. He had a subtle NVOA, characterized by grogging when attempting to click his tongue and occasional vocalization during nonspeech oromotor tasks. Speech was characterized by short phrases, with about two syllables per breath group; moderate strained-harsh voice quality; moderate-to-marked slow rate; marked hypernasality and weak pressure consonants; moderate-to-marked imprecise articulation; moderate-to-marked monopitch and monoloudness; occasional slow initial sound or syllable repetitions; subtle articulatory grogging movements within multisyllabic words; occasional distorted substitutions; and moderate-to-marked slow-but-regular speech AMRs. Vowel prolongation was mildly strained with equivocal vocal flutter. Intelligibility was mild-to-moderately reduced.

The clinician concluded that the patient’s speech problem was atypical of that usually associated with MND. He had an unequivocal spastic dysarthria, but there was only equivocal evidence of an LMN/flaccid component. His short phrases per breath group, in spite of adequate maximum vowel prolongation, were noteworthy and suspicious for difficulty with articulatory/respiratory programming or coordination. In combination with the patient’s subtle articulatory grogging and off-target speech movements, AOS was considered present.

**Patient 7**

An 84-year-old right-handed man presented for evaluation of primary complaints of progressive speech and swallowing difficulty that began about 15 months previously. His gait also had become stiff and unstable. Neurological examination noted dysarthria, exaggerated muscle stretch reflexes, spastic gait, slow AMRs, and bilateral weakness and fasciculations in the upper extremities. MND, primarily bulbar, was suspected. Subsequent EMG of several upper and lower extremity muscles was consistent with a diagnosis of ALS.

During the speech-language pathology workup, he admitted to mild lifelong stuttering, but no other speech difficulty until his current problems began and speech progressively became “hard to get out.” He also had developed difficulty with swallowing, especially for liquids and pills. His verbal comprehension was normal. He read aloud slowly, with some errors, but basic comprehension was normal. Writing skills were poor, but possibly consistent with his eighth-grade education, although he and his family had noted some recent deterioration in his spelling. He had no difficulties with confrontation naming and made no semantic or phonemic paraphasic errors on any speaking task. His narrative speech was clearly telegraphic, but it was unclear whether this reflected efforts to economize motor effort in response to his moderate-to-marked AOS and dysarthria, grammatical/ syntactic deficits reflecting aphasia, or a combination of both.

Oral mechanism examination was difficult because of apparent motor impersistence and significant NVOA. Equivocal chin fasciculations were observed. Conversational
speech was characterized by moderate-to-marked strained voice quality; moderate-to-marked slow rate; syllable and word segregation; apparent poor coordination of respiration, phonation, and articulation; and off-target articulatory movements. Vowel prolongation was markedly strained; the patient was unable to sustain a vowel for more than 2 s. He was unable to produce speech AMRs. Speech intelligibility was very poor.

It was concluded that the patient had a moderate-to-marked spastic dysarthria and AOS of about equal severity. Therapy to address augmentative and alternative communication issues was recommended.

Discussion

The cases described in this article establish that AOS can occur in individuals with MND. This has not been explicitly documented previously, with the exception of Duffy (2006), from which the patients in the current study were derived. Nonetheless, as noted in the introduction, the association between AOS and MND is compatible with observations that AOS can occur in neurodegenerative disease, and that MND can be associated with aphasia or other cognitive deficits. In fact, descriptions of aphasia in some patients with MND have identified the aphasia as “nonfluent,” a designation that might have included AOS, even if not explicitly identified. It is reasonable to assume that the patients in this study had involvement beyond the upper and lower motor neuron system that included the left hemisphere structures and pathways involved in the planning/programming of speech movements (e.g., frontal-parietal and related subcortical circuits; Duffy, 2005).

This study also establishes that AOS can be among the first symptoms or signs of MND and that it can be the prominent presenting sign on initial neurological and speech-language pathology examination. Speech difficulty was the initial symptom in 5 of the 7 patients, the only unequivocal presenting complaint in 4 of the 7 patients, and a prominent presenting complaint in all 7 patients. It is important to recognize that these results do not establish that AOS, when present, typically presents as an initial or prominent symptom or sign of MND because the individuals described here were selected on the basis of AOS prominence. Whether AOS can emerge later in the course of the disease (e.g., after development and progression of limb deficits, dysarthria, or language or cognitive problems) or can be present but less prominent than other motor or cognitive deficits will require longitudinal observations of the disorder in unselected samples of people with MND.

Dysarthria was present in all 7 cases. Dysarthria type (spastic or mixed spastic-flaccid) was consistent with what occurs in MND without AOS, but the absence of a flaccid component in 3 of our 7 patients is, in our experience, disproportionately high relative to the MND population as a whole. Whether this apparent difference is generally true for patients with MND and AOS will require further accumulation of cases.

It is noteworthy that 3 and perhaps 4 of the 7 patients had what were perceived as short breath groups (typically two to four syllables interspersed by brief, relatively rapid, and not deep inhalations) during connected speech, in the presence of maximum vowel duration that suggested adequate respiratory support for speech purposes. This feature is not typically associated with dysarthria or with AOS in nondegenerative neurological disease. It was, however, noted by Duffy (2006) in a significant minority (26%) of 80 patients with AOS associated with a variety of degenerative diseases (which included the patients in this article, but was not confined to them). If confirmed prospectively, this raises the possibility that this short breath group feature may be a perceptual “marker” for neurodegenerative etiology in individuals presenting with AOS of undetermined etiology.

The cases summarized here suggest that MND should be a diagnostic consideration in people with a progressive AOS of unknown etiology. Conversely, it is important to recognize that people with a confirmed diagnosis of MND can have AOS and that, in some cases, the AOS can be more prominent than any accompanying dysarthria. We do not intend to imply, however, that AOS is common in MND. It very likely is a rare occurrence (e.g., AOS was unequivocally present in only 1 and equivocally present in only 2 of 128 patients with MND evaluated by the first author during a 3-year period). Our findings do suggest (but are insufficient to firmly establish) that people with MND and AOS are more likely to have language or other cognitive deficits, and possibly that people with MND plus language or other cognitive deficits are more likely to have AOS than those without such deficits.

It is necessary to recognize this study’s weaknesses. First, its retrospective nature means that data collection and reporting were not standardized and, therefore, are more subject to error than in prospective studies. Second, its retrospective nature precluded, in most instances, formal assessment of reliability for perceived speech features and diagnostic conclusions about them, although the crude estimates that were possible suggest acceptable reliability. Third, case selection was biased in that cases were drawn from a patient group that had AOS as a prominent problem. Thus, it remains uncertain whether AOS can be much less prominent than any dysarthria (or aphasia or dementia) or whether it can emerge later in the disease course. Finally, longitudinal follow-up was limited, so the natural evolution of AOS remains to be established.

The presence of AOS in some patients with MND has implications for communication management strategies that are commonly associated with the disease. First, in patients with a predominant AOS and mild dysarthria, it may be appropriate to implement treatment strategies specific to improving the AOS (regardless of cause), recognizing that the motor learning principle of high repetition might not be appropriate in MND and that benefits may not endure. Broadly speaking, such strategies might include articulatory kinematic efforts, modifications of rate and/or rhythm, and intersystemic facilitation/reorganization (for a summary of these approaches, see Wambaugh et al., 2006). Probably more often, however, the presence of significant AOS in people with MND will complicate overall speech management. For example, alphabet supplementation strategies (e.g., Duffy, 2005; Yorkston, Beukelman, Strand, & Bell, 1999) may not be as reliably helpful in patients with a predominant AOS as they are in people with dysarthria alone (e.g., distorted...
substitutions and additions may complicate interpretation of letter cues). In addition, the combination of dysarthria and AOS may require earlier implementation of comprehensibility strategies, such as modifying the environment or providing topic cues (Yorkston, Strand, & Kennedy, 1996), perhaps well in advance of significant reductions in intelligibility. If, in addition to AOS and dysarthria, aphasia or other cognitive deficits are present, there are additional challenges to developing effective and efficient use of alphabet supplementation strategies and low- or high-technology alternative means of communication. Patients with a combination of these problems are generally less likely to benefit from speech modification and patient-oriented augmentative communication strategies, and perhaps more likely to require (or require earlier) a primary focus on environmental modifications to enhance communication. Finally, because the communication disorders are degenerative, strategies to facilitate communication will change not only as the disease, in general, progresses but also as the relative contributions and predominance of AOS versus dysarthria (and in some cases, aphasia or dementia) change.

In summary, the cases summarized in this article establish that AOS can occur in people with MND and that, in some cases, it may be an early manifestation of the disease and more prominent than any accompanying dysarthria. Although AOS in people with MND is probably very uncommon, it is important that clinicians, as well as researchers investigating motor speech disorders in people with MND, recognize that a diagnosis of MND does not preclude the presence of AOS. Perhaps more important, MND should be a diagnostic consideration when AOS is the only or an early prominent sign of undiagnosed neurodegenerative disease.

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