Perceptual Detection of Subtle Dysphonic Traits in Individuals with Cervical Spinal Cord Injury Using an Audience Response Systems Approach

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Summary: Objectives. Reduced respiratory function following lower cervical spinal cord injuries (CSCIs) may indirectly result in vocal dysfunction. Although self-reports indicate voice change and limitations following CSCI, earlier efforts using global perceptual ratings to distinguish speakers with CSCI from noninjured speakers have not been very successful. We investigate the use of an audience response system-based approach to distinguish speakers with CSCI from noninjured speakers, and explore whether specific vocal traits can be identified as characteristic for speakers with CSCI.

Methods. Fourteen speech-language pathologists participated in a web-based perceptual task, where their overt reactions to vocal dysfunction were registered during the continuous playback of recordings of 36 speakers (18 with CSCI, and 18 matched controls). Dysphonic events were identified through manual perceptual analysis, to allow the exploration of connections between dysphonic events and listener reactions.

Results. More dysphonic events, and more listener reactions, were registered for speakers with CSCI than for noninjured speakers. Strain (particularly in phrase-final position) and creak (particularly in nonphrase-final position) distinguish speakers with CSCI from noninjured speakers.

Conclusions. For the identification of intermittent and subtle signs of vocal dysfunction, an approach where the temporal distribution of symptoms is registered offers a viable means to distinguish speakers affected by voice dysfunction from non-affected speakers. In speakers with CSCI, clinicians should listen for presence of final strain and nonfinal creak, and pay attention to self-reported voice function and voice problems, to identify individuals in need for clinical assessment and intervention.

Key Words: cervical spinal cord injury–dysphonia–perceptual assessment–respiration–Voice Handicap Index (VHI).

BACKGROUND

Permanent voice change is a common result of reduced respiratory function following injuries to the lower part of the cervical spinal cord (CSCI), that is, below the third cervical vertebrae,[1–3] and Voice Handicap Index (VHI) ratings are higher in groups with CSCI than in matched peers.[3,4] Yet few studies have addressed voice assessment for individuals with CSCI.[1–3,5] Possibly, one reason is that voice issues are relatively mild, compared with the more extensive and severe physical limitations that individuals with CSCI are faced with. Also, the often subtle voice symptoms can make it difficult to identify those who need professional voice intervention, which may be attributed to a lack of sensitivity in the assessment instruments employed. In this paper, we explore a novel approach for the perceptual identification of characteristic vocal symptoms in individuals with CSCI.

Worldwide, CSCI affects 29.5 per 1,000,000 individuals on average per year, and the mean prevalence is 485 per 1,000,000 persons.[6] In Sweden, both prevalence and incidence figures are lower, with CSCI affecting around 1–2 per 100,000 persons per year, and a prevalence of approximately 5000 individuals.[7] Complete injuries shut down motor and sensory functions below the level of injury, whereas incomplete injuries leave some residual function. Whereas injuries affecting spinal nerves C1–C3 involve serious restrictions to the respiratory function, injuries below the cervical vertebrae C3 partially sparing the innervation to the diaphragm and breathing without respiratory aids are possible. However, the intercostal and abdominal muscles are paralyzed; hence, vital capacity is reduced. Moreover, whereas passive expiration is preserved (as this is largely driven by elastic rather than muscular forces), forced expiration is often largely decreased.[8–10]

Although CSCI does not, in general, result in any laryngeal motor dysfunction or specific tissue lesion, the impaired respiratory function may impact the vocal function indirectly. Individuals with CSCI are generally able to generate sufficient subglottal pressure for speech in a calm environment, but the paralyzed intercostal and abdominal muscles lead to reduced lung volumes and capacities, as well as limitations in controlling the subglottal pressure. Specifically, these restrictions in respiratory muscle function affect the generation of subglottal pressure over longer phrases, and in the production of loud voice.[11] Indeed, beside the motor and respiratory impairments, voice limitations reported following CSCI include difficulties making oneself heard and producing prolonged speech.[11] In interviews,

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individuals with CSCI have reported voice as being one of three functions most negatively affected by the restricted breathing.[12] Moreover, comparisons between how individuals with CSCI and how noninjured individuals rate their voice function and voice problems on the VHI[13] have shown significantly more self-rated voice problems in the group with CSCI than in controls.[3,4] Hence, although vocal function may not be primarily affected, the reduced respiratory function can lead to vocal limitations and perceived voice disability.

To meet communicative demands, self-reported compensatory strategies include putting more effort into speaking.[3] Presumably, this effort can be related both to the increased respiratory work needed because of dyspnea[14] and to the phonatory effort when increased laryngeal valving is needed to economize the airstream—the latter being a vocal behavior consistent with a strain-strangled voice quality.[15] In fact, strained voice is a vocal trait that has been reported in perceptual descriptions of voice quality in individuals with CSCI, together with features like reduced loudness, unstable pitch, breathiness, hoarseness, glottal fry (or creak), and long inspirations, which are all more directly linked to respiratory limitations.[1,2,4,5,16] Also, the variation of voice symptoms and symptom severity in this population is large, and the range of voice quality in individuals with CSCI partly overlaps with that observed in noninjured individuals.[2,3] Consequently, part of the population with CSCI is expected to be affected by vocal fatigue as a result of increased vocal effort, and, in the long run, at risk of developing a voice disorder.[17]

Perceptual evaluation is often considered the gold standard in voice assessment and the benchmark for all the other measurements.[18,19] Commonly used perceptual assessment methods are, for example, the GRBAS scale, consisting of five parameters: G, grade; R, roughness; B, breathiness; A, asthenia; S, strain; see for example Hirano[20] and the Stockholm Voice Evaluation Approach (SVEA).[21] The typical procedure for perceptual evaluation of voice quality involves listeners providing their rating of some specific vocal dimension (or of general vocal function) as a global measure for an entire voice sample. In addition to global ratings of voice traits, the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V) includes binary rating for each voice parameter assessing the consistent/intermittent nature of the vocal trait.[22] With GRBAS, as well as with other perceptual assessment instruments, agreement within and between listeners vary. In general, agreement between raters is higher on global parameters (eg, "grade" in GRBAS) than on more specific parameters (eg, "breathiness").[23–25] Moreover, inter-rater reliability is often higher for voices with either very clear or very deviant voice qualities than those with some presence of a specific voice trait.[18,26,27] For subtle voice problems like those observed in individuals with CSCI, some disagreement between listeners in their evaluations is therefore expected. Also, these procedures offer limited sensitivity to the temporal distribution of the dysphonic events within the sample. In assessing vocal function in speakers with intermittent dysphonic symptoms—such as in those observed in individuals with CSCI—traditional global measures may therefore not be sensitive enough. Although CAPE-V offers a possibility to identify intermittent voice traits, it still does not indicate the specific locations in the speech sample. Thus, within this population, alternative perceptual instruments may be more successful in identifying or distinguishing vocal traits.

Attempts to capture the specific voice characteristics of individuals with CSCI using audio-perceptual assessment have shown presence of prosodic features[2] and of dysphonic voice traits.[3,5] MacBean and colleagues[2] used a 33-parameter protocol by Fitzgerald et al,[28] which showed that general stress pattern and variation in pitch were more prominent features in the group with CSCI than in the noninjured control group. Johansson and colleagues[3,5] used a modified SVEA protocol where the presence of voice and speech characteristics related to respiratory-phonatory dysfunction was rated on a 100 mm visual analog scale. In Johansson et al.,[5] both intra- and inter-reliability within and between the two judges were high, whereas the ratings performed by four judges in Johansson et al.[3] of 19 individuals with CSCI and 19 matched controls showed large variability in the ratings and very low average presence even of the most deviant voice traits, such as glottal fry, harshness, and strain-strangled voice (all less than 10 mm on a 100 mm visual analog scale with the end points 0 = not at all present, and 100 mm = highly present). Thus, individuals with CSCI still experience reduced/changed voice function according to self-rated VHI and interviews,[12] but audio-perceptual assessments seem to have limited success in identifying the impact of respiratory restrictions on voice function. Therefore, a more sensitive method to capture subtle and/or intermittent voice characteristics may be needed.

Perceptual evaluation by means of audience response systems (ARS) has been suggested as a viable approach to explore connections between misarticulated or otherwise nontypical events in recorded speech and the extent to which these evoke reactions in listeners.[29–31] In these perceptual listening tasks, listeners are instructed to push a button whenever they perceive something in the spoken material as unintelligible or deviant (depending on the instruction), and each time they do, their "clicks" are registered. There are potential benefits of applying this methodology to the domain of vocal functioning in individuals with CSCI. Apart from the fact that the collected number of "clicks" per speech sample may serve as a measure of the degree of severity of vocal dysfunction, the listeners' "clicks" may also serve as pointers to loci of interests, for example, specific events in the speech signal that are most perceptually salient. If coupled with qualitative speech analysis, for example, with manually annotated instances of creak and strain, this method opens up for new ways of exploring the relation between different vocal traits and how these are perceived. For individuals with CSCI, who often exhibit only subtle and intermittent vocal dysfunction, using ARS may constitute a valuable instrument in exploring connections between vocal traits and the perceptual reactions these may evoke.

Despite the self-assessment of limited vocal function and the risk of voice problems, individuals with CSCI are seldom referred to a speech-language pathologist (SLP) for professional voice assessment and treatment/intervention.[3,5] This suggests limited awareness regarding both the nature of the impairment and its potential vocal consequences, as well as insufficient audio-perceptual methods and instruments in the SLP clinic. For these reasons, exploring novel approaches—such as ARS—may be