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Vocal Loudness as Contributory to the Occurrence of Obligatory Posterior Nasal Turbulence: Case Reports

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Abstract

Two cases are presented that show increased loudness as contributory to the occurrence of audible posterior nasal turbulence as an obligatory symptom. Case 1 was an 18 month-old boy with repaired cleft palate who exhibited sporadic posterior nasal turbulence with velar flutter that was associated with increased loudness. Case 2 was a 4 year-old boy with repaired cleft palate who exhibited relatively frequent posterior nasal turbulence with velar flutter that was associated with pervasive and excessive loudness. Following three therapy sessions, loudness was reduced and audible nasal turbulence was eliminated. Clinical implications are discussed.

Keywords

velopharyngeal dysfunction; nasal turbulence; loudness

Introduction

Audible posterior nasal turbulence is an obligatory symptom of incomplete velopharyngeal closure that occurs during production of high-pressure consonants such as stops, fricatives, and affricates. As noted by Peterson-Falzone et al. (2010), nasal turbulence is a perceptually severe symptom due to its distracting nature. Zajac and Preisser (2016) presented acoustic evidence to show that tissue vibration (or flutter), in most cases, is responsible for the distracting perceptual characteristic of posterior nasal turbulence. As further noted by Kummer and colleagues, audible posterior nasal turbulence – which they call “nasal rustle” – is associated with relatively small velopharyngeal gaps (Kummer et al., 1992; Kummer et al., 2003). Small gaps will cause relatively large pressure-drops that can create turbulent airflow and/or tissue vibration or flutter.

Surprisingly, little is known regarding speech production factors that may contribute to the occurrence of audible posterior nasal turbulence. Baylis et al. (2011) reported that nasal air emission, including nasal turbulence, occurred more frequently during production of

fricatives as compared to stop consonants. Zajac and Preisser (2016) further reported that posterior nasal turbulence with velar flutter occurred more frequently in consonant-vowel syllables containing high rather than low vowels, presumably due to higher velar height of the vowels (Moll, 1962). They also reported that the occurrence of audible nasal turbulence with flutter varied widely among the 30 children studied. This variability suggests the influence of other factors.

One factor that may contribute to the occurrence of audible posterior nasal turbulence with flutter is loudness. Although there is little research on this topic, it is reasonable to assume that increased loudness may trigger posterior nasal turbulence. It is well known that respiratory effort as reflected by subglottal (or tracheal) air pressure is directly related to vocal intensity and loudness (Ladefoged and McKinney, 1963; Isshiki, 1964; Titze, 1994). Increased loudness, therefore, is likely to be associated with increased oral air pressure (Hixon, 1966) that may trigger the occurrence of audible posterior nasal turbulence during production of high-pressure oral consonants. If so, then behavioral management strategies that reduce loudness may also be effective in reducing the occurrence of posterior nasal turbulence. Kummer (2008) has suggested that teaching “light” and/or “quick” articulatory contacts may be effective in reducing audible nasal air emission and nasal rustle. This approach seems reasonable given that light or quick articulatory contacts may also indirectly reduce overall respiratory effort and loudness. In support of this, Golding-Kushner (2001) noted that the use of strong articulatory contacts – recommended to improve overall intelligibility – “may result in an increase in nasal turbulence” (p. 89). Typically, speech-language pathologists (SLPs) are reluctant to recommend speech therapy, even on a trial basis, given the obligatory nature of audible posterior nasal turbulence and limited evidence to support behavioral treatment approaches.

This report describes two young children with repaired cleft palate who presented with audible posterior nasal turbulence characterized by velar flutter during production of high-pressure oral consonants. The first child exhibited sporadic nasal turbulence that appeared to be associated with utterances produced with increased loudness. The second child exhibited more frequent nasal turbulence that appeared to be associated with pervasive and excessive loudness. Trial behavioral management not only reduced vocal loudness in this child, but it also eliminated posterior nasal turbulence.

Case Report 1

The first child was an 18 month-old boy with a repaired cleft of the soft palate. He was born full term without complications. His palate was repaired at 11½ months of age by intravelar veloplasty. Ventilation ear tubes were inserted at the time of palate repair. Hearing was within normal limits (20 dB HL) in the better ear at 12 months of age as determined by sound-field testing. At 18 months of age, he was audio recorded as part of a study investigating velopharyngeal closure of stop consonants. To determine velopharyngeal closure, nasal ram pressure (NRP) was detected at the anterior nares using a two-pronged, nasal cannula as described by Thom et al. (2006). The end of the cannula was connected to a bidirectional, differential pressure transducer (Setra, model 239, range ± 1 inch WC, Acton, MA) referenced to atmosphere. Following Thom et al., the pressure transducer was not

calibrated as NRP is actually a measure of localized airflow, not volume airflow, and the purpose was simply to determine the status of the VP port as open or closed. Estimates of velopharyngeal orifice size, therefore, could not be determined as differential oral-nasal air pressure and volume nasal airflow were not obtained (Warren and Dubois, 1964; Zajac, 2000). To record the boy's speech, an omnidirectional condenser microphone (Shure, model MX150, Niles, IL) was attached to his clothing under the chin. Both the NRP and audio signals were digitized to a computer using an A/D converter (Data Translation, model 9804, Marlboro, MA) and TF32 Lab Automation software (Milenkovic, 2005).

During the recording, the boy produced 63 stop consonants, mostly /b/ and /d/ with 32 and 24 productions, respectively. He achieved velopharyngeal closure on 43 (68%) of the stops as indicated by the lack of positive NRP during the segments. Twenty-three (32%) of the stops were produced with positive NRP indicating some magnitude of velopharyngeal opening. Eight (13%) of the stops were produced with velopharyngeal openings and audible posterior nasal turbulence with flutter. This was determined using perceptual and spectral evidence as described by Zajac and Preisser (2016). Figure 1 shows the audio, NRP, root-mean-square (RMS) relative intensity, and spectrogram of the boy producing the utterance /bə bɑɪ/. The spectrogram shows evidence of posterior nasal turbulence with flutter during the closure interval of the second /b/. This is indicated by quasi-periodic noise (vertical striations) appearing in the interval. The noise is more intense (darker) in the low-frequency region, consistent with tissue flutter. Perceptually, the utterance was produced with increased loudness, especially on the first syllable, with intensity peaking at -11.5 dB. Posterior nasal turbulence, however, did not occur during the first /b/. This was likely due to prevoicing as seen in the spectrogram. Prevoicing is characterized by the start of vocal fold vibration before the oral release of the stop. Vocal fold vibration will increase aerodynamic resistance and cause a decrease in oral air pressure. This is supported by the NRP signal that shows reduced NRP for the first (prevoiced) /b/ segment as compared to the second /b/ segment that has posterior nasal turbulence with flutter.

Figure 2 shows the audio, NRP, RMS relative intensity, and spectrogram of the boy producing the utterance /bə bə bɑɪ bə bɑɪ/ from the same recording session. As shown in the figure, all syllables in the breath group were produced with consistently low intensity, with the first syllable peaking at -20.0 dB, compared to -11.5 dB for the first syllable in Figure 1. More important, none of the /b/ segments in Figure 2 were produced with perceptual or spectral evidence of posterior nasal turbulence with flutter. Two points regarding the figure should be noted. First, although the closure interval of the fourth /b/ shows evidence of positive NRP, posterior nasal turbulence did not occur. Second, the noise in some of the closure intervals (e.g., the third and fourth /b/) was due to background noise and was not posterior nasal turbulence with flutter.

Case Report 2

The second child was a 4 year-old boy also with a repaired cleft of the soft palate. He was born at 37 weeks gestation without complications. His palate was repaired at 10 months of age via a buccal flap due to a wide cleft. No ear ventilation tubes were inserted at the time of palate repair. When he was seen for a team evaluation at age 4, he had patent bilateral

ventilation tubes. Although an audiogram was not obtained, parents reported no hearing concerns. He was receiving speech therapy once per week for articulation. Articulation was characterized by inconsistent stopping of fricatives (e.g., b/v), gliding (e.g., w/l), and interdental production of /s/. Resonance was judged to be within acceptable limits by the first author, a speech-language pathologist with extensive experience with cleft palate speech. The boy was also judged to use an excessively loud voice and exhibited audible posterior nasal turbulence characterized by flutter during production of stops, fricatives, and affricates. During administration of the Arizona Articulation Proficiency Scale-3 (AZ-3) (Fudala, 2000), he exhibited audible posterior nasal turbulence with flutter on 20 of 60 (33%) high-pressure consonants.

Due to the boy's age, modified pressure-flow testing was done using differential oral-nasal air pressure during production of the syllable /pi/ (see Zajac, 2008, Figure 15–21, p. 441). Oral air pressure was detected with a catheter placed behind the lips and connected to a calibrated differential pressure-transducer (Setra, model 239, range ± 15 inches WC) referenced to atmosphere. Nasal air pressure was detected with a catheter embedded in a foam plug inserted into one nostril and connected to a second calibrated differential pressure-transducer (Setra, model 239, range ± 15 inches WC) referenced to atmosphere. The oral-nasal air pressure signals were digitized to a computer using PERCI-SARS hardware and software (version 4.01, Microtronics, Inc., Chapel Hill, NC). Results indicated inconsistent velopharyngeal closure as evidenced by the presence of nasal air pressure during production of some but not all /p/ segments. Because nasal airflow was not obtained using the modified approach, velopharyngeal gap size could not be estimated. Nevertheless, the boy's high differential oral-nasal air pressure levels were consistent with relatively small openings. Oral air pressure levels often approached 11 centimeters of water. This level is approximately twice as high as expected for an adult (Zajac, 2000) and was consistent with excessive loudness as judged by the first author.

Figure 3 shows the audio, RMS relative intensity, and spectrogram of the word “horse” that was recorded during articulation testing. The boy was recorded using a head-mounted condenser microphone (AKG, model C520, Northridge, CA) and Computerized Speech Lab (model 4400, KayPentax, Lincoln Park, NJ) at a sampling rate of 44.1 kHz. The word “horse” was one of the AZ-3 test words that the boy produced with audible posterior nasal turbulence and flutter. As seen in the figure, there is spectral evidence of velar flutter during production of /s/. Flutter is indicated by the relatively dark (intense) and periodic vertical striations in the spectrogram. This pattern was also present during production of stops and affricates produced with posterior nasal turbulence with flutter. The noise floor in the intensity trace of the figure was approximately -59 dB compared to the vocalic portion of the word “horse” that peaked at approximately -8 dB. This reflects an 86% increase in intensity relative to the floor and was consistent with an excessively loud voice.

The boys' parents were willing to consider secondary palatal surgery to manage the audible posterior nasal turbulence if needed. Based on all findings of the evaluation, however, speech therapy was recommended to continue for articulation but also to include behavioral management of loudness on a trial basis. The boy was seen for three 30-minute therapy sessions over a period of approximately 2 weeks by an outside, private SLP. Although details

of therapy activities were not described, the SLP reported that she instructed the boy to whisper as one way to reduce loudness. A summary report from the SLP indicated that “nasality” was eliminated by the third therapy session.

The boy was seen for a follow-up evaluation approximately 2 weeks after his last therapy session, approximately 3 months after his previous team evaluation. At follow-up, the boy’s vocal loudness was judged to be appropriate, neither excessively loud nor too quiet or whispered, and he exhibited no audible posterior nasal turbulence with flutter during conversation or administration of the AZ-3. Resonance was within normal limits.

Figure 4 shows the audio, RMS relative intensity, and spectrogram of the phrase “a horse” produced by the boy during administration of the AZ-3 at follow-up. As seen in the figure, there is only noise associated with normal oral frication during production of /s/. The intensity signal of Figure 4 also shows evidence of reduced loudness as compared to Figure 3. Although the noise floor in Figure 4 was approximately the same as in Figure 3 (i.e., –60 dB), the vocalic portion of the word “horse” peaked at approximately –20 dB. This reflects only a 67% increase in intensity relative to the floor as compared to Figure 3 and was consistent with reduced vocal loudness.

Discussion

Audible posterior nasal turbulence is a common and highly distracting perceptual symptom of incomplete velopharyngeal closure. Limited information, however, is available regarding speech production factors that may contribute to its occurrence. The cases presented in this report provide some evidence that increased loudness may be a significant factor that triggers posterior nasal turbulence, either sporadically or more pervasively.

Young children with repaired cleft palate may be especially prone to exhibit audible posterior nasal turbulence. This may be due to the tendency of young children in general to produce speech using higher oral air pressures (Zajac, 2000; Fahey and Zajac, 2013; Searl and Knollhoff, 2013) and higher conversational intensity levels (Gelfer and Denor, 2013). Given that both oral air pressure and intensity tend to decrease with increasing age, clinicians and parents should not be too concerned if a very young child with repaired cleft palate exhibits posterior nasal turbulence, especially if sporadic in nature, not accompanied by other symptoms of velopharyngeal dysfunction, and appears related to excessive loudness. Concerns should be further relieved if posterior nasal turbulence is reduced or eliminated when loudness is decreased.

Typically, obligatory symptoms of velopharyngeal dysfunction are considered manageable only by surgical and/or prosthetic approaches. In most cases, SLPs are rightly cautious not to recommend behavioral approaches for hypernasality and/or audible nasal air emission – symptoms typically associated with large velopharyngeal gaps. Audible posterior nasal turbulence with or without velar flutter, however, typically occurs because of relatively small velopharyngeal gaps that create large pressure-drops. In theory, reducing the pressure-drop should reduce or eliminate the turbulence. The second case report provides evidence that supports this assumption. Perceptually, the boy presented with pervasive and excessive

loudness and high oral air pressure prior to trial therapy. Following therapy, loudness was reduced and audible posterior nasal turbulence was eliminated. Resonance did not change. Due to the elimination of the perceptual symptoms, there was no need to consider secondary surgical management at the time. Based on the outcome of this case study, SLPs might want to consider stimulability testing and trial behavioral management for some young children who present with audible posterior nasal turbulence in conjunction with excessive vocal loudness. Clinical research with an adequate number of children, however, is needed to confirm the effectiveness of reducing vocal loudness and to determine if benefits persist over longer periods of time.

Finally, the present report may have implications for the related phenomenon of “soft voice syndrome.” As noted by Peterson-Falzone et al. (2010) and others, some older children with repaired cleft palate tend to habitually speak with reduced loudness. One reason may be to camouflage or mask obligatory symptoms of velopharyngeal dysfunction. SLPs who encounter such children should actually stimulate louder voice to determine if perceptual symptoms occur. If so, then physical management may be indicated.

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Figure 1. Audio, nasal ram pressure (NRP), root-mean-square (RMS) relative intensity, and spectrogram of the utterance /bə bæ/ produced by an 18 month-old boy with repaired cleft palate. Audible posterior nasal turbulence with flutter occurred during production of the second /b/ as indicated by the spectrogram.

Figure 2. Audio, nasal ram pressure (NRP), root-mean-square (RMS) relative intensity, and spectrogram of the utterance /bə bə bəɪ bə bəɪ/ produced by the same child in Figure 1. No evidence of posterior nasal turbulence with flutter is apparent.

Figure 3. Audio, root-mean-square (RMS) relative intensity, and spectrogram of the word “horse” produced by a 4 year-old boy with repaired cleft palate who exhibited pervasive and excessive loudness. Audible posterior nasal turbulence with flutter occurred during production of /s/ as indicated by the spectrogram.

Figure 4. Audio, root-mean-square (RMS) relative intensity, and spectrogram of the phrase "a horse" produced by the same child in Figure 3 following behavioral management of excessive loudness. No evidence of posterior nasal turbulence with flutter is apparent in the spectrogram.