Articulatory Features of Tones in Whispered Chinese

Man Gao, John H. Esling
Department of Linguistics, Yale University
P.O. Box 208366 Yale Station, New Haven, CT 06520-8366

Department of Linguistics, University of Victoria,
P.O. Box 3045, Victoria, B.C. V8W 3P4 Canada

ABSTRACT

Whisper is a common modality of speech communication, regardless of language. Fibre-optic laryngoscopic photographs in research by Esling (2002) show that the vocal folds are parted for whisper, but that the laryngeal aryepiglottic sphincter is engaged during whisper inquiring from the perspective of the vertical plane into the larynx. The objective of this study is to seek further evidence on the existence of sphincter mechanism during whisper and investigate how whispered tones are produced Laryngoscopic endoscopy is used to observe the pharynx and larynx when Mandarin tones are produced. Comparisons are made between phonated and whispered speech and among four Mandarin tones, and a set of relationship among sphinctering, larynx height and tongue root retraction is illustrated.

1. INTRODUCTION

The essential physiological characteristic of whisper lies in the configuration of the glottis and epilarynx: the vocal folds remain opening for whispering, thus friction is produced when the airstream from the lungs is forced through the passage. There are different descriptions at the glottal level for whisper: Catford (1977) and Kallail & Emanuel (1984) describe the vocal folds as "narrowing", "slit-like" or "slightly more adducted"; according to Tartter (1989), "whispering speech is produced with a more open glottis than normal voicing". Based on the observations of phonation with photographs taken with a fibre-optic bundle inserted through the mouth, Buuren (1983: 13) claims that we would expect to see the "familiar triangular opening between the arytenoids". However, all the above descriptions were made at the cross-sectional or horizontal level of the glottis.

Esling (1996, 1999) found that the aryepiglottic sphincter mechanism is responsible for the sound category 'pharyngeal' based on his observations from fibreoptic laryngoscopy. The aryepiglottic sphincter is engaged when 'the aryepiglottic folds (linking the adducted arytenoids with the margins of the epiglottis) press up under the body of the epiglottis as the tongue retracts' (Esling & Clayards, 1999: 28). The aryepiglottic folds obscure the vocal folds and form a triangular shape epilaryngeally. Observations from the laryngoscopic video files for phonated and whispered vowels in Bai[i] show that laryngeal sphincter mechanism is active in all whispered vowels. To summarize the laryngeal sphincter as a physiological function of whispering: no vocal fold vibration is found in whisper, and there is a narrow 'Y'-shape opening between the aryepiglottic folds in whispered lax vowels. The ventricular folds come over and obscure the vocal folds. The aryepiglottic folds press up and draw close to the middle of the airway, reducing the epilaryngeal tube area to a small triangular opening. They are observed in contact posteriorly, as are the apexes of arytenoids, and in contact laterally with the epiglottis. A slight larynx raising but no tongue root retraction is found in lax vowels.

This aryepiglottic mechanism is also related to tone in tone languages such as Tibeto-Burman Mpi (Esling, 1996). Some Asian languages have tones that involve some degree of pharyngealization, in the sense of sphinteric narrowing, such as Yi and Bai. With evidence of the mixed results from tone perception tasks in whispered Mandarin, Abramson (1972) argued that some speakers make use of special maneuvers to compensate for the missing pitch information, while others just use the usual instructions to their speech production mechanisms minus fundamental frequency control. Given the importance of tone in this issue, I hope that this research is able to provide some insightful findings into articulatory reorganization in whisper.

2. PROCEDURE

A Kay Elemetrics Rhino-Laryngeal Stroboscope 9100 was used to observe articulations of four Mandarin tones in phonation and whisper. This is a computer-controlled system with a halogen light source, a Mitsubishi S-VHS video cassette recorder BV-2000 and an oral endoscope. The rigid endoscope was put into the mouth of the subject over the tongue so as to have a clear view of the pharynx and larynx on the monitor. Using the oral technique, only a vowel sound similar to vowel in si 'to think' in Mandarin Chinese can be produced by the subject of this observation, Dr. John H. Esling, a second-language speaker whose Chinese was acquired at the University of Michigan in 1971-73. Articulation of four Mandarin tones in both phonated and whispered speech is videotaped at 30

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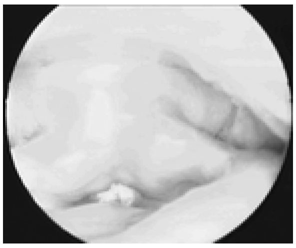
frames/sec. Videotapes were edited into clips containing one tone in both phonation type each for observation and evaluation.

3. OBSERVATIONS AND DISCUSSIONS

Tone differences are not as articulatorily obvious (by observation) as they are auditorily. It is difficult to view directly the cricothyroid mechanism, but its effect on vocal fold length can be seen. For phonated tones, the observed length of the vocal folds decreases from Tone 1 to Tone 2, and to Tone 3. The length of the vocal folds is taken as a primary indication of changing pitch. The higher the pitch (Tone 1), the longer the vocal folds. Larynx raising is observed in the later part of Tone 2 articulation, which might be related to the rising fundamental frequency of Tone 2; and it is not observed in Tone 1. Larynx raising is observed in Tone 4 at the beginning of the articulation, followed by lowering. The raising of the larynx found in Mandarin tones, therefore, is a secondary feature of pitch shifting, which provides some evidence for the assumption that larynx-height is related to pitch. It is also possible that both larynx raising and tongue-root retraction are related to increase in pitch, but we will consider these two mechanisms primarily in connection with the laryngeal sphincter, which is not traditionally thought of as having a role in pitch change. The only phonated tone that involves the aryepiglottic laryngeal sphincter mechanism is Tone 3. Figure 1 shows the pharynx and larynx in the production of phonated Tone 3. In Tone 3, the aryepiglottic folds narrow to reduce the epilaryngeal tube area to a small triangular opening to the extent that part of the vocal folds is obscured. The aryepiglottic folds form an angle of about 150° with the arytenoids (see Figure 1-middle) as compared to almost a straight 180° line found in other tones in modal phonation and in the state of breath.



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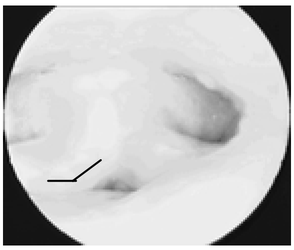

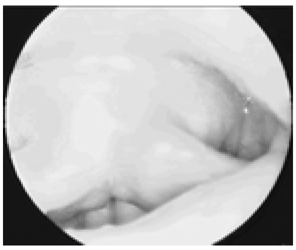

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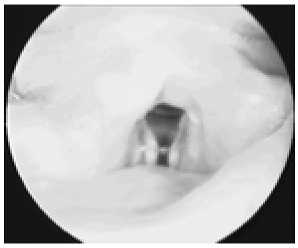
Fig. 1 Pharynx and larynx in phonated Tone 3

All the whispered tones are found to involve this aryepiglottic laryngeal sphincter mechanism (Esling, 1996, 1999). No vibration is observed between the vocal folds, which adduct slightly anteriorly to produce a ‘Y’ shape. The aryepiglottic folds adduct anteriorly and press up under the body of the epiglottis to reduce the epilaryngeal tube area to a narrow channel above the triangular posterior glottal opening. Larynx raising and tongue root retraction as concomitant features are observed. In addition, it is found that all whispered tones in these careful productions are preceded by an epiglottal stop. Because the tones were produced in citation, the speaker held his breath before each production in whisper, which would probably not occur in running speech.

Some differences are observed among the four tones. Tone 1 has a relatively larger triangular shaped lumen resulting from sphinctering, the open vocal folds are not obscured, and the aryepiglottic angle is about 120° as shown in Figure 2 (cf. Esling & Clayards, 1999). The larynx rises at the beginning of Tone 1, and both vocal folds opening and larynx height remain stable until the end of the syllable.



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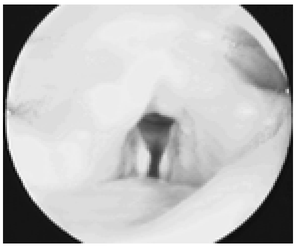

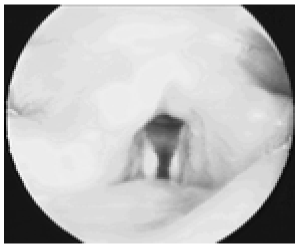

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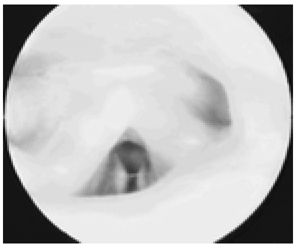
Fig. 2 Pharynx and larynx in whispered Tone 1

Tone 2 has a smaller triangular opening in the area of the epilaryngeal tube than Tone 1, which is interpreted as a feature of larynx lowering, but the narrowing is still not small enough to obscure the vocal folds. The aryepiglottic angle seen in Figure 3 is also about 120° at syllable onset, similar to that of Tone 1. In addition to larynx raising as one of the concomitant features of the sphincter, the larynx is observed to rise after the beginning part of Tone 2, as can be observed in Figure 3 (middle and final). This corresponds to what is found in the phonated version.



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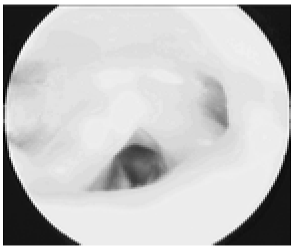
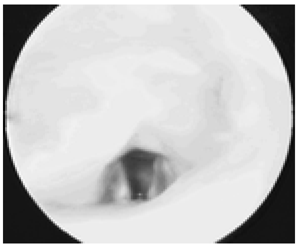
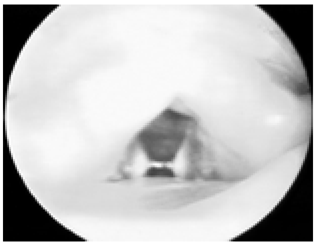




Middle Final

Fig. 3 Pharynx and larynx in whispered Tone 2

Figure 4 shows the pharynx and larynx of whispered Tone 3, where more activation of the sphincter mechanism is incorporated, and both glottal and sphinteric changes take place as the pitch contour proceeds. Tone 3 has a sharper aryepiglottic angle of about 90°. The glottal airway is gradually reduced to a smaller opening, where the opening in the middle is smaller than Tone 2, but the vocal folds are still visible. The larynx is lowered towards the middle of Tone 3, which relates to the falling contour. In the later half (rising), the larynx rises as the opening between the vocal folds is increased. This observation of Tone 3 reaffirms findings from Tone 2 that larynx height is related to pitch; the higher the pitch, the higher the larynx. Thus, in the absence of vocal fold vibration, larynx height appears to be the primary feature for pitch shifting in whispered tones.



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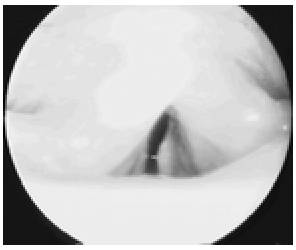
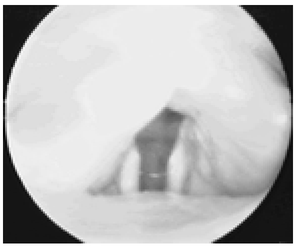
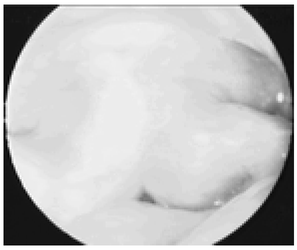




Middle Final

Fig. 4 Pharynx and larynx in whispered Tone 3

Tone 4 has a dynamic articulation given that it has the greatest pitch range and is reported as the shortest tone in most of the literature. At the beginning, following full sphincteric occlusion, the vocal folds adopt a wide opening initially, accompanied by a further elevation of the larynx after the epiglottal stop. Then the larynx lowers abruptly and at the same time the glottal opening decreases in size until the end. The aryepiglottic angle remains around 100°. Figure 5 shows the state of the pharynx and larynx starting from the epiglottal stop for the articulation of Tone 4.



epiglottal stop

Beginning Final

Fig. 5 Pharynx and larynx in whispered Tone 4

Many researchers suggested with collected data that the perceived pitch of either whispered or phonated vowels is more directly related to F2 than to the fundamental frequency or to F1 (Peterson & Barney, 1952; Thomas, 1969; McGlone & Manning, 1979), and it is assumed that F2 is retained in whisper and is related to the height of larynx. When the larynx is raised, F2 goes up; while when the larynx is lowered, F2 goes down. In company of the sphincter mechanism, however, the effect of sphinctering on F2 would be the same as for pharyngealization if larynx height does not change, i.e. F1 increases and F2 decreases. This complicates the evaluation of pitch in whisper using acoustic spectral means.

4. CONCLUSION

In summary, the laryngeal sphincter mechanism as the primary physiological characteristic of whispering is observed and described in this study. No vocal fold vibration is found in whisper, and there is a 'Y' shaped glottal opening observed in all whispered tones, with the vocal folds parted anteriorly. The aryepiglottic folds press up and forward to draw close to the middle of the airway over the glottis, thereby reducing the epilaryngeal tube area to a small channel which differs among tones. Larynx raising and tongue root retraction occur as concomitant features of sphinctering, as in phonated speech, but in whisper, larynx height is primarily related to shifting of

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pitch, substituting for the length and vibratory frequency of the vocal folds in phonation. In other words, the larynx rises in rising contours and lowers in falling contours during whisper. This is suspected to influence F2 frequency by changing the shape of the pharyngeal resonating cavity. As to the degree of sphincteric narrowing, it might primarily relate to the noise production in whisper that controls the intensity of tones. Kratochvíl (1968) accounts for the loudness of phonated tones in citation in such a way that loudness increases in rising contours and decreases in falling contours. The tendency is observed from the laryngoscopic images in this study that the sphincteric opening enlarges in the rising contour while reducing in the falling contour, showing that the degree of sphincteric narrowing may relate to the intensity of tones.

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[i] Bai speech data were produced by Li Shaoni (Central University of Nationalities, P.R.China) at the University of Victoria, and are provided by Dr. John H. Esling.

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