**The aryepiglottic folds and voice quality in the Yi and Bai languages: laryngoscopic case studies**

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1. Introduction. This paper will present data and analysis from a laryngoscopic study of the voice qualities in the Yi and Bai languages.[1] We believe that the experiments to be described below are the first examples of direct observation of the larynx and supralaryngeal area of native speakers (Lama and Li, respectively) during production of the remarkable voice qualities that are hallmark features of Yi and Bai. While other languages of the area will need to be studied in depth, we believe our results are suggestive for other Tibeto-Burman languages spoken in southwest China and perhaps for languages outside of Tibeto-Burman and outside this geographic area. Because the larynx is deep in the throat, shrouded in darkness, rapidly moving during phonation, and most importantly because laryngoscopes are expensive and cannot be easily transported to where native speakers of these languages live, descriptions of voice quality in Yi and Bai have heretofore been based on the impressions of native speaker linguists. Other accounts have relied on reconstructive experimental techniques that are capable of describing Yi and Bai voice quality only by inference, e.g. by means of acoustic data (spectral tilt), by means of electroglottographic studies, or airflow data (inverse filtering). We were fortunate in being able to bring Mr. Lama (in June 1998) and Mr. Li (in October 1999) to the University of Victoria, Canada, where the experiments to be described below were carried out.

Voice quality is an important trait of the Tibeto-Burman languages. Many linguists have investigated the role of voice quality as a phonologically contrastive category for this language group. Also, general phonetics has studied the possibilities of voice qualities by human speakers (Laver 1980, Catford 1977). Nevertheless, there has been little detail about which anatomical structures are involved and how they function in the production of actual speech sounds in native speakers. As we will make precise below, our Yi and Bai speakers both showed persuasive similarity (there were also some differences) in producing tense voice quality by sphinctering the aryepiglottic folds and

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elevating the epilaryngeal tube sometimes almost completely closing the entrance of the larynx into the pharyngeal cavity at the *aditus laryngis*, a triangular-shaped opening between the larynx and the pharynx. We would note, though, that Bai exhibits voice qualities other than tense voice contrast and therefore can be said to have finer phonetic distinctions than Yi. Thus, it has beside tense voice contrast a kind of harsh voice and breathy voice and for some syllables even sequences of voice qualities harsh-modal and breathy-tense.

2. The Yi and Bai languages. The Yi and Bai language are both languages with relatively large numbers of speakers.

2.1. The Yi language (in former times often called *Lolo*) is one of the largest in China and is spoken in many areas, including southwestern Sichuan, many areas of Yunnan, western Guizhou, and the northwestern tip of Guangxi. The total population in China amounts to 7 million.[2]

The first systematic study of Yi phonology is attributed to Chen 1963 and Chen et al. 1984, although there have been scattered reports by others. In his later treatment there are 10 vowels, five with tense voice and five with lax voice. There are three tones with the values 55, 33, and 21. (A fourth tone exists in sandhi position according to Lama Ziwo 1998, though Chen regards this tone as a basic tone with the other three tones.) Chen describes the tense voice quality as follows. For the lax vowels, the muscles of the articulators are always tight; for the tense vowels, the muscles of the articulators are much tighter, but the tightness is not prolonged throughout the syllable. Li and Ma 1983 suggest that some of the vowels are "tight throat" or "glottal tense", which is in some way different from "tense". As these accounts show, “tense” and “lax” are regarded as endpoints on a scale in Yi, whereby “lax” usually means modal voice without special stricture whereas “tense” entails some form of tension. The extact nature of this tension and other related voice qualities is what this paper intends to examine. Moreover, it is a very important feature of Yi that vowel quality and voice quality are linked in the sense that some of the vowels with lax voice quality are higher and further front than the corresponding vowels with tense voice (in acoustic terms lax vowels have lower first formant frequencies and higher second formant frequencies), cf. 3.1.

2.2. Bai. The Bai language has today 1.6 million speakers as determined by the census of 1996 and is divided into three vernacular areas that center on Dali, Jianchuan, and Bijiang Counties of Yunnan Province. Mr. Li originates from Jianchuan, but comes from a mountain village and not the county seat.

[2] Edmondson, in fieldwork in 1998 and 1999, has found small communities of Yi speakers in Hà Giang, Lao Cai, and Cao Bang Provinces of Vietnam. Malyrzyr (p.c.) has reported to us the existence of Yi in Myanmar, which confirms evidence in the hands of Jimmy G. Harris, who possesses a tape made by Ron Morse of the Morse family of an Yi speaker from Putao-O district in Kachin State, northern Myanmar. Lama senses that Putao-O Yi is quite similar to his own Liangshan Yi, Sichuan Province, China.

On the descriptive side, notable research contributions to the study of Bai have been made by: Xu and Zhao (1964, 1984), François Dell (1981), Grace Wiersma (1990) and Starostin (1994). Of relevance are also the essays on voice quality in related languages by: Hu and Dai (1964), Ma Xueliang et al (1981), Maddieson and Ladefoged (1985) and Chen Kang (1988).

In our earlier work we have noted systematic voice quality contrast in both Dali and Jianchuan Bai, cf. Edmondson and Li (1988, 1994, 1997). As we will outline below, Jianchuan Bai possesses not only a distinctive set of pitch contrasts: 55, 33, 35, 31, and 21, but also four different kinds of voice quality contrasts: (a) modal voice, (b) tense voice, (c) breathy voice, and (d) harsh voice.

2.3. Aryepiglottic folds. Articulations in the supralaryngeal area have attracted considerable interest in recent years. Although Maddieson and Ladefoged (1985) conclude that the tense-lax difference in Yi is a glottal distinction between phonation types, our previous research on the role of the tongue, pharynx and epilaryngeal structures on laryngeal stricture (Esling, 1996) led us to predict that this larger set of articulators might be responsible for *tense* voice quality in Yi and for *tense* and *harsh* voice qualities in Bai.[3] Supralaryngeal articulations occur occasionaly and in particular they occur as distinctive phonemes in Semitic (for example, Arabic), Caucasian (e.g., Abkhaz), and Amerindian (Salish, as in Thompson, and Wakashan, as in Nootka) languages or as a secondary characteristic where a series of sounds is modified by the presence of a supralaryngeal posture as is found in Formosan (e.g., Amis), and Mongolic (e.g., Khalkha) languages. We also feel that Tibeto-Burman, Miao-Yao, Sinitic, and Mon-Khmer languages offer an opportunity to study register systems with contrastive phonation types using direct laryngoscopic observation.

Major research on covert structures of the throat, including supralaryngeal articulations, remained basically in a rudimentary state until this century, cf. Zemlin (1998:138). In early radiographic work at University College London, it was found by Stephen Jones that in Somali pharyngeals the larynx not only elevated but that there also appeared to be some sort of vibration around the epiglottis during forceful articulations (1934). Catford (1968, 1977, 1983) described these sounds as *epiglottopharyngeal* and also identified the possibility of what he called *epiglottal trilling*. Documentation of such trilling in certain tense larynx conditions can be found in Traill (1985, 1986) for Khoisan and in Rose (1989) for Zhenhai Chinese. Esling (1996) presents laryngoscopic evidence that it is the laryngeal (aryepiglottic) sphincter which is

[3] According to Zemlin, (1981:145), "the aryepiglottic folds form a sphincterlike superior aperture for the larynx. Contraction of the aryepiglottic muscles, during swallowing or gagging, may close the laryngeal aperture, either by drawing the sides medially or by depressing the epiglottis."

responsible for the production of both pharyngealized voice and what Laver terms *raised larynx voice* (1980).

Recent work has suggested that the aryepiglottic folds contribute to other domains of vocalization. Yanagisawa, Estill, Kmucha and Leder (1989) and Honda, Hirai, Estill and Tohkura (1995) have shown that the epilaryngeal tube is elevated into the pharynx during many singing styles. But it was not traditional western singing styles that have focus widespread interest on supraglottal structures. There is, for example, the case of *throat singing* or biphonic/overtone singing, which reaches its full flower among the Tuvans of Central Asia, cf. the role of the aryepiglottal folds in throat singing discussed in Levin and Edgerton 1999. Inuits and Tibetans are also known to show special *chant modes*. Esling's own study of a Tibetan monk confirmed the role of the aryepiglottic folds in chant modes. In the high chant mode our Tibetan subject appeared to demonstrate raised larynx, whereas in the deep chant mode the tube funneled in a way similar to the harsh voice quality of Bai.

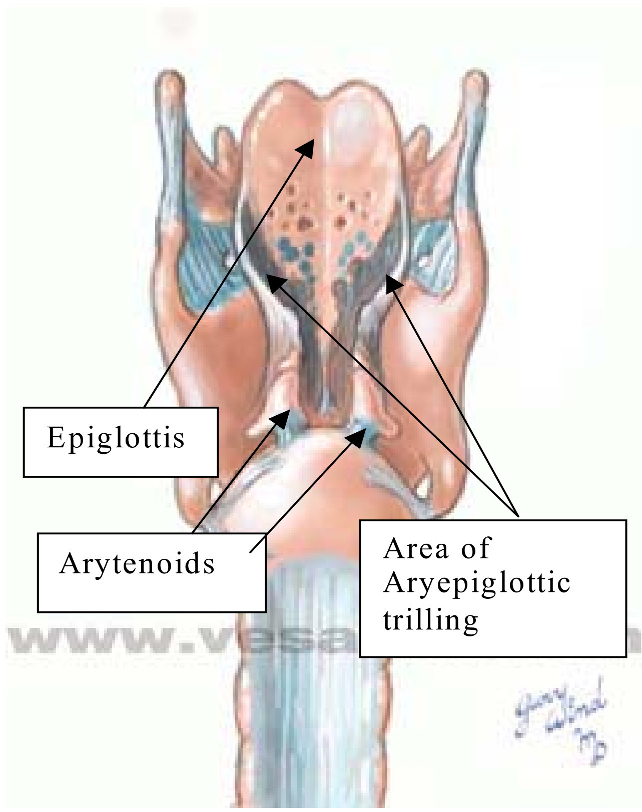


Figure 1: Aryepiglottic folds and the area where trilling was observed during harsh voice in Bai

In Figure 1 one can see the aryepiglottic folds and their relative position above the arytenoids, true and ventricular vocal folds. We also indicate the area where we observed trilling in Bai.

3. Methods. In this study the production of Yi and Bai syllables were observed with a stroboscopic *laryngoscope*, which is an imaging device with a very flexible fiber optic tip devised by Sawashima and Hirose in 1968, and improved and reduced in size in recent years. In particular, the instrument in this research was the Kay Elemetrics Rhino-Laryngeal Stroboscope 9100 with a package halogen light source, an Olympus ENF-P3 fiber optic laryngoscope, and a Panasonic KS with 152 camera and 28mm wide-angle lens. The procedure for use of the device is to insert the fiber optic bundle through a nostril and then lower it into the nasal-pharyngeal cavity until it is positioned over the glottis just above the level of the apex of the epiglottis. Once the scope is adjusted for optimal viewing, the subjects utter sets of lexical items from a prepared word list that includes voice quality contrasts as determined by our previous research (Edmondson and Li 1994, Chen 1963, Chen et al 1984, Lama Ziwo 1998). During production of the sounds we made S-VHS video recordings for later observation, analysis, and measurement. Mr. Li, the Bai subject, also produced contrastive sets of items using whisper and then voice so that we could determine if aryepiglottic trilling was possible while the true vocal folds were in a voiceless position. For Mr. Lama the recording lasted about 20 minutes in duration and for Mr. Li about 37 minutes.

From our previous experiments with the laryngoscope we knew that front vowels allowed optimal viewing, as test syllables with open vowels, such as [ɑ], tended to result in the tongue moving back and obscuring the view. We, therefore, spent most of our time in recording examples with non-open vowel nuclei.

3.1. Yi data. Data were selected that showed the linkages of voice quality and vowel quality. We divided examples into lax and tense categories on the basic of our previous research.

Table 1: Yi test syllables

| Lax voice | Tense voice |
|---|---|
| [i33] he (in indirect discourse, first person) | [ɛ̰33] duck |
| [o33] head | [ɔ̰33] hen’s call to chicks |
| [ɯ33] no meaning | [ɑ̰33] no meaning |
| [ɿ33] to urinate | [ɿ̰33] to press |
| [u33] intestine | [ṵ33] to hatch |
| [pi33] to read | [pɛ̰33] to kick |
| [po33] to blow out | [pɔ̰33] to split |
| [pɯ33] to exclaim | [pɑ̰33] to exchange |
| [pɿ33] eagle call | [pɿ̰33] baby excrement |
| [pu33] male animal | [pṵ33] to go back |

3.2. Bai data. Previous research showed 15 contrastive syllables in Jianchuan Bai distributed as shown in Table 2. In order to test for voice quality, we constructed several minimal sets of 15 lexical items (one shown here) that differed in pitch and voice quality (for one set we alternated between aspirated and unaspirated initials, in order that every example represent a real lexical item.)

Table 2: Bai test syllables

| Lax | Tense | Lax, Nasal | Tense, Nasal |
|---|---|---|---|
| [tɕi55] much | [tɕi6̲6̲] to mail | [tɕi5̃5̃] a bear, gold | [tɕi6̲̃6̲̃] sword |
| [tɕi33] to pull | [tɕi4̲4̲] crowded, leech | [tɕi3̃3̃] near, sour plum | [tɕi4̲̃4̲̃] naughty |
| [tɕi3̤1̥] earth | [tɕi4̤2̲] to chase | [tɕi3̤̃1̥̃] decrease, alkalai | [tɕi4̤̃2̲] to soak, arrow |
| | [tɕi2̤̲1̤̲] owe money, flag | | [tɕi2̤̲1̤̲̃] bracelet |
| | [tɕi3̤̲5] nervous, active | | |

The first two rows of Table 2 have only the features [+tense] or [-tense]. Row three has breathy voice; row four harsh voice; and row five has harsh voice in the first half of the syllable and modal voice in the second. Moreover, our transcriptional system makes use of the following designations: (a) some treat the graph [ɿ] as a fricativized central vowel, called *apical vowel* by Karlgren. We treat the symbol as a syllabic fricative co-occurring with homo-organic sibilant or affricate initials, (b) the graph [u] in Yi is also a fricativized vowel and is sometimes represented as [v̩],[4] (c) in Bai the tone value 66 suggests a very high pitch above a 55 tone level; the duration of such tense syllables is also somewhat reduced and ends in a constriction, (d) the graphs [tɕi3̤1̥] express that the first part of a Bai syllable has a breathy quality, while the second half of the syllable is whispered without voice, (e) the graph [tɕi2̤̲1̤̲] indicates a harsh voice quality with a 21 pitch shape, (f) nasalization is represented with a superscripted tilde, and (g) in Table 2 we have also given the spelling of the test items in the Bai script.

4. Results of observations. Several anatomical landmarks were clearly identified in the photographic output of Lama Ziwo and Li Shaoni. Specifically, we were able to identify: (1) the apices of the arytenoid cartilages, (2) the

[4] We have used with minor modifications the transcriptional system of Chen et al. 1984.

apices of the cuneiform cartilages of Wrisberg, (3) the lateral line of the aryepiglottic folds, (4) the lateral margins of the epiglottis, (5) the tubercle of the epiglottis at the anterior commissure of the vocal folds, (6) the vocal folds and ventricular folds, and (7) the pyriform sinuses.

4.1. Lax voice. It is customary to view lax voice as the opposite of tense voice in the phonological system of contrasts of Yi and Bai. In actuality, we believe that lax voice in these languages often resembles modal voice, as defined by Laver 1980.

4.2. Tense voice. Three main aspects of the difference between tense and lax registers were made clear from our laryngoscopic observations. The *tense* series in both Yi and Bai involved the engagement of the *laryngeal (aryepiglottic) sphincter* mechanism while the corresponding lax series did not show the sphincter mechanism, cf. Figures 3, 5, and 7 in contrast to Figures 4, 6, and 8 for Yi and Figure 9 in contrast to Figure 10 for Bai. Moreover, the tense series involved *larynx raising*, while the lax series had neutral larynx height. In both Yi and Bai the tense counterpart showed the epiglottic root (base) moving back while the apexes of the lateral aryepiglottic folds were drawn tightly together toward the center covering the entrance to the glottis and the sphinctering mechanism causes the constriction to appear to bulge upward. The ventricular folds also adduct covering the true vocal folds especially posteriorally. For the voice quality we described as *breathy followed by tense* we observed the same sort of "bag closing" gesture with the reinforcement of the ventricular folds.

In contrast to Bai, the Yi tense and lax vowels differ significantly so that in the tense set the first formant frequency is raised and the second formant frequency is lowered. Thus, it appears as if the tongue root reinforces the posterior movement of the epiglottis during production of tense vowels. This vowel quality difference is confirmed acoustically Lama (1998:87). In Bai the vowel qualities do not show drastic changes in the different registers.

4.3. Breathy voice. Zemlin 1998:175 has reported, "the most commonly cited correlate [of breathy voice] is a persistent chink in the posteriormost portion of the glottis." As can be seen in Figure 11 Bai breathy voice (Yi does not possess breathy voice quality) also shows this hallmark chink configuration. The photo in Figure 11 was taken at point in the syllable where voicing has just ceased and whisper had just begun. In this snapshot the glottis is still open (especially the area between the arytenoids), allowing large quantities of air to escape into the pharyngeal cavity. This chink lasts throughout the syllable.

4.4. Harsh voice. The voice quality called *harsh* demonstrates the most extreme sphinctering, ventricular reinforcement, and laryngeal raising of all the voice qualities covered in this paper, as the opening over the larynx become very tiny at its most occluded. It was thus the most extreme form of tense. Moreover, the harsh series was predisposed to aryepiglottic trilling while the lax series was such that the larynx was not sufficiently raised and the sphincter not sufficiently engaged and thus, in the lax series the possibility of trilling was excluded. The effects of trilling was most pronounced in the space between the arytenoid cartilages, cf. Figure 13, though the trilling cannot be seen in still pictures. Sometimes bubbles of air in mucus could be seen emerging from between the adducted muscle tissue of the aryepiglottic folds. Mr. Li was also able to produce the aryepiglottic trilling during whisper, a mode with no regular vibration of the true vocal folds, showing that, to some degree, the vibration of the true vocal folds and the trilling of the aryepiglottic folds are independent.

5. Discussion. It is clear that the tense register of Tibeto-Burman languages such as Yi and Bai can be interpreted as a constriction of the supraglottal cavity involving the aryepiglottic sphinctering mechanism, which is formed anterioraly by the epiglottis, posteriorly by the apexes of the arytenoid cartilages, and laterally by the aryepiglottic folds. This constriction is accompanied by a raised larynx posture. The label we use to describe this phenomenon is *sphinctered voice*. It is logical to expect this sphinctered voice series to contain a degree of "laryngealization" in the sense of tense voice or harsh voice, because of the predisposition of the vocal folds to shorten and close that a sphinctered larynx affords. We did not find in Bai the *tongue root effect* on individual vowels, such as that found in Yi, as reported. In this regard the two languages have developed along separate paths. Nevertheless, we did see evidence that Bai vowels, just like Yi tense vowels were sphinctered in nearly the identical manner.

Breathy voice in Bai can be described as mostly whisper preceded by a few periods of vibration of the true vocal folds. Thereafter, the arytenoid abducted slightly, a chink was created between them and vibration stopped.

As for harsh voice, the videolaryngeographic photos also showed trilling in the tissue between the arytenoid cartilages especially in the split. This secondary vibration did not begin contemporaneously with vocal fold vibration, but only after a slight delay. This trilling can be viewed and analyzed as a primary impedance factor with a feedback effect on the glottal source. Close observation also suggested that aryepiglottic trilling was not always regular, nor sustained unlike chant mode or throat singing styles mentioned above.

We are thus proposing to associate sphinctering with raised larynx (and retracted tongue in Yi) to the tense register. If we can say that the true vocal folds impede the air stream, then they constitute the *first or lowest laryngeal valve*. And, if we can say that the ventricular folds can sometimes also be used to modify the laryngeal tone or reinforce a closure, then they constitute the *second or middle laryngeal valve*. In the case of tense and harsh voice quality, our video evidence suggests that Yi and Bai rely not only on these two but also on the *third or highest laryngeal valve* or the aryepiglottic folds through sphinctering or through sphinctering and trilling.

The field of Sino-Tibetan, Mon-Khmer, Miao-Yao, and Kadai languages is replete with statements about "tense", "lax", and other terms without the accompanying detailed anatomical and photographic descriptions of what these terms mean. Although auditory descriptions of different phonation types have been better described since Laver (1980), there have been until now no good photographic images of what is actually happening in the larynx in real language data from native-speaking informants. We hope to have made a contribution to better clarifying the physiology involved in these various phonation types.

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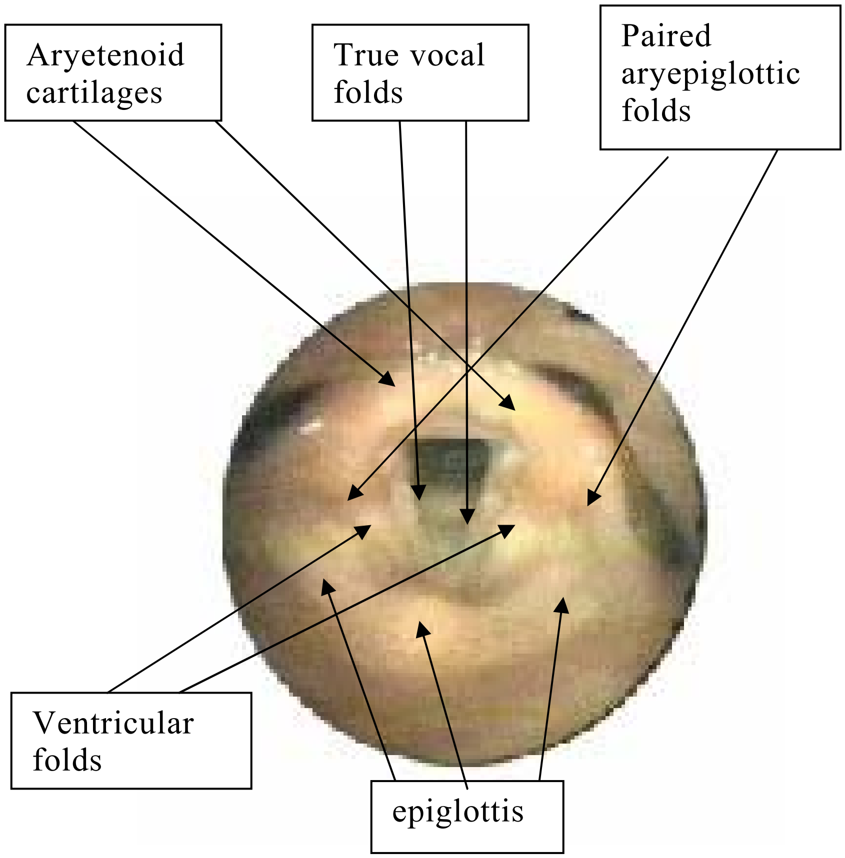


Figure 2:  Glottis in position for breath

Figure 3: Yi *pɿ*$^{33}$ ‘eagle call’ showing a lax setting at the maximum position of closure

Figure 4: Yi *pɿ*$^{\underline{33}}$ ‘baby excrement’ showing a tense setting at the maximum position of closure

Figure 5: Yi *o*$^{33}$ ‘head’ showing a lax setting at the maximum position of closure

Figure 6: Yi $ɔ^{\underline{33}}$ 'hen's clucking', showing a tense setting at the maximum position of closure

Figure 7: Yi $\textit{vɿ}^{33}$ 'intestine' showing a lax setting at the maximum position of closure

Figure 8: Yi *vɿ*$^{33}$ 'kidney' showing a tense setting at the maximum position of closure

Figure 9: Bai *phi*$^{55}$ 'slow', showing unsphinctered aryepiglottic folds just after adduction of true vocal folds to produce lax voice

Figure 10: Bai *phi*$^{66}$ 'break wind', showing aryepiglottic sphinctering just after adduction of true vocal folds to produce tense voice

Figure 11: Bai *phi*$^{31}$ 'round object, chives' just after incomplete adduction of true vocal folds that are still separated to produce breathy voice

Figure 12: Bai *phi*$^{42}$ 'skin' just after adduction of true vocal folds that still show some separation to produce breathy voice with sphinctered aryepiglottalization

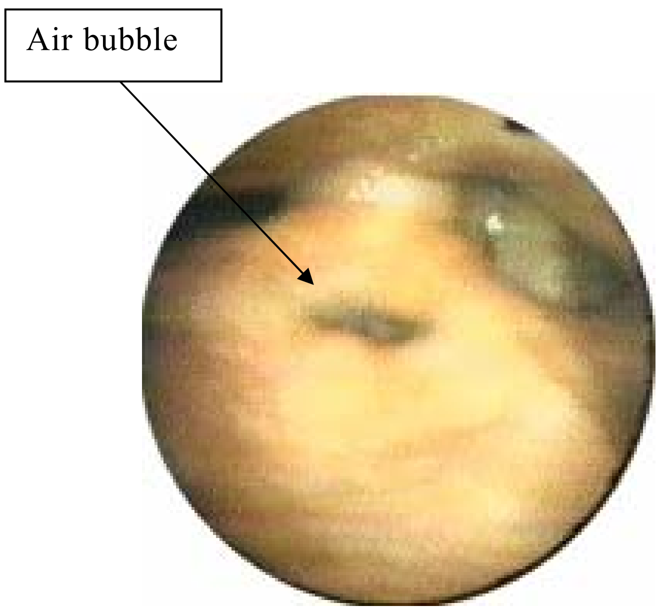


Figure 13: Bai Harsh voice in initial half of *pi*$^{21}$ 'mucus' with an air bubble coming out of the left of the glottal opening