

# STATES OF THE GLOTTIS FOR VOICELESS PLOSIVES

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## ABSTRACT

While the state of glottis of voiceless aspirated stops has been well documented, the state of the glottis of voiceless unaspirated stops has not. We have therefore concentrated on the states of glottis of voiceless unaspirated stops including glottal stop. Breath and nil phonation are traditionally regarded as the phonation types of voicelessness. Catford has described both as having a wide open glottis, but differing in airflow turbulence. By contrast, stops made with either the glottis closed or no air passing through it he termed “unphonated”. We consider existing definitions of nil phonation, breath, and unphonated to be inappropriate for describing the state of the glottis during the articulatory stricture phase of voiceless unaspirated oral stops. We describe that state of the glottis and propose the term *prephonation* be used to refer to it. We also offer a detailed description of the state of the glottis during the stricture phase of glottal stop.

## 1. INTRODUCTION

The development of photography and the laryngoscope during the first half of the nineteenth century enhanced our viewing of the vocal folds and states of the glottis. However, we feel there is still a need for a more widely accepted detailed description of the states of the glottis and the supraglottal activities that occur during the closure phase of the articulatory stricture of voiceless unaspirated oral stops including glottal stop.

The articulatory stricture of an oral stop has traditionally been divided into three phases: 1) the closing (or onset) phase; 2) the stricture (or closure) phase; and 3) the release (or offset) phase. Perhaps the best early European descriptions of these three phases were those of Ellis [6] and Sweet [15] in the nineteenth century. They called the three phases the on-glide, the consonant itself, and the off-glide. In this century, Abercrombie [1] and Laver [10] gave good descriptions of the three phases of a stop. Laver clearly describes the overlap phase between the release (or offset) phase of an initial consonant and the closing (or onset) phase of a following vowel.

Catford's [2,3] classic works on phonation types and the articulatory possibilities of man are pioneering systematic treatments of the laryngeal activities involved in different states of the glottis, phonation types, and voice qualities used in the production of human speech. Another important work of this century on voice qualities is Laver [9].

Recent acoustic studies by Lisker and Abramson [12,13], following in the articulatory phonetic tradition of the on-glides and off-glides of Ellis and Sweet, have concentrated on the release phase of the articulatory stricture of initial oral stops and the closing (or onset) phase of the following voiced vowel. They focused on the time lag between the moment of release of the oral stricture and the onset of voicing of the following vowel. Zero time was assigned to the moment of release of the oral stricture. Voice onset before the release of the oral stricture was stated as a negative value, and voice onset after the release was stated as a positive value. The time lag between the release of the oral

stricture and the voicing onset of the following vowel has been called Voice Onset Time (VOT). The results of the VOT studies have added another important acoustic dimension to the study of the overlapping stricture release phase of oral stops and the stricture closing (or onset) phase of following voiced vowels. The results concerning voiceless oral stops point to a direct correlation between the degree of opening of the glottis and the amount of positive VOT lag. The wider open they are, the longer the VOT lag.

Our purpose in this article is to provide a more detailed and systematic description of the states of the glottis during the closure phase of the articulatory strictures of voiceless unaspirated oral stops and glottal stop. We have mainly limited our discussion to our fiberoptic laryngoscopy study of the states of the glottis of voiceless unaspirated oral stops and glottal stop followed or preceded by vowels in modal voice.

## 2. TRADITIONAL VIEWS

Sweet [15] stated that in the production of a voiceless (unaspirated) stop with voiced offglide, “in (k[ $\Lambda$ ]a), as in (ga-), the glottis is in the position for voice during the stop, but without any air being forced through it, and consequently the stop is inaudible as in the case of (k), but voice begins the moment the stop is loosened, and the glide is therefore voiced”. In many English dialects, initial written “b, d, g” are pronounced phonetically as partially voiced [b̥, d̥, g̥], and in a few dialects of English initial written “b, d, g” are pronounced phonetically as voiceless unaspirated stops [p, t, k]. Anyone unaware of these facts would find Sweet's statement, “k[ $\Lambda$ ]a as in (ga-),” very confusing. However, in Ellis [6] and in a quote of Ellis in Sweet [15], Ellis considered initial “g” as in [ga] to be fully voiced with a voiced off-glide, initial voiceless unaspirated “k” as in [ka] to be voiceless with a voiced off-glide, and initial aspirated “k” as in [kha] to be voiceless with a voiceless (breath) off-glide.

Unfortunately, since Ellis and Sweet, the state of the glottis during the articulatory stricture phase of initial voiceless unaspirated oral stops has been frequently confused with either a breathed /bre $\theta$ / state of the glottis or a complete glottal closure. The author [8] of this article used to call it a weak glottal closure or a loosely closed glottis, thus implying that the glottis was neither completely adducted nor widely abducted. Grammont [7] stated that the state of the glottis for initial voiceless unaspirated oral stops in French is completely closed. It is not clear if he is saying completely closed like a glottal stop or that the vocal folds are simply drawn together.

Catford [3] in his classic article on the articulatory possibilities of man, states that breath and nil phonation are the phonation types for “voicelessness”. Catford's nil phonation and breath both have a wide open glottis. His difference between breath and nil phonation appears to be in the turbulence of the airflow. Breath has a wide open glottis with a turbulent airflow, and nil phonation has a wide open glottis with a non-turbulent airflow. Both have air flowing through a wide open glottis, but nil phonation flows through as in silent breathing, and breath

flows through as in audible breathing. In Catford [2,3], no specific mention is made of the state of the glottis for voiceless unaspirated oral stops.

The confusing term here is a “wide(ly) open” glottis. Catford [2] states that the configuration of the glottis is the same for both breath and nil phonation. They both have a widely open glottis with air flowing through the glottis, which by definition would be voiceless. The widest open glottis is the one used in forced inhalation, and perhaps the next widest open glottis is used during forced exhalation. In both of these, the ventricular folds and the arytenoid cartilages are also widely abducted. According to Zemlin [16], citing Negus [14], the width of the glottis for an adult male during normal quiet breathing is about 13mm at its widest point but may almost double during forced exhalation. Our laryngoscopic findings show that during the stricture phase of voiceless aspirated oral stops the opening of the glottis is similar to or slightly wider than that of normal quiet breathing. The ventricular folds and arytenoid cartilages are abducted but not to the widest degree of forced inhalation or the next widest degree of forced exhalation. Stressed syllables can also influence the width of the glottal opening with stressed syllables slightly wider than unstressed syllables.

The unphonated state of the glottis for glottal stop is frequently defined simply as a closed or tightly closed glottis without any reference to the ventricular folds, arytenoid cartilages, or supraglottal activities. We feel the terms “closed glottis” and “tightly closed glottis” are neither precise nor complete definitions of a glottal stop. Sweet [15] defined glottal stop as an ordinary cough or the sudden shutting and opening of the glottis, as in a cough. His analogy to a cough may be closer to reality. An ordinary cough is not simply suddenly closing and opening the vocal folds without other constrictions within the supraglottal cavity. There can be quite a bit of supraglottal constriction in an ordinary cough.

In Catford [4], voiceless unaspirated oral stops are said to have a narrowed (though not completely closed) glottis that is restricted in a cross-sectional area. Voiceless aspirated oral stops are said to have a more or less widely open glottis. Catford [5] called stops made with either the glottis closed or no air passing through the glottis “unphonated” sounds. Recently, Catford (personal communication) states that he is inclined to think that neither nil phonation or unphonated is appropriate for what happens in the larynx during the stricture (closed) phase of a voiceless unaspirated oral stop. We agree that Catford’s [2,3,4,5] definitions of both nil phonation and unphonated are not appropriate for describing the state of the glottis during the closure phase of the articulatory stricture of a voiceless unaspirated oral stop.

### 3. RECENT OBSERVATIONS

From fibreoptic studies done at the University of Edinburgh in 1977 with a Bangkok Thai speaker, it was clear that the state of the glottis for initial voiceless unaspirated oral stops and for voiceless aspirated oral stops were not both wide open voiceless breathed states of the glottis. Our recent laryngoscopic studies at the University of Victoria, British Columbia, have confirmed many of the published observations of Ellis [6], Sweet [15], and Catford [2,3,4,5], plus our own 1977 unpublished observations on the state of glottis for voiceless unaspirated oral stops. Our observations, however, show that the nil phonation state of the glottis of silent breathing appears sometimes to have a slightly narrower glottal opening than the breath state of the glottis

accompanying initial [h] and voiceless aspirated oral stops in stressed syllables.

Images of the larynx were obtained using the Kay 9100 Rhino-Laryngeal-Stroboscope system, Panasonic KS152 camera with 28mm wide-angle lens, Mitsubishi S-VHS video cassette recorder BV-2000 (30 frames/ sec), Mitsubishi photo printer, and Kay rigid oral laryngoscope to observe, record and print states of the glottis. Oral observations were obtained from systematic productions of cardinal articulations and, using the Olympus ENF-P3 flexible fiberoptic nasal laryngoscope with the Kay system, from speakers of languages with contrastive aspirated and unaspirated oral stops (e.g., Thai, Cantonese).



Figure 1. State of the glottis for voiceless aspirated oral stops: Breath. Example from cardinal [phə].



Figure 2. State of the glottis for voiceless unaspirated oral stops: Prephonation. Example from cardinal [pə].

The views of the larynx in Figures 1 and 2 were selected from numerous laryngoscopic photographs and show that during the prephonation state of the glottis, as distinct from breath, the arytenoid cartilages are adducted as for modal voice but the vocal

folds are not completely closed. The vocal folds form a narrowed convex-convex opening medially in the glottis, during which there is presumably insufficient subglottal air pressure to initiate an airflow through the partially open glottis throughout the closure phase of the articulatory stricture. In the articulatory stricture release phase of the initial oral stop and the overlapping onset phase of voice for a following vowel, subglottal air pressure increases and a small amount of air flows through the narrowed convex-convex opening at a higher velocity. The elasticity of the vocal fold tissue and the resulting Bernoulli effect causes a negative pressure between the medial edges of the vocal folds that literally sucks the vocal folds together and initiates the voicing cycle of the vocal folds being repeatedly sucked together and blown apart at a very rapid pace [16]. The small amount of airflow used to initiate the first glottal cycles of the vowel produce an acoustically predictable minimal amount of voice onset time (VOT) lag before the full voicing of the following vowel is attained.

The state of the glottis for breath during the closure phase of the articulatory stricture of [h] and voiceless aspirated oral stops can be described as having an abducted glottis, abducted ventricular folds, abducted arytenoid cartilages, and a slightly turbulent airstream through the wide open glottis. The breath state of the glottis has been well described by Catford [2,3,4] and others, and need not be elaborated further here.



Figure 3. State of the glottis for glottal stop. Example from cardinal [əʔp].

The unphonated state of the glottis has been described by Catford [5] as appropriate for describing the state of the glottis for a glottal stop. As stated above, the most common definition of a glottal stop is simply a closed glottis or a tightly closed glottis without any reference to the ventricular folds, the arytenoid cartilages, or the laryngeal vestibule with its sphincter mechanism. Our observations show that the closure of the vocal folds for a moderate glottal stop includes not only the adduction of the vocal folds but also the adduction, though usually not complete, of the ventricular folds as in Figure 3. The partially adducted ventricular folds used in the production of both a moderate glottal stop and an unreleased voiceless glottal stop + oral stop double articulation normally cover part of the upper surface of the true vocal folds, apparently helping to reinforce the glottal closure. We feel it is safe to say that when we form a final moderate glottal stop in a stressed syllable there is a slight

constriction of the whole laryngeal vestibule. The laryngeal vestibule, according to Zemlin [16], is defined as the supraglottal cavity that extends from the ventricular folds upwards through the aditus laryngis. It is formed anteriorly by the epiglottis, posteriorly by the apexes of the arytenoid cartilages, and laterally by the aryepiglottic folds. The sphincteric constriction of this supraglottal cavity is on a continuum beginning with a moderate glottal stop and increasing until the aryepiglottic sphincter mechanism achieves a complete closure as in an epiglottal stop. Although the sphincteric constriction of a moderate glottal stop is very slight when compared to an epiglottal stop it should not be ignored. It is a basic setting for a moderate glottal stop.



Figure 4. State of the glottis for voiceless unaspirated oral stops in Thai: Prephonation. Example from [tci].

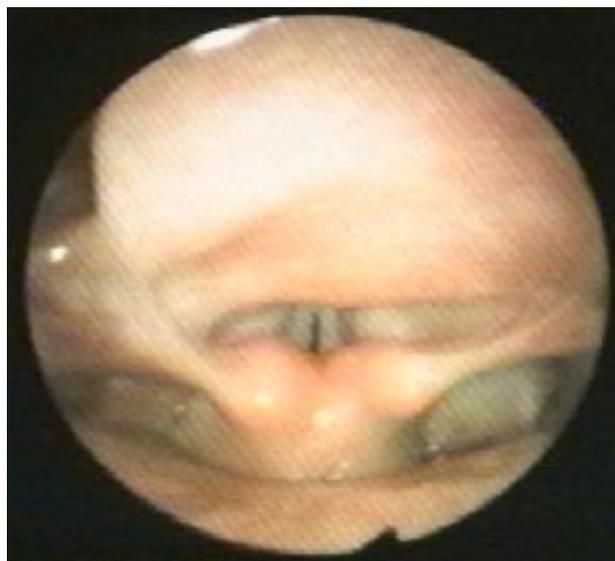


Figure 5. State of the glottis for voiceless unaspirated oral stops in Cantonese: Prephonation. Example from [ti].

In English and Thai the so-called word-initial glottal stop is, in normal non-emphatic conversation, not a glottal stop at all but simply a prephonation state of glottis just prior to the onset of voicing of the initial vowel. This prephonation state of the glottis is the same state of the glottis used in initial voiceless unaspirated stops and affricates, illustrated in Figures 4 and 5 for Thai and Cantonese. Initial prevocalic glottal stop versus (zero or) no initial prevocalic glottal stop, although rare, does occur contrastively in two Austronesian languages: Rennellese (Mungaba) spoken on the islands of Rennell and Bellona in the Solomon Islands (/haŋga/ ‘pandanus’ vs. /aŋga/ ‘road’ vs. /ʔaŋga/ ‘wake up’), and Nga’da spoken on the island of Flores in Indonesia (/inu/ ‘drink’ vs. /ʔinu/ ‘tiny’). Glottal stop in final position in Thai is illustrated in Figure 6 to compare with Figure 3 and to contrast with prephonation in Figure 4.

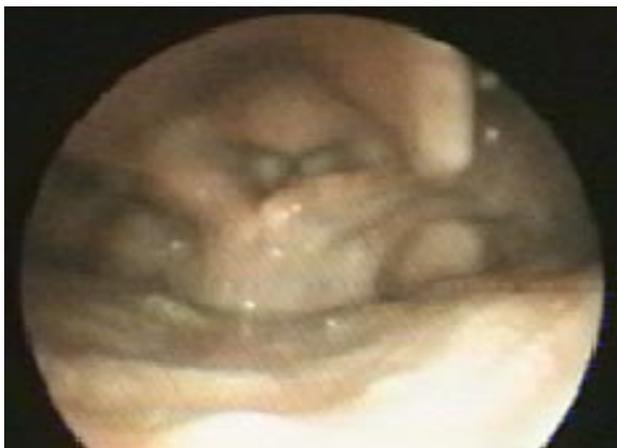


Figure 6. State of the glottis for glottal stop in Thai. Example from [iʔt].

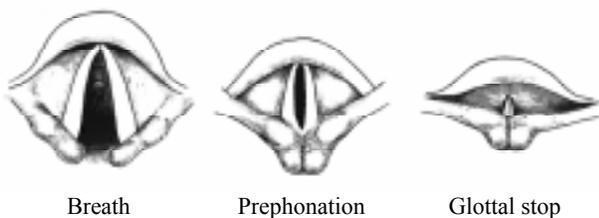


Figure 7. Illustrations of the states of the glottis for voiceless aspirated and unaspirated oral stops, and glottal stop.

#### 4. CONCLUSION

We propose that the term *prephonation* be used to refer to the state of the glottis accompanying the oral closure phase of voiceless unaspirated oral stops. We suspect that a shorter version of this state of the glottis more commonly precedes a word-initial vowel in modal voice than does glottal stop in languages such as English and Thai. We propose that basic voiceless states of the glottis such as breath, nil phonation, whisper, and unphonated be expanded to include the *prephonation* state of the glottis found in voiceless unaspirated oral stops. Our definition of this state of the glottis is, in some ways, a remarkable confirmation of Sweet’s [15] description of

1877. We also propose that the description of the unphonated state of the glottis accompanying a moderate glottal stop be expanded to include the partial adduction of the ventricular folds reinforcing the glottal closure, and the slight sphincteric constriction of the laryngeal “tube” or vestibule. These contrasts are illustrated in the drawings in Figure 7. Earlier conflicting views concerning the function of the ventricular folds in the production of glottal stops can be found in Lindqvist [11] and Catford [4]. Our observations are that the ventricular folds play an important role in the production of glottal stops.

#### ACKNOWLEDGMENTS

I acknowledge the collaboration of Dr. John H. Esling, comments on states of the glottis by J. C. Catford, and the cooperation of Speech Technology Research Ltd. and the University of Victoria in making the laryngoscopic images of the vocal tract. The assistance of Jocelyn Clayards is also appreciated, as is the cooperation of Anak Pattanavibool and Vicky Man. The equipment, materials and personnel support for laryngoscopic observation and filming of the larynx and pharynx were made possible through Research Grant 410-93-0539 from the Social Sciences and Humanities Research Council of Canada to the University of Victoria.

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