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Laryngeal Movements during Cough.

by

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A cough is one of the most common symptoms of respiratory disease; yet a review of the literature reveals little factual information about the cough mechanism at the level of the larynx. The duration of this phenomenon is so brief that the common methods of investigation can not arrest this violent explosion for detailed study. This report summarizes the effects of a cough on the soft structures of the larynx as illustrated by ultra high speed photography. The technique of this examination and the subsequent frame-by-frame analysis have been described by one of the authors (HvL) and his associates in previous communications (1, 2).

A schematic representation (fig. 1) demonstrates that each cough burst consists of three distinct parts, an opening, a closing, and another opening of the glotttis. The first opening movement of the glottis facilitates the inspiration of a large amount of air. This deep inspiration is followed by a rapid closure of the glottis. It is characteristic of a cough that the glottis remains closed much longer than during ordinary phonation; the ventricular folds reinforce this closure. When the subglottic pressure reaches a certain limit, the glottis opens and the intratracheal air is expelled through the glottis. This third stage presents a more complicated picture, because the soft structures of the larynx are brought to vibration by the passage of the air stream through the glottis.

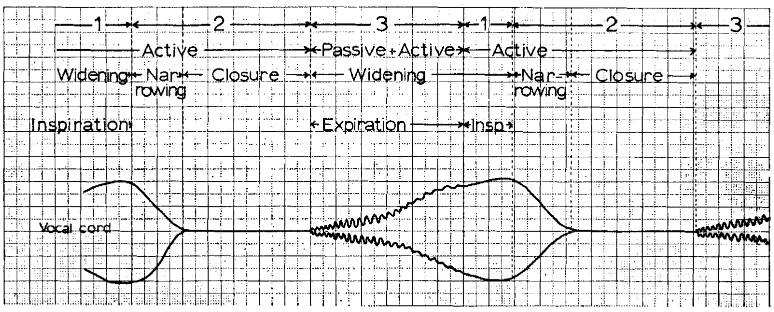

Fig. 1 : Scientific representation of laryngeal movements during cough, demonstrating three stages.

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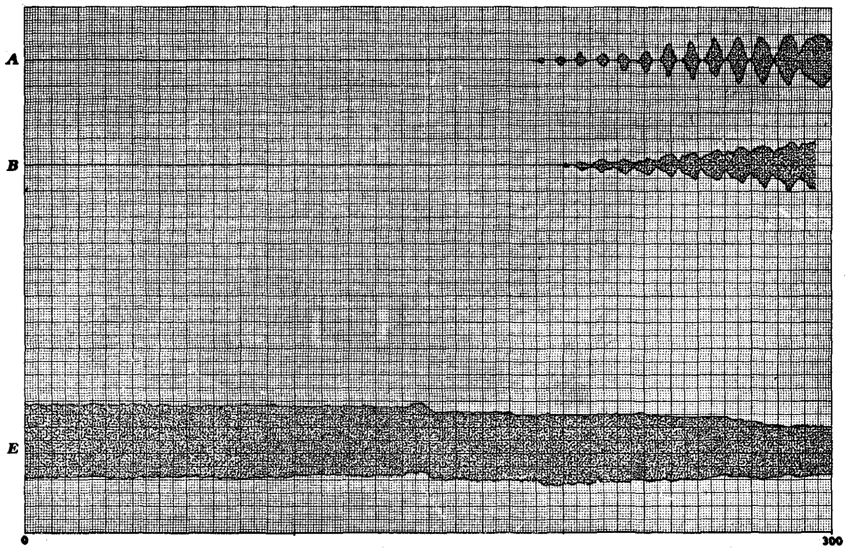

Fig. 2 : Measurements of laryngeal vibrations during cough burst. The horizontal axis indicates time, as measured by individual motion picture frames (0–300). Graph A depicts the glottis at the antero-posterior midpoint of the membranous vocal folds ; graph B just anterior to the vocal processes of the arytenoid cartilages ; and graph E measures the interarytenoid distance.

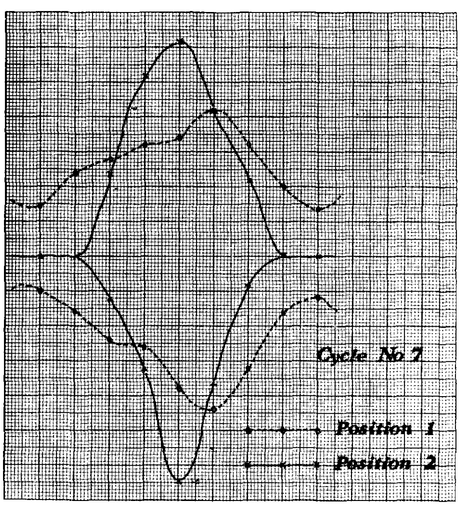

Fig. 3 : Magnification of vibratory cycle 7 from figure 2, showing phase shift at midpoint of membranous vocal folds (position 2) and posterior end (position 1).

A comparison of measurements at different locations on the vocal cords indicates that the first opening of the glottis occurs at or near the antero-posterior midpoint (fig. 2). For a brief instant, the amplitude of vibration increases rapidly cycle by cycle, while the frequency shows a slight decrease. In a normal subject, the movements of the two vocal cords are almost symmetrical. After a few cycles the vocal cords do not approximate during the "closed" phase of the vibratory cycle. A magnification of a single vibratory cycle from the same cough (cycle 7) shows the phase shift of the vibratory movements at different positions, near the center and near the posterior end of the membranous vocal folds (fig. 3).

After the initial augmentation in the amplitude of vibration, the vibratory movements of the vocal cords decrease both in frequency and amplitude (fig. 4).

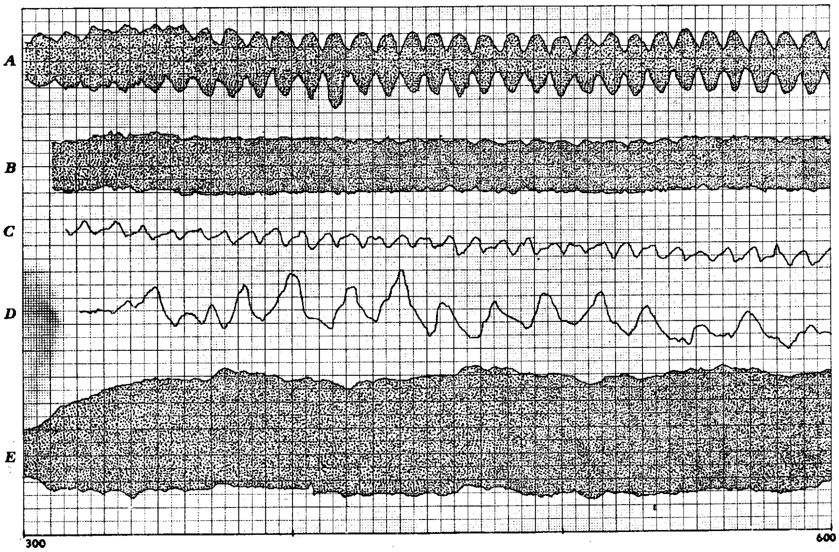

Fig. 4 : Measurements of laryngeal vibrations during cough burst (frames 300–600). Graph C indicates motion of mucous membrane on posterior wall, and graph D the ary-epiglottic fold in the left cuneiform area.

Concurrently, the air current exerts a sucking effect on the supraglottic structures, principally the epiglottis and the ary-epiglottic folds which are set in irregular motion.

After this stormy episode, a somewhat milder air flow through the glottis results in relatively steady vibrations of the vocal folds, constant in frequency and amplitude (fig. 5). At the posterior end of the membranous cords, the amplitude of vibration is extremely small, and the graph indicates wide separation of

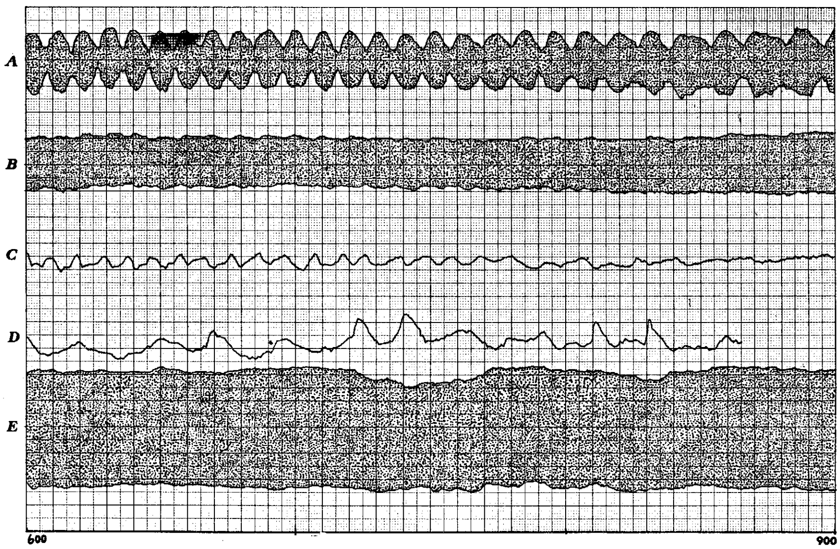

Fig. 5 : Measurements of laryngeal vibrations during cough burst (frames 600–900).

the arytenoid cartilages and the posterior one third of the glottis. The vibratory movements of the posterior laryngeal wall duplicate the vibrations of the vocal cords and are of special interest. By contrast, the motions of the ary-epiglottic fold are irregular and do not follow the pattern of the vocal cord vibrations.

As the velocity of the air stream decreases further, all vibratory movements decrease in amplitude and frequency (fig. 6). The glottis opens wider and wider, apparently in an active motion. This period gradually passes into the inspiratory stage. No further vibrations of the posterior laryngeal wall or of the supraglottic structures are apparent at this stage.

During a strong cough the epiglottis performs an unusual maneuver, which we have never observed during ordinary phonation. This movement consists of

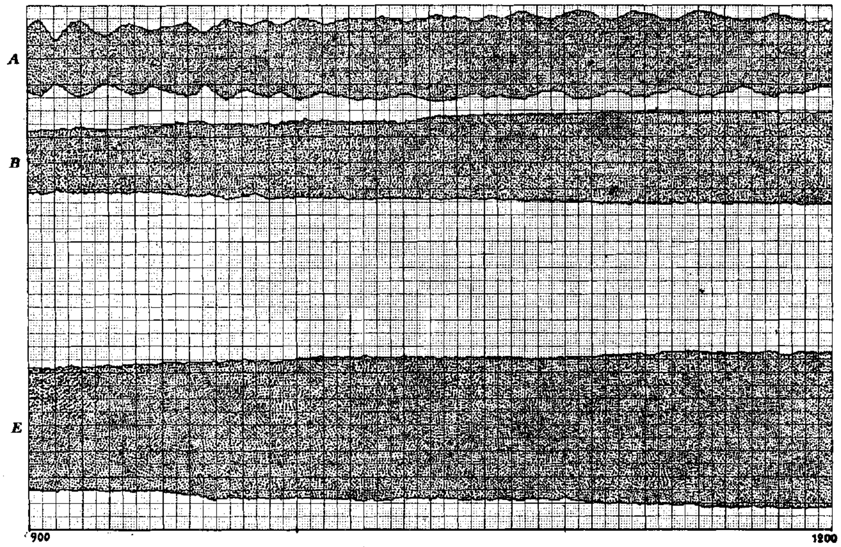

Fig. 6 : Measurements of laryngeal vibrations during cough burst (frames 900–1200).

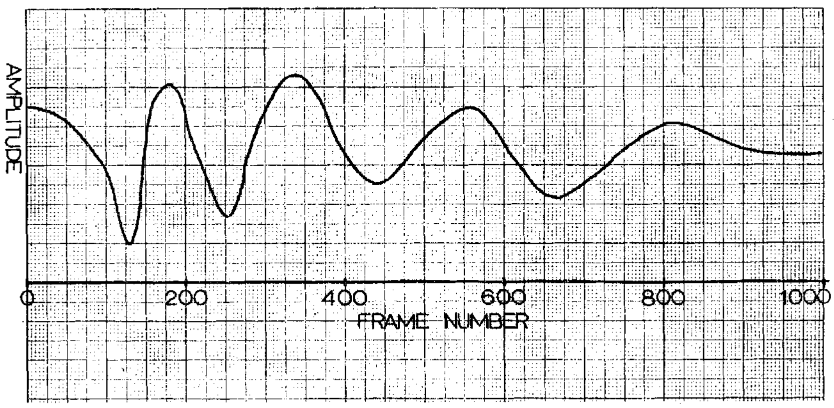

Fig. 7 : Motion of epiglottis, measured during single cough burst. Vertical axis represent amplitude of motion from anterior position (top of graph) to posterior position (bottom of graph).

a vigorous swing backward during which the top of the epiglottis may strike the posterior pharyngeal wall, and a characteristic recoil (fig. 7). Depending upon the force of the air current, this excursion may be repeated two, three or more times.

A review of the laryngeal vibrations during an active cough burst demonstrates several interesting observations (fig. 8):

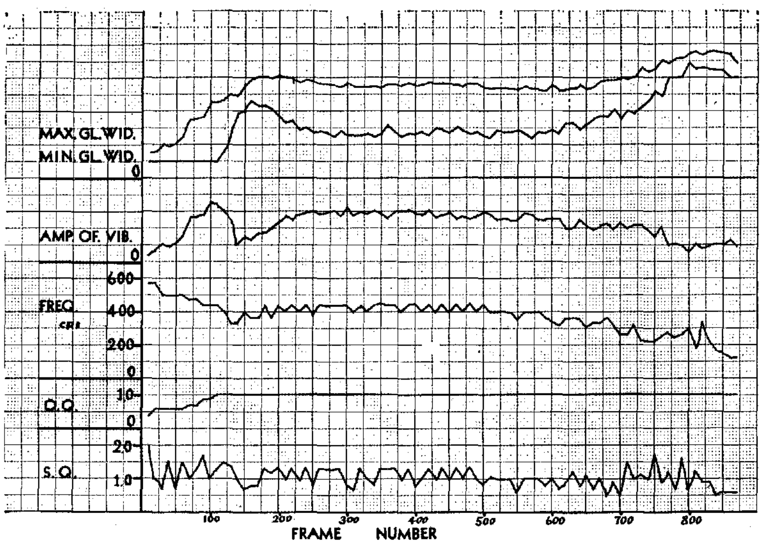

Fig. 8 : Measurements of laryngeal vibrations. The horizontal axis indicates time in motion picture frames. Starting at the bottom, the vertical axis shows a) the speed quotient (S.Q.), b) the opening quotient (O.Q.), c) the frequency (in cycles/sec), d) the amplitude of vibration, and e) the minimum and maximum glottic width.

a) The *speed quotient* fluctuates irregularly throughout the episode.

b) The *opening quotient* reaches "1" soon after the onset of vibrations and remains at that level.

c) The *frequency* of vibration is high at the beginning, and decreases gradually throughout the attack.

d) The *amplitude* of vibration increases at the beginning, and gradually attenuates during the second half.

e) The glottic *width* tends to increase throughout the period.

Summary

An analysis of ultra high speed motion pictures of the larynx indicates that each cough burst consists of three stages:

1) a wide opening of the glottis for deep inspiration,

2) an extraordinary tight closure of the glottis, and

3) dynamic vibrations of the laryngeal structures, including the vocal folds, the mucous membrane of the posterior laryngeal wall, the ary-epiglottic folds, and the epiglottis.

The vibratory movements are apparently not active, but caused by the strong air current, in accordance with Bernoulli's law. The vibrations are characterized by constant and rapid changes. The entire episode is extremely short and all laryngeal activities are transient.

Additional experiments have been initiated to correlate these findings with aerodynamic studies, electromyographic investigations, and acoustic measurements of a cough.

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