SGP Analysis of Excised Larynges in Anechoic Chamber

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Abstract: SGP analyses of tokens from excised larynx in anechoic chamber are compared with those of in vivo larynx investigated by Sondhi tube to reveal common acoustic sources.

The excised larynx, due to its small size compared to wavelength, when made to phonate in an anechoic chamber, radiates as point source and therefore emits sound pressure proportional to time derivative of the volume flow rate through the glottis. To demonstrate this proportionality the pressure traces of single glottic pulses (SGP), phonating in modal register, were integrated to reveal the similarity of their source function trace to the familiar fluctuating glottic area function.

To the degree that jet flow through the glottis is constant over the open phase of the glottic cycle, volume flow rate should be proportional to area times jet speed. Thus the running integral of the pressure trace should resemble glottic area function. In this study we present evidence for such an effect.

Figure 1 shows a typical SGP analysis, from an excised larynx phonating in modal register at 446 Hz in an anechoic chamber. The analysis consists of four simultaneous time traces:

(a) electroglossotographic (EGG) trace obtained by suturing EGG paddles to the outer tissue of the larynx in the vicinity of the folds,
(b) derivative of EGG (DEGG) trace obtained by numerical differentiation of the EGG trace,
(c) sound pressure trace measured with a 1/4" B&K type 4135 condenser microphone placed 6 cm away from the glottis (time-adjusted for simultaneity with the EGG),
(d) integrated, inverted sound pressure trace, or source surrogate, obtained from numerical integration of the sound pressure.

The portion of EGG curve shown, in which positive vertical axis indicates the direction of increasing conductivity, begins near the phase of fast-down motion (marked by a small elbow, or kink, in the trace) and continues for a little more than one period. Near the midpoint of the trace a second elbow, or kink, marks the beginning of fast-up motion of the EGG. Between these two markers along the EGG, whose presence may be detected whenever the phonation is in modal register, the glottis is open to jet flow.

The positions of opening and closing elbows of the EGG are most easily detected from locations of the negative and positive peaks along the DEGG trace, respectively. Thus a large positive peak occurs along the DEGG at about 1.5 ms, just after the fast-up phase and a small negative peak at about 2.1 ms, just after the fast-down phase.

A further indication of the position of the large positive DEGG peak may be seen in the pressure trace, where a coincident positive peak appears.

The main feature of the pressure trace is the pair of positive peaks. The presence of the DEGG-coincident second peak is another indication of the proportionality of sound pressure to time derivative of volume flow, since the slope of the EGG function is a rough measure of time derivative of volume flow.

The final curve, an inverted trace of integrated sound pressure waveform, is useful as a facsimile of whatever source, or pseudo source functions are hidden in the pressure trace. For our purposes, only the portion of the source trace between the opening and closing EGG elbows is significant, since this corresponds to sources present while the glottis is open. The shape of the source trace from 0 to 1.2 ms may be seen to bear a remarkable resemblance to the area waveform tokens for "medium intensity" phonation found in Figure 4 of Childers et al. (1990). A similar effect was observed by van den Berg (1968) who measured area function and sound pressure. There the inverted, integrated sound pressure function is also a facsimile of the area function.

To test whether this effect is peculiar to modal phonation in excised larynges or is evidence of a more general principle in living larynges, one of the investigators produced low modal voice tokens at 88.7 Hz in a Sondhi tube and the same SGP analysis was performed. As shown in Figure 2, again the sound pressure and integrated sound pressure traces are phased to adjust for acoustic delay relative to the EGG. The EGG curve displayed has the identifying DEGG-positive and negative markers at 4 and 10.5 ms that we believe are characteristic of modal speech. There is again a small pointed peak along the sound pressure trace at 10.5 ms, the location of the positive DEGG spike. Gratifyingly, the inverted, integrated sound pressure trace falls mostly between the DEGG markers at 4 and 10.5 ms and closely resembles the area function for Childers' "medium intensity" tokens. One might ask, why should the sound of a live larynx resemble that for a point source like the excised larynx? The reason seems to be...
that, although sound in the larynx in basically a plane wave, there is a region close to the glottis where the acoustic flow is diverging so that the pressure wave that merges into a plane wave, over a distance comparable to the laryngeal diameter, is related to the volume flow like a point source. (This follows from the equation of motion, since in the near field, a diverging particle velocity produces a pressure component at 90 degrees due to integration over the position vector \( r \).) As the plane wave is formed, the phase relation between \( u \) and \( p \) becomes frozen in. In this way measurement by Sondhi tube allows the true origin of the sound to be detected.

In conclusion we have found evidence for the assertion that for modal phonation the radiated sound pressure is proportional to the time derivative of the glottic area function and therefore to the time derivative of the volume flow rate through the glottis, over widely varying conditions.

![FIGURE 1. Anechoic Chamber F0=446 Hz](image1)

![FIGURE 2. Sondhi Tube F0=88.7 Hz](image2)

REFERENCES