INITIAL VALIDATION OF AN INDIRECT MEASURE OF SUBGLOTTAL PRESSURE DURING VOWELS[+]

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ABSTRACT

Some methods for direct measurement of subglottal pressure during speech are invasive and thus cannot be used on a routine basis. The development of noninvasive techniques is thus desirable and a simple indirect method for measuring subglottal pressure from records of oral pressure during consonants has recently been proposed and applied to studies of glottal resistance during phonation. In order to be useful, indirect measurement procedures should be validated by comparisons with direct measurements, and the present experiment was designed for such a comparison. Miniature pressure transducers were used to obtain records of pressure below and above the glottis. Results showed nonsignificant differences and a high correlation between the direct and indirect measurements. This indirect method for measuring subglottal pressure thus appears to provide valid results.

INTRODUCTION

Measurements of subglottal pressure during speech may be obtained by four different methods: 1) A needle-tap is passed through the pretracheal wall and connected to a pressure transducer; 2) A small transducer is passed through the glottis and placed directly in the trachea (in a variant of this approach, a small catheter is passed through the glottis with the open end of the catheter in the trachea and the other end of the catheter coupled to a transducer outsied the subject);

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3) The subject swallows a small inflatable balloon into the oesophagus with the balloon connected by a catheter to a transducer; 4) The subject is placed in a body plethysmograph and alveolar pressure is determined indirectly.

The first three of these procedures are invasive, cause a certain degree of discomfort for the subject, and thus cannot be used on a routine basis. The use of an oesophageal balloon requires, in addition, simultaneous recordings of lung volume, since the balloon itself will record intrathoracic pressure (Bouhuys, Proctor and Mead, 1966). If a body plethysmograph is used, the subject has to participate in rather elaborate calibration procedures (Hixon, 1972). Due to the practical problems associated with these methods for making measurements of subglottal pressure, a simple noninvasive technique has recently been proposed as a routine clinical procedure (Holmberg, 1980; Smitheran and Hixon, 1981).

This method makes use of the fact that pressure below and above the glottis is equalized during the closure period of voiceless stops (e.g., Shipp, 1973). During this period, the glottis is open and the oral cavity is closed. Measurements of oral pressure during this phrase of voiceless stop production thus provide measures of subglottal pressure as well. By constructing a suitable speech material, where voiceless stop consonants and vowels alternate in a regular manner, successive measurements of oral pressure can be made during the stop closures. A linear interpolation between the oral pressure registrations can then be made in order to get indirect measurements of subglottal pressure during the vowels occurring between the voiceless consonants.

Applications of this procedure to studies of glottal resistance during phonation under both normal and clinical conditions have recently been described by Holmberg (1980) and by Smitheran and Hixon (1981).

Glottal resistance is defined here as the ratio between the pressure drop across the glottis and the transglottal airflow. Its calculation thus requires measurements of subglottal pressure, and the simplified procedure outlined above has been used for that purpose. The reliability and usefulness of such studies thus depend on the validity of the indirect technique for estimating subglottal pressure. The measurement of transglottal airflow is not a major problem in this case.

In support of the validity of the method, two types of argument have been used. Smitheran and Hixon (1981) argue that values of glottal resistance during phonation obtained with the indirect technique are more or less identical to values of the same parameter obtained with direct measurements of subglottal pressure. Holmberg (1980) shows that calculated values of glottal resistance will discriminate between different phonation types where differences in glottal resistance can be assumed to occur on a priori grounds.

The technique appears to be a promising one, and arguments such as these are obviously useful in demonstrating its validity. A more direct evaluation of the procedure would, however, compare simultaneous direct and indirect measurements of subglottal pressure. The present experiment was designed for such a comparison.

METHOD

Subglottal pressure was recorded using a technique described in detail elsewhere (Kitzing and Löfqvist, 1975; Kitzing, Carlborg and Löfqvist, in press). Briefly, a small miniature transducer (Millar Instruments PC 350 5F) with adequate high frequency response was introduced through the nose and passed through the glottis under topical anesthesia of the pharyngeal and laryngeal mucosa.

The cable connecting the transducer to power supply and amplifier was positioned in the posterior commissure with the transducer itself about 2 cm below the glottis. A second transducer of the same type was used for recording oral pressure. This transucer was also introduced through the nose and placed in the pharynx about 4 cm above the glottis. The transducer output signals were recorded on FM tape together with a microphone signal for later processing.

The experimental procedure required anesthetization of the laryngeal mucosa and the introduction of catheters through the velopharyngeal port. Auditory and acoustic analysis of the voice during the experiment did not reveal any excessive breathiness or hoarseness. A complete velopharyngeal closure could also be made with the catheters in place. This was verified by recording egressive airflow during preliminary trials.

The speech material consisted of CVCVCV syllables. In order to make the material as similar as possible to that used in studies applying the indirect measurement procedure, the labial voiceless stop /p/ and the low back vowel /ɑ/ were used. A male speaker with a normal larynx and without any known history of voice disorders, one of the authors, served as subject. Twenty repetitions of the speech material were obtained.

For processing, the signals were played back on an ink-writer. During play-back, the pressure signals were low-pass filtered at 70 Hz to remove most of the rapid pressure fluctuations due to voicing and thus facilitate measurements.

The method of linear interpolation between the oral pressure records is shown in Fig. 1. The interpolation was made from the point at which oral pressure started to fall rapidly at the stop release, to the point at which a stable elevated pressure occurred shortly after stop implosion. This is illustrated by the broken line in Fig. 1.

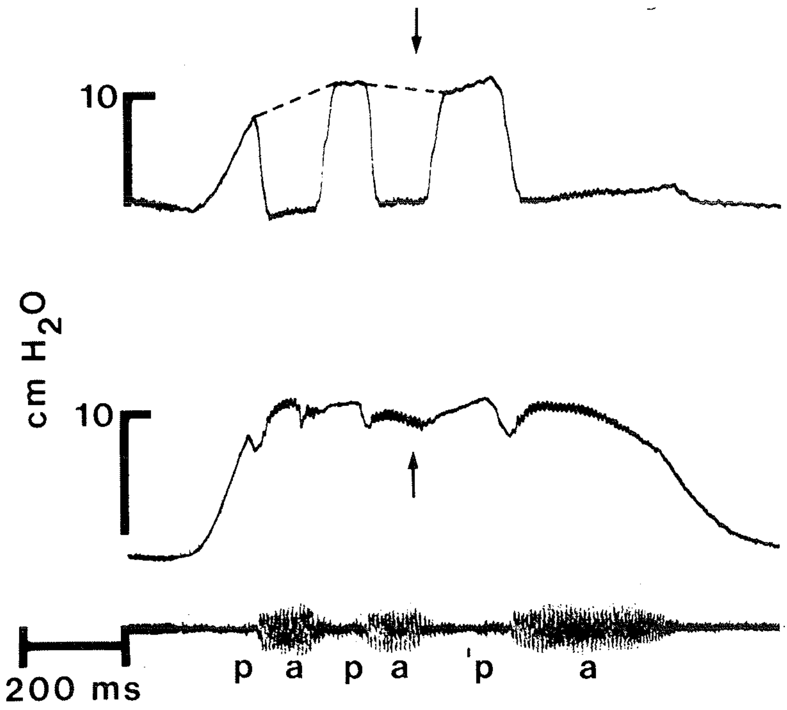

Figure 1. Simultaneous records of oral pressure (top), subglottal pressure (middle) and audio signal (bottom) during production of the nonsense syllables papa'pa. The pressure signals have been low pass filtered at 70 Hz. The broken line in the oral pressure curve illustrates the method of linear interpolation between the pressures associated with the voiceless stops in order to get an estimate of subglottal pressure during the vowels between the voiceless consonants. The arrows indicate the point during the utterance at which the measurement was made of direct and indirect subglottal pressure.

Pressure was measured in the middle of the second vowel of the utterance; this point is shown by the arrows in Fig. 1. For each utterance, two measurements of subglottal pressure were thus obtained. One represented a direct measure, and was made from the output of the transducer in the trachea. The other represented an indirect measure, and was made from the interpolated oral pressure curve.

RESULTS

The mean difference between the two sets of measurements was 0,85 mm of water, with a standard deviation of 3,73. A paired t-test showed this difference to be insignificant (t_{19} = 1.019). The two sets of measurements are plotted against each other in Fig. 2. A Pearson product moment correlation coefficient of 0,92 was obtained for the two sets. As can be seen from Fig. 2, the data points are about evenly distributed around the diagonal line drawn in the figure.

DISCUSSION

The results of the present experiment indicate that indirect measurements of subglottal pressure interpolated between measures of oral pressure during voiceless stops provide a valid estimate of the "true" subglottal pressure during the vowel of the interpolated interval. In order to avoid possible influences from extraneous factors, measurements should be made in the middle of the vowel between the voiceless consonants, since airflow during the period of aspiration after stop release may perturb the subglottal pressure (cf., Löfqvist, 1975). With this caveat, the simplified procedure appears to be valid.

We should add a final note on its clinical application. Here, one may be interested in following changes in glottal resistance as a result of therapy or phonosurgery.

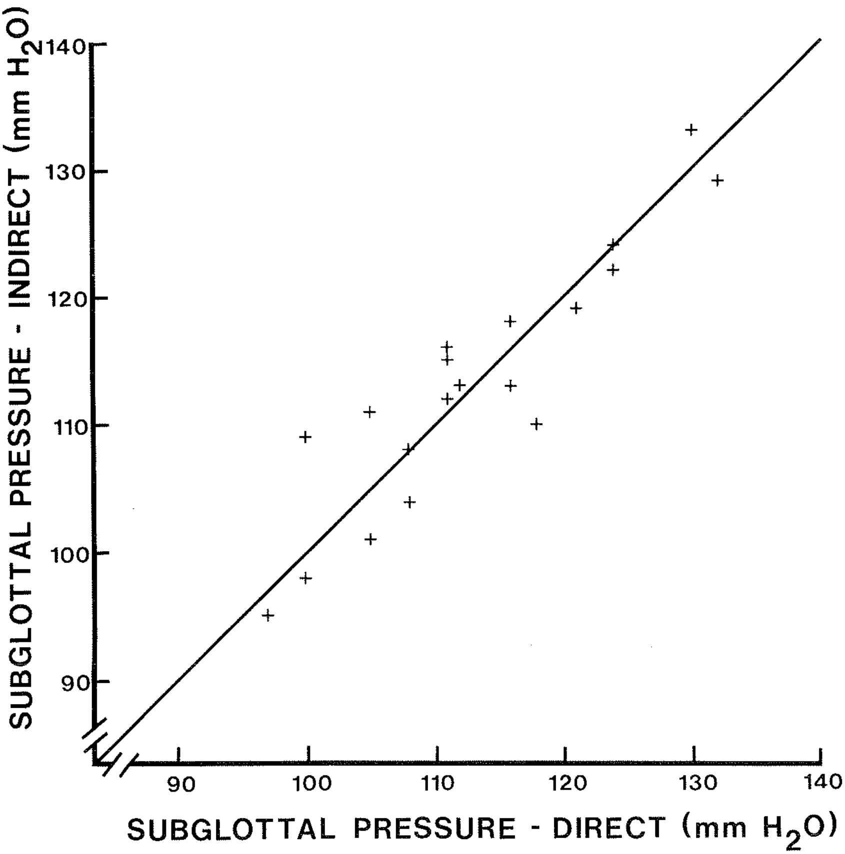

Figure 2. Plot of direct and indirect measurements of subglottal pressure (n = 20).

Comparisons of repeated measurements over a period of time are thus of more interest than the absolute values of glottal resistance on single occasions. In this case, minor deviations of the estimated subglottal pressure from the "actual" subglottal pressure would not seem to be a serious concern, since the error can be assumed to be constant across measurements.

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