On the Reliability of the Intraoral Measuring of Subglottal Pressure

G.L.J. Nieboer, H.K. Schutte and T. de Graaf
Groningen, the Netherlands

1. Introduction

Measuring subglottal pressure is a useful tool in diagnosing patients with voice problems. And of course it is a necessary part of a complete physiological description of speech events.

But up to now none of the established methods to measure this subglottal pressure is simple enough to be applied in every day practice. These established methods are:

- first, the transcutaneous needle;
- secondly, the oesophageal balloon;
- thirdly, the tip-catheter or the small tube-catheter through the glottis.

None of these methods is easy-to-do, and the help of a medical doctor is nearly always needed. So the search for easier methods deserves our attention, not in the last place because research in the Groningen ENT Clinic has revealed that the subglottal pressure is an important parameter in establishing vocal dysfunction.

2. The intraoral method

An interesting and easy-to-do method proposed by Rothenberg in 1973 and used again by Smitheran and Hixon in 1981 is: to measure the subglottal pressure during phonation indirectly, by estimating it from the intraoral pressure during the occlusion phase of adjacent voiceless plosive consonants. This is what makes this method simple: the intraoral pressure can be measured in a comparatively uncomplicated way by inserting a small catheter into the mouth through the lips.

The method is based on two assumptions: the first is that the peak oral pressure obtained in this way corresponds to the subglottal pressure during phonation. The second assumption, though it is never mentioned as such as far as we know, is that the glottis is open during the occlusion phase of voiceless plosive consonants. It is known for French and Russian speakers that the glottis is not open during this occlusion phase. For Dutch speakers we are not sure at all, because, like in French, there is no aspiration after voiceless plosive consonants; this may point to a closed glottis before the phonation starts.

3. Comparative measurements

We carried out measurements on two Dutch-speaking subjects in order to test the reliability of the method. The most obvious way to do this is to compare data from simultaneous measurements of first the intraoral pressure and secondly the subglottal pressure, assessed by one of the afore-mentioned established methods. In our study we used the oesophageal balloon.

Figure 1 shows the parameters we recorded in our measurements.

The oesophageal pressure is measured with an oesophageal balloon, fixed to a long thin catheter passing through the nose. The oral/nasal flow is measured with a Lilly flowhead, fixed to a rubber mask. The flow curve provides information on the moments of lip opening of the plosive consonant /p/. A signal related to the lung volume is computed by integration from the flow curve. We need to know this lung volume because it is related to the oesophageal pressure by lung mechanical factors. The microphone signal is used to assess the moments of voice onset and offset. The intraoral pressure was measured with a small catheter through the mask, with a pressure transducer fixed directly to the mask.

The way in which the intraoral and oesophageal pressure are compared is shown in Fig. 2.

In order to assess the value of the subglottal pressure we must have a reference point. This is necessary because the intraoesophageal and intratracheal pressures are different to a varying degree, depending upon lung mechanical factors. We have chosen the reference point to be the moment of

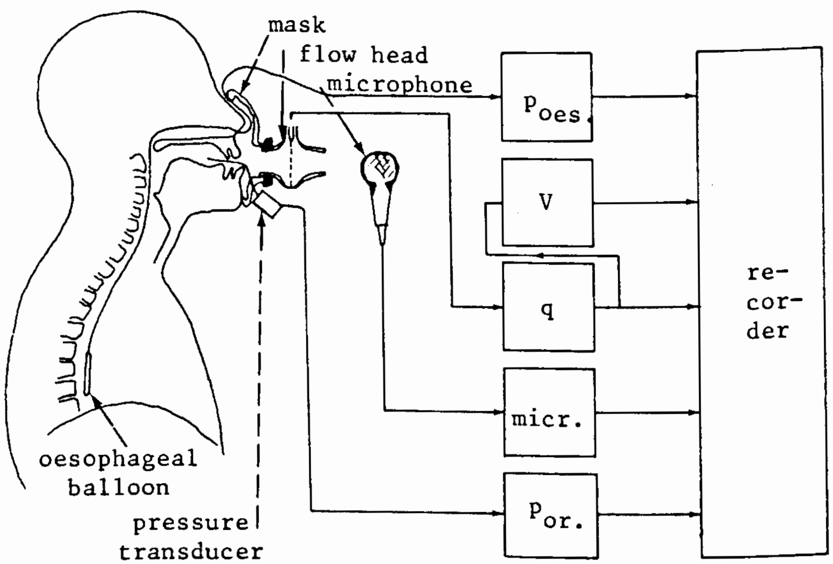

Figure 1. Diagram of the experimental set up. The curves are recorded on a Mingograph.

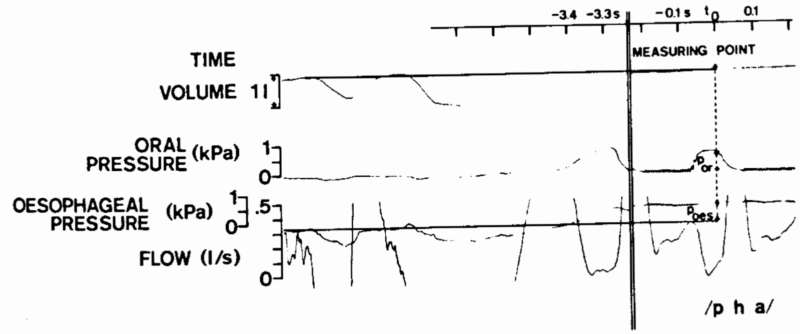

Figure 2. The way in which the subglottal pressure is derived from the oesophageal pressure and compared to the intraoral pressure. The subject repeats /pha/ at a rate of ca. 4 per second.

minimal lung volume (on top of the curve) during quiet breathing. The real intraoesophageal pressure at that moment is about -0.4 kPa. We will call the pressure at this moment the reference pressure. When the lung volume curve during the repeated phonations indicates that the lung volume is the same as at the reference moment, we can consider the amount of pressure in the oesophageal pressure curve above the reference pressure to be equal to the driving pressure of the lungs, that is the mean subglottal pressure. So at this moment of the curves this mean subglottal pressure can be directly compared to the simultaneously measured intraoral pressure.

Schutte (1980) gives a more complete description of the intraoesophageal measuring of subglottal pressure, and of the registration of flow and volume curves.

4. Results of the measurements

In Figures 3 and 4, the reference pressure, which was always assessed in the way we described, is indicated by a solid horizontal line; an arrow points to the moment of measuring.

In Figure 3 the subject repeats /pa/ at a rate of about 4 per second. The oesophageal pressure above the reference pressure and the intraoral pressure have both the value of 0.6 kPa. When /pa/ utterances are repeated at a slower rate, the two pressures are equally well comparable.

But as soon as aspiration occurs, differences show up as is shown in Figure 4, representing a /pha/ utterance, aspirated. We see that the oesophageal pressure curve shows different values when we compare the moments of occlusion and of phonation.

The speech rate is 2 per second and the pressure difference is 0.2 kPa. At a speech rate of 4 per second this difference is 0.1 kPa.

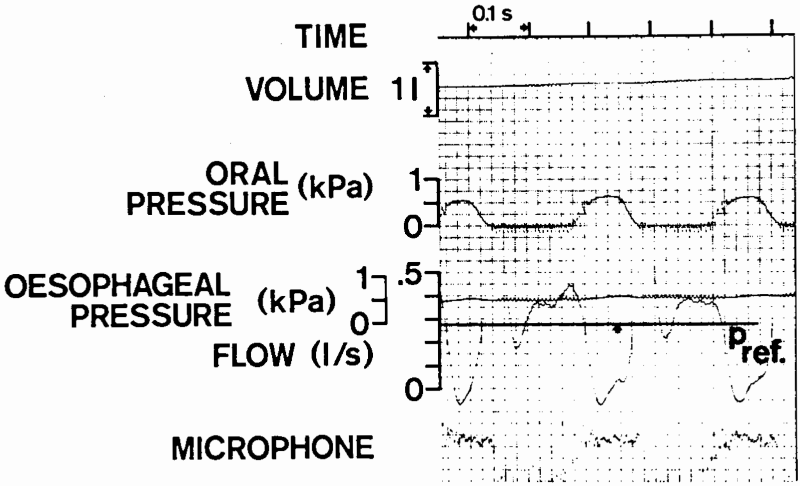

Figure 3. Lung volume, oral pressure, oesophageal pressure, flow and microphone curves of one of our subjects repeating /pa/ at a rate of ca. 4 per second. The arrow points to the moment of measuring.

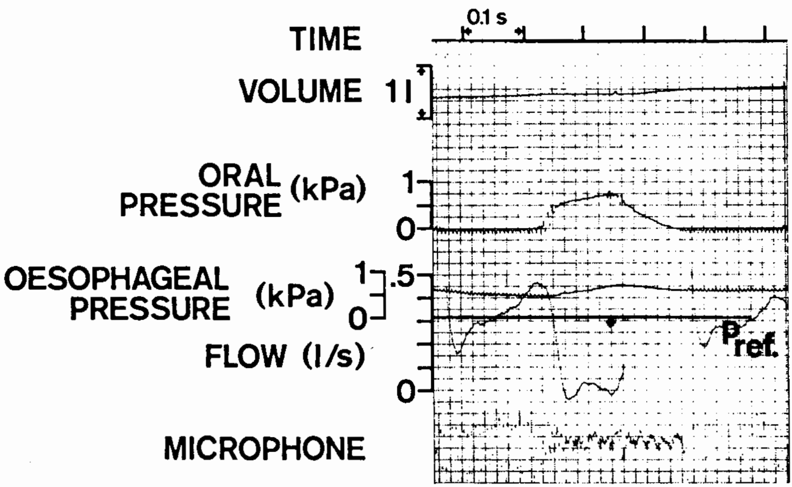

Figure 4. Lung volume, oral pressure, oesophageal pressure, flow and microphone curves of one of our subjects repeating /pha/ at a rate of ca. 2 per second. The arrow points to the moment of measuring.

5. Conclusions

Our first conclusion from these experiments is that the reliability of the method described does not depend on the rate of the utterances, when it varies between 2 and 4 per second. Of course, this and the following conclusions are valid for Dutch speakers.

A second conclusion is that when aspiration occurs the curve of the oesophageal pressure shows fluctuations, indicating that the moment of intraoral measuring provides a deviant estimation of the mean subglottal pressure. In this case, as can be seen in Figure 4, the estimate is too high. The differences amounted to 0.2 kPa, which means a measuring error of about 25%.

A third conclusion is that the intraoral pressure curve must have a horizontal part. This can be obtained by using a pressure measuring system with a response time within 30 ms, as was pointed out by Rothenberg in 1981. The need of such a short response time is illustrated by the fact that we found the pressure build-up in the mouth to take place in 40-100 ms for /pa/ and /pha/ utterances.

Our last conclusion is that on the basis of these and other measurements, the intraoral method to estimate the mean subglottal pressure is not, or not yet, a reliable tool when patients are involved with articulatory or vocal dysfunction. When for example a patient aspirates his /p/ consonants, or closes his glottis more or less violently during the occlusion phase, we can be almost sure that the estimates become unreliable. So we think that this method, as far as it has been developed up to now, is a reliable tool to measure subglottal pressure in trained phoneticians; but it needs more research in order to be a reliable method for the untrained voice patient.

References

Rothenberg, M. (1981). Interpolating subglottal pressure from oral pressure. *Journal of Speech and Hearing Disorders,* **47**, 218-219.

Schutte, H.K. (1980). *The efficiency of voice production.* Doct. thesis, Groningen.

Smitheran, J.R., Hixon, T.J. (1981). A clinical method for estimating laryngeal airway resistance during vowel production. *Journal of Speech and Hearing Disorders,* **46**, 138-146.