VERTICAL AND SAGITTAL POSITION OF LARYNX IN SINGING

Pertti Hurme[1] and Aatto Sonninen[2]
Department of Communication, University of Jyväskylä, Jyväskylä, Finland[1]
Sibelius Academy, Helsinki, Finland[2]

ABSTRACT

Teachers of singing recommend a comfortably low position of the larynx in singing. Some studies have corroborated a low vertical larynx position (VLP) in singers, whereas others have observed that the larynx rises with pitch. In this study, VLP was measured from roentgenograms of singers producing a rising pitch series. The roentgenological method permits the measurement of several other variables in addition to VLP, such as the sagittal (anterior–posterior) movement and position (SLP) of the larynx when singing.

LARYNX POSITION

Several factors affect larynx position: anatomical differences, vital functions such as breathing and swallowing, habitual position and movements during speech and singing. It is well known that larynx position has an effect on vocal tract resonances and on the biomechanical properties of the vocal folds [1, 2].

Several studies on professional singers have concluded that during singing the larynx is in a low position irrespective of pitch. For instance, in a roentgenological study of singers of the Bolshoi ballet Dmitriev [3] observed relatively little variation in larynx height (VLP) as a function of pitch. He also observed a connection between larynx height (related to the cervical spine) and voice type. The observations of Shipp [4] are similar. On the other hand, Johansson, Sundberg and Wilbrand [5] and Pabst and Sundberg [6] report that the larynx rises with pitch at least in some subjects, especially at higher pitches. Measurements pertaining to this question will be presented in this paper.

Methodical limitations often confine the study of larynx movements to VLP measurements. However, it is well-known that the larynx can move in an anterior–posterior (sagittal) direction as well. In this paper we focus on biomechanical factors, the exterior forces affecting the larynx, which is a relatively elastic structure, mainly consisting of cartilages, muscles and connective tissue. Laryngeal joints are not rigidly hinged, but allow gliding in addition to rotation, e.g. in the cricothyroid joint [7]. We study the vertical (superior–inferior) and sagittal (anterior–posterior) position of the larynx in relation to the cervical spine and to the mandible; our subjects are singers producing a series of vowels spanning the musical range.

PROCEDURE

This study is a reanalysis of a data corpus collected by Aatto Sonninen [8]. The corpus consists of 12 singers (9 females [sopranos and mezzo-sopranos] and 3 males [tenors and baritones]) as well as a number of nonsingers (not reported here; see [9]. The singers were of high national or international level. Lateral spot roentgenograms were taken as the subjects sustained the vowel /a/ on an ascending scale. The distance of the posterior superior part of the cricoid cartilage (point d) was measured along x and y coordinates defined by a vertical line connecting the 2nd and 6th cervical vertebra (dy, vertical larynx position or VLP) and a horizontal line at the 6th cervical vertebra perpendicular to the vertical line (dx, sagittal larynx position, SLP). In addition, we measured the distance between the anterior–inferior part of the thyroid cartilage (point C), the anterior–inferior part of the hyoid bone (point B) and the mandible (point A; placed as anterior as possible, in each subject at a fixed distance from the 2nd cervical vertebra); the measurement points can be seen in Figure 3.

RESULTS

There was considerable interindividual variation in the vertical and sagittal measurements of singing a rising pitch series (see Figure 1): the medians for the subjects' VLP varied up to 40 mm and the medians of SLP up to 15 mm. Figure 1 also shows that the subjects differed in VLP as compared to the zero point (the 6th cervical vertebra): in some subjects VLP is clearly above zero (e.g. MV, JH), in some at or below zero (e.g. HN, AK). The subjects also differed in SLP: MH in particular has

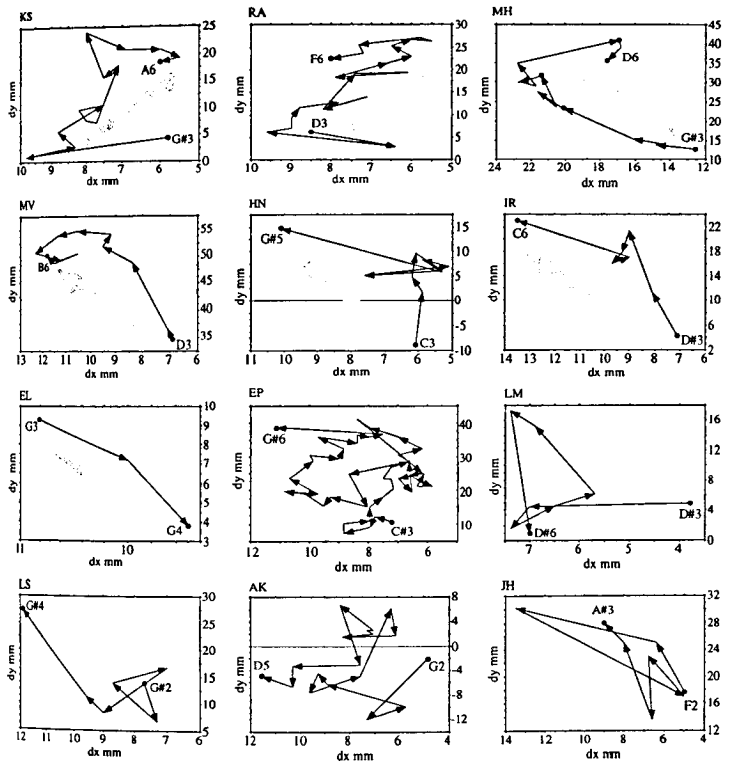

Figure 1. Vertical (dy) and sagittal (dx) position of larynx in female (three top rows) and male (bottom row) singers in a rising pitch series. Arrows indicate general direction of movement.

more anterior values than the others.

Figure 1 also shows the movement of the position of VLP and SLP as the subjects produced sustained phonation at various pitches (shown in the figure). The three top rows describe female singers, the bottom row male singers. The movements of the posterior superior part of the cricoid cartilage (point d) for female and male singers appear not to differ in any systematic way. The over-all movements can be described by 4 patterns (indicated with arrows in the figure): (1) movement in the posterior–superior direction (subjects KS, RA), (2) movement in the posterior–inferior direction (subject EL), (3) movement in the anterior–superior direction (subjects MV, HN, MH, IR, LS) and (4) complex zig-zagging movement (subjects AK, LM, JH, EP).

The results of the measurements of the distances between the thyroid cartilage, the hyoid bone and the mandible are not described in detail here. However, by means of selected examples (schematicized from the roentgenograms) Figure 2 shows the relation of the thyroid cartilage and the hyoid bone to each other. Case A is a textbook case. The other examples show that the hyoid bone and the thyroid cartilage can assume a wide variety of positions in relation to each other. Case F is very extreme: in relation to the thyroid cartilage the hyoid is very anterior and inferior. Case F (subject IR) is shown in more detail in Figure 3, showing the production of a vowel at D#3, D#4, D#5 and C6. With increasing pitch the hyoid bone moves in an anterior and inferior position: however, it can also be seen that the thyroid cartilage moves in a superior and slightly anterior direction. The extreme position is accomplished by moving both the hyoid bone (and the mandible) and the thyroid cartilage.

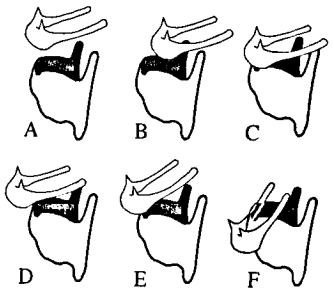

Figure 2. Various observed positions of hyoid bone and thyroid cartilage.

DISCUSSION

VLP and SLP in singers

Some voice pedagogues claim that in trained singers the larynx is not raised with pitch, implying that individuals without training or with insufficient training raise their larynx with pitch. In our subjects we see much variation between individuals: we have evidence both for larynx-raising with pitch and for nonraising (or even lowering) at high pitches. However, our data show that the larynx does not move only along one dimension, up/down. There is another dimension, forward and backward. Figure 1 shows that singers use 4 strategies in positioning the larynx when singing an ascending pitch series. One of these strategies is mixed; the others can be described as a result of three forces in competition, pulling the larynx in an anterior–superior (up and forward) direction, in a posterior–superior direction (up and backward) and in an inferior direction (down). If these forces acting on the larynx follow the principle of motor equivalence [10], each contributing to achieve a common goal, good singing results. Larynx position is determined by these three forces within the larger context of the singer's body posture and artistic expression.

VLP: Supported vs. Unsupported

We have recently published data on VLP and a number of other variables in singers producing supported and unsupported singing on a variety of tasks (low and high pitch, messa di voce, etc; see [11]. Our data showed that VLP was generally lower in supported voice as compared to unsupported voice. VLP was invariably lower in supported voice in 4 subjects out of 9, lower in the majority of cases in 4 subjects and higher in 4 tasks out of 5 in one subject. In all, VLP was lower in supported voice than in unsupported voice in 32 cases, about the same in 2 cases and higher in 11 (n=45: 9 subjects and 5 tasks). Thus, when asked to sing with support and without support, one of the means by which to differentiate voices is VLP.

Hyoid Bone

Our measurements of the position of the hyoid bone in relation to the thyroid cartilage and mandible show that the textbook conception (graph A in Figure 2) is limited and overly simplified. Real constellations of these structures show variation even to a surprising degree. From a biomechanical point of view such diverse behavior on the part of these structures is motivated: the extreme constellations guarantee the vital function of air flow when singing at extreme pitches (which require extreme maneuvers in the laryngeal region). A comparison of the laryngeal behavior of subject IR in Figures 1-3 shows that drastic measures have been to taken to secure air flow: Figure 1 shows that IR's larynx moves in an anterior–superior direction when singing an ascending pitch series, and graph F (=IR) in Figure 2 (which is a simplification of the rightmost drawing in Figure 3) shows that the hyoid bone is in an extremely anterior–inferior position when singing at C6. Thus, during singing

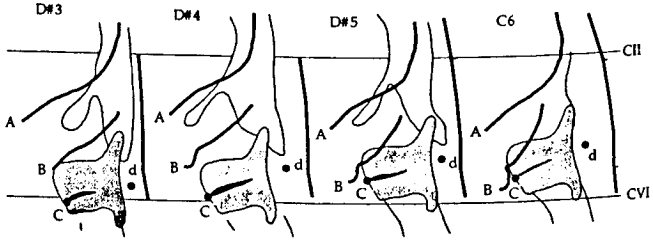

Figure 3. Schematicized roentgenograms of subject IR singing at various pitches.

the larynx can sometimes rise considerably, but it is still possible to sing (the air flow is not obstructed). This is apparently accomplished by the controlled balance of the three forces described above.

Methodical Considerations

The measurement procedure used in this study compares favorably with the Twin-Channel Electroglottograph of Rothenberg [6, 11]. Our roentgenological measurements give data that cannot be obtained by means of the Rothenberg method: we obtained data on the SLP in addition to the VLP. We have shown that there is more variation in VLP (up to 40 mm) than the amount that can be registered by the Rothenberg method (maximum 20-25 mm). Our method allows for inter-individual comparison, whereas the Rothenberg device needs individual calibration and thus does not really allow for interindividual comparison. On the other hand, it is true that the use of X-rays is limited and potentially dangerous, whereas the Rothenberg system is noninvasive (but does not work very well on fat necks). The Rothenberg system is also very accurate in registering time-varying data, whereas roentgenological measurements are necessarily more limited in the time domain.

CONCLUSION

In our data the singers exhibit very varied larynx positions when singing an ascending pitch series. Some singers raise the larynx with pitch, others do not – and even more complex patterns occur. In our opinion, many kinds of laryngeal maneuvers (including larynx raising) are possible when singing, as long as the forces affecting the vocal folds are kept in balance. Larynx position may be connected with the chest–falsetto transition in singing (to be discussed in a forthcoming article by the present authors and Erkki Vilkman).

It is inadequate to describe the position of the larynx by VLP alone. In addition to superior-inferior movement, the larynx also moves in an anterior–posterior direction. What is needed is an understanding of such complicated movements: to know when they are harmful, and when they are necessary for achieving a certain goal (in pitch or vocal quality).

Laryngeal tension – which in itself is a vague concept – is often regarded as a cause of poor performance [12]. To relieve such tension, it would be desirable to understand the forces operating on the larynx, both internal and external. It may be useful to massage the neck area in general, but a more detailed analysis of the contribution of external muscles to laryngeal movements would help in getting to the root of voice problems.

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