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Statement on the Need for an Arytenoid Motion Knowledge Base

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*This memo serves as a statement of the need for a compiled knowledge base of arytenoid cartilage movement (*i.e.*, range of motion, speed of motion, etc.). As biomechanical models of the larynx increase in complexity, there is a need to verify their predictions with laboratory data. Fundamental is a knowledge of the basics of the arytenoid motion about the cricoarytenoid joint. This memo introduces this need and suggests a course of action. Updates to this memo can be downloaded at* http://www.ncvs.org/research_techbriefs.html *.*

Keywords: laryngeal skeleton, cricoarytenoid joint, vocal process, arytenoid motion, range of motion, speed of motion, literature review, cricoid cartilage, arytenoid cartilage, biomechanical models, vocal posturing, vocal fold models, abduction, adduction.

Introduction

Vocal fold abduction/adduction, or posturing, has been hypothesized to be key to vocal onset and self-sustained oscillation (Titze, 1988; Cooke *et al*., 1997). Variation of adduction in particular has been shown to affect the intensity of the voice (Titze and Sundberg, 1992; Murry *et al*., 1998), as well as pitch (Hirano and Ohala, 1970; Honda, 1983). Beyond phonation, vocal fold posturing in general is important for ventilation, swallowing, and effort closure of the airway (Kraus *et al*., 1996).

Numerous studies have attempted to expand this understanding of posturing mechanisms by focusing on the arytenoid cartilage motion around the cricoarytenoid joint (CAJ), as well as the attached muscles causing this motion. Misconceptions about CAJ movement were corrected in a few early studies (*e.g*., Frable, 1961; von Leden and Moore, 1961; Ardran *et al*., 1967; Sellars and Sellars, 1983). More recent studies examined details of the CAJ, such as joint axis and stiffness (*e.g*., Berry *et al*., 2003; Bryant *et al*., 1996; Selbie *et al*., 1998), or arytenoid and vocal fold motion about the CAJ (*e.g*., Wang, 1998; Hirano *et al*., 1988).

The need for a knowledge base

Notwithstanding the importance of these studies, the results have not yet been consolidated into a concise, usable knowledge base. Not only would this consolidation merge the data in one location, but it would also highlight similarities and differences in methodology (*e.g.*, landmark choice or plane of motion) and resulting measures (*e.g.*, average range of motion). By doing so, best-practice study protocols for such investigations could be identified.

An accurate, thorough understanding of posturing is particularly of interest to researchers who explore CAJ mechanics and their effects on phonation through biomechanical models (*e.g.*, Farley, 1996; Titze, 1996, Hunter, *et al.,* 2004; Kob, 2004). Thus, a knowledge base of arytenoid motion could be used to verify the base assumptions of such models.

Additionally, enhancing the understanding of vocal fold posturing mechanics could advance this and other phonosurgical procedures. It would further the goal of many current laryngeal models (of both phonation and posturing) to lay the foundation for vocal injury prediction (Gunter, 2003; Gunter, 2004). Moreover, as these models improve, they could be used to non-invasively simulate the results of small variations in phonosurgical interventions such as vocal fold medialization (Rosa Mde *et al.,* 2003), a treatment of unilateral vocal fold paralysis in which the vocal fold is artificially postured to set the shape and stiffness so that phonation is improved (Neuman *et al*., 1994).

Finally, such a knowledge base would draw attention to seemingly unintuitive observations. For example, Hunter *et al*., 2004, showed a potential physical mechanism behind the observation of Woodson *et al*. (1998) that the cricothyroid muscle did not contribute to vocal fold adduction. Observations like these could then be explored through further laboratory studies or through biomechanical models. This is particularly important when considering individual differences within anatomy and physiology (Hunter and Titze, 2005A; Hunter, Hunter and Titze, 2005)[1]

Suggested approach

Because of the complexity of arytenoid cartilage motion, previous studies have used different methodologies to study this motion. One such difference is the choice of landmarks (*e.g.*, mid-membranous vocal fold, CAJ axis point, or vocal process). Therefore, it is proposed by the authors that a compiled knowledge base be built focusing on at least one common landmark to quantify the motion; this common landmark would allow for inter-study comparability. Ideally, the primary landmark would be the vocal process (commonly used to quantify glottal width and glottal length in vocal posturing).

[1] It should be noted that at the same time this Technical Memo was published, a review of arytenoid cartilage motion ranges was under review and later published in Hunter and Titze, (2005B).

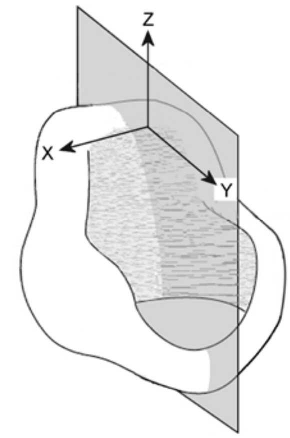

Figure 1. Coordinate system from vantage point of cricoid cartilage.

As the knowledge base is compiled, doubtless gaps in research will become evident. Thus, the authors propose specific guidelines for future studies of the CAJ mechanics or movement to facilitate comparisons between studies. First, the authors propose that future studies include (at a minimum) a direct measurement of, or correlates to, the vocal process (regardless of other landmarks that may be measured). Although the vocal process is the ideal common landmark, it is not always easy to pinpoint its exact position (Cooke *et al.*, 1997). Thus, it is further proposed that clarification be included on how the vocal process is defined. For example, Hunter and Titze (2004) incorporated the range of potential vocal process definitions by using two nearly identical, commonly used vocal process landmarks: (1) the true anatomical vocal process at the tip of the arytenoid, VP_T; and (2) the medial vocal fold edge near the vocal process, VP_M.

Further, with the vocal process as the proposed landmark, it is proposed that a compiled knowledge base describe the motion of the vocal process with respect to the cricoid cartilage (after Selbie *et al.*, 1998), as shown in Fig. 1 (*x*: medio-lateral, rightward positive; *y*: anterio-posterior, anterior or frontward positive; *z*: inferio-superior, superior or upward positive, after Hunter *et al.*, 2004). Figure 2 illustrates the relation of the arytenoid to the cricoid, with the approximate position of the vocal process labeled as VP.

Conclusions

As biomechanical models increase in complexity and realism, they can become a more useful tool to study vocal injuries and phonosurgeries. However, before models can be tuned specifically to a subject for testing individual phonosurgeries and/or therapies, the assumptions (not related to geometry or anatomy) that have been built into a biomechanical model (*e.g.*, various modeling techniques) must be verified using laboratory data. Therefore, the need for a knowledge base of arytenoid motion ranges (via vocal process motion) was proposed.

Such a knowledge base is essential to the progress and use of biomechanical models of the larynx. Once a usable vocal process range knowledge base is available and posturing models are able to predict the ranges, it will become important to ascertain the speed of posturing motion. Tools such as high-speed stroboscopy using new calibration techniques might be used to obtain these speed measures (Larsson and Hertegard, 2004), allowing researchers to make absolute, rather than relative, measures of abduction/adduction speed.

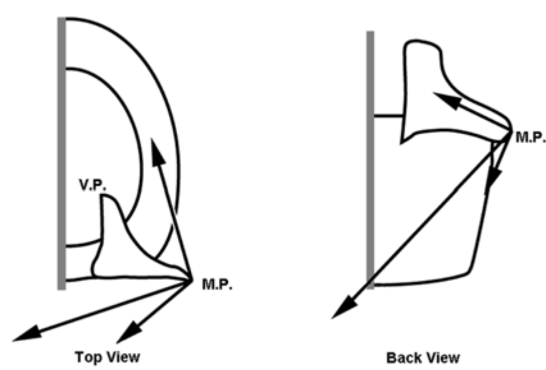

Figure 2. The right half of the cricoid and the arytenoids. Arrows represent the approximate direction of the adductor/abductor muscles, which attach around the muscular process (M.P.). The vocal process, near the attachment of the vocal ligament, is also labeled (V.P.).

Other potential, new techniques use a prism to capture three-dimensional movement of vocal fold surface dynamics (Dollinger and Berry, 2005); these techniques might be adapted to capture overall vocal fold motion on a lab bench.

It is essential that the researchers design future laryngeal studies with an eye on how their data might be used in the future. First, it is crucial that studies be designed to allow for inter-study comparisons. Further, as the computational power behind biomechanical models improve, models will become more important for medical and therapeutic purposes; thus, studies should provide data for the use of verifying laryngeal models.

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