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Stroboscopic Laminagraphy of the Vocal Folds*

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To the present time application of conventional laminagraphy for the study of laryngeal structure and physiology has suffered from the basic limitation that it has provided only a single exposure of rapid vibratory motion. The result has been an x-ray photograph in which the shadow outlining the vocal folds results from the blurring of many complete vibratory cycles. Because of this complexity, it is impossible to know the nature of the time function summation of vocal fold motion which is represented by the x-ray shadow. It is obvious, however, that the resultant image does not represent any single position of the vocal folds during a vibratory cycle. Moreover, both the shape and size of the shadow obtained are possibly affected by dynamic factors such as amplitude of motion, relative duration of the closed phase, etc. Since some of these factors could vary differentially for certain vibratory conditions, measurements made on conventional laminagrams may be contaminated by the inadequacy of the observational technique. Thus, the validity of vocal fold cross sectional area and thickness measurements can be questioned.

A stroboscopic laminagraph (Strol) was developed in order to resolve these problems. It provides a series of laminagraphic x-ray photographs which show coronal views of the vocal folds at each of several phases distributed equally throughout the vibratory cycle. Although each picture is a composite of several short exposures obtained from a number of vibratory cycles, each x-ray firing occurs when the folds are in the same position. Thus, the folds are seen in

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several different positions throughout a cycle and accurate measurements of area and thickness can be performed.

The availability of Strol also permits the study of laryngeal vibration. Until this device was constructed, the only satisfactory way of investigating the vibratory patterns of the vocal folds during phonation was by means of indirect laryngoscopy and associated ultra-high speed photography. Virtually all the basic information relative to laryngeal vibration has resulted from this and allied methodologies. While a substantial research tool, ultra-high speed photography of the vocal folds has two limitations. First, since many individuals are unable to expose their vocal folds due to anatomical unsuitability or severe gag reflex, only a relatively few individuals can be used as subjects. Moreover, since the image photographed is of the superior surface of the folds, activity below this level is visualized imperfectly. On the other hand, stroboscopic laminagraphy can be used with virtually any subject and clear images of vocal fold cross section may be obtained during actual phonation. Of course, this technique also has limitations, the most serious being that the resulting images do not portray successive cycles but rather are a composite image of numerous cycles. Moreover, only one plane along the anteroposterior extent of the vocal folds can be visualized at any given time. Nevertheless, Strol provides important information relative to the dynamics of vocal fold vibration as well as data on the mass and thickness of the folds.

It was the purpose of this presentation to briefly describe Strol primarily by means of photographs of the prototype model being used at the Communication Sciences Laboratory. Finally, photographs of the vocal folds during phonation were presented.

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Discussion

Snidecor (Santa Barbara): The previous commentator showed a distrust of singers in saying that their vibrato would make them less usable in a stroboscopic study. Some years ago, working with *Tiffin* and *Saidveit*, and with relatively crude equipment, we needed to have subjects who could phonate within one or one and one half cycles at 130 cycles per second. Singers proved to be the best subjects although it was necessary to train them to use a steady state tone rather than a fluctuating one. Their precision in holding a given frequency more than compensated for any difficulty with vibrato. Our best subject could not only hold a steady tone, but we could also photograph the total length of the vocal cords at various pitches and intensities. Your method does not, of course require more than a steady tone.

Falc'hun (Rennes): La technique dont M. *Hollien* vient de nous montrer un si beau spécimen nous laisse espérer une solution satisfaisante et définitive d'un grand problème de phonétique historique: celui du passage des occlusives sourdes aux aspirées. On a autrefois expliqué l'aspiration des occlusives germaniques par une articulation à glotte ouverte pendant la tenue, sans doute parce qu'on pensait ne pouvoir expliquer l'aspiration que par un retard dans la fermeture de la glotte après l'explosion marquant la fin de la tenue.

A cette époque, aucune technique ne permettait d'observer ni surtout d'enregistrer la position de la glotte pendant la tenue d'une occlusive. La laminographie stroboscopique, synchronisée avec l'enregistrement de la parole, permettra d'observer la position de la glotte à chaque phase de la tenue et de l'aspiration d'une occlusive. Il est à souhaiter que M. *Hollien* applique bientôt sa nouvelle technique à l'étude de ce problème, et fournisse aux linguistes une série de «laminogrammes stroboscopiques» synchronisés avec des oscillogrammes et des sonagrammes représentant des occlusives, aspirées et non aspirées. Cette documentation sera des plus précieuses pour les linguistes qui essaient de mettre sur pied une théorie générale de la mutation consonantique, et surtout de l'altération des occlusives. Elle leur évitera du moins d'asseoir leur argumentation sur un mécanisme du larynx qui ne serait qu'une vue de l'esprit.

Smith (Hellerup): Your interesting technique has shown – as far as I can see – some gross mobility in the heavy structure of the vocal cords not realized before.

What cannot be observed on your pictures is a longer closure phase. This may partly be dependent on the voice of the subjects at just the moment of take (husky, or breathy voice?), partly on the fallacy of X-ray to give a picture of the movements of the thin mucosa.

It seems as if a movement in the vertical plane of ventricular bands may be observed in your film – unobservable from above.

Answer *Hollien:* I wish to thank Mr. *Smith* for his kind comments concerning my film on Stroboscopic Laminagraphy. He is most correct in suggesting that my technique can be used to study 1. the mass and thickness of the vocal folds under a variety of phonatory conditions and 2. the dynamics of vocal fold vibration in a manner not previously realized.

I should like to differ with Mr. *Smith*, however, relative to his second comment, i.e., that the longer closed phase associated with certain phonatory events, cannot be seen in *Strol* pictures. In this regard, it is possible that the vocal fold vibratory action of the two subjects seen in my movie is somewhat misleading. I should like to point out that in both instances, the individuals were producing a relatively low fundamental frequency (100 cps – 125 cps respectively) at *very soft vocal intensities*. Thus, the closed phase for one of the subjects is a little over 10% of the total cycle and for the other about 20%. Quite obviously, in other modes of vibration, a much longer closed phase would be produced and seen on the films. Such materials are being developed currently and will be discussed in later reports.

I agree with Mr. *Smith* that a possible movement in the vertical plane of the ventricular vocal folds seemed to be the case but I do not know if it resulted from mispositioning the x-rays for motion picture photography or whether such action is universally true for these modes of phonation. In any event, subsequent research may clarify these observations.