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Flexible fiberoptic videonasendoscopy (FFVN) insertion study

by

Kara Louise Ryan ©

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The undersigned certify that they have read and recommended to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **FLEXIBLE FIBEROPTIC VIDEONASENDOSCOPY (FFVN) INSERTION STUDY** submitted by Kara Louise Ryan in partial fulfillment of the requirements for the degree of Master of Science, in Speech-Language Pathology.

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Abstract

This study investigated the effects of insertion nostril of the flexible fiberoptic nasendoscope on the image width of the vocal folds. Seventeen healthy young adults with no visible vocal fold pathologies or nasal cavity abnormalities provided the laryngeal images. The flexible nasendoscope was inserted through the left and right nostrils of each subject, and the laryngeal images were captured on video-cassette tape. Video frames of adducted and abducted folds were digitized to yield two separate, independently treated measurement conditions, mid-line and open. Left and right vocal fold widths were measured by mouse-driven image analyzing software, and left-to-right vocal fold width ratios were generated for each insertion side. Within-group comparisons were made between ratios derived from the images captured via left nostril and right nostril insertions. A dependent measures t-test comparing the mean left vocal fold width ratio with the mean right vocal fold width ratio revealed a statistically significant difference in each measurement condition. Results indicated that the vocal fold contralateral to the nostril of insertion was measurably wider than the ipsilateral fold. This finding is consistent with previous reports on the potential for image artifact in flexible fiberoptic video nasendoscopy. The clinical significance of the findings, as well as factors influential to the results are discussed.

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Chapter I. Problem Under Investigation

Recent and increased attention to imaging charateristics of flexible, fiberoptic endoscopic instrumention has clinical investigators questioning the integrity of laryngeal and velopharyngeal images (Colton, Casper, Brewer & Conture, 1989; D'Antonio, Muntz, Marsh, Marty-Grimes, Backensto-Marsh, 1988; Fex, Fex & Hirano, 1991; Yanagisawa & Yanagisawa; 1993). Two factors relating to placement of a fiberoptic imaging endoscope, distance and angle of orientation, have been shown by measurement analysis to introduce optical distortion that affects the validity of an image (Hibi, Bless, Hirano & Yoshida, 1988; Casper, Brewer & Colton, 1988; Pigott & Makepeace, 1982).

Laryngeal visualization by nasal induction of a flexible fiberoptic nasendoscope is performed in the clinical setting (Bastian & Levine, 1988; Brewer & McCall, 1974; D'Antonio, Chait, Lotz & Netsell, 1987; McFarlane & Lavorato, 1984; Welch, 1982). An image artifact, if present, resulting from insertion of the nasendoscope may not be detected during qualitative, diagnostic evaluations of the video-taped laryngeal image. Clinical investigations of laryngeal imaging have yielded, at best, only subjective estimations of the distortion effects relating to nostril of insertion (Cantarella, 1988; Casper et al., 1988; Yanagisawa & Yanagisawa, 1993).

The intent of this study was to investigate the effects of varying the insertion nostril of a flexible nasendoscope on vocal fold image width by applying measurement analysis to the video-taped laryngeal images. The purpose of this research was to determine if transnasal insertion produces an image artifact that results in consistent changes in the image width of the left and right vocal fold depending on the insertion nostril.

Chapter II. Review of the Literature

Topics pertinent to the literature review are discussed under the headings Flexible Fiberoptic Instrumentation, Position of the Nasendoscopic Lens, Image Interpretation and Flexible Fiberoptic Video Nasendoscopic Insertion Procedures. First, the properties of the flexible fiberoptic imaging instrument are examined. It is important for the reader to be familiarized with the results of previous investigations of the effects of nasendoscope lens position on laryngeal images and their interpretation. Finally, insertion procedures are reviewed, as well as clinical and experimental findings that indicate nostril of insertion affects the appearance of the image of laryngeal structures, including the vocal folds.

Flexible Fiberoptic Instrumentation

Imaging techniques, including rigid, oral endoscopy and flexible fiberoptic nasendoscopy have been used to obtain laryngeal images. This study will focus on the flexible fiberoptic instrumentation and the clinical procedures used to obtain laryngeal images. The instruments required to perform flexible fiberoptic nasendoscopy are a nasendoscope and an adequate light source, either arc xenon or halogen. In voice clinics and voice laboratories that are equipped with video recording technology, routine clinical procedure includes recording and displaying the laryngeal images by coupling the nasendoscope to a video camera and video-recording unit. It is important for the reader to comprehend that the visual image, obtained by flexible or rigid imaging instrumentation, is affected by inherent distortion associated with the imaging properties (Fex et al., 1991).

Nasendoscope

The nasendoscope has a flexible optical system. The inserted portion or "working length" of the flexible fiberoptic nasendoscope is approximately 30 cm with diameters ranging between 3.3 mm for smaller pediatric models and 4.0 mm for adult models (Inouye, 1983; Selkin, 1983).

The optical component is comprised of bundles of fiberoptic light-delivery and image-transfer fibres that are arranged in concentric circles; the image carrying bundles located in the inner circle are encircled by the light carrying bundles (Selkin, 1984; Wilson, Kudryk & Sych, 1986). The fiberoptic lens, located at the distal end of the flexible portion of the nasendoscope, is oriented in most models to facilitate frontal viewing. It is important to consider that the image is displayed as if one were facing the subject and looking directly down into the vocal tract. For example, the left vocal fold is located on the right side of the image, and anterior structures, such as the anterior commissure, are located in the lower portion of the image.

The distal tip of the flexible fiberoptic nasendoscope can be deflected along the vertical axis. The amount of distal tip deflection is controlled through manipulation of an external control knob. The maximum range of tip deflection in most nasendoscope models ranges from 50 degrees to 90 degrees from its vertical axis (Selkin, 1984; Yanagisawa, Owens, Strothers & Honda, 1983).

Light Source

Proper illumination of the laryngeal cavity is critical to the process of recording the laryngeal images on video-cassette tape (Wilson et al., 1986; White & Knight, 1984; Yanagisawa et al., 1983). Light sources that supply "cold" light are required for flexible fiberoptic video nasendoscopy due to the susceptibility of fiberoptics to damage when exposed to heated elements. Sources of "cold" light are arc xenon, which is most common in the clinical setting, or halogen. Halogen light sources have been used successfully and provided quality laryngeal images (Casper et al., 1988; D'Antonio et al., 1986; Wilson et al., 1986).

Video Camera and Recording Unit

The laryngeal images obtained from the video camera are recorded on a video-cassette tape. The video camera is coupled to the eyepiece of the nasendoscope. Standard studio size video cameras anchored by a tripod, or miniature hand-held cameras have been used to capture laryngeal images (Wilson, 1988; Wilson et al., 1986; Yanagisawa & Yanagisawa, 1993). In some video nasendoscopy systems, an external image magnifier is attached to the eyepiece (Wilson et al., 1986). The function of the video camera is to transmit the point-to-point light values to a photosensitive surface which converts incoming signals to electronic impulses (Selkin, 1984). Most cameras used in clinical nasendoscopy have superior photosensitive surfaces and produce adequate video-taped images given proper illumination of the laryngeal cavity (D'Antonio, Chait, Lotz & Netsell, 1986; Wilson et al., 1986). Because these cameras are highly sensitive to light, they are slow to adjust to changes in intensity (Selkin, 1984; Wilson et al., 1986). Therefore the visibility of laryngeal structures may be affected by "whiteouts," if intensity of the light reflected back to the camera is too great.

The electronic impulses are transmitted from the video camera to the video recorder and stored on a video-cassette tape (Selkin, 1984). The format of video-cassette tape and video-recorder must be compatible; both the 3/4 and 1/2 inch video cassette formats produce video images of acceptable quality for research and clinical applications (Cantarella, 1988). It is important to understand that the image recorded on the video-cassette tape is the result of direct transmission of incoming light signals from the nasendoscope eyepiece via the video camera and recorder. In some systems with an external image magnifier the image, as received by the video-cassette recorder, has been enlarged. However the image has been transmitted, there are inherent characteristics of the imaging instrument that affect the video image.

Inherent Distortion

One of the inherent characteristics of flexible fiberoptic or rigid endoscopic imaging instruments is presentation of a flat, plane disc as a hemispheric image (Pigott & Makepeace, 1982). As a result, the size of objects located in the periphery of the image will be compressed (Cantarella, 1988; Fex et al., 1991; Hibi et al., 1988; Pigott & Makepeace, 1982). Therefore a structure located in the periphery of the image will appear smaller than it would if it was located in the centre of the image (Cantarella, 1988; Pigott & Makepeace, 1982). This inherent distortion associated with flexible fiberoptic imaging instruments has been termed "wide-angle distortion" or "barrel-shaped distortion" (Casper et al., 1988; Hibi et al., 1988). Both terms refer to the same optical effect. "Wide-angle" refers to the capacity of the lens to visualize a greater circumference of surface area than that encompassed by the actual diameter of the nasendoscopic lens. "Barrel-shaped" suggests the optical effects of distortion by a wide angle lens on the image (Hibi et al., 1988). The degree of "barrel-shaped" or "wide-angle" distortion is a function of the distance of the structure in the field of view from the centre of the image (Cantarella, 1988; Casper et al., 1988; Hibi et al., 1988; Pigott & Makepeace, 1982).

Position of the Nasendoscope Lens

Placement of the nasendoscope tip in relation to the surface can exacerbate the effects of the inherent distortion and/or introduce new sources of distortion upon the resultant image (Hibi et al., 1988). From theoretical investigations, it has been determined that both the distance from and the angle of the nasendoscope lens to the surface affect the size and relative dimensions of structures being imaged (Peppard & Bless, 1990).

Distance

The perpendicular distance of the nasendoscope lens to the flat plane of the tissue surface determines the image size of the objects (Cantarella, 1988; Casper et al., 1988). As the perpendicular distance is decreased between the nasendoscope lens and the flat plane of the structure, the circumference of surface area included in the image decreases and size of objects in the image increases (Casper et al., 1988; Hibi et al., 1988; Pigott & Makepeace, 1982). Therefore it is impossible to conclude from the video nasendoscopic image the actual size of structure, unless the surface-to-lens distance is known (Casper et al., 1988) or the image contains a structure of known dimensions (Hibi et al., 1988).

Angle

If the nasendoscope lens is oriented 90 degrees to the surface, the image will be affected only by the inherent, "barrel-shaped" distortion which would be uniform (Hibi et al., 1988). As the nasendoscope tip is deviated from a perpendicular orientation to the horizontal axis new distortion effects are introduced into the image (Casper et al., 1988; Hibi et al., 1988; Peppard & Bless, 1990). To determine the consequences of altering the angle of orientation, Hibi et al. (1988) systematically varied the nasendoscope lens angle in relation to an imaged surface. The theoretical model, as designed by Hibi et al. (1988), used angles and distances derived from actual measurements of lateral radiographic images of nasendoscope tip placement in the vocal tract. A flexible fiberoptic nasendoscope was suspended above grid paper and photographs of the video recorded images were analyzed using a magnetic screen digitizer connected to a personal computer. The actual coordinates of the grid paper stored on the digitizer were compared to the coordinates obtained from flexible fiberoptic nasendoscopic images. The results obtained by Hibi et al. (1988) indicated that, if the angle of orientation of the nasendoscope tip deviates more than 5 to 10 degrees from the perpendicular, distortion effects, separate from inherent distortion, are introduced into the image.

The theoretical model proposed by Hibi et al. (1988) was based upon manipulation of the angle of the nasendoscopic lens to the surface from a vertical axis that bisected the hemispheric image into ipsilateral and contralateral sections. The contralateral field was defined as the area contained in the surface plane tilted away from the nasendoscope lens, and the ipsilateral field was defined as the area contained in the surface plane tilted towards the nasendoscope lens. The bilateral sections of the hemispheres were differently affected. The contralateral field was elongated and ipsilateral field was compressed. As a result the contralateral field contained a greater number of square grids than the ipsilateral field. The effect of the size distortion upon a gridded surface was predictable, those objects in the ipsilateral field appeared larger than those in the contralateral field. The compression and elongation effects were not proportionally related for the contralateral and ipsilateral fields of view. The structures in the ipsilateral field of view experienced more distortion relative to objects the contralateral field of view, given the same distance from the centre of the circular image.

Corroborative evidence for the presence of the size distortion as a result of nasendoscope lens displacement along an axis was provided by Casper et al. (1988). In that study, the nasendoscope lens was displaced from the left to right, estimating the effect of this axial displacement of the scope tip upon the image with objects representing the left and right vocal folds. The nasendoscope was focused on a square to the viewer's left, then the tip of the nasendoscope was angled approximately 30 degrees to the right along the horizontal axis in relation to the surface plane. The nasendoscope tip was deviated from a perpendicular orientation and placed on an angle. Casper et al. (1988) reported an "apparent difference" in the size of the two symmetrical squares. The size difference was consistent with what was predicted by Hibi et al. (1988); the right square decreased in size as it moved away from the image mid-line.

Further, Casper et al. (1988) reported and also provided visual evidence of compression distortion producing an image artifact of alignment misrepresentation of two parallel lines. An apparent convergence of two parallel lines was observed after the nasendoscope lens was tilted 40 degrees from the perpendicular in the direction of the parallel lines (Casper et al. 1988). Compression distortion, producing the convergence effect, was restricted to the outer periphery of one half of the image. Results from Casper et al. (1988) provided further evidence for the hypothesis by Hibi et al. (1988) that compression and elongation distortion differentially affect image size of objects.

Summary

The model proposed by Hibi et al. (1988) suggested that the effects of distortion upon a structure are a result of interaction between distance and angle parameters of nasendoscope placement. The research by Hibi et al. (1988) indicated that image size of a structure was dependent upon three interrelated factors: (1) angle of orientation of the nasendoscope in relation to the flat surface in the field of view (2) location of the structure from the centre of the field of view and (3) vertical distance of the nasendoscope lens to the surface of interest.

The theoretical findings of the effect of nasendoscopic tip placement on video images have indicated that distance and orientation of the nasendoscope lens to the tissue surface of interest may be a critical aspect of the imaging process in the clinical context.

Image Interpretation

Although it has been demonstrated that positioning of the nasendoscope tip is important, the implications of such information for clinical flexible fiberoptic nasendoscopic procedures are not well understood (Casper et al., 1988; Hibi et al., 1988; Peppard & Bless, 1990). For example, the effect of nasendoscope tip placement upon laryngeal images has yet to be investigated in a systematic, controlled manner in light of investigations reported. Therefore, measurement techniques and interpretation of image laryngeal structures used in previous applied clinical research will be discussed with respect to nasendoscope placement and comparison of data obtained from rigid endoscopic and/or flexible fiberoptic instrumentation within and across subjects.

Image interpretation can be conducted by qualitative or quantitative means. Although qualitative evaluation of video-taped images of laryngeal structures is routine in the clinical setting, its reliability is questionable (D'Antonio, Marsh, Province, Muntz & Philips, 1989). Quantitative image analysis involves measuring laryngeal or velopharyngeal structures. The research applications involving imaging instruments and quantified photographed and videotaped data will be reviewed with respect to dimension and ratio techniques.

Dimension Comparisons

Peppard and Bless (1990) used quantified laryngeal images obtained via a rigid oral endoscope to try to replicate the original position of the imaging instrument tip upon reinsertion in the oral cavity. By attaching a gridded transparency to the front of the TV monitor displaying the laryngeal images, Peppard and Bless (1990) traced the vocal cords, arytenoid cartilages and ventricular folds onto the transparency. The investigators then withdrew and reinserted the endoscope and by using the transparency as a guide manipulated the endoscope tip until the image on the TV monitor best fit the superimposed trace of the laryngeal structures. According to Peppard and Bless (1990), using trace-size comparison "would ensure that lens-object distance was the same," although the absolute distance is unknown (p. 281).

Ratio Comparisons

McFarlane and Watterson (1990) used vocal fold length measurements from rigid endoscopic video prints to document variation in the position of vocal nodules across different subjects. The location of the vocal nodule was expressed as a ratio of the distance of the nodule from the anterior commissure to the entire vocal cord length measured from the anterior commissure to the vocal process. Similarly, width measurements of the nodules were represented as a ratio of nodule width to vocal cord and nodule width. McFarlane and Watterson (1990) reported that expressing length relations as ratios instead of absolute measures, "helps to minimize the effect of optic distortion on the laryngeal image" (p. 48) and enables clinicians to make comparisons across laryngeal data obtained from different subjects.

Recently, clinical researchers have begun to use video digitizing software with compatible computer hardware to measure the relative area of laryngeal anatomical structures from the same video image. Secarz, Berke, Arnstein, Garrett and Natividad (1991), using a video digitizer with mouse-driven computer software, calculated the area of video-taped images of the left and right vocal cords obtained from rigid video endoscopy with a strobe light source. Area was expressed in digitized light units, referred to as pixels.

Secarz et al. (1991) also used area measurements obtained from digitized video frames to investigate the possibility of demonstrating a quantitative difference in the function of a paralysed vocal cord prior to and after surgical intervention. Glottic area was measured in two vibratory conditions: (1) most open phase of phonation and (2) most closed phase of phonation and at two points in time relative to treatment: (1) pre-intervention and (2) post-intervention. Ratios of the most closed phase to most open phase obtained pre-intervention were compared to the post-intervention ratios.

Ratio measures were used by Secarz et al. (1991) to document the symmetry of vocal fold movement or excursion. The visible width of the left and right vocal folds were measured in pixels at two points in the vibratory cycle: 1) most open phase of phonation and 2) most closed phase of phonation. To estimate the degree of variation in left and right vocal fold excursion, the difference in same side vocal fold widths across measurement conditions was calculated and used to yield a ratio. The ratio value was a quantitative estimate of the relative movement of each vocal fold. Using this measurement technique, Secarz et al. (1991) reported that the non-paralysed vocal fold's excursion during the vibratory cycle was 3.1 times as great as that of the paralysed fold.

Ducharme, Hackett, Fubini and Erb (1991) used ratio measurements obtained from digitized video nasendoscopic images of the laryngeal structures of horses to determine if nostril of insertion affected the integrity of the image. Video frames that displayed full arytenoid abduction were chosen for measurement analysis. The anatomical image was divided into right and left halves by connecting the posterior and anterior midpoints of the rima glottis. The left and right areas of the rima glottis were measured and a ratio of left-to-right areas was calculated for every insertion. Ducharme et al. (1991) stated

> "Our technique, using the left to right ratio, does not require radiographic measurements of the height of the rima glottis as a simultaneous adjustment for an unknown distance and obliquity (in the rostro-caudal plane) of the rima glottis in relation with the endoscope.... "
> (p. 184)

Since Ducharme et al. (1991) found a statistically significant difference between ratios within the same horses obtained from left and right side insertion, they concluded that the use of the left-to-right ratio emphasized image differences associated with the angular variations in nasendoscope tip placement in the horizontal plane.

To summarize, two basic quantitative analysis techniques of images obtained from fiberoptic imaging instrumentation have been reviewed: size and ratio comparisons. First, investigators, such as Peppard and Bless (1990), used simple size comparisons to replicate imaging tip placement in the vocal cavity and reported that differences in the size of imaged structures are directly related to imaging instrument tip placement. Second, other investigators have demonstrated that use of ratio measures can compensate for the unknown lens-to-object distance and provide a simple and accurate means of comparing the location of vocal nodules across subjects (McFarlane & Watterson, 1990), determining symmetry of vocal fold excursion or comparing the pre and post-operative function of a surgically treated paralysed vocal cord (Secarz et al., 1991).

Of specific interest to this study, Ducharme et al. (1991) established the use of left-to-right area ratios as a means of controlling for the unknown lens-to-surface parameter when comparing size differences between anatomical structures located on opposite sides of a field of view. A significant difference was found, between the ratios obtained from left side and right side insertion in horses, indicating that nostril of insertion affects imaging characteristics.

Flexible Fiberoptic Nasendoscopic Insertion Procedures

Components of a laryngeal examination conducted via the flexible fiberoptic nasendoscope will be described, beginning with rationale used by the otolaryngologist to select nostril of insertion, insertion procedures associated with nasendoscopy and a description of vocal tasks used to assess laryngeal function and structures. There is evidence that insertion factors, such as the nostril chosen for insertion of the nasendoscope, affects images obtained by flexible fiberoptic nasendoscopy. The clinical observations and research findings presented seem to suggest that nostril of insertion is related to an observable and/or measurable image artifact.

Laryngeal Examination

Rationale for choosing insertion nostril. In clinical practice, the left and right nasal passages are examined to identify the easier nostril of insertion (McFarlane & Lavarato, 1984), and the flexible fiberoptic nasendoscope is inserted through the larger or less obstructed of the two nasal cavities (Selkin, 1984; Williams, Farquharson & Anthony, 1975). Clinical investigators have reported that deviations in the nasal septum or lateral walls can obstruct the passage of the flexible fiberoptic nasendoscope making transnasal visualization of the larynx impossible (Williams et al., 1975; Yanagisawa et al., 1983).

Insertion procedures. Once the nostril of induction has been selected, the nasendoscope is inserted through the naris and passed along the floor of the nasal cavity. As the nasendoscope tip approaches the posterior pharyngeal wall, the patient is instructed to open the velopharyngeal port by breathing through the nose or humming. Opening of the velopharyngeal port facilitates the passage of the flexible fiberoptic nasendoscope through the nasopharynx. The articulating tip of the nasendoscope is deflected inferiorly and the flexible nasendoscope is then lowered into the hypopharynx and approaches the laryngopharyngeal cavity (McFarlane & Lavarato, 1984; D'Antonio et al., 1986; White & Knight, 1984). Clinical investigators have reported lowering the nasendoscope tip past the epiglottis, to obtain an unobstructed view of the vocal cords and arytenoid cartilages (Selkin, 1984; Yanagisawa et al., 1983). Most of the clinical descriptions of flexible fiberoptic nasendoscope examinations report manipulation of the external controls on the nasendoscope so that the tip is aligned in the laryngeal cavity to obtain an optimal view of the laryngeal structures (Brewer & McCall, 1974; Silberman, Wilf & Tucker, 1976; Welch, 1982; Williams et al., 1975; Wilson et al., 1986).

Laryngeal examination and vocal protocol. A laryngeal examination involves determining the integrity of laryngeal structures and their function (Boone & McFarlane, 1988; D'Antonio, et al., 1987; McFarlane, Watterson & Brophy, 1990; Selkin, 1984). As discussed previously, the nasendoscope is inserted through the nasal passageway and is suspended in the hypopharynx at the supraglottic level. Therefore, the laryngeal structures can be viewed in a variety of phonatory and respiratory states with minimal interference occurring as a result of imaging instrument placement.

During the laryngeal examination conducted via flexible fiberoptic nasendoscopy, the vocal folds are typically viewed in abducted and adducted positions (Cantarella, 1988; McFarlane et al., 1990; Yanagisawa et al., 1983). To obtain a view of the vocal folds abducted for inspiration and expiration, the patient is asked to engage in quiet breathing, which will open the glottis for a prolonged period of time. To obtain a view of vocal folds adducted for phonation, the patient is instructed to produce an /i/ vowel. Phonation of an /i/ vowel requires a high tongue carriage which results in laryngeal body elevation and lifting of the epiglottis. In most individuals, laryngeal elevation exposes the entire length of the phonating vocal folds, including the anterior commissure.

Effect of Nostril of Insertion

Because the position of the nasendoscope tip in the supraglottic airway is manipulated by the examiner in an attempt to provide an optimal view of the larynx, it is difficult to ascertain the exact orientation of the nasendoscope lens to the tissue surface (Casper et al., 1988). Clinical researchers applying both qualitative and quantitative analysis procedures have noted the presence of a nostril-of-insertion effect for vocal fold and velopharyngeal images (Cantarella, 1988; Ibuki, Karnell & Morris, 1983).

Qualitative observations. Casper et al. (1988) also investigated the effects of insertion nostril on the size and movement of structures in the laryngeal image. One normal subject was scoped once through each nostril. After comparing the appearance of laryngeal images obtained from left and right insertions it was concluded that "there was no observable difference" (p. 351) in the appearance of structures based upon nostril of insertion (Casper et al., 1988).

Cantarella (1988) stated the flexible fiberoptic nasendoscope is manipulated in the vocal cavity until "the (nas)endoscope is brought to the best obtainable position for monitoring laryngeal activity" (p. 354), concurring with other clinical opinions offered on nasendoscopic viewing procedures. Using a methodology similar to those described above to observe the larynx, Cantarella (1988) indicated that several scopings resulted in an oblique view of the vocal folds, suggesting that lens orientation was not perpendicular to tissue surface. The vocal fold located "closer" to the nasendoscope tip looked much bulkier than the fold on the opposite side. When this type of optic effect was suspected, Cantarella (1988) suggested that a more symmetrical view of the folds could be obtained by insertion through the other nostril. It appears that Cantarella, when referring to the "closer" vocal fold, was referring to the fold ipsilateral to the insertion nostril. It is difficult to reconcile Cantarella's observation with the findings of Hibi et al. (1988), however. It could be hypothesized that because of the effects of elongation distortion in the model proposed by Hibi et al., the vocal fold in the contralateral field of view might appear "wider" than the ipsilateral fold.

In a more recent article comparing flexible nasendoscopic and rigid, oral endoscopic video stroboscopy, Yanagisawa and Yanagisawa (1993) indicated that images obtained via flexible fiberoptic nasendoscope were susceptible to distortion effects related to optical factors, and anatomical factors. Anatomical factors contributing to the distortion effects were a narrow nasal cavity, a large turbinate or a septal deviation. The effect on the stroboscopic image, according to Yanagisawa and Yanagisawa (1993), was that vocal fold and supraglottic laryngeal structures were perceived as asymmetrical. In the one case presented, the vocal fold contralateral to the insertion nostril was visibly larger than the ipsilateral fold. Yanagisawa and Yanagisawa (1993) stated that it was difficult to correct the angular placement of the flexible nasendoscope to eliminate the asymmetrical distortion effect on vocal fold size. Since the contralateral vocal fold may appear wider or larger than the fold ipsilateral to insertion nostril, this provides some indirect evidence that angular orientation of the nasendoscope results in elongation distortion affecting the contralateral field of view and subsequently the image appearance of the vocal fold contained in that field of view.

Ibuki et al. (1983) and Karnell, Ibuki, Morris and Van Demark (1983) also noted the presence of a nostril effect when investigating the reliability and validity of nasendoscopic procedures to observe the velopharyngeal mechanism. For both studies the right nostril was selected for insertion of the nasendoscope to observe the velopharyngeal mechanism. Still photographs obtained from a side-viewing nasendoscope were used to trace the velopharyngeal landmarks for comparison between re-insertions of the nasendoscope. Ibuki et al. (1983) mentioned experiencing some difficulty achieving reliable subjective estimates of the left lateral wall movement during closure of the velopharyngeal port. Both Ibuki et al. (1983) and Karnell et al. (1983) attributed this difficulty to an artifact of inserting the nasendoscope through the right nostril.

Quantitative evidence. Ibuki et al. (1983) also noted the presence of a nostril effect when analyzing traces of still photographs · the velopharynx. For images obtained when the nasendoscope was inserted in the right naris, the vertical centre line, part of X and Y coordinates drawn to intersect on the posterior margin of the soft palate, was displaced to the viewer's right of the image mid-line.

Displacement of the anatomical mid-line to the viewer's right, although not validated by Ibuki et al. (1983), seemed to suggest that the right anatomical structures occupied a greater proportion of the image than those on the left. Again this image artifact was attributed to insertion of the nasendoscope through the right naris (Ibuki et al., 1983). No direct comparisons of image size of bilateral structures were conducted to determine if there were relative size differences between left and right velopharyngeal structures. The findings of Ibuki et al. (1983) seem to suggest that, when the nasendoscope is inserted through one nasal cavity, it is difficult to obtain a balanced view of the velopharyngeal port.

A nostril-of-insertion effect has been referred to in the clinical flexible fiberoptic nasendoscopic literature. The findings from the clinical observations indicate that an oblique angle orientation of the nasendoscope tip results in an asymmetrical view of the vocal folds or velopharyngeal mechanism. However, the effects of size distortion on vocal fold image asymmetry reported has differed depending on researcher. A clinical observation from Cantarella (1988) indicated that an oblique nasendoscopic lens angle resulted in an optical illusion of bulkiness of the vocal fold ipsilateral to insertion nostril. Yanagisawa and Yanagisawa (1993) strongly suggested that nostril of insertion can affect the perceived symmetry of the vocal folds and that images of the vocal folds obtained via flexible fiberoptic nasendoscopy often exhibited a distortion effect that was opposite to that reported by Cantarella. The model proposed by Hibi et al. (1988) is consistent with the observations of Yanagisawa and

Yanagisawa (1993), and indicates the image appearance of the vocal folds is affected by nasendoscopic lens angle of orientation, and that the elongation distortion associated with the contralateral field of view may affect image size of the vocal fold contained within that field of view.

Findings from the research conducted by Hibi et al. (1988) and Casper et al. (1988) stated that angular placement of the nasendoscope in relation to the surface of interest produced a predictable image artifact. If nostril of insertion results in oblique orientation of the nasendoscope tip, then quantitative analysis might detect this image artifact in vocal fold image size.

Summary

Evidence presented in the literature indicates that nostril of insertion may affect the integrity of nasendoscopic images of the vocal folds, resulting in an image artifact of relative size distortion for bilateral structures (Cantarella, 1988; Yanagisawa & Yanagisawa, 1993). Although the bilateral size differences reported are not consistent across researchers, there seems to be the consensus that a result of transnasal insertion is an oblique orientation of the nasendoscope lens to the vocal folds. It is known that an angular orientation of the nasendoscope tip to the surface of interest can introduce predictable distortion.

The left-to-right ratio has been used as an analysis technique to compare bilateral anatomical structures in the hemispheric image obtained during rigid, oral endoscopy and flexible nasendoscopy

(Ducharme et al., 1991; Secarz et al., 1991). Recent advances in video analysis techniques combined with a use of ratio measures have enabled investigators to make relative size comparisons between laryngeal images acquired from repeat insertions of fiberoptic endoscopes within the same subject (McFarlane & Watterson, 1988; Secarz et al., 1991).

Much of the evidence for a nostril-of-insertion effect has been reported on the basis of subjective evaluation of laryngeal data or as the result of interpretation of an image artifact of video-taped images or still photographs (Cantarella, 1988; Ibuki et al., 1983; Karnell et al., 1983; Yanagisawa & Yanagisawa, 1993). If the recent advances in video analysis techniques and the ratio measure used to detect left and right image size differences can be successfully applied to a controlled investigation of nasendoscopic insertion, this effect may be documented objectively. Quantitative analysis may indicate that a relative size difference is predictable in bilateral structures imaged from right and left side insertions of the flexible fiberoptic video nasendoscope.

In a typical laryngeal examination, vocal folds are observed during phonation and respiration. The presence of a nostril-of-insertion effect in both positions, folds adducted for phonation or abducted for quiet respiration, would suggest that the image artifact is independent of vocal fold position, but strongly dependent on vocal fold laterality. Further, it would imply that the effect is inherent to the insertion procedure; this will have important implications for future research and clinical applications using flexible fiberoptic video nasendoscopy. Evidence of an insertion effect will call into question the clinical validity of subjective and objective comparisons between left and right laryngeal structures, including the vocal folds.

Research Questions

It has been documented that positioning of the nasendoscope lens for visual assessment of the larynx can introduce an image artifact of size distortion. Because the nasendoscope can be inserted in the right or left nostril, there is a possibility of image alteration as a result of the different orientation of the nasendoscope lens in relation to the surface of the vocal folds. This investigation addresses the following research questions:

1. Does insertion side of the nasendoscope affect the relative image width of adducted vocal folds imaged during phonation of /i/ ?
2. Does insertion side of the nasendoscope affect the relative image width of abducted vocal folds imaged during respiration?

Chapter III. Methodology

Subjects

Description of Subjects

Twenty-seven adults from the community and the University of Alberta agreed to participate in the study. Subjects were informed of the nature and intent of the study and were advised of possible discomfort associated with flexible fiberoptic nasendoscopy prior to giving their written consent to participate. The thirteen females and fourteen males who volunteered ranged in age from 18 to 42 years ($\underline{M}$ = 26.9 years). Thirteen participants were recruited through a local singing teacher, and the remaining fourteen participants were students from the University of Alberta: twelve from the Department of Drama, Faculty of Arts, one from the Faculty of Rehabilitation Medicine and one from the Faculty of Medicine.

Preliminary Performance Data

Historical data on vocal and respiratory health, performance data on sustained vowel and fricative production tasks, and an estimate of pitch-matching ability were recorded for each participant. Although not used as exclusion criteria for study purposes, these data were gathered to appraise the laryngeal function of subjects who volunteered for the scoping procedure.

Voice and respiratory status. A voice and respiratory status questionnaire was used to probe for medical or health conditions that could affect the condition of the airway and/or the vocal mechanism. The questionnaire was adapted from the Voice Evaluation Laboratory's Brief Voice History questionnaire, Department of

Otolaryngology and Communication Sciences, State University of New York, Syracuse (Colton & Casper, 1991) (Appendix A). The questions probed for a history of previous voice and resonance disorders, surgery, respiratory illness, allergies, smoking and use of certain medications. All subjects reported themselves as being non-smokers. Reports from subjects concerning: 1) evaluation by a speech pathologist or an otolaryngologist for a speech or resonance disorder, 2) presence of neurological or endocrinal/hormonal problems, 3) regular use of nasal decongestants or anti-histamines or 4) allergic reaction to zylocaine or any other dental anesthetics were all negative. One subject reported having undergone nasal surgery to correct a deviated nasal septum. Five subjects reported some type of food or airborne allergy; one subject reported childhood asthma. Two subjects reported non-serious neck injuries, and one subject indicated exposure to chemical substances. Four of the subjects indicated experiencing pain, difficulty swallowing, vocal strain or fatigue in the previous month.

Sustained vowel and fricative production. Ability of an individual to sustain vowel phonation provides information about respiratory and vocal cord vibration efficiency (Colton & Casper, 1991; Kent, Kent & Rosenbek, 1987). Maximum phonation time (MPT) performance standards differ across age and gender. Participants were given three trials to generate an MPT for /a:/. The MPT on this production task ranged from 11.66 to 36.06 seconds ($\underline{M}$ = 18.4 seconds) for female participants and from 16.39 to 38.78 seconds ($\underline{M}$ = 24.4 seconds) for male participants.

A voiceless-to-voiced sustained fricative ratio is used to differentiate the respiratory and laryngeal influences contributing to a phonation disorder (Kent et al., 1987). The homorganic phonemes /s/ and /z/ are normally used to generate a sustained fricative production ratio. If the valving efficiency of the vocal cords is compromised, airflow through the glottis will encounter reduced resistance on the voiced phoneme /z/, presumably resulting in a faster loss of respiratory supply and a shorter sustained performance duration than that associated with sustained production of /s/ (Casper & Colton, 1991; Wilson, 1987). Kent et al. (1987) cautioned that within and across subjects maximum times can be highly variable. With all maximum performance tasks, subject performance may be influenced by the instructions given to the subject or by practice effects. With careful instructions and proper encouragement, Kent et al. suggest that 3 trials are sufficient to obtain an adequate estimate of -sustained production ability.

Sustained s/z production ratios were calculated for each participant. Production times for three trials of each fricative were recorded and the longest durations of /s/ and /z/ were used to compute the s/z ratio. Resultant s/z ratios from the twenty-seven subjects ranged from 0.55 to 1.69 with a mean ratio of 1.13. Results of maximum performance tasks are summarized in Table 1 by gender and presented with performance standards.

Table 1. Summary of maximum performance task results (performance standards in brackets)

	Females	Males
Number	14	13
Mean duration of /a:/ vowel (secs) Standard deviation	18.4 (19.6*) (4.7*)	24.4 (29.0*) (5.5*)
Mean s/z ratio Range	1.18 (0.99@) (0.41-2.67)	1.09 (0.99@) (0.41-2.67)

* Kent et al., 1987; @ Boone & Eckel, 1981

Pitch-matching. It is important that a subject phonate at approximately the same pitch on repeated insertions of the nasendoscope, because changes in fundamental frequency may impact on image size of the vocal folds and may affect the reliability of comparisons of laryngeal images over time (Peppard & Bless, 1990). Changes in fundamental frequency may result in changes in the elevation of the larynx (Hollien, 1960) and may affect the length of the vibrating vocal folds (Hollien, 1960; Hollien & Moore, 1960; Hollien & Curtis, 1960). Both of these factors will affect the image size of the vocal folds.

Pitch-matching ability of individual participants was assessed by audio-recording their productions of /i/ at a comfortable pitch and loudness level, then playing back the audio-cue with the subject attempting to match the pitch of the previously recorded /i/. In a preliminary screening task, all subjects demonstrated the ability to provide an audio-cue and then match its pitch to the investigator's satisfaction. A more objective measure of a subject's ability to pitch-match was obtained during the training segment of the study described later in this chapter under "Procedures".

Laryngeal Data Exclusion

Of the twenty-seven subjects who originally agreed to participate in the study, vocal fold width measurements were taken from laryngeal image data on only seventeen. Ten subjects were excluded from the study because of nasal cavity abnormalities, vocal fold pathology or laryngeal images that were judged unacceptable for measurement and analysis. Specifically, two subjects could not be included in the study for medical reasons; one exhibited bilateral vocal fold nodules which were visible upon insertion of the nasendoscope, and one exhibited a deviated septum during the preliminary examination conducted by the otolaryngologist. One subject refused second insertion of the nasendoscope, and another subject failed to appear for the scoping procedure. Data from the remaining six subjects were excluded because the video images were rated as unacceptable. A summary of the subjects excluded and pertinent exclusion factors are presented in Table 2.

Table 2. Summary of Factors for Exclusion of Subjects

Exclusion Factor	Female	Male	Total
Vocal fold pathology*	1	0	1
Did not attend / complete scoping*	0	2	2
Abnormal nasal cavity*	0	1	1
Video images rated as unacceptable	2	4	6
Total	3	7	10

(* determined at time of scoping procedure)

Instrumentation and Materials

Instrumentation needed for subject assessment and training was acquired from the Department Speech Pathology and Audiology at the University of Alberta. Instrumentation included a video-cassette recorder (VCR) unit, TV monitor, microphone, two audio-cassette recorders, IBM-compatible computer with voice analysis hardware and software, audio-cassette tapes, sound level meter and stopwatch. A 1/2" format VCR was connected to the TV monitor for viewing an instructional video-cassette tape. A digital stop watch was used to time maximum performance tasks. The audio-cassette recorder (Marantz model PMD221) and remote microphone (Shure Prologue 14H LC) were used to record the operating noise of the imaging system and to assess subjects' pitch-matching abilities. The Marantz audio-cassette recorder and the Visi-Pitch (Model 6087, Kay Elemetrics Inc., Pine Brook, New Jersey) were used to estimate pitch-matching abilities during subject training. Another audio-cassett recorder (Realistic CTR-51) was used to play the operating noise of the nasendoscope for subject training. A sound level meter (Radio Shack, Realistic Model 12A8) was used to train consistency of loudness production for vowel phonation during scoping.

Instrumentation required to collect laryngeal images and associated voice signals was accessed through the Glenrose Rehabilitation Hospital. Instrumentation included a video-cassette recorder and tapes, microphone, flexible fiberoptic video nasendoscopic imaging system and a high quality TV monitor. A flexible fiberoptic nasendoscope (Olympus ENF Type 3) illuminated by a halogen light source (Olympus CLK-4) was used to view the laryngeal structures. A video camera (Panasonic GP-KS102 CCD) was coupled to the eye piece of the nasendoscope. The video camera relayed images to a video-cassette recording unit for storage on 30-minute 1/2 inch professional quality video-cassette tapes (3M Scotch Colour Plus High Grade). An electret microphone (Sony ECM-150), connected to the video-cassette recorder, was used to obtain a simultaneous audio recording. A TV monitor (JVC TM 1400 SU) was used to display the video image of the laryngeal structures.

Instrumentation needed for fundamental frequency analysis of the audio portion of the recorded data was accessed through the Department of Speech Pathology and Audiology at the University of Alberta. It included a video-cassette recorder, colour TV, low-pass filter, digitizing board, IBM-compatible computer with speech analysis software, stereo amplifier and loud speaker. The video-cassette recorder (NEC VHS HQ Model PV-1400A) and a TV monitor (Panasonic Model PC-21S54R) were used to display the laryngeal images. The associated vowel signals on the audio channel were low-pass filtered (Frequency

Devices Model 901), digitized by means of a 12-bit A/D board (Data Translation 2821) and analyzed in CSpeech (Milenkovic, 1990) on a Zenith 286 computer. The digitized audio signal was played back from Cspeech by means of the 12-bit data translation board's D/A converter coupled to the stereo amplifier (Realistic Model SA-150) and loud speaker.

Instrumentation required for measurement and analysis of the laryngeal images was accessed through the Department of Anthropology at the University of Alberta. The instrumentation included a computer, video-cassette player, video-rate digitizing card, video digitizer software package and image analysis software program with the capabilities to isolate and quantify laryngeal images. A video-cassette player (Panasonic Omnivision VHS HQ, Model PV-2003K) and a TV monitor (Sony KV-27TR20) were used to display the laryngeal images. A Macintosh II was connected to the video-cassette recorder for processing the video signal. The PTB PixelGrabber (Perceptics, 1991), video-rate digitizing card, with NuBus (Perceptics, 1991) adapter and IPLab (Signal Analytic, 1991) software application were used to digitize video frames for measurement of the vocal folds. Laryngeal data measurements were conducted using NIH Image 1.41 (Rasband, 1991) software program. Digitized laryngeal images were stored on high density diskettes (Sony & BASF).

Procedures

Procedures were conducted in four stages, subject assessment and training, collection of laryngeal images, fundamental frequency analysis of vowels and measurement and analysis of vocal fold data.

Assessment and Training

Participants were assessed and trained individually or in pairs at the University of Alberta by the investigator. Sessions ranged in length from 60 - 90 minutes and were conducted during the two-week period prior to the scoping date. All subjects who attended the assessment and training were scheduled for one of two scoping sessions conducted at the Glenrose Rehabilitation Hospital. Subject assessment included: 1) familiarizing the subject with the procedure of flexible fiberoptic video nasendoscopy, 2) obtaining each subject's written consent to participate in the study and to be admitted to the Glenrose Rehabilitation Hospital and 3) administering a voice and respiratory status questionnaire and a vocal battery.

Familiarization with scoping procedure. All potential participants were given a brief description of the laryngeal imaging procedure. They were provided with an information sheet that discussed the purpose, diagnostic validity and insertion procedures of flexible fiberoptic video nasendoscopy (Appendix B). Potential participants were shown an instructional video-cassette tape, "Flexible Fiberoptic Video Nasendoscopy" (Wilson, 1984). The video-cassette tape demonstrated subject preparation, insertion of a nasendoscope and the images obtained from flexible fiberoptic nasendoscopic examination of the larynx. Candidates willing to proceed in the study were asked to sign a consent form (Appendix C). Administration of the laryngeal performance tasks and voice and respiratory health screening questionnaire followed completion of the consent form.

Laryngeal performance data. Order of the tasks used to assess laryngeal integrity was the same for each candidate, sustained production of /a/, /s/ and /z/, followed by a pitch-matching task. Subject performance was recorded on a Laryngeal Performance Data Sheet (Appendix D). The vocal battery was administered in four parts over the assessment session to allow participants to rest after each maximum production task. In the intervals between these tasks, portions of the voice and respiratory status questionnaire were administered, and consent to admit the subject to the Glenrose Rehabilitation Hospital was obtained (Appendix E).

For each of the sustained production tasks, the participants were provided with an example of the sustained sound performance by the investigator. They were reminded to take a deep breath prior to beginning, to sustain the sound for as long as possible, and then instructed to begin when ready. Participants were timed for three sustained productions of the same sound. The longest duration among the three trials was entered as the maximum production time (MPT) (Colton & Casper, 1991). An s/z ratio was calculated using the MPT recorded for /s/ and for /z/.

For the pitch-matching task, the investigator instructed the subject to produce an /i/ vowel at a comfortable pitch and loudness level. The subject's subsequent /i/ phonation was audio-recorded. The recorded phonation was replayed with the instruction "try to match the pitch of the audio-recording by joining in with the audio-cue."

Questionnaire and admitting forms. Subjects were asked to fill out the voice and respiratory status questionnaire (Appendix A) as accurately and thoroughly as possible. A "consent to admit" form for the Glenrose Rehabilitation Hospital was completed by all participants (Appendix E). The form required participants to provide the following information: Provincial Health Card number, age, birth date, local address, phone number, and information about next of kin in case of an emergency. After all components of the preliminary assessment were completed, subjects were trained for the scoping procedure.

Training. Training consisted of having subjects produce pitch-matched vowels while monitoring loudness in quiet conditions and then under conditions simulating the operating noise of the halogen light source for the nasendoscope. This training was considered necessary for the participants, because in the presence of background noise it has been documented that speakers will phonate with greater intensity (Baken, 1987). Speakers also may change fundamental frequency of phonation when required to phonate with greater effort (Baken, 1987; Coleman, Mabis & Hinson, 1977; Gramming, Sundberg, Ternstrom, Leanderson & Perkins, 1988; Komiyama, Hiroshi & Ryu, 1984; Stone, Bell & Clack, 1978). Changes in intensity and/or fundamental frequency across vowel phonations may alter the phonating length of the vocal folds, and may cause the vertical position of the larynx to vary, which may affect consistency of the vocal-fold-to-nasendoscope-lens distance on repeated insertions of the nasendoscope. The relationship between pitch and loudness to laryngeal positioning was explained to all participants. It was explained that vowels produced at a similar pitch would help minimize changes in the vertical displacement of the larynx, thus helping to reduce the variability vocal-fold-to-nasendoscope-lens distance during the scoping procedure and minimze changes in length of the vibrating vocal folds.

The participants were seated in front of an instrumental array that included a sound level meter, an audio-cassette recorder and the Visi-Pitch to begin training. Participants were instructed to produce an /i/ vowel while monitoring their vocal loudness on the sound level meter (SLM). The SLM was preset to deflect to the centre of its display in response to a signal at 70 dB. It was positioned at the subject's eye level so that meter deflection was easily visible to the subject. All subjects demonstrated the ability to phonate /i/ within a target loudness range of 64 to 74 dB.

The Visi-Pitch was introduced; participants were familiarized with the microphone, the screen display of the voice signal and the fundamental frequency (Fo) analysis capabilities of the Visi-Pitch. It was explained that the Visi-Pitch provided an estimation of the pitch of vowel productions. Therefore, it was possible to estimate accuracy of pitch-matching attempts by comparing the fundamental frequency of a previously recorded audio-cue to the pitch-matching attempt.

The Visi-Pitch operational settings were: channel C frequency range (0-313 Hz), normal trigger function, and sweep speed of 6 seconds. The Visi-Pitch microphone was connected in parallel to the computer and an audio-cassette tape recorder. Subjects practised one sustained phonation of /i/ with the instructions to continue until the end of the screen display. For the next /i/ phonation the subject was instructed to monitor loudness on the SLM while phonating into the Visi-Pitch microphone. This second phonation performance was captured on audio-tape as well as on the Visi-Pitch. The mid-four seconds of the most recent phonation were analyzed via the Visi-Pitch for a mean fundamental frequency (Fo) in Hz. The recording served as the Fo target to be matched on subsequent /i/ phonations. On the next phonation, subjects were instructed to match the pitch of the audio-cue while continuing to monitor their loudness production with the SLM. When the subject was ready, the audio-cue was played. The Fo of the pitch-matching attempt was analyzed using Visi-Pitch and compared to the Fo of the audio-cue. Training was discontinued after the mean Fo of a least one phonation attempt, as revealed by Visi-Pitch analysis, was within 3 Hz of the target Fo of the audio-cue.

Noise. Conditions for training "in noise" were identical to those used "in quiet," except for the presence of pre-recorded light-source noise. The tape-recorded noise was played while the subjects attempted to pitch-match to an audio-cue. Training was discontinued after at least one pitch-matching attempt was within 3 Hz of the fundamental frequency of the audio-cue.

Collection of Laryngeal Images

Two scoping sessions, held one month apart, were conducted in the Voice Clinic at the Glenrose Rehabilitation Hospital. Present at both scoping sessions were the speech-language pathologist and otolaryngologist associated with the Voice Clinic and the principal investigator. Procedures and personnel were kept as constant as possible across the two data collection sessions. Participants were scheduled to arrive in groups of two on the half hour. The entire scoping procedure, including preparation took approximately 30 minutes per subject.

Instrumentation preparation. Instrument preparation involved initial set up of the video-cassette recorder (VCR), TV monitor and the video camera. Cable connections from the camera to the VCR and to the TV monitor were made and verified. The TV monitor, VCR and camera were turned on and remained on for the duration of the scoping procedure for all subjects in a session. Microphone and recording checks were performed prior to the collection of laryngeal images.

A simple grid was placed on the television monitor to orient the laryngeal images contained in the circular field of view. The grid for the television monitor was prepared by placing strips of masking tape from the centre of the screen to the top right and left corners of the TV monitor.

Nasendoscope insertion preparation. Subject preparation involved an intranasal examination and topical anesthetization of the nasal cavities. The subject was seated upright facing the otolaryngologist for a standard nasal cavity examination. The otolaryngologist examined the left and right nostrils to ensure the nasendoscope could be passed safely through each nasal cavity and to check for septal deviation or any other nasal abnormalities.

After establishing the subject's acceptability for scoping, the otolaryngologist prepared both nostrils for passage of the nasendoscope. Strips of cotton batting saturated with a solution of 4% lidocaine and 1% neosynephrine were inserted with forceps into both nasal cavities and removed after five to ten minutes.

In some instances, subjects were examined and prepared in pairs to expedite the scoping process. Two subjects declined complete nasal anesthetization, one of whom refused second insertion of the nasendoscope, and therefore their laryngeal data were unusable for study purposes.

Imaging system preparation. The nasendoscope and light source were prepared by the principal investigator while the subject was being examined by the otolaryngologist. Nasendoscope and light source preparation was similar for all participants. The flexible fiberoptic nasendoscope was removed from a germicidal solution (Cidex Tuberculocidal, Bactericidal, Pseudomonacidal; Manufacturer: Surgikos, Johnson & Johnson, Surjikos Canada Limited Inc, Peterborough, Ontario), rinsed with water and dried with a paper towel. The nasendoscope was connected to the video camera and to the light source. The light source was turned on, and sufficient time was given for it to reach maximum illumination.

A water-based, lubricating gel (Muko, Lubricating Jelly, Manufacturer: Ingram & Bell Medical, Don Mills, Ontario, Canada) was applied to the nasendoscope around the tip, and five to six centimetres along the flexible body of the nasendoscope. The gel was used to facilitate passage of the scope through the nasal cavities, and was applied for the first insertion only.

Adequacy of image quality. Prior to first insertion of the nasendoscope, the otolaryngologist performed a check of image integrity. The adequacy of image resolution and colour balance was determined by suspending the nasendoscope above the otolaryngologist's fingers and observing the resultant image on the TV monitor. Light intensity was adjusted to the satisfaction of the investigators. If needed, focal adjustments were made to the nasendoscope to enhance image resolution.

First insertion. After the nasendoscope and light source were prepared, the subject was seated in an examination chair. If required, the chair elevation was adjusted to accommodate height variation among subjects. A microphone was attached to the subject's collar, on the left-hand side. The investigator ensured that a video-cassette tape was inserted in the VCR to record the vowel phonations and laryngeal images.

The right nostril was scoped first in fifteen subjects, and the left nostril was scoped first in eight subjects. After the record function was activated by the investigator, the otolaryngologist began insertion of the nasendoscope in the appropriate nasal cavity. The subject was instructed to hum while the nasendoscope was passed through the velopharyngeal port. Once the vocal folds were visible, the otolaryngologist manipulated the nasendoscope to align the vocal folds in the centre of view. The lines on the TV monitor were used to ensure that the anterior commissure was located in the lower section of the circular image.

The nasendoscope was lowered and suspended above the vocal folds. Distance from vocal folds to nasendoscope lens was determined by each subject's tolerance and the otolaryngologist's discretion. Once a comfortable distance was established, the nasendoscope was manipulated to achieve a clinically acceptable view. A clinically acceptable view was defined as an unobstructed view of the vocal folds, ventricular folds, posterior aspect of the laryngeal structures and anterior commissure. If the image quality was affected by fogging of the lens or mucous obstruction, the subject was asked to swallow or cough to clear the lens. If required, focal adjustments were made to the nasendoscope lens to improve image resolution.

Once a clear, clinically acceptable view was established and agreed upon by the investigator, speech-language pathologist and otolaryngologist, the subject was asked to sustain the /i/ vowel three times for four to five seconds each time. If the length of vowel phonation was not sufficient, the subject was asked to produce subsequent vowel phonations of longer duration. If the image resolution deteriorated over the period of vowel phonations, subjects were asked to produce more than three vowels and were instructed to swallow or cough prior to initiation of phonation. After three acceptable vowels were produced by the subject, the nasendoscope was removed and its length of insertion was recorded.

Length of insertion. Length of insertion was determined by the otolaryngologist upon removal of the nasendoscope after the first insertion. While the nasendoscope was inserted, the otolaryngologist held the nasendoscope at its point of exit from the naris. When the nasendoscope was removed the otolaryngologist kept his finger on this point on the scope. The length of insertion was estimated by approximating the distance from his finger placement to the lens tip using the 5 cm grid markings on the exterior casing of the nasendoscope. The otolaryngologist maintained his finger placement on the nasendoscope for the second insertion.

Second insertion. The nasendoscope was inserted through the second nostril using the same procedures as described for the first insertion. The otolaryngologist used his finger placement at the point of exit from the naris for the first insertion to approximate a similar length of induction for the second insertion.

Criteria for a clinically acceptable view and procedures for improving image integrity during the second insertion were identical to those used for the first. Subjects were asked to phonate three vowels of approximately four to five seconds in duration similar in pitch to those produced during the first insertion. Once three acceptable views of vowel phonation were obtained, the nasendoscope was removed and its length of insertion was recorded.

Following removal of the nasendoscope after the second insertion in a subject's nose, the nasendoscope was immersed in the Cidex solution for disinfection. After recording the laryngeal images of two subjects, the video-cassette tape was removed, labelled and placed in a secure location. A fresh video-cassette was inserted in the VCR to record laryngeal images of two more participants.

Exclusion of subjects. Laryngeal images from both right-and left-side insertions were recorded for twenty-three of the twenty-seven participants who were scheduled to be scoped. Of the eleven subjects who attended the first scoping session, 10 completed the procedure; one individual refused second insertion of the nasendoscope. Of the sixteen subjects scheduled for the second scoping session, laryngeal images were collected from only thirteen. Table 2 summarizes the reasons for subject exclusion.

Fundamental Frequency Analysis

Exclusion of data. Prior to fundamental frequency (Fo) and laryngeal image analysis, data from three of the twenty-three subjects who completed the scoping procedure were excluded. The laryngeal structures of one subject were not adequately illuminated due to poor light delivery. The presence of visual interference on the video-cassette tape resulted in degraded image quality for another subject. Due to difficulties with nasendoscope-camera attachment, orientation of the laryngeal image was reversed (anterior commissure was located at the top of the image) on a third subject.

Fundamental frequency of the vowel phonations was analyzed on data collected from twenty of the twenty-three subjects scoped. Analyses were performed to determine if the fundamental frequency (Fo) of phonation differed between vowels recorded from left and right side insertions. A significant difference in Fo of vowel phonations would suggest that vertical displacement of the larynx varied from first to second insertion of the nasendoscope. It was important to establish that vowels were phonated at approximately the same pitch across insertions, thereby providing indirect evidence that vertical laryngeal position was consistent and minimizing the possibility of lens-to-vocal fold distance differences from first to second insertions.

Digital acoustical analysis. Cspeech digital speech analysis software (Milenkovic, 1990, Version 3.1), a Zenith-IBM 286 personal computer, a low-pass filter (Frequency Devices Model 901), a 12-bit A/D board, (Data Translation 2821) an NEC video-cassette recorder and a TV monitor were used to estimate fundamental frequency.

Only three phonations from each insertion side were selected for fundamental frequency analysis. The vowel signals were low-pass filtered at 8500 Hz, then digitized at a sampling rate of 20 kHz. The duration of phonation was measured by placing the right and left cursors at the onset and offset of phonation.

A mid-section of the vowel was analyzed. Right and left cursor placements marked the end points of vowel mid-section. Fundamental frequency was estimated for each 10 ms period of the section enclosed by the cursors. The minimum, maximum and average fundamental frequencies were displayed and recorded.

A test for homogeneity of related variances was performed to determine if variance of fundamental frequencies of vowel phonations from left-side insertion differed significantly from those obtained from right-side insertion. The non-significant results, $t(18)=0.4756$, $p>.5$, indicated that the two variances were homogeneous. Results of a paired t-test performed on fundamental frequency data from twenty subjects were nonsignificant, $t(19)=0.443$, $p=.6625$, indicating that fundamental frequency of phonation did not differ significantly for vowels produced during left and right insertions.

Laryngeal Video Image Analysis

Video frames for the two measurement conditions, vocal folds abducted during inhalation and exhalation (open condition) and vocal folds adducted during phonation (mid-line condition) were obtained from twenty subjects. Laryngeal images from the video-cassette frames were digitized, selected and then stored. Width measurements were conducted on vocal folds from suitable laryngeal images only. Laryngeal data from three of the remaining twenty subjects were found to be unsuitable for measurement and analysis in either condition, open or mid-line.

Frame digitization and selection. Video frames were collected using similar procedures and instrumentation. A Panasonic video-cassette player, connected to a Sony television monitor, was coupled to a Macintosh IIsi computer. The PixelGrabber video digitizing card with NuBus adapter and an image processing software application, IPLab, were used to display and select video frames.

The video frames were acquired using the following parameters: (1) "grab sequence" with external trigger activation function was selected, (2) number of consecutive frames grabbed was set to 7, (3) video input channel was set to number 4, (4) image resolution size was preselected for a default setting of 640 pixels (height) by 480 pixels (width), (5) Input Look-Up Table (ILUT) was preselected for default ILUT #1 and (6) video signal input was set to RS-170. Due to the limitations in available memory on the Macintosh computer, the number of consecutive frames actually grabbed ranged from 6 to 7. This restricted the number of frames that could be selected for image analysis.

To begin laryngeal image acquisition, the video-cassette tape was rewound to the start. The time counter function of the video tape recorder was set to zero prior to being activated and was superimposed on the video image. It provided a time reference for selection of the video images. For each subject, six frames per insertion side were selected, three in mid-line condition, three in open condition.

Mid-line condition. Mid-line condition was defined as "vocal folds in steady state of /i/ phonation". If more than three phonations were produced, frames from the three most suitable vowel phonations (i.e., unobstructed by mucous & appropriately aligned) were digitized for measurement.

The video tape was advanced to frames preceding the first suitable vowel phonation. While viewing the laryngeal images on the computer screen, the investigator activated the external trigger at the point of onset of vowel phonation to begin digitization. Six or seven video frames of the vocal folds were digitized. Of the digitized images that showed the vocal folds in the mid-line position, a frame from the middle of the sequence was captured for measurement. The video cassette tape was advanced to the next suitable vowel phonation, and this selection process was repeated for each of the remaining vowels until 3 images were obtained.

Open condition. Images of the vocal folds captured in the open condition were obtained during two different respiratory states: quick inhalation between vowel phonations or during slower inhalation or exhalation at the end of the vowel phonations. The first two images of abducted vocal folds were captured during quick inhalation.

The video-cassette tape was rewound to the first suitable vowel phonation. While viewing the laryngeal images on the computer screen, the investigator activated the external trigger to begin capturing the laryngeal images near the conclusion of phonation. Of the digitized frames that displayed vocal folds in an abducted position, a mid-sequence frame was selected. The video-cassette tape was advanced to the end of the next suitable vowel phonation and the selection procedure was repeated to capture laryngeal images of the vocal folds in an open condition, abducted for quick inhalation. To capture the third image of vocal folds in an abducted position for slower respiratory exchange, the video-cassette tape was advanced to the end of the record of vowel phonation tasks and the procedure was repeated.

Image storage. Laryngeal images were stored in files on 3 1/2" diskettes according to subject and order of insertion, first or second. The six images captured from the first insertion for one subject were stored in one file, and the six images captured from the second insertion were stored in a separate file. Complete data sets (first & second insertion) for two subjects were stored on one diskette.

Measurement acceptability. The digitized images captured from the twenty subjects were determined acceptable for measurement if the following criteria were met: 1) clinically acceptable orientation of the vocal folds, aligned without extreme twisting of the nasendoscope, 2) clear, observable mid-line of the vocal folds, 3) discernable point at the anterior commissure, common to both vocal folds and 4) visual confirmation of vocal and ventricular fold boundaries.

Laryngeal images obtained for the mid-line condition were evaluated separately from those obtained for the open condition. Laryngeal data for each subject were identified using numbers ranging from 1 to 20. The investigator reviewed the laryngeal images by order of insertion and condition; images obtained from all first insertions were reviewed first in numerical order, starting with subject 1. Only those subjects whose images of the same measurement condition (open or mid-line) that satisfied acceptable criteria for both the first and second insertions were included.

Overall, seventeen of the twenty subjects provided data meeting the inclusion criteria for either the mid-line condition, open condition or both. The digitized laryngeal data from three subjects were totally excluded from measurement because they failed to meet the measurement criteria for either condition. Twelve subjects supplied acceptable data for inclusion in the open condition, and thirteen subjects provided acceptable data for inclusion in the mid-line condition. Acceptable laryngeal data are summarized by subject gender and measurement condition in Table 3.

Table 3. Summary of acceptable laryngeal data

Acceptability	Female	Male	Total
Mid-line only	4	1	5
Open only	1	3	4
Mid-line & open	6	2	8
Total	11	6	17

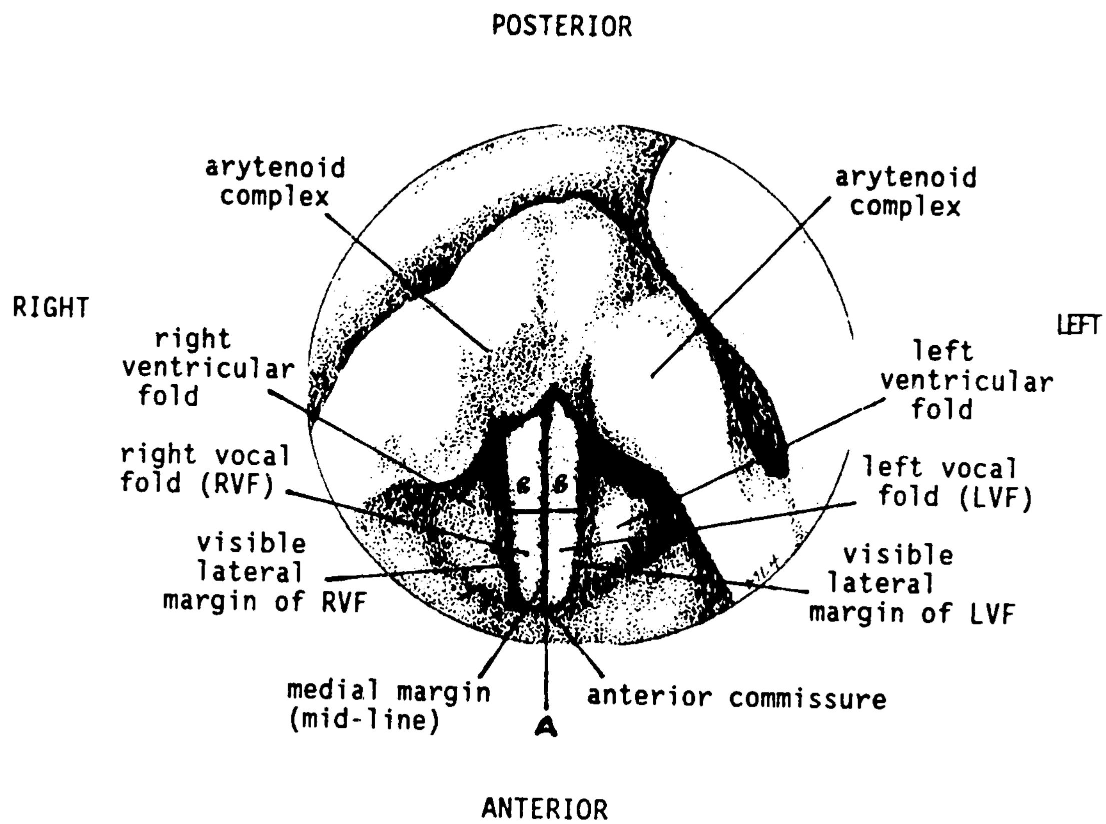
Vocal fold measurements. The NIH Image 1.41 image analysis software application program was used to measure width of vocal folds in open and mid-line conditions. Mid-line condition was measured first. Measurements were conducted in numerical order, beginning with subject number 1. All images obtained from first insertions were measured first, followed by those obtained from second insertions. For each insertion side, there were three estimates of left and three estimates of right vocal fold width.

A hand-operated mouse was used to measure width dimensions of the vocal folds. The standard unit of measurement was a pixel. All vocal fold width measurements were interval level measurements conducted on an integer scale. The pixel data for each image were stored in a separate data file from which they could be retrieved and compiled for later statistical analysis.

Mid-line condition. Vocal fold width measurements were conducted by establishing a common mid-point on the mid-line created by the medial margins of the vocal folds and then determining the perpendicular distance from this point to the visible lateral aspect of each vocal fold.

To establish a common mid-point, the length of the mid-line created by the medial edges of the adducted vocal folds was estimated. A line was extended from the anterior commissure posteriorly along the mid-line to the end-point of the shorter vocal fold marked line A on Figure 1. The posterior end-point of the vocal fold was determined by a change in colour, visible juncture of the vocal fold with the vocal process, or the point where the fold became obscured by the overhanging arytenoid complex. Half the length of the mid-line (line A, Figure 1) was measured from the anterior commissure. This mid-point served as the starting point of width measurements of the left and right vocal folds. Figure 1 shows the laryngeal landmarks used to determine the mid-point on the medial margins of the vocal folds.

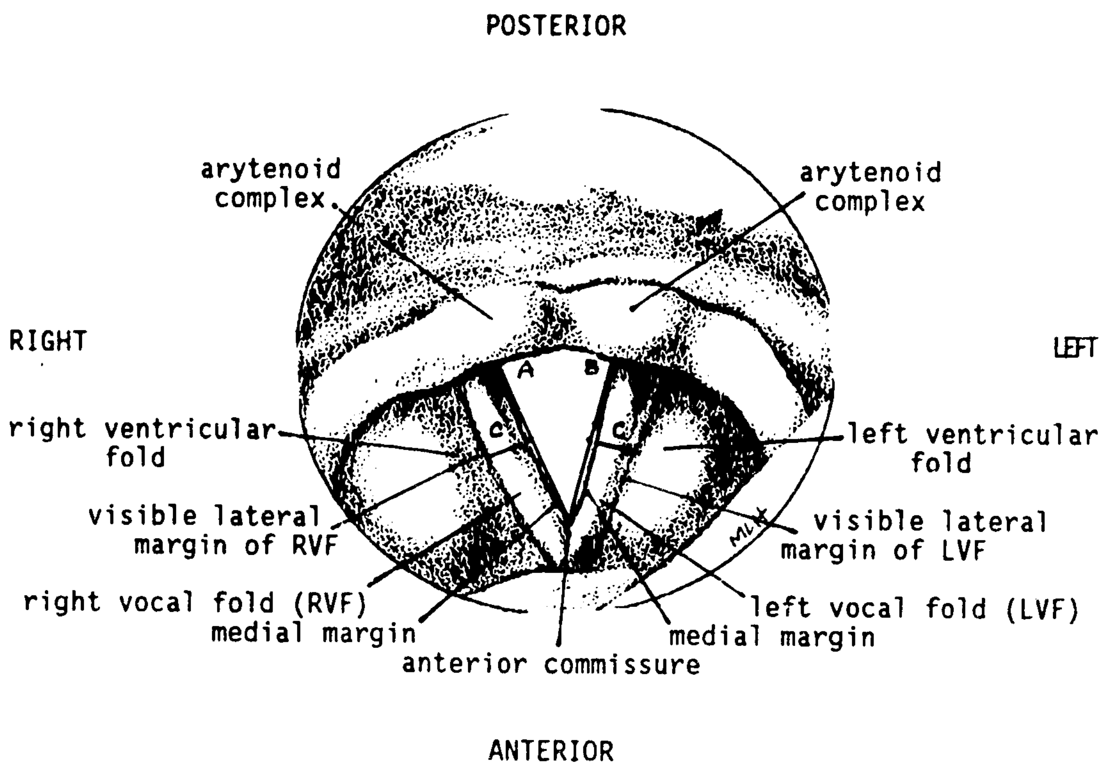
Figure 1. Laryngeal landmarks and linear reference points used for mid-line (adducted) condition measurements. [Larygeal image reproduced from "Variations in Normal Human Laryngeal Anatomy and Physiology as Viewed Fiberscopically" by J.K. Casper, D.W. Brewer and R.H. Colton, 1987, *Journal of Voice*, 1,(2) 180-185. Copyright 1987 by Raven Press. Reprinted with permission.]



From the mid-point on the left vocal fold, a perpendicular line (line B on LVF in Figure 1) was drawn in the direction of the left ventricular fold. The distance from the medial margin to the visible lateral margin of the true vocal fold was measured in whole pixels and represented an estimate of visible vocal fold width. The lateral margin was identified via tissue change (boundary formed by medial edge of ventricular fold) or colour change. From the mid-point on the medial edge of the right vocal fold, a perpendicular line (line B on RVF in Figure 1) was drawn in the direction of the ipsilateral ventricular fold. The distance from the mid-point to the visible lateral margin of the vocal fold represented an estimate of right vocal fold width.

Open Condition. In the open condition, points equidistant from the anterior commissure were established on the medial edges of the right and left vocal folds. The length of each vocal fold was measured by drawing a line from the anterior commissure along the medial margin of the vocal fold to the posterior commissure, as indicated by lines A and B in Figure 2. The posterior aspect of each vocal fold was identified via visible change in structure, tissue colour or curvature of the fold as it met the vocal process. In some of the images, positioning of the arytenoid complex resulted in the posterior aspect of the fold bending in a medial direction. The distance from the anterior commissure to the mid-point of the medial edge of the shorter fold was determined, and a comparable point was measured along the medial margin of the opposite vocal fold. Therefore, measurements of vocal fold widths occurred at approximately the same distance along the medial margins of the left and right vocal folds. Figure 2 shows the laryngeal landmarks used to determine mid-points on the medial edges of the vocal folds for measurement in the open condition.

Figure 2. Laryngeal landmarks and linear reference points used for open (abducted) condition measurements. [Larygeal image reproduced from "Variations in Normal Human Laryngeal Anatomy and Physiology as Viewed Fiberscopically" by J.K. Casper, D.W. Brewer and R.H. Colton, 1987, *Journal of Voice*, 1,(2) 180-185. Copyright 1987 by Raven Press. Reprinted with permission.]



From the mid-point on the left vocal fold, a perpendicular line (line C on LVF in Figure 2) was drawn from the medial margin in the direction of the ipsilateral ventricular fold. The distance between the medial and visible lateral margin of the true vocal fold was measured in whole pixels and represented a measure of vocal fold width. The lateral margin was identified by colour change, or tissue change at the boundary formed by the medial edge of the ipsilateral ventricular fold. Right vocal fold width was estimated using identical procedures. On the right vocal fold, a perpendicular line (line C on RVF in Figure 2) was drawn from the mid-point on the medial margin in the direction of the ipsilateral ventricular fold. The distance between the medial margin and visible lateral margin was measured in whole pixels and represented a measure of vocal fold width.

<u>Data entry and storage.</u> Vocal fold width measurements were exported to a spreadsheet (Excel Version 2.2a). Left and right vocal fold width measurements from one image were stored in one file and labelled by subject, image number (1,2 or 3), insertion order (1st or 2nd) and condition (open or mid-line) resulting in six data files per subject. The six data files were compiled into the appropriate data file (open condition first insertion, open condition second insertion, mid-line condition first insertion & mid-line condition second insertion).

<u>Vocal fold width ratios.</u> Calculations of vocal fold width ratios were identical for each measurement condition. For each subject, a ratio of left to right vocal fold width was calculated for each insertion side. To calculate the ratio, averages of the three pixel measurements for right vocal fold width and left vocal fold width were obtained. Left vocal fold width average (LA) was divided by the right vocal fold width average (RA). Each subject had one LA/RA ratio for the first and second insertion.

Reliability Measures

Reliability measures were conducted on the instrumentation used to obtain and measure vocal fold images, laryngeal data collection procedure, vocal fold width measurements and data entry and storage.

Calculation of Measurement Error

The measurement error associated with the digitization of video data obtained via the flexible fiberoptic video nasendoscopic (FFVN) imaging system was determined. It was calculated using a ruler, 2mm marked grid paper and the same FFVN imaging instrumentation as used during data collection.

The ruler was attached by tape to the nasendoscope. The ruler was placed on its end, suspending the nasendoscope lens 1.5 cm above the grid paper simulating the vertical distance of the lens to vocal fold surface during a laryngeal examination. Video images of the grid paper were obtained with the nasendoscope in this position and digitized using the same computer and measurement analysis software that were applied to the laryngeal image data.

The measurement procedures were similar to those used for calculation of vocal fold widths. The length of line (9 grid markings) was measured in pixels and a mid-point was determined. The perpendicular distances from that mid-point to the closest left and right grid markings were measured in whole pixel values. The entire procedure, beginning with measuring the length of the set line, was repeated ten times. A standard deviation, representing measurement error, was calculated from the average of the perpendicular distances. Measurement error was calculated to be 0.763 pixels. The average of vocal fold width measures was 19.86 pixels. Applying the measurement error to the average pixel value of vocal fold width, yielded a 4% error associated with vocal fold width measures.

Scoping Procedure

Two reliability measures of the scoping procedure were conducted: (1) a comparison of the fundamental frequency of vowels produced by subjects during left and right insertions of the nasendoscope and (2) a comparison of original vocal fold width measurements to those obtained from laryngeal data acquired from a second scoping of the same subject.

Fundamental frequency comparison. Changes in fundamental frequency can alter vertical positioning of the larynx and affect length and tension of vibrating vocal folds. Therefore, vocal fold image length and overall image size can be affected by changes in fundamental frequency of phonation. This can impact the reliability of images obtained from repeated insertions of the nasendoscope (Peppard & Bless, 1990). To determine if fundamental frequency was consistent across insertions, the investigator compared the average fundamental frequencies and variances for vowels recorded during right and left side insertions. A test for homogeneity of related variances was performed to determine if variance of fundamental frequencies from left-side insertion differed significantly from variance of fundamental frequencies of right side insertions. The non-significant results, $t(18)= 0.4756$, $p> 0.5$ indicated that the two variances were homogeneous. The results of a paired t-test, $t(19)= 0.443$, $p= 0.6625$

indicated that fundamental frequency of phonation did not differ significantly for vowels produced during left and right insertions.

Reliability of insertion procedures. One subject was rescoped 14 weeks after the original scoping session to test the reliability of nasendoscope insertion and laryngeal data collection procedures. Procedures and instrumentation were kept as consistent as possible from original scoping to repeat scoping. The subject was scoped once through each nostril. Insertion order was consistent, beginning with the right nostril.

Analysis of fundamental frequency. Analysis of fundamental frequency was performed on vowel phonations produced by the subject who consented to be rescoped. Fundamental frequencies obtained for vowels produced during the repeat scoping are presented in Table 4 for comparison with those obtained for vowels recorded during the original scoping.

Table 4. Fundamental frequency (Fo) comparison of vowels obtained during first and repeat insertion

	Original		Repeat	
Vowel	Left	Right	Left	Right
1st Fo (Hz)	134.88	128.11	129.94	129.28
2nd Fo (Hz)	135.61	135.32	130.02	127.47
3rd Fo (Hz)	134.53	133.15	127.78	128.79
Ave. Fo (Hz)	135.00	132.19	129.25	128.51

Measurement analysis. Because the original laryngeal images from this subject were rated as acceptable only for open condition, only those images of his vocal folds in the abducted position during the repeat scoping were digitized and measured. A comparison of the original and repeated measurements of this subject's vocal fold widths and associated ratios is provided in Table 5.

Table 5. Comparison of repeated measurement of vocal fold widths (open condition)

	Original				Repeat			
Insertion	Left		Right		Left		Right	
Frame	LVF	RVF	LVF	RVF	LVF	RVF	LVF	RVF
1st	18	21	20	12	15	17	19	20
2nd	14	18	24	16	16	19	18	18
3rd	13	17	21	15	13	17	19	19
Average	15	18.7	21.7	14.3	14.7	17.7	18.7	19
LA/RA	0.804		1.512		0.830		0.982	

(width measurements are in pixels)

Measurement Reliability

Reliability was calculated by comparing the left average (LA) and right average (RA) vocal fold width values obtained from repeated measurements to those estimates obtained from original measurements. Laryngeal data from eight randomly selected subjects were totally remeasured from the previously digitized video images (four subjects per each measurement condition) representing 32% of the total data sample. For each subject, the left and right vocal fold width averages were calculated as described previously. There were 4 comparisons for each of the 8 subjects; right and left vocal fold averages for each insertion side were compared to original values, resulting in 32 possible agreements for determining measurement reliability. Agreement was defined as being within one pixel value of the original value. Total number of agreements were tabulated across the 32 possible agreements of vocal fold width averages and divided by the total number of possible agreements to yield a measurement reliability ratio. The overall measurement reliability ratio was 81.25%.

A paired t-test and a test for homogeneity of variance were performed to determine if estimates of vocal fold width averages and variances differed statistically between the original and reliability measurements. Results of the paired t-test, $t(31)=0.635$, $p=0.5319$ and test for homogeneity of related variances, $t(30)=1.19$, $p>.20$ (2-tailed) were non-significant, indicating that original and reliability measurements did not differ in terms of either their averages or their variances.

Reliability of Data Entry and Storage

Reliability checks of data entry and storage were conducted. All measurements from the original data files were compared to those found in measurement analysis files that were used for calculation of vocal fold width averages and ratios. Point-to-point agreement was defined as exact pixel value. Total number of agreements was tabulated across 300 measurement comparisons and was divided by total number of agreements plus disagreements to yield a data entry reliability ratio of 99%.

Data Analysis

Ratios calculated from vocal fold width averages were organized by measurement condition, open or mid-line, nostril of insertion, left or right, and subject. A paired t-test was performed on the LA/RA ratios obtained from left and right insertion for each measurement condition (open & mid-line) to determine if side of insertion resulted in significant differences in ratio values.

Chapter IV. Results

Mid-line Condition

Ratio Comparison

LA/RA vocal fold width ratios obtained from width measurements of vocal folds in the adducted position are presented in Table 6 for comparison between insertion sides. Left side insertion ratios were subtracted from those obtained from right side insertion, resulting in a mean difference of -0.22 for matched pairs. For 11 of the 13 subjects, LA/RA ratios obtained from right side insertions were greater than those obtained from left side insertions.

Table 6. Comparison of vocal fold width ratios (mid-line condition)

	Left Insertion	Right Insertion	Left - Right Ratio Difference
Subject	LA/RA ratio	LA/RA ratio	
1	0.910	1.172	-0.262
2	0.767	0.864	-0.097
3	1.239	1.200	+0.039
4	0.885	1.115	-0.230
5	0.833	1.143	-0.310
7	0.900	1.208	-0.308
8	1.026	1.814	-0.788
13	0.915	1.041	-0.125
14	1.132	1.189	-0.058
17	0.944	0.914	+0.030
18	0.932	1.049	-0.117
19	0.852	1.180	-0.328
20	0.944	1.250	-0.306
Mean	0.945	1.164	-0.220

Statistical Analysis

A paired t-test, $t(12) = -3.703$, $p < .0015$, indicated that the mean LA/RA vocal fold width ratio for right insertions, $\underline{M} = 1.164$, was significantly larger than the mean LA/RA vocal fold width ratio for left side insertions, $\underline{M} = 0.945$, suggesting that the observed difference was related to side of insertion.

Open Condition

Ratio Comparison

LA/RA vocal fold width ratios obtained from width measurements of vocal folds in the abducted position are presented in Table 7 for comparison between insertion sides. Left side insertion ratios were subtracted from those obtained from right side insertion, resulting in a mean difference of -0.27 for matched pairs. For all 12 subjects, LA/RA ratios obtained from right side insertions were greater than those obtained from left side insertions.

Table 7. Comparison of vocal fold width ratios (open condition)

	Left Insertion	Right Insertion	Left - Right Ratio Difference
Subject	LA/RA ratio	LA/RA ratio	
1	0.837	1.173	-0.336
2	0.762	0.885	-0.123
3	0.854	1.133	-0.279
4	1.034	1.553	-0.519
5	0.750	1.082	-0.332
6	0.866	1.000	-0.134
7	0.889	1.098	-0.209
9	0.925	1.045	-0.121
10	1.222	1.415	-0.192
13	0.788	0.971	-0.187
16	0.804	1.512	-0.708
19	0.897	1.000	-0.103
Mean	0.886	1.156	-0.270

Statistical Analysis

A paired t-test, $t(11) = -5.103$, $p < 0.0002$, indicated that the mean LA/RA vocal fold width ratio for right insertions, $\underline{M} = 1.156$, was significantly larger than the mean LA/RA vocal fold width ratio for left side insertions, $\underline{M} = 0.886$, suggesting that the observed difference was related to side of insertion.

Chapter V. Discussion

Results of the investigation are presented as they relate to each research question. Findings are discussed with regards to previous imaging studies mentioning or investigating vocal fold width, glottic area or velopharyngeal bilateral asymmetry. Issues relevant to interpretation of the findings are examined under the headings Lens Placement of Imaging Instrument and Laryngeal Airway Configuration. Clinical implications arising from the research findings are discussed and finally, limitations of the study are addressed under the headings Internal Validity and External Validity.

Research Question #1

Does insertion side of the nasendoscope affect the relative image width of adducted vocal folds during phonation of /i/?

Nostril of insertion was found to differentially affect left and right vocal fold image widths during phonation of /i/. LA/RA ratio values were significantly larger in images obtained from right side insertion, $\underline{M} = 1.164$, than from left side insertion, $\underline{M} = 0.945$. During adduction of vocal folds, image width of the vocal fold contralateral to the side of nasendoscope insertion was larger relative to image width of the fold ipsilateral to insertion side.

Research Question #2

Does insertion side of the nasendoscope affect the relative image width of abducted vocal folds imaged during quiet respiration?

Nostril of insertion was found to differentially affect left and right vocal fold image widths during respiration. LA/RA ratio values were significantly larger in images obtained from right side insertion, $\underline{M}$ = 1.156, than from left side insertion, $\underline{M}$ = 0.886. During abduction of vocal folds, image width of the vocal fold contralateral to the side of nasendoscope insertion was larger relative to image width of the fold ipsilateral to insertion side.

The comparable findings obtained in both measurement conditions, open and mid-line, strongly suggest that nostril of insertion affects the relative image size of vocal fold width and perceived vocal fold symmetry. The effect, as revealed by the ratio differences in LA/RA vocal fold widths between insertion sides, can be described as asymmetry in vocal fold image widths. The vocal fold contralateral to the side of nasendoscope insertion is imaged wider than the ipsilateral fold. It is important to interpret this finding relative to the results of other imaging studies mentioning image size asymmetry. Those factors that have been demonstrated to affect integrity of images are examined to determine their relevance to this particular study. Evidence from the imaging literature indicates that vocal fold length, width and area comparisons are affected by factors associated with placement of an imaging instrument, either an endoscope or a nasendoscope and laryngeal airway configuration (Casper et al. 1988; McFarlane et al., 1990; Peppard & Bless, 1990; Secarz et al., 1991; Yanagisawa & Yanagisawa, 1993). The additional evidence contributed by the results of this study suggests that those same factors may have interacted to systematically affect the image size of the left and right vocal folds.

Lens Placement of Imaging Instrumentation

Previous research with imaging instruments conducted in strictly controlled conditions found that image size of a structure was dependent upon two factors: (1) vertical distance of the imaging instrument to the surface of interest and (2) angle of orientation of the imaging instrument in relation to the flat surface.

Vertical Distance of Lens to Tissue Surface

Variation in the distance of an endoscope or a nasendoscope lens to the vocal fold surface affects the image size of vocal folds (Casper et al., 1988; Peppard & Bless, 1990). As the imaging instrument lens is brought closer to the surface of interest, given that the object being imaged does not move and the angle of lens orientation is kept constant, image size of that object becomes larger. Ratio measures have been used to control for variations in lens-to-vocal-fold-surface distance which affects laryngeal measurements used for comparison within and across subjects (McFarlane & Watterson, 1990). To control for distortion effects on images obtained from rigid endoscopy and to "equalize" the parameters of vocal fold length and width, McFarlane and Watterson (1990) used ratio measures to compare location and width of nodules on left and right vocal folds across different subjects.

Effect of insertion nostril. In the present study, altering the nostril of insertion affected the consistency of vertical distance of the nasendoscope lens to the vocal fold surface. Variations in vertical distance of scope lens to vocal fold surface were minimized by recording the length of insertion of the nasendoscope and having the subjects phonate at approximately the same fundamental frequency during the first and second insertions. The effects of variation in lens-to-tissue-surface distance on image size were controlled by the use of left-to-right width ratios, similar to the method of Ducharme et al. (1991) to compare the relative differences in vocal fold widths across insertion nostrils.

Angle of Scope Orientation

To observe distortion effects in the image, Hibi et al. (1988) stated that angular placement of nasendoscope lens had to be deviated 5 to 10 degrees from a perpendicular orientation relative to the surface of interest. Positioning the nasendoscope on an angle in relation to the horizontal plane of a flat surface resulted in two predictable events occurring to the hemispheric image; elongation of the contralateral field and compression of the ipsilateral field of view (Hibi et al., 1988; Casper et al., 1988). Regarding judgements of vocal fold symmetry, researchers advise that left and right vocal fold size may appear different depending on the orientation of the rigid oral endoscope and the flexible nasendoscope to the tissue surface (Peppard & Bless, 1990; Yanagisawa & Yanagisawa, 1993).

Rigid, oral endoscopy. Depending on the orientation of the endoscope lens to the vocal fold surface, distortion effects can occur across the anterior-posterior or left-right halves of the image (Hibi et al. 1988). Yanagisawa and Yanagisawa (1993) stated that with proper endoscope orientation, the laryngeal image was minimally affected by distortion, and discrepancies in size of folds could be corrected by readjusting the endoscope viewing angle.

Flexible fiberoptic nasendoscopy. An oblique orientation of the nasendoscope lens relative to the surface of the vocal folds during phonation has been reported to produce an image in which one vocal fold appeared narrower than the other fold (McFarlane et al., 1990). Elongation distortion was minimized when the plane of the lens was brought parallel to the plane of the vocal folds. Whether the effects of elongation distortion on vocal fold images were related to nostril of insertion of the flexible fiberoptic nasendoscope was not investigated by McFarlane et al. (1990).

Effect of insertion nostril. In the current study, LA/RA vocal fold width ratios were greater when the folds were viewed from the right nostril than when they were viewed from the left nostril, which is consistent with Hibi et al.'s (1988) model. That is, the appearance of vocal fold width was differentially affected depending on whether a fold was located on the same or opposite side of the image relative to the nostril of insertion. When viewed from the right nostril, as a result of the angular placement of the nasendoscope, the width of the left vocal fold appeared elongated; hence the LA/RA width ratio was large. When viewed from the left nostril, the width of the right fold appeared elongated; hence the LA/RA width ratio was small.

Other researchers have suggested that there is an interaction between the insertion nostril and angle of nasendoscope orientation. Yanagisawa and Yanagisawa (1993) reported that the nasendoscope was displaced from desired mid-line of the laryngeal airway because of anatomical factors involving the nasopharynx, such as a narrow nasal cavity, a deviated septum or a large turbinate, and as a result the "fiberscope view often showed a distorted image" (p.259). Differences in vocal fold image size were difficult to correct without inserting the nasendoscope through the other nostril, suggesting that an asymmetrical view was the result of insertion nostril (Cantarella, 1998; Yanagisawa & Yanagisawa, 1993). The distortion effects were described by Yanagisawa and Yanagisawa (1993) as asymmetry in size of the left and right vocal folds. Size differences reported were consistent with the findings of this study; the fold contralateral to insertion side was imaged as larger than the ipsilateral fold. Cantarella's observations (1988) were inconsistent with the findings of this study, however; he reported that the fold closer to the nasendoscope lens appeared "bulkier" than the opposite fold (p. 358).

The effect of insertion nostril on the laryngeal or velopharyngeal image seems to be more difficult to conclusively define. Ducharme et al., 1991 reported that the hemilarynx ipsilateral to the insertion nostril was imaged as larger, or occupied a greater proportion of the image than the contralateral side in laryngeal images obtained from horses. Using a left-to-right ratio, Ducharme et al. (1991) controlled for the effects on image size related to the variation in lens-to-tissue-surface distance between the first and second insertions. Ibuki et al. (1983), although not comparing between insertion nostrils, reported a similar finding for images of the velopharyngeal mechanism. They noted that anatomical structures located on the same side as the nasendoscope occupied a greater a proportion of the image than the homologous structures on the opposite side. Although a similar finding was reported by Ducharme et al. (1991), and Ibuki et al. (1983), the significance of their studies to the present study may be limited due to the population and/or anatomical structures being studied.

To summarize, the vocal fold width asymmetry observed in this study is consistent with the effects predicted by Hibi et al. (1988) and Casper et al.(1988) and observed by Yanagisawa and Yanagisawa (1993). The results of this study are not consistent, however, with those of Cantarella (1988), Ducharme et al. (1991) or Ibuki et al. (1983). The disparity in results across these studies suggests that the effects of nostril of insertion on the orientation of the nasendoscope lens and the resulting nasendoscopic image are the result of complex optical and structural interactions that are not yet completely understood.

Laryngeal Airway Configuration

The laryngeal airway is a long cylindrical tube reinforced with movable bilateral structures including the ventricular folds, true vocal folds and arytenoid cartilages. During phonation and respiration, these structures function in uniformity to close and open the glottis. One issue to consider in this discussion of image size of the vocal folds is the inherent anatomical symmetry of the vocal folds. Other factors related to laryngeal airway configuration, including ventricular fold positioning and vocal fold thickness also may have influenced the visibility of the vocal folds and subsequently their observable image width.

Symmetry of Vocal Folds

Considerable individual variation exists within the normal limits of bilateral symmetry (Hirano, Kurita, Yukizane & Hibi, 1989; Kahane, 1976). Hirano et al. (1989) investigated asymmetry of the laryngeal framework across three different age groups in the Japanese population. In adult and older adult age groups, length and angle measurements of bilateral laryngeal landmarks differed between right and left side structures, leading Hirano et al. (1989) to summarize that "all larynges were more or less asymmetrical" (p.137).

Effect of insertion nostril. There are normal and natural variations in laryngeal structure that could affect vocal fold size and perceived symmetry of the vocal folds as imaged by flexible fiberoptic nasendoscopy. To control for the natural variation between left and right vocal fold size in the present study, the nasendoscope was inserted through both the left and right nostrils, and the relative differences between left and right folds within each laryngeal image were compared. Therefore, if one vocal fold was anatomically larger than the other fold, a nostril of insertion effect could still be detected, and the anatomical difference would be exaggerated when the larger of the two vocal folds was located in the contralateral field of view. The LA/RA width ratios for subject number 10 in the open condition (Table 7) highlight this point. Both LA/RA ratios for this subject were greater than 1.0 (left insertion 1.222, right insertion 1.415), which suggests that the left fold is anatomically wider than the right fold. Nevertheless, the value of the LA/RA width ratio was greater for the right nostril insertion than for the left nostril insertion indicating that the fold contralateral to the insertion nostril was imaged larger than the ipsilateral fold. Therefore the nostril-of-insertion effect observed in the group data was preserved. In reviewing the data from both measurement conditions, however, it is apparent that only one subject exhibited an anatomical difference that was consistent. The LA/RA width ratios for subject number 2 were less than 1.0 for both insertions (left & right) and both conditions (mid-line & open, Tables 6 & 7), suggesting that the right vocal fold is anatomically wider than the left fold.

Previous research has indicated that artificial differences between right and left vocal fold lengths were created by bilateral variations in arytenoid complex positioning in images obtained from flexible nasendoscopy (Casper, Colton & Brewer, 1987). It is possible that a similar effect occurred in this study; artificial differences in vocal fold widths were created by other laryngeal structures that, by their positioning, decreased or enhanced visibility of the vocal folds.

Ventricular Fold Positioning

Ventricular fold position has been reported to affect degree of visibility of the underlying vocal folds in the adducted and abducted positions (Casper et al., 1987; Yanagisawa & Yanagisawa, 1993). In Casper et al.'s (1987) investigation of configuration of the laryngeal airway and movement of selected structures including the vocal folds, the ventricular folds and the arytenoid complex, individual differences in ventricular fold movement and positioning were reported. In one individual, wide-set ventricular fold positioning during respiration exposed the vocal folds. In another individual, ventricular fold movement during phonation obscured the view of the underlying vocal fold, while the other vocal fold remained visible. Yanagisawa and Yanagisawa (1993) reported that images taken from several of the 134 subjects scoped they showed partial or complete obstruction of the view of the true vocal folds by the ventricular folds because of ventricular fold "constriction or obstruction" (p.262). This obscuring effect was found to be worse in the majority of cases when the laryngeal examination was conducted with a flexible nasendoscope versus a rigid, oral endoscope.

Effect of insertion nostril. In this study, if one or both vocal folds were completely obscured by the ventricular fold, the laryngeal images were not included for measurement analysis. However, since the boundary of the lateral edge of a true vocal fold was defined by the ventricular fold tissue above it, the ventricular fold was covering the true vocal fold more or less.

The ventricular folds will approximate to laryngeal airway mid-line to protect the lower airway. The presence of a foreign body (such as a flexible fiberoptic nasendoscope) in the nasopharyngeal airway could have affected ventricular fold position. Placement of the flexible nasendoscope in the laryngeal airway may have stimulated bilateral ventricular fold movement in a medial direction. It is possible that because of the angular orientation of the nasendoscope lens to the vocal fold surface, the ventricular fold ipsilateral to the nostril of insertion may have obscured the full view of the underlying vocal fold. Therefore, artificial differences in vocal fold widths may have been introduced into the image because the ventricular fold ipsilateral to the insertion nostril might have appeared to cover a greater surface area of the underlying vocal fold.

Vocal Fold Thickness

Although not previously mentioned as a factor that can affect image size of vocal folds in other imaging studies, thickness of folds may have been a factor in this study that influenced width differences between left and right folds in the open measurement condition.

Effect of insertion nostril. Angular placement of the nasendoscope, as a consequence of transnasal insertion could have resulted in greater exposure of the medial edge of the contralateral than the ipsilateral vocal fold. While vocal folds are abducted for inspiration or expiration, the medial edge of the vocal fold opposite to the imaging instrument may be more exposed and therefore appear to be "wider" than the ipsilateral fold. Subsequently, the width measurements may have included the medial edge of the contralateral vocal fold, as well as the exposed superior surface tissue. A superficial mucosal layer covers deeper muscular (vocalis) tissue and extends from the superior to the inferior surface of vocal folds (Colton & Casper, 1990). Because the surface tissue of the superior and medial edges of the vocal folds is continuous, the depth or thickness of the vocal fold may be undifferentiated from its width. Therefore the observed image size difference may reflect the relative degree of exposure of vocal fold tissue volume bilaterally, rather than actual differences in the widths of their superior surfaces.

Distortion versus Visibility

The viewing angle of the nasendoscope appears to be critical to the image integrity or perceived symmetry of bilateral structures from the research conducted by Hibi et al (1988) and Casper et al (1988). The theoretical model proposed by Hibi et al. (1988) involved comparing the image size of two-dimensional areas of known length and width while strictly controlling nasendoscope orientation to the imaging surface. It is unrealistic to assume that these measurement parameters would be applicable to the laryngeal images obtained via flexible fiberoptic nasendoscopy in a clinical setting. Given the dynamic nature of the structures being studied, the bilateral differences in vocal fold width measurements could have been influenced by other factors besides distortion effects associated with angular placement of the nasendoscope lens. Visibility of the folds appears to be affected by insertion nostril of the flexible fiberoptic nasendoscope and factors related to ventricular and vocal fold structure and position. It is difficult from these results to determine to what degree the angular placement of the nasendoscope resulted in the contralateral vocal fold being more visible than the ipsilateral fold. The data as reported do not differentiate between differences related to "exposure" due to laryngeal airway factors and those possible differences related to "distortion" as a result of nasendoscope lens placement.

To summarize, transnasal insertion of the nasendoscope seems to affect image size of the vocal folds, and results of this study strongly suggest that the viewing angle of the nasendoscope is affected by nostril of insertion. Further reasons for differences in the observable width of vocal folds can only be hypothesized but may relate to laryngeal structures and their positions relative to each other and the nasendoscope lens. The results indicate that nostril of insertion affects the relative image size of left and right vocal fold widths, a finding that has meaningful clinical implications.

Clinical Implications

The intent of this study was to determine the effect of nostril of insertion of the nasendoscope on image width of normal vocal folds. In a static image of the vocal folds, the image width of the vocal fold contralateral to the insertion side of the nasendoscope is larger than the image width of the ipsilateral fold. The clinical implications of this phenomenon are discussed on the following pages with respect to their effect on judgments of vocal fold status and clinical procedures used for obtaining laryngeal images via flexible fiberoptic video nasendoscopy.

Vocal fold image evaluations usually involve comparing the right and left folds with respect to length, width and movement (Cantarella, 1988; D'Antonio et al., 1987; Watterson, McFarlane & Brophy, 1990). Judgments of bilateral symmetry between the vocal folds may be impaired by the inherent effects of transnasal insertion of the nasendoscope and the imaging characteristics of the nasendoscope on the field of view (Yanagisawa & Yanagisawa, 1993). Speech-language pathologists, voice specialists and otolaryngologists should be aware of this image artifact when evaluating vocal fold images obtained from flexible fiberoptic video nasendoscopy.

Results of this investigation call into question the validity of one insertion of the flexible fiberoptic video nasendoscope (FFVN) to assess the vocal folds. Cantarella (1988) indicated that misdiagnosis of vocal fold hyper- or hypotrophy could be avoided if the FFVN was inserted through both nostrils. On insertions of the FFVN through both nostrils in the normal subjects of the present study, measures of vocal fold width differed depending on insertion side. In the mid-line condition, analysis of the width data indicated that the LA/RA ratios obtained for 8 of the 13 subjects varied systematically above and below 1.0 with nostril of insertion. In the open condition, the LA/RA ratios obtained for 8 of the 12 subjects also varied systematically above and below 1.0 with nostril of insertion. Only one subject (# 2, Tables 6 & 7) provided consistent evidence of a natural anatomical difference in vocal fold widths. Thus, the effects of transnasal insertion were responsible for the majority of the discrepancies in bilateral vocal fold width measures. Therefore caution should be exercised in evaluating whether apparent vocal fold asymmetry is a "true" anatomical difference or if it is related to an image artifact.

Given the clinical realities of scoping time and patient numbers, for the experienced otolaryngologist and speech pathologist who are making judgements regarding vocal fold status, a single insertion of the flexible fiberoptic nasendoscope may be adequate. The clinicians should satisfy themselves, however, that the observed vocal fold asymmetry is most likely related to nostril of insertion. If vocal quality or case history strongly suggests a pathological cause for the vocal fold asymmetry, then a second insertion through the other nostril may be prudent.

In the case of single insertions, the larger, more patent of the nasal cavities should be used to minimize the degree of image distortion (Yanagisawa & Yanagisawa, 1993). If no differences are observed in vocal fold symmetry, and the otolaryngologist and speech-pathologist are satisfied with the integrity of the laryngeal images, then it may be concluded that transnasal insertion effects on image have been minimized. Certainly, the vocal folds should be observed in both adducted and abducted conditions to determine if their appearance differs depending on laryngeal posturing for phonation or respiration.

Reliable images of laryngeal structures are critical, if change of vocal fold status over the course of treatment or time is to be documented. Peppard and Bless (1990) suggested that maintaining a stable angle of view on repeated endoscopic examinations of the larynx will reduce the chances of observing differences in image size of laryngeal structures across original and repeat examinations. Clearly, once the otolaryngologist has achieved a laryngeal image that is satisfactory, every attempt should be made to obtain a similar view of the vocal folds on repeated insertions. Therefore it might be argued that to increase the probability of obtaining reliable laryngeal images over time, the same nostril should be used for all insertions of the nasendoscope on a given patient. With the one subject who was rescoped in this study in an attempt to replicate nasendoscope position in the laryngeal airway, the LA/RA width ratios obtained from left nostril insertions (original 0.804, repeat 0.830) were more similar than those obtained from right nostril insertions (original 1.512, repeat 0.982). These results suggest that more research is needed to evaluate the consistency of images obtained on repeat insertions of the nasendoscope and the reliability of nasendoscope placement in the laryngeal airway.

Limitations

The limitations of this study are presented and discussed under the following headings, Internal Validity and External Validity. Internal validity issues influence the confidence with which the findings are reported. External validity issues affect generality of the findings to other clinical settings, subjects and methods. Careful consideration of such issues that influence both internal and external validity will assist in future research conducted with video digitization instrumentation and flexible fiberoptic video nasendoscopy.

Internal Validity

Internal validity is influenced by the effectiveness and reliability of the procedures and instrumentation used in the study. The methodological issues considered to affect internal validity of this study are summarized under the following headings: digitizing and imaging instrumentation, data collection and analysis, and reliability of nasendoscope placement in the hypopharynx.

Digitizing and imaging instrumentation. A threat to the internal validity of this study is the lack of published research supporting the effectiveness of the digitizing instrumentation used for this investigation. Since actual size of the vocal folds was impossible to determine from the video nasendoscopic image, the digitizing instrumentation was useful in that it established a common unit of measurement, the "pixel", with which to make comparisons between vocal fold images. Clinical reports investigating the effectiveness of using computer applications to perform quantitative analysis of single video-cassette frames have been favourable, however, they usually include a cautionary note regarding the reduction of image resolution associated with the digitizing procedure (Colton et al., 1989; Secarz et al., 1991). Clear, well-illuminated, focused images are essential for image processing (Colton et al., 1989). In the case of this investigation, over a third of the data obtained for each measurement condition had to be excluded due to one or more of the following factors that compromised measurement accuracy: insufficient lighting, degraded image quality, and poor visibility of measurement landmarks.

Instrument calibration and standardization of procedures are other potential threats to the internal validity of the results. Calibration of imaging instrumentation for this study followed those procedures used by the voice clinic where the scoping was conducted. For this particular study, it was difficult to determine the parameters associated with laryngeal image collection that needed to be standardized. Lens focus, degree of illumination of the laryngeal airway and depth of insertion of the flexible nasendoscope are all variables that directly influence the quality of the laryngeal images obtained. In the clinical setting, these variables are routinely determined at the time of scoping and by the person who conducts the scoping. Stricter control of the variables (focus, light source power setting & maintenance of lens-to-vocal-fold distance) during the scoping procedure would have enhanced the internal validity of this study and would have increased the likelihood that all laryngeal images were collected in exactly the same manner across all insertions. However, to restrict the degree to which these variables could have been adjusted would have introduced artificial constraints on the scoping procedure, and that would have further reduced the generality of these findings to other clinical settings.

Data collection and analysis. A methodological limitation, and therefore a threat to internal validity of the study, was the fact that the investigator was not blind to the variable being investigated. Therefore the methodological design arguably did not completely control for the possibility that examiner bias influenced data collection and measurement procedures. During laryngeal image selection, nostril of insertion was not concealed. While selecting video frames for digitization the investigator was aware of nostril of insertion because it was recorded on the video-cassette tape. Digitized laryngeal data were labelled only by subject and insertion order (first or second), however, so that during measurement of vocal fold image, the investigator was unaware of nostril of insertion. However, in some instances it could be determined by orientation of the laryngeal structures. Future investigations could conceal the identity of insertion nostril throughout collection and measurement of data.

Reliability of nasendoscope placement. Results of scoping reliability are critical to the assessment of the internal validity of the study. The lack of evidence that nasendoscope placement in the hypopharynx can be replicated has serious implications for assessing the validity of the results. Only one subject was rescoped, and the original measurements of that subject's vocal fold data were compared to the measurements obtained from the repeated insertions. Examination of the LA/RA vocal fold width ratios presented in Table 5 indicate that the nostril-of-insertion effect was preserved, but the observed difference was reduced between images obtained from the second insertion.

The lack of consistency between original and repeated vocal fold measures may reflect a clinical reality. It is difficult to place the nasendoscope in exactly the same position in the hypopharynx on repeated insertions because exact distance from the vocal fold surface to the nasendoscope lens can not be easily controlled for or determined. In this study, the finger-placement method was used to control for the variation in the vertical distance of the nasendoscope lens to the vocal fold surface between insertions. This method can not control for a change in head and velum position that could affect the alignment of the nasendoscope in the nasal cavity, nasopharynx and hypopharynx as it approaches the larynx, or a change in nasal cavity volume, e.g., swelling of turbinates, that could affect the angle of insertion of the nasendoscope in the hypopharynx.

It is possible that the finger placement technique with the following modifications could be more effective in minimizing the variations in lens-to-vocal-fold surface distance across insertions: (1) the casing of the nasendoscope could be marked in smaller increments (e.g., centimetres) to increase measurement accuracy; (2)

the clinical procedures could include positioning a patient's head in a similar posture across all insertions to reduce the effects of head and velum position on the alignment of the nasendoscope within the nasal, nasopharyngeal and hypopharyngeal airways.

The difficulties associated with determining the vertical distance of the nasendoscope lens to the vocal fold surface also could be circumvented by using the luminous energy of the nasendoscope tip and an external landmark on the neck. As the nasendoscope is lowered toward the laryngeal airway, its descent through the pharynx can be observed by tracing the point of light that is visible transcutaneously at its tip. When the tip is satisfactorily positioned, the distance from that point of light to an external landmark (e.g., the thyroid notch) would indicate the vertical position of the nasendoscope lens relative to the vocal fold tissues and could be measured and recorded for use on subsequent insertions. Vertical position of the larynx would have to be consistent across all insertions if this method were used. Additional investigation is required to determine the clinical feasibility and validity of these techniques designed to improve the clinician's ability to replicate the placement of the nasendoscope lens in the laryngeal airway.

External Validity

External validity relates to the generality of research findings to other subjects, settings, or research endeavours. One threat to the external validity of this study was the manner in which the vocal fold data were evaluated for this research. These results are based upon single frame video digital analysis and may not be applicable to evaluations of the larynx performed in a voice clinic or an otolaryngologist's office. The advantage of flexible fiberoptic video nasendoscopy in the clinical setting is the ability to observe and interpret on-line the behaviour and appearance of the laryngeal structures as the subject/patient performs a range of phonatory and respiratory tasks. The availability of computer technology and instrumentation to isolate single frames from a video-cassette for later analysis of laryngeal data may be limited and impractical for such settings.

A second threat to the external validity of the study is that the population studied was a select group of voice and/or drama students who have had some voice training. It is difficult to know if individuals without voice training could perform the required phonation tasks as well as those who participated in the study did.

A third threat to external validity is that the findings of this study are limited to those laryngeal images obtained from adults of an age group similar to the one sampled, young adults with normal larynges. The presence of a vocal fold pathology could affect the size, movement, and visibility of the folds. Furthermore, factors that could affect nasendoscope placement in the hypopharynx, such as nasal cavity volume and/or the diameter of the vocal tract, change with age. It is not yet known if the findings of this study based upon data from young adults with normal voices would apply to other individuals in different age groups, such as infants, adolescents, and older adults with normal voices or vocal pathologies. A nostril-of-insertion effect would have to be investigated independently within specific age groups.

A further threat to the external validity of the study is that factors unique to the voice clinic could decrease the impact of the findings on other voice clinics. Issues to consider are: (1) scoping technique and experience of the otolaryngologist, and (2) the nasendoscope instrumentation, including lens diameter and the degree of optical distortion. These factors may differ across voice clinics, and may differentially affect the image size of the laryngeal structures obtained in each venue. To determine if a nostril-of-insertion effect is present regardless of the above-mentioned factors, a broader sample of video-taped laryngeal data from many different voice clinics could be collected and analyzed.

In conclusion, speech-pathologists, voice specialists and otolaryngologists have been limited to subjective observations of the structure and function of the laryngeal mechanism by means of various forms of visual imaging techniques. This study represents an attempt to implement a quantitative analysis of laryngeal structures by digitization of laryngeal images. Clinical procedures used to obtain laryngeal images and perceptions of normal laryngeal anatomy will be affected by the results of this and future investigations. In light of the findings of this investigation, methodological issues, such as side of insertion of the imaging instrument for nasendoscopy, are [illegible] not only to future research but also to future clinical [illegible] involving flexible fiberoptic video nasendoscopy.

References

Baken, R.J. (1987). Clinical measurement of speech and voice. Pro-Ed. Austin. 203-205.

Bastain, R.W. & Levine, L.A. (1988). Visual methods for the office diagnosis of voice disorders. Ear, Nose and Throat Journal, 67, 363-379.

Boone, D., & McFarlane, S. (1988). The Voice and Voice Therapy. (4th Ed.). Prentice Hall. Englewood Cliffs, New Jersey.

Brewer, D.W., & McCall, G. (1974). Visible laryngeal changes during voice therapy. Annals of Otology, Rhinology and Laryngology, 83, 423-427.

Cantarella, G. (1988). Value of flexible videolaryngoscopy in the study of laryngeal morphology and functions. Journal of Voice, 1(4), 353-358.

Casper, J.K., Brewer, D.W. & Colton, R.H. (1988). Pitfalls and problems in flexible fiberoptic videolaryngoscopy. Journal of Voice, 1(4), 347-352.

Casper, J.K., Brewer, D.W. & Colton, R.H. (1987). Variations in normal laryngeal anatomy and physiology as viewed fiberscoptically. Journal of Voice, 1(2), 180-185.

Coleman, R.F., Mabis, J.H., & Hinson, J.K. (1977). Fundamental frequency-sound pressure level profiles of adult male and female voices. Journal of Speech and Hearing Research, 20, 197-204.

Colton, R.H., & Casper, J.K. (1990). Understanding voice problems: A physiological perspective for diagnosis and treatment. Williams & Wilkins. Baltimore, MD.

Colton, R.H., Casper, J.K., Brewer, D.W., & Conture, E.G. (1989). Digital processing of the laryngeal images: A preliminary report. Journal of Voice, 3(2), 132-142.

D'Antonio, L.L., Chait, D., Lotz, W., & Netsell, R. (1986). Pediatric videonasendoscopy for speech and voice evaluation. Otolaryngology, Head and Neck Surgery, 94, 578-583.

D'Antonio, L.L., Chait, D., Lotz, W., & Netsell, R. (1987). Perceptual-physiologic approach to evaluation and treatment of dysphonia. Otolaryngology, Head and Neck Surgery, 96, 187-190.

D'Antonio, L.L., Muntz, H.R., Marsh, Marty-Grimes, L., & Backensto-Marsh, R. (1988). Practical application of flexible fiberoptic nasopharyngoscopy for evaluating velopharyngeal function. Plastic and Reconstructive Surgery, 82 (4), 611-618.

D'Antonio, L.L., Marsh, J.L., Province, M.A., Muntz, H.R., & Phillips, C.J. (1989). Reliability of flexible fiberoptic nasopharyngoscopy for evaluation of velopharyngeal function in a clinical population. Cleft Palate Journal, 3, 218-225.

Ducharme, N.G., Hackett, R.P., Fubini, S.L. & Erb, H. (1991) The reliability of endoscopic examination in assessment of arytenoid cartilage movement in horses. Part II. Influence of side of examination, Reexamination and sedation. Veterinary Surgery, 20(3), 180-184.

Eckel, F.C. & Boone, D.R. (1981). The s/z ratio as an indicator of laryngeal pathology. Journal of Speech and Hearing Disorders, 46, 147-149.

Fex, S., Fex, B., & Hirano, M. (1991). A clinical procedure for linear measurement at the vocal fold level. Journal of Voice, 5(4), 328-331.

Gramming, P., Sundberg, J., Ternstrom, S., Leanderson, R. & Perkins, W.H. (1988). Relationship between changes in voice pitch and loudness. Journal of Voice, 2(2), 118-126.

Hibi, S.R., Bless, D.M., Hirano, M., & Yoshida, T. (1988). Distortions of videofiberscopy imaging: Reconstruction and correction. Journal of Voice, 2(2) 168-175.

Hirano, M., Kurita, S., Yukizane, K. & Hibi, S. (1989). Asymmetry of the laryngeal framework: A morphological study of cadaver larynges. Annals of Otology, Rhinology and Laryngoscopy, 98, 135-140.

Hollien, H. (1960). Vocal pitch variation related to changes in vocal fold length. Journal of Speech and Hearing Research, 3(2), 150-156.

Hollien, H. & Curtis, J.F. (1960). A laminagraphic study of vocal pitch. Journal of Speech and Hearing Research, 3(4), 361-371.

Hollien, H. & Moore, G.P. (1960). Measurements of the vocal folds during changes in pitch. Journal of Speech and Hearing Research, 3(2), 157-165.

Ibuki, K., Karnell, M.P., & Morris, H.L. (1983). Reliability of the nasopharyngeal fiberscope (NPF) for assessing velopharyngeal function. Cleft Palate Journal, 18, 100-109.

Inouye, T. (1983). Examination of the child larynx by flexible fiberoptic laryngoscope. International Journal of Pediatric Otorhinolaryngology, 5, 317-323.

Kahane, J.C. (1978). A morphological study of the human prepubertal and pubertal larynx. American Journal of Anatomy, 151, 11-20.

Karnell, M.P., Ibuki, K. Morris H.L. & Van Denmark, D.R. (1984). Reliability of the nasopharyngeal fiberscope for assessing velopharyngeal function: Analysis by judgement. Cleft Palate Journal, 20, 199-208.

Kent, R.D., Kent, J.F. & Rosenbek, J.C. (1987). Maximum performance tests of speech production. Journal of Speech and Hearing Disorders, 52, 367-387.

Komiyama, S., Watanabe, H., & Ryu, S. (1984). Phonographic relationship between pitch and intensity of the human voice. Folia Phonatrica, 36, 1-7.

McFarlane, S.C., & Lavorato, A.S. (1984). The use of videoendoscopy in the evaluation and treatment of dysphonia. Communicative Disorders, 9 (8), 117-125.

McFarlane, S.C., & Watterson, T.L. (1990). Vocal nodules: Endoscopic study of their variations and treatment. Seminars in Speech and Language. 11, 47-59.

McFarlane, S.C., Watterson, T.L., & Brophy, J.W. (1990). Transnasal videoendoscopy of the laryngeal mechanism. Seminars in Speech and Language, 11, 9-14.

Peppard, R.C. & Bless, D.M. (1990). A method for improving measurement reliability in laryngeal videostroboscopy. Journal of Voice, 4(3), 280-285.

Pigott, R.W. & Makepeace, A.P. (1982). Some charateristics of endoscopic and radiological systems used in elaboration of the diagnosis of velopharyngeal incompetence. British Journal of Plastic Surgery, 35, 19-32.

Rasband, W. (1991). Image: Image processing software [Computer program]. Knoxville, TN: Perceptics Corporation.

Secartz, J.A., Berke, G.S., Arnstien, D., Gerratt, B. & Natividad, M. (1991). A new technique for quantitative measurement of laryngeal videostroboscopic images. Arch Otolaryngoly Head Neck Surgery, 117, 871-875.

Selkin, S.G. (1983). Technical note: Flexible fiberoptic and pediatric otolaryngology. A simple technique for examination and photodocumentation. International Journal of Pediatric Otorhinolaryngology, 5, 325-333.

Selkin, S.G. (1984). Kinelaryngoscopy for documentation of laryngeal pathophysiology. Laryngoscopy, 94, 58-62.

Silberman, H.D., Wilf, H., & Tucker, J.A. (1976). Flexible fiberoptic nasopharyngolaryngoscope. Annals of Otology, Rhinology and Larnygoscopy, 85, 640-645.

Stone, R.E., Bell, C.J., & Clack, T.D. (1978). Minimum intensity of voice at selected levels within pitch range. Folia Phoniatrica, 30, 113-118.

Watterson, T.L., McFarlane, S.C., & Brophy, J.W. (1990). Some issues and ethics in oral and nasal videolaryngoscopy. Seminars in Speech and Language, 11, 1-7.

Welch, A.R. (1982). The practical and economic value of flexible fiberoptic system. Journal of Laryngology and Otology, 96, 1125-1129.

White, J.F., & Knight, R.E. (1984). Office videofiberoptic Laryngoscopy. Laryngoscope, 94, 1166-1169.

Williams, G.T., Farquharson, I.M., & Anthony, J. (1975). Fiberoptic laryngoscopy in the assessment of laryngeal disorders. Journal of Laryngology and Otology, 89, 299-316.

Wilson, F.B. (producer). (1984). Flexible fiberoptic video nasendoscopy. {videotape}. Bellingham, Washington: Voice Tapes Inc.

Wilson, F.B. (1988). The importance of laryngeal visualization in voice management. In S. Gerber & G. Mencher (Eds.) Speech Language and Audiology: An international perspective. Gaulledet Press. Washington, D.C. 150-167.

Wilson, F.B., Krudyk, W.H., & Sych, J.A. (1986). The development of flexible fiberoptic video nasendoscopy: Clinical teaching, research applications. ASHA, 28(11), 25-30.

Wilson, D.K. (1987). Voice problems of children. (3rd Ed.). Williams & Wilkins. Baltimore, MD.

Yanagisawa, E. & Yanagisawa, K. (1993). Stroboscopic videolaryngoscopy: A comparison of fiberscopic and telescopic documentation. Annals of Otology, Rhinology and Laryngoscopy, 102, 255-265.

Yanagisawa, E., Owens, T.W., Strothers, G. & Honda, K. (1983). Videolaryngoscopy: A comparison of fiberoptic and telscopic documentation. Annals of Otology, Rhinology and Laryngoscopy, 92, 430-436.

Appendix A
Flexible Fiberoptic Video Nasendoscopy (FFVN) Insertion Study

Voice and Respiratory Status Questionnaire

Name ________________________________

Date of Birth ______________________

Date of Screening _______________ **Age** _____

Please complete the following questions as accurately as possible.

Please indicate if you have experienced the following sensations in your throat within the last month:
____ pain
____ difficulty swallowing
____ strain
____ fatigue

Do you have any of the following?
____ Allergies
____ Respiratory Problems (include asthma)
____ Neurological Problems
____ Endocrine/Hormone Problems

Are you or have you been seen by an ENT or a Speech Pathologist for a voice or resonance disorder?
____ Yes
____ No

Have you had any of the following (please check all that apply):
____ Surgery on your Larynx
____ Heart Surgery
____ Chest Surgery
____ Thyroid Surgery
____ Stroke
____ Injury to the Neck
____ Chemical Inhalation
____ Surgery on your Nasal Cavities

Do you (please indicate with a check all that apply):
____ Smoke (cigarettes or other substances)?
____ Take any antihistamine and/or decongestant medications on a regular basis?

Appendix B
Information Form for Potential Participants
Flexible Fiberoptic Video Nasendoscopy (FFVN) Insertion Study
Investigator: Kara Ryan 492-5990

I. What is flexible fiberoptic video nasendoscopy?

Flexible fiberoptic video nasendoscopy (FFVN) is a clinical procedure used to observe and record vocal cord movement on video-cassette tape. It is used to detect the presence of an abnormal mass on the vocal cords and to observe vocal cord function during speech. The instrument used to observe the vocal cords is a nasendoscope. It has a flexible optical lens system contained in a long tube approximately 4.0 mm in diameter. The vocal cords are observed by inserting the nasendoscope through the nasal passage.

II. What is the purpose of this study?

The purpose of this study is to determine if the nostril of insertion of the flexible fiberoptic nasendoscope affects the picture of the vocal cords that is observed and recorded on the video-cassette tape.

III. What does the study involve?

The study involves comparing the measured area of the vocal cords obtained through left and right nostril insertion of the nasendoscope. Subjects are needed who are willing to be scoped twice, once through the left and once through the right nostril.

IV. What is scoping?

Scoping is the term used to describe the insertion and viewing procedures associated with flexible fiberoptic nasendoscopy. The flexible lens of the nasendoscope is inserted through the nasal passageway and passed into the throat. A licensed physician, skilled in nasendoscopy techniques, will conduct the scoping. A topical anesthetic will be applied in the nasal passage and a lubricating gel will be applied to the nasendoscope to make the procedure as comfortable as possible. This procedure has been performed on infants, children and adults.

V. Who can participate?

To be eligible as a subject you must: 1) be willing to participate, 2) be a non-smoker, 19 to 45 years of age, 3) have no history of voice or respiratory illness, chronic allergies and/or asthma, and 4) pass a simple voice screening procedure.

VI. What is required of subjects?

There will be an overall time commitment of a maximum of two hours, broken down into three sessions. In a 30 minute assessment session, conducted at Corbett Hall, you will be required to view a video-cassette tape on flexible fiberoptic nasendoscopic procedures, complete a voice and respiratory status questionnaire and go through a vocal screening battery. There will be a simple, 30 minute training session to be conducted at Corbett Hall. The actual scoping session will be scheduled at the Glenrose Rehabilitation Hospital and should take approximately 30 minutes.

VII. What can I do if I am interested?

Please contact the principal investigator, Kara Ryan, at the Speech Pathology and Audiology Department at 492-5990.

Appendix C
Consent Form
Flexible Fiberoptic Video Nasendoscopy Insertion Study
Department of Speech Pathology and Audiology
University of Alberta, Edmonton

Subject's Informed Consent

Name :____

I have read the information regarding the flexible fiberoptic video nasendoscopy insertion study to be conducted by Kara Ryan. I have viewed the video cassette tape "Flexible Fiberoptic Video Nasendoscopy". I am fully aware of the contents of the "Information Form for Potential Participants" and the video. I am fully aware of the procedures to be undertaken in accordance with my participation in the research project and the two-hour time commitment required. All of my questions concerning the study and involvement in the investigation have been addressed to my satisfaction.

I understand that:

1) A voice and respiratory status questionnaire will be administered to establish my eligibility for the study. There will be questions asked concerning my history of voice and respiratory problems, allergies, asthma, surgery, neurological disease, antihistamine and/or decongestant drug use and smoking. The information will be recorded on a form which will be seen only by the investigator and Dr. G. Misko, the licensed otolaryngologist performing the scoping. A vocal screening battery, consisting of two vocal tasks will be administered. I must meet a minimum standard on both tasks to be eligible for participation in the study.

2) I understand that the Flexible Fiberoptic Video Nasendoscopy (FFVN) procedure involves some discomfort. This has been described to me as a "pinching sensation" and demonstrated by the investigator.

3) I am consenting to participate in a study that involves an invasive procedure, Flexible Fiberoptic Video Nasendoscopy. This procedure will be conducted once through the right nostril and once through the left nostril by Dr. Misko at the Glenrose Rehabilitation Hospital. A local topical anesthetic will be applied to the inside of my nose by Dr. Misko to make this procedure as comfortable as possible for me. Video-tapes of my vocal cords will be made while I say a vowel and breathe quietly.

4) The investigator will be using data from the video-tapes to perform vocal cord measurements. The information obtained from this research will help with the standardization of the procedure Flexible Fiberoptic Video Nasendoscopy.

5) I understand that some individuals have experienced "gagging" sensations while the nasendoscope is inserted. I could experience a similar reaction to insertion of the nasendoscope. The nasendoscope will be withdrawn upon my request for whatever reason.

6) I understand that this procedure may cause a vocal cord spasm. A vocal cord spasm is a temporary closure of the vocal cords. It is a natural reflex designed to protect the lungs. Although extremely rare, occurrence of vocal cord spasm has been associated with flexible fiberoptic nasendoscope insertion. If this occurs, I would experience a sensation similar to choking and the associated difficulty with catching my breath. I understand that this event is unlikely. No occurrence of vocal fold spasm has been recorded by the Glenrose Rehabilitation Hospital Voice Clinic. In any case, I am aware that normal Voice Clinic procedures will be followed and Dr. Misko will be in attendance for the entire procedure.

7) I understand that this procedure could irritate my nose and my nasal passages resulting in soreness, and I could experience some mild discomfort as a result of this procedure.

8) I understand that I could experience an allergic reaction to zylocaine, the dental anesthetic used in the procedure. If this happens, adequate measures will be taken to ensure my safety.

9) I understand that a nosebleed could occur as a result of nasendoscopic insertion. Nosebleeds are not a common side-effect of this procedure. There have been no nosebleeds associated with this procedure at the Glenrose Rehabilitation Hospital Voice Clinic. In the event of a nosebleed during insertion of the nasendoscope, my involvement in the study will be terminated.

10) The research project is conducted under the guidelines governing ethics in human research at the University of Alberta and at the Glenrose Rehabilitation Hospital. Therefore, my welfare and dignity will be preserved during my involvement in this study, and my anonymity will be guaranteed. Data collected will be coded and stored in a secure location accessible only by the investigator. My identity will not be disclosed in any written or oral reports of findings. The data will be erased or destroyed when no longer needed.

11) I am free to withdraw from further participation any time during the course of this study without consequences.

12) My signature confirms that I have received a copy of the consent form, and I have given my voluntary consent to begin participation in the project.

______________________ Subject's signature	______________ Date
______________________ Subject's printed name	______________ Witness

____
Investigator's signature
Kara Ryan
M.Sc candidate

Presently, I am willing to undergo the entire scoping procedure a second time for data collection reliability purposes, however I am free to decline at a future date: yes no

Subject's signature	Date
Subject's printed name	Witness

Investigator's signature
Kara Ryan
M.Sc candidate

If questions or concerns arise about participation, the investigator can be contacted at 492-5990 during the day or at 439-9576 in the evenings. Messages can be left at the following address:

Department of Speech Pathology and Audiology
2-70 Corbett Hall
University of Alberta

Appendix D
Flexible Fiberoptic Video Nasendoscopy (FFVN) Insertion Study

Laryngeal Performance Data Sheet

Name: ____

Gender: M ____ F ____

Date of Screening: ______________________________

Maximum Phonation Time for /a/ Vowel

M - 20 secs F - 15 secs

Trial #	Duration (in seconds)	Study Requirements
1.		
2.		
3.		

Maximum Production Time for S/Z Ratio
S Trials

Trial #	Duration (in seconds)	Rank order
1.		
2.		
3.		

MPT for S: _____

Z Trials

Trial #	Duration (in seconds)	Rank order
1.		
2.		
3.		

MPT for Z: _____

Acceptable range of S/Z Ratio: under 1.35

MPT S/Z Ratio: _______ S/Z Ratio Acceptable: yes no

Appendix E
Glenrose Rehabilitation Hospital
Consent to Admit Form

Glenrose
Rehabilitation
Hospital

ROOM NR/PROG.	LAST NAME	FIRST	MIDDLE	PATIENT'S I.D. NR.				
ACC. CL.	A.H.C.I.C. NUMBER	SOC. INS. NR.	DATE OF BIRTH	AGE	SEX	M/W/S/D	REL.	ADMISSION DATE
ACC. REQU.	RES. CD.	HOW LONG	POSTAL CODE	PRESENT ADDRESS AND/OR P.O. BOX NR.				
HOME PHONE	BUS. PHONE	ATTENDING PHYSICIAN	NUMBER	SERVICE PROG.				
REFERRING PHYSICIAN	ADDRESS AND/OR P.O. BOX NR.							
BASIC CHARGES (DVA. RCMP. WCB. PROV., ETC.)	REFERENCE NR.	EXPIRY DATE	CAR. CD.					
PREFERRED CHARGES (BLUE CROSS OR OTHER INS.)	REFERENCE NR.	EFFECTIVE DATE	CAR. CD.					
ADM. CON.	TR. HOSP. NR.	ELS	E.D.D.	DIAGNOSIS				
EMERG. NOTIFIC. (LEGAL N.O.K.)	ADDRESS	TELEPHONE						
RESPONSIBLE PARTY	REL'N.	ADDRESS						
OCCUPATION	EMPLOYER	ADDRESS						
DEPOSIT	SAFEKPG.	VALUABLES	PREVIOUS ADM.	D.D.D.	ARR. TIME	ADM. TIME	ADM. O.	
REMARKS (ADDITIONAL EMERG. NOTIFICATION, ETC.)								

DISCHARGE DATE

SEND COPIES TO

GLENROSE REHABILITATION

CONSENT TO ADMIT

FOR USE WHEN PATIENT ADMITS HIMSELF

I HEREBY REQUEST THE GLENROSE REHABILITATION HOSPITAL TO ADMIT ME AS A PATIENT

DATE _____ WITNESS _____ SIGNATURE OF PATIENT _____

OR

FOR USE WHEN PATIENT IS A MINOR OR IS BEING ADMITTED BY ANOTHER PERSON

I HEREBY REQUEST THE GLENROSE REHABILITATION HOSPITAL

TO ADMIT: _____ _____
AS A PATIENT.

DATE _____ WITNESS _____ SIGNATURE OF PERSON ADMITTING PATIENT _____ RELATIONSHIP _____

C.R. 1-11/82 A

CAUTION: THE HOSPITAL MAINTAINS FACILITIES FOR SAFEKEEPING OF PATIENTS VALUABLES SUCH AS MONEY, JEWELLERY, ET[illegible]
THE HOSPITAL ASSUMES NO RESPONSIBILITY FOR LOSS OF VALUABLES FROM PATIENTS ROOMS OR WARDS.