ENDOSCOPIC IMAGING OF THE HUMAN LARYNGEAL COMPLEX IN AN EXPERIMENTAL SETTING – METHODOLOGY AND CLINICAL SIGNIFICANCE

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ABSTRACT

AIM: **The human laryngeal complex has been an endoscopic sight since the late 19th century, however despite the technological advances little has changed in the standard observational methodology, with optical distortion of the image being a major setback in all endoscopic studies. The aim of this study is to evaluate different endoscopes and image correction algorithms in the endoscopic imaging of the laryngeal complex.**

METHODS AND MATERIALS: **Conventional rigid 0^0, 30^0, 70^0 and 90^0 endoscopes and a flexible otorhinolaryngoscope with two-dimensional imaging capabilities, a digital camera and a direct laryngoscope were used together with an intubation mannequin to obtain endoscopic images of the laryngeal complex. Images of a custom made lens distortion grid were taken to compare the different optical systems and used as a benchmark for image correction. Both sets of images were superimposed in order to digitally correct for angle and lens distortion and to show the true size and proportions of the human laryngeal complex, so far seen only during an intubation or autopsy.**

RESULTS: **After comparing the fiber optic and rigid endoscope obtained images, the rigid endoscopes proved to have better imaging qualities and therefore a better potential for future in depth study of laryngeal anatomy. The rigid 70^0 endoscope, compared to other rigid systems, allowed for an atraumatic perpendicular to the glottis view of the laryngeal complex, best suited for the study, despite the higher image distortion.**

CONCLUSION: **Based on the collected data the 70^0 rigid otorhinolaryngoscope together with a standard software correction is an affordable, atraumatic and reliable method for anatomical and proportionate measuring of the human laryngeal complex in a model study.**

Keywords: *endoscope, ENT, laryngeal complex, laryngoscopy, distortion; digital correction*

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AIM

Endoscopic techniques are a big advantage in modern surgery and diagnostic medicine (1-2). Their advancement in the last decades has opened new possibilities for the development of numerous minimally invasive observation and surgical manipulations, resulting in minimal traumatism, faster patient recovery and less postoperative complications (3-4). Endoscopy of the larynx and the upper airways is a medical field in itself and nowadays various endoscopes belong to the standard armamentarium in ENT (5). Even so the specificity of endoscopic examinations has remained low, due to the optical distortion of the image, created from the lens systems in the endoscope.

The aim of this study is to create and set an easy to apply digital algorithm for post process correction of images taken with ENT endoscopes and correct the distortion rate given, while at the same time selecting the most appropriate endoscope for indirect laryngoscopy in an experimental setting and visualize the true size and proportions of the human laryngeal complex using standard endoscopic techniques.

MATERIALS AND METHODS

For the aim of the study a set of standard Hopkins rod lens endoscopes – 0° (Spiggle & Theis Medizintechnik GmBH, Overath, Germany), 30° (Karl Storz, Tuttlingen GmbH & Co KG, Germany), 70° (Karl Storz GmbH & Co KG, Tuttlingen, Germany), 90° (Karl Storz GmbH & Co KG, Tuttlingen, Germany) and a flexible nasopharyngolaryngoscope (11001RD1™, Karl Storz GmbH & Co KG, Tuttlingen, Germany), widely available in the ENT practice were used. The endoscopes were connected to an endoscope compatible Nikon® E 4500™ digital camera and images of a custom made calibration grid were obtained thru the systems to determine the rate of image distortion of each of the available optical systems.

The first step in the process of creating a correction algorithm is to determine the lens distortion on a custom made calibration grid. The grid in our case was created using Adobe® Photoshop® CS6™ and is composed of a grid of 11 by 11 lines, constructing a 10 by 10 square system, with a central calibration point. The grid was then printed on an A4 piece of paper so that images of it can be obtained using all of the available endoscopes (Figure 1a). The distortion rate for each system was then determined with the help of the Adobe® Photoshop® CS6™ build-in software capabilities. The task was carried out by measuring the pixel deviation between identically set points on the superimposed images of the original grid and images taken through the endoscopes. The distortion rates were measured on 3 separate points for each system, starting from the central calibration point and projecting to the outer border of the grid with vertical, horizontal and diagonal projection – the inner, middle and outer third (Figure 1b and Table 1).

The correction was then carried out on Adobe® Photoshop® CS6™ using the lens correction function with the fish-eye setting with three vertical and three horizontal correction lines used to converge the image, with the precalibrated pixel deviations used as correction constants for each individual system, so that the original size and proportions of the grid would be restored (Figure 1c). The collected data on the rate of distortion of each endoscope was later used as a starting point for the correction process of images obtained with it without the need for calibration grid superimposing (Figure 1d).

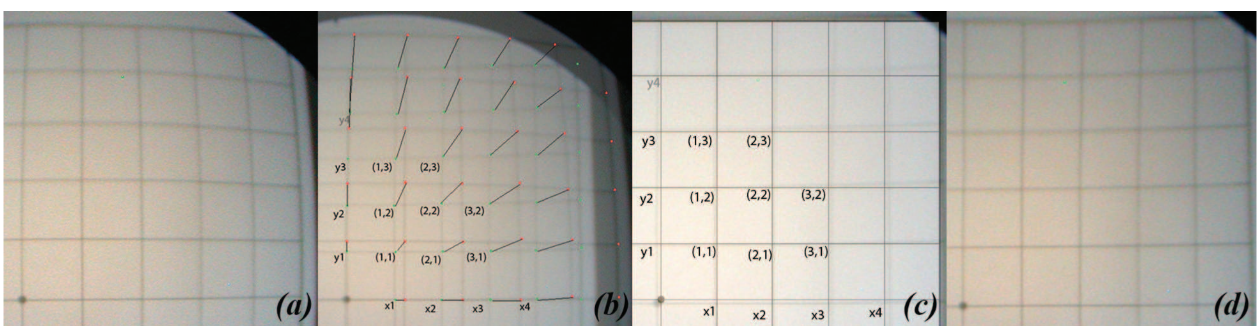

Figure 1. An endoscopic image of the printed out calibration grid obtained with the 70° Hopkins rod lens endoscope (a). The same image with the calibration grid superimposed and calibration points set on the X, Y and diagonal checkpoints, with the deviation distance shown (b). The same image with the calibration grid superimposed and corrected for image distortion (c). The same endoscopic image with the post process correction algorithm complete (d)

With the rates of distortion for all the systems measured and an easy to apply post-process software correction algorithm developed, the endoscopes were field tested on an adult intubation mannequin with the help of a warm light stainless steel Macintosh Gr.4 blade direct laryngoscope modified with an adapted scale bar on the lingual end of the blade. The endoscopes were tested and compared for ease and traumatism of approach and time needed to capture an image at the optimal angle.

RESULTS

Due to significantly lower image quality compared to the rigid systems and distortion rates dependent on the angle at which the tip of the system was pointing, image distortion rates could not be determined for the fiber optics system. Therefore a correction algorithm could not be carried out for it at this stage of the study. Further assessment of the fiber optic system was also not carried out on the mannequin due to the model type, which did not have a connection between the nasal cavity and hypopharynx, needed to carrying out a proper by the book protocol of examination with this type of endoscopic system.

Form the collected data on the rigid systems it became clear that the endoscopic system with the least amount of optical distortion is the 0º one and the system with the highest distortion of the obtained images was the 70º , while the 30º system gave an image slightly less distorted than that of the 70º one (Table 1). The 90º system however was not in-depth field tested on the mannequin, as it was not considered suitable, due to the point of view which was further away from the larynx, compared to the other rigid systems, which would decrease the precision of the visualization of the laryngeal complex.

The comparison between the three rigid endoscopic system deemed appropriate for fine imaging of the human larynx proved that the 70º optical sys-

Table 1. Deviation of identical points from the central point on the calibration grid compared to the original endoscopic images obtained, in pixels.

	Centered distortion factor in the inner third	Centered distortion factor in the middle third	Centered distortion factor in the outer third
0º endoscope	13 pixels	28 pixels	40 pixels
30º endoscope	23 pixels	47 pixels	72 pixels
70º endoscope	27 pixels	64 pixels	92 pixels

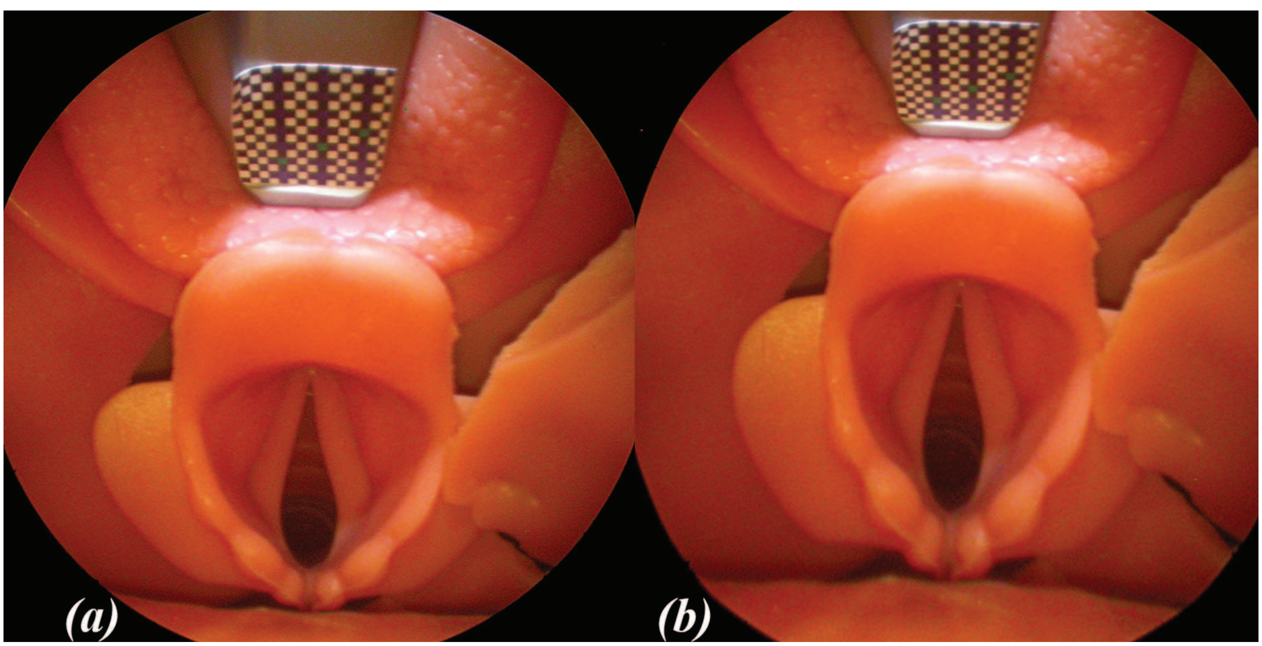

Figure 2. The non-corrected endoscopic image of the laryngeal complex of the mannequin obtained with the 70º rigid Hopkins rod lens endoscope (a). The same endoscopic image with the applied post process correction algorithm (b). Note the lingual end of the blade of the direct laryngoscope with the adapted scale bar, seen at the root of the tongue

tem, despite the higher distortion rate was the most suitable for the further in-depth evaluation, due to it being the least traumatic one and granting the easiest access to the laryngeal complex in the experimental setting described above.

The created software correction algorithm proved to be useful and easily applicable as a post process step for image correction and provided great results with the laryngeal complex of the intubation mannequin, allowing for the first time an anatomically and proportionally correct image of a human model larynx to be obtained using a standard 2-dimentional Hopkins rod lens endoscope (Figure 2).

DISCUSSION

The history of looking at the larynx in vivo dates back to 1854 when Spaniard Manuel Garcia used a dental mirror to directly visualize the vocal cords (6). The first in vivo photography and stereoscopic photography of a larynx was taken by Czermak only several years later in 1861 (7). After that further methods were developed for photographing the larynx with mirrors and in later years using television cameras (8).

Nowadays the gold-standard ENT endoscope is the classical Hopkins rod lens endoscope. ENT is also a medical specialty allowing for a single-hardware diagnostic approach, as the Hopkins rod endoscope is used with the same efficiency to visualize the laryngeal-hypopharyngeal complex, the trachea and bronchi, the esophagus, the nasal and paranasal cavities, the nasopharynx, the external and even the middle ear. However like all rigid endoscopes the Hopkins rod lens endoscope is plagued by image distortion and access limitations due to the way it is build. Therefore it can only be used to observe given structures, and cannot be used to measure the size and proportions of structures.

For now the most widely used modern endoscopic system is the flexible chip-on-the-tip nasopharyngolaryngoscope with the two being evenly matched in pros and cons. In the last decade 3-dimentional endoscopes have become commercially available, giving better space and depth perception than their 2-dimentional counterparts, but have been widely neglected by specialists due to their much higher market prices (9).

At the end of the day, image distortion due to the nature of the process of lens manufacturing stays the major drawback in the portfolio of endoscopes (10). Like with an ultrasound examination, an endoscopic one is only as good as the specialist carrying it out and the rate at which he has become accustomed to the status quo of image distortion (11).

With the described post process algorithm, anatomically correct imaging and measuring of structures is possible with a standard 2-dimentional Hopkins rod lens endoscope not only for ENT specialist, but for everyone using a similar system such as orthopedicians, gynecologists and thoracic surgeons to name only a few. The image correction process also allows the corrected endoscopy recordings to be used as a better educational tool than their distorted counterparts (12).

This could further prove helpful if a similar calibratable image correction algorithm is directly programed into the imaging system of standard endoscopes and endoscope aided surgical systems. This would not only portray structures in their anatomical proportions and size, but would also significantly shorten the learning curve and time needed to adapt and perfect endoscope aided surgery.

CONCLUSION

Despite the recent advances in endoscopy over the last 30 years its major setback – image distortion has remained in its status quo, with a lot left to be desired in the field of both post process image correction and live-feed direct correction.

The presented model algorithm allows for further anatomical research of the human laryngeal complex in vivo. This would give a good opportunity for both better surgical preparation and correct scientific in vivo measuring and studying of anatomic structures, not only in the area of ENT but everywhere where endoscopes are used.

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