Flexible Laryngoscopy: A Comparison of Fiber Optic and Distal Chip Technologies. Part 1: Vocal Fold Masses

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Summary: This study was designed to evaluate the usefulness of fiber optic (FO) and distal chip (DC) flexible imaging platforms in the diagnosis of true vocal fold pathology when compared to the gold standard rigid transoral laryngeal telescopic examination. The recorded strobovideolaryngoscopic examinations of 34 consecutive patients were evaluated retrospectively by five raters. All stroboscopy segments were evaluated by two laryngologists, an otolaryngologist, a laryngology fellow, and an otolaryngology resident. Seventeen patients were examined with a high-quality, large-diameter, FO flexible laryngoscope (FO group) and 17 random patients were examined with a DC flexible laryngoscope (DC group). Each patient was also examined using rigid laryngeal videostroboscopy at the same sitting. Examinations of three patients from each group were presented twice to monitor internal consistency. Diagnoses of intrinsic vocal fold pathology made with the flexible laryngoscopes were compared for accuracy to the diagnoses provided using the rigid laryngeal telescope. The ability to make clinical diagnoses via stroboscopy was statistically equivalent with FO technology and DC technology. Rigid examination provided more information than the flexible examination in 27% of the FO examinations and in 32% of the DC examinations. DC technology did not add diagnostic information to the examination when compared to a high-quality, large-diameter, FO endoscope. Rigid endoscopy provides superior images of the true vocal folds and is necessary for precise diagnosis in patients with true vocal fold pathology. Thus, the most cost-effective means of evaluation of voice disorders remains FO flexible endoscopy for dynamic voice assessment and the neurolaryngologic examination followed by rigid stroboscopy for evaluation of the vocal fold edge and mucosal wave. Strobovideolaryngoscopy using high-quality FO or DC flexible equipment should be reserved for patients who cannot tolerate transoral rigid examination, such as children and those with a very strong gag reflex.

Key Words: Flexible laryngoscopy–Fiber optic–Distal chip–Stroboscopy–Videostroboscopy–Vocal fold–Larynx–Digital–Videoendoscope–Laryngoscope–Mass–Mucosal wave–Larynx–Imaging–Cyst.

INTRODUCTION

Laryngoscopy is much different today than when Manuel Garcia first used a dental mirror to visualize his own vocal folds in 1854.[1] The introduction of the fiber optic (FO) laryngoscope in 1976 allowed visualization of the larynx in a natural state.[2] Since then, refinements in optics and lighting have improved the image obtainable with FO endoscopes. Recently though, the camera, or charged coupled device (CCD), has been miniaturized and placed at the distal (patient) end of the endoscope. This eliminates the optical fibers (and the image degradation that occurs within their course) used in FO endoscopes and produces remarkably clear images. Initially, only a monochromatic CCD was available for distal chip (DC) endoscopes. Color images were produced by rotating a disc of red, blue, and green filters between the light source and light cable.[3] The brain fused the rapidly alternating colors and allowed the viewer to "see" a full-color image. Newer models have a multichromatic CCD, allowing the use of white light and produce a much improved color image.

Laryngoscopy is not complete without slowing the rapid vibrations of the vocal fold for cycle-to-cycle inspection. As technology improves and cost declines, high-speed video may be used more widely to augment or replace stroboscopy. However, until then, the illusion of slow motion provided by stroboscopy is adequate in most situations for accurate diagnosis of structural vocal fold pathology. The diagnostic value of stroboscopy is well documented.[4–8] (A very complete bibliography on the clinical value of stroboscopy is available for those with further interest.)[9] Laryngeal stroboscopy is traditionally and excellently accomplished using a transoral rigid telescope with a 70° or 90° angled lens. Transoral rigid strobovideolaryngoscopy provides a superb view of the endolarynx with very little distortion or color misrepresentation provided the equipment is color balanced optimally. Rigid strobovideolaryngoscopy has been shown to be superior to FO imaging for diagnosing vocal fold lesions.[10] Not all patients tolerate rigid laryngoscopy, especially those with a sensitive gag reflex or who have limited jaw or neck mobility. It is also possible, but difficult to perform in most children.[11,12]

Although transnasal flexible laryngoscopy is unpleasant for some patients, with adequate topical anesthesia, it can be performed on nearly every patient, including children. Furthermore, it offers the examiner the ability to examine the vocal folds during connected speech. Dynamic voice assessment is limited with a telescope in the mouth and the tongue extracted.

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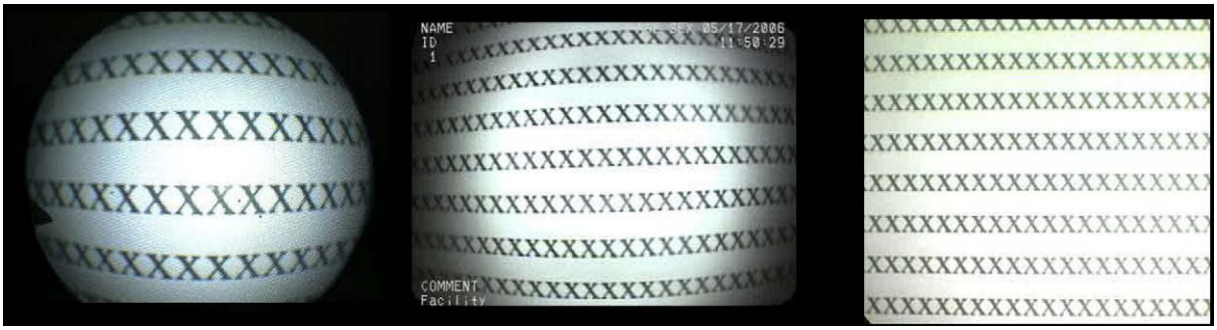

FIGURE 1. Barreling phenomenon with FO endoscope (left) and DC endoscope (center). No barreling with rigid endoscope (right).

The flexible scopes' advantage in evaluating gross motion does not extend to evaluating the fine details of the vibratory margin because of the optical limitations of flexible endoscopes and magnifying lenses. The small diameter of flexible endoscopes requires them to have a wide-angle lens which gives the appearance that an object is bent or rounded when it is straight (Figure 1). This distortion is called barreling and is always present in flexible FO and DC systems and essentially absent in rigid telescopes.

The main goal of this study was to determine whether DC endoscopes provide more diagnostic information than high-quality FO endoscopes. We also sought to determine whether DC endoscopes provide an image of high enough quality that they can replace the rigid telescope for routine strobovideolaryngoscopy.

METHODS

New patients at our voice center sequentially undergo both flexible and rigid laryngeal examination, and videostroboscopy is performed routinely with both endoscopes on the patient's initial visit. Subjects in the study were evaluated retrospectively. Equipment settings were set by the manufacturer at the time of installation, and cameras were white balanced and black balanced (for cameras that had a black-balance feature) at the beginning of each patient day. As in most centers, no other color adjustments of our equipment were made routinely. The flexible neurolaryngologic examination is performed first, followed by flexible strobovideolaryngoscopy. A rigid telescope is then used to obtain videostroboscopic images from a different perspective. One laryngologist (Y.H.-A.) routinely uses the FO endoscope (Olympus ENF-L3, Olympus Medical, Center Valley, PA) for the flexible portion of the examination, whereas the other (R.T.S.) uses the DC endoscope (Pentax VNL-1170K with EPK-1000 processor, KayPENTAX, Lincoln Park, NJ). The less-expensive and smaller (3.4 vs 4.2 mm) Olympus ENF P3/P4 models are more commonly used by otolaryngologists than the ENF-L3. The smaller size provides a lower-quality image. We chose to use the larger FO endoscope as a "best case" for this comparison (see Discussion).

The videostroboscopic examinations of 20 consecutive new patients for each type of flexible endoscope were extracted from the strobe database (KayPENTAX, Lincoln Park, NJ) and transferred to a personal computer. Six patients (three FO and three DC) were excluded due to poor video quality or flexible strobovideolaryngoscopy time of less than 20 seconds. This left 17 patients in the FO group and 17 patients in the DC group. For the patients who were included, all personal identifying information and all parts of the examination except stroboscopy were removed. The flexible stroboscopy segment was separated from the rigid stroboscopy segment, the segments were grouped by type, and then put in random order. Six patients (three FO and three DC) were randomly chosen to be presented twice in each group to allow assessment of intra-rater reliability. Each rater was given a DVD containing the randomized examinations.

All stroboscopy segments were evaluated individually by two laryngologists, an otolaryngologist, a laryngology fellow, and an otolaryngology resident. The raters were asked to make a diagnosis, if possible, of any abnormality on the vocal folds and to grade the normalcy of the mucosal wave (Table 1). The diagnosis obtained from imaging using the rigid laryngeal telescope, because it is widely regarded as the gold standard for awake laryngeal imaging, was used as the basis for comparison in this study. The two flexible endoscopes are compared to each other based on their degree of similarity to the rigid exam. The data were cataloged using *Microsoft Excel* (Microsoft Corporation, Redmond, WA) and analyzed using *SPSS* (SPSS, Inc.,

TABLE 1.
Possible Vocal Fold Diagnoses

Vocal Fold Masses and Lesions	Mucosal Wave Ratings
1. Mass (NOS)	1. Stiff—less than 30% lateral travel
2. Cyst	2. Normal—30–50% lateral travel
3. Nodule	3. Increased—greater than 50% lateral travel
4. Polyp	
5. Fibrous mass	
6. Pseudocyst	
7. Sulcus vergeture	
8. Sulcus vocalis	
9. Scar	
10. White lesions	
11. Reactive thickening	
12. Other	

TABLE 2.
Intrarater Reliability (Pearson's Coefficient)

Variable	Reviewer	*P* Value	
		Flexible With Duplicate Flexible	Rigid With Duplicate Rigid
Total surface lesions	Laryngologist 1	1	1
	Laryngologist 2	−0.316	0.926
	General otolaryngologist	0.707	0.485
	Fellow	0.959	0.842
	Resident	1	0.728

Chicago, IL) with the assistance of a biostatistician (D.L.). Statistical analysis was completed using Pearson's chi-squared coefficients and Cronbach's alpha calculation when appropriate.

RESULTS

Intrarater reliability paralleled experience level and was generally good. Pearson's correlation coefficients for the number of lesions identified are shown in Table 2. The senior laryngologist was most reliable. The resident, although consistent, did not identify most lesions, leading to a less-meaningful high score.

Interrater reliability was assessed using Cronbach's alpha; a score of greater than 0.7 is desirable. The FO endoscope had the most interrater variability with a Cronbach's alpha of 0.74. The best was the rigid endoscope for the patients in the DC group. Both rigid endoscopes had higher alpha scores than their corresponding flexible endoscopes (Table 3).

All raters diagnosed more lesions on the rigid endoscopic examinations compared with the flexible examinations (Table 4). When specifically considering vocal fold masses, the most common diagnosis for both flexible and rigid examinations was "No mass." On the flexible technology, the second most common diagnosis was "Bilateral Mass," whereas a more specific diagnosis was made on the rigid examinations: "Bilateral Cyst" and "Right Cyst" (Table 5).

When considering just the vocal fold mass diagnoses, the FO endoscope identified 86.3% of the lesions identified on the same patients using a rigid telescope. The DC endoscope was similar, identifying 87.3% of masses, an insignificant difference between flexible endoscopes.

The percent of diagnoses that agreed with the diagnosis made using the rigid endoscope was equal between the FO and DC endoscopes. The FO endoscope provided a specific diagnosis slightly more often than the DC endoscope (FO: 20%, DC: 16%), but this was statistically insignificant ($P = 0.613$).

The rigid examination provided more detail about the mass on the vocal fold in about one third of patients (FO: 27%, DC: 32%) (Table 6). With increasing rater experience, there was less discrepancy between the flexible diagnosis and those obtained by the corresponding rigid examinations. With the FO endoscope, a more detailed rigid diagnosis was found in 20% of the cases by laryngologist 1 (R.T.S.) and 5% by laryngologist 2 (Y.H.-A.). For the DC endoscope, both laryngologists made more detailed diagnoses with the rigid endoscope in 25% of the cases.

The increased detail afforded by the rigid telescope was scrutinized to determine its meaning by looking at each case in which the rigid examination provided more detail to see if the added detail would have changed the treatment plan. For example, if the flexible endoscope had provided a diagnosis of "Bilateral Mass NOS" and the rigid endoscope provided "Bilateral Cyst," the treatment would likely change, but "Bilateral Mass NOS" and "Bilateral Nodules" would likely be treated similarly in our practice. From this review, the increased detail provided by the rigid examination in the FO group (27 ratings) would have led to a change in treatment 81% of the time (22/27). For the DC group (32 ratings), the added information from the rigid exam would have changed

TABLE 3.
Interrater Variability (Cronbach's Alpha >7, Desirable)

	FO Group		DC Group	
Variable	Flexible	Rigid	Flexible	Rigid
Overall total lesions	0.741	0.816	0.822	0.831

TABLE 4.
Comparison of Mean Number of Overall Lesions Identified by Endoscope and Reviewer

Reviewing Doctor	Examination Type	Total Overall Lesions	
		Flexible	Rigid
Laryngologist 1	FO	1.06	1.29
	DC	1.24	1.53
	Total	1.15	1.41
Laryngologist 2	FO	1	1.35
	DC	1.24	1.65
	Total	1.12	1.5
General otolaryngologist	FO	0.88	1.53
	DC	1.24	1.76
	Total	1.06	1.65
Fellow	FO	1.41	2
	DC	1.59	1.82
	Total	1.5	1.91
Resident	FO	0.12	0.88
	DC	0.73	1.06
	Total	0.41	0.97

TABLE 5.
Top Three Diagnoses Made With Each Endoscope

	FO Group		DC Group	
	Flexible	Rigid	Flexible	Rigid
1	No mass (46)	No mass (40)	No mass (37)	No mass (30)
2	Bilateral mass NOS (11)	Right cyst (6)	Bilateral mass NOS (10)	Bilateral cyst (12)
3	Left cyst (5)	Bilateral reactive thickening (5)	Right mass NOS (6)	Reinke's edema (7)

the treatment in 63% of cases (20/32). This difference was insignificant ($P = 0.1$).

In evaluating the ability of the endoscopes to provide information regarding the mucosal wave, raters were asked if the wave was stiff, normal, or increased. For a more meaningful comparison, we grouped patients according to the presence or absence of mass lesions on the vocal fold. As expected, more mucosal waves were rated as stiff in patients with mass lesions than those without masses. Both flexible endoscopes trended toward identifying more mucosal wave pathology than was seen on rigid endoscopy. This was more apparent with the FO than the DC technology, but neither trend approached significance ($P = 0.6$).

DISCUSSION

The new generation DC flexible endoscopes typically provide a better image than the high-quality FO technology used. Our question was not which provides a better image, but is that "better" image any more useful than what we already have?

When comparing flexible endoscopes against the "gold standard" rigid laryngeal telescopes, our data do not show that the DC technology provides any advantage over the traditional FO technology in terms of its ability to detect lesions. If a lesion was detected, there was also no difference between FO and DC technology in how accurate the diagnosis would be compared to traditional rigid endoscopy. In fact, the FO endoscopes were 5% better at providing a specific diagnosis than the DC endoscopes across all raters, and in the most experienced hands, the FO endoscopes were 5–20% more accurate than the DC endoscopes. This difference might have been due to how familiar the users were with the endoscopes, as raters who used the DC endoscopes more often had a closer agreement between flexible and rigid diagnoses using the DC endoscope.

Considering how the level of detail provided by the rigid endoscope compares to the flexible systems and how useful that information is, both systems were about 30% less detailed than the rigid scope. In the cases where the specific diagnoses from the flexible and rigid endoscopes differed, the DC system may have more closely approximated the rigid system clinically, as 28% fewer treatment changes would have been made using the DC endoscope compared to the FO endoscope. However, treatment changes were still likely in more than half of patients when the DC and rigid diagnoses differed. Thus, the FO endoscope provided more detail than the DC endoscope, but this may be balanced by some improved clinical applicability of the information from the DC examination.

For mucosal wave evaluation, the DC technology was slightly more accurate than FO technology, but there was a marginal trend toward over-calling mucosal wave abnormalities with both flexible endoscopes. This may be a function of the barreling effect caused by the small diameter lens on the flexible endoscopes.

The following are cost averages for similar products by two different companies at the time of this writing. The approximate average cost (including cameras, etc) to produce a recordable image (as quoted by Pentax and Olympus sales representatives to the primary author) using a top-quality FO laryngoscope is approximately $16,000. The average cost of a DC flexible endoscope is $26,000 and the required processor is an average of an additional $15,000, for a total nearing $41,000 to produce a recordable image. Given the equal sensitivity of the flexible systems and the superiority of the rigid examination in providing detail, the added expense does not seem justified for the average practicing otolaryngologist at the present time.

There are a few areas that need to be highlighted when interpreting these data. This study was conducted comparing deluxe-model FO endoscopes to DC technology. Less-expensive FO endoscopes are used more commonly by otolaryngologists, and our use of the ENF-L3 FO endoscope may have blunted differences between FO and DC equipment that would have been apparent otherwise. Also, ideally, all patients would be examined with all three endoscopes by one examiner in the same sitting using a standard protocol and all raters would make their diagnosis on the same equipment at the same time as the other raters. Because this study was retrospective, those elements in study design were not possible. Finally, although the range of experience among the raters may mimic the demographics of those who would use these endoscopes, it may have influenced the results by introducing too many variables. We hope to repeat the study in the future optimizing as many of these issues as possible, and including a more commonly used, less-expensive FO endoscope.

TABLE 6.
Comparison of Diagnosis Results by Examination Type

	% Within Exam Type	
	DC and Rigid	FO and Rigid
Same diagnosis	52	53
Different diagnosis	7	12
Flexible more detailed	9	8
Rigid more detailed	32	27
Total	100	100

CONCLUSION

In light of the data presented in this report, the authors recommend using either high-quality FO or DC flexible technology for examining the neurologic integrity of the larynx and dynamic voice evaluation, and rigid strobovideolaryngoscopy for examining the structural integrity of the membranous vocal fold and mucosal wave. In the event that the patient cannot tolerate transoral rigid strobovideolaryngoscopy, either flexible system is acceptable to use for stroboscopy. Current DC technology is not good enough to replace the laryngeal telescope. We look forward to assessing new DC technology in the future and are hopeful that DC images will eventually be equivalent to those obtainable by rigid laryngoscopy. If this occurs, it may eliminate the need for the routine use of rigid transoral telescopes in a general otolaryngology practice.

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