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Diagnostic utility of flexible fiberoptic nasopharyngolaryngoscopy recorded onto a smartphone: A pilot study

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Abstract *Objectives:* To evaluate the diagnostic accuracy of flexible fiberoptic examinations of the larynx recorded onto smartphones.

Methods: Prospective, blinded study of inpatients requiring laryngoscopy. A live exam was performed, then a smartphone was attached to the endoscope using a novel coupling device and the same examination was recorded. The live and recorded exams were evaluated by two laryngologists, each blinded to the findings of the other.

Results: Eighteen subjects were evaluated. Evaluation of airway patency was identical (Kappa = 1.0 [1, 1]). Evaluation of vocal cord motion was identical for 14 subjects: 9 normal, 3 paretic, 2 paralytic (Kappa = 0.69 [0.38, 1]).

Conclusion: There is high correlation between laryngeal diagnoses using live flexible fiberoptic laryngoscopy and recordings using a coupling device to transfer the recordings on to smartphones. Critical findings such as airway patency and vocal fold motion showed the highest correlation.

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Introduction

The use of smartphones, especially those with cameras, is widespread in medicine. A recent survey found over 85% of physicians at ACGME accredited programs use smartphones.[1] These devices contain cameras that can take photographs and video in high-definition, store a large amount of data, and transmit wirelessly.

Studies evaluating the use of photos taken and transmitted by cellular telephones have been performed in several clinical settings including outpatient evaluation of nasal fractures, emergency room triage of hand trauma, monitoring of the status of free flap reconstructions, and emergency evaluation of airway radiology.[2-5] These have shown improvements in triage and immediate patient care through the use of this technology versus the standard consultation methods. Other studies have evaluated the use of more traditional methods of transmitting photographs and videos in otolaryngology, showing the advantages of remote consultation with specialists.[6] Similar methods would be useful for the documentation and rapid sharing of laryngeal examinations given its complex anatomy and possible need for acute intervention. There has been recent interest in the use of smartphone technology for video recordings, and a recent study demonstrated that there was no significant difference in the video quality ratings between mobile and tower video recordings.[7]

The current method for recording Flexible Fiberoptic Nasopharyngolaryngoscopy (FF-NPL) examinations requires a camera to be attached to the optical eyepiece of the endoscope, which is then wired to a video tower. Alternatively, distal-chip endoscopes can provide excellent images, however are limited by cost and the physical size of the infrastructure needed to utilize their capabilities. It would be of benefit to physicians and patients to have a method that allows high quality recording of FF-NPL examinations which is portable, reliable, and secure. As utilization of a new method requires assurance that diagnostic accuracy is not degraded by use of the new technology, the goal of this study is to evaluate the diagnostic accuracy of flexible fiberoptic examinations of the larynx recorded onto smartphones as compared to the live examination.

Methods

IRB

This study was approved by the Institutional Review Board at the Hospital of the University of Pennsylvania under protocol number 814831.

Patient recruitment/endoscopy

Consecutive inpatients at the Hospital of the University of Pennsylvania whose primary medical team requested an Otorhinolaryngology consult were considered for participation. The primary consulting otorhinolaryngologist would evaluate the patient, and if a bedside FF-NPL examination was required the patient would be asked to participate in the study. If they agreed the senior author (NM) would perform the endoscopy at the bedside through the optical eyepiece using a flexible laryngoscope (Karl Storz Tuttlingen, Germany). Once her exam was complete, but before the endoscope was withdrawn, she would attach the smartphone adapter and record approximately 30 s of video on an iPhone 4 (Apple Corporation, Cupertino, California, USA). Videos were extracted from the smartphone and transmitted electronically to a second laryngologist (KL) who was blinded to the history and pathologic findings of

the original exam. A diagnostic survey was created for this study, which was completed by both physicians immediately following their respective examinations (Fig. 1).

Smartphone adapter

A custom-designed adapter which included a plastic casing surrounding a lens designed for telephoto pictures on an iPhone 4 (Apple Inc., Cuppertino, CA) with an approximately 8× optical zoom (Apexel Technology Co., Shenzhen, China) was used (Figs. 2 and 3). The same adapter and phone were used for all examinations.

Statistical analysis

Statistical analysis was performed using R version 3.1.1 (http://cran.us.r-project.org) via RStudio 0.98.953 (http://www.rstudio.com). Un-weighted Cohen's Kappa correlation coefficients were calculated with their 95% confidence intervals, and categorical interpretation was based on Landis and Koch.[8]

Results

Eighteen patients were evaluated between July 2013 and January 2014. There were a significant number of blank responses on the following survey sections: Nasal Cavity, Nasopharynx, Oropharynx, and Base of Tongue, which were excluded from the statistical evaluation. Data is displayed in Table 1.

Evaluation of airway patency was identical by the 2 methods, with 17 determined adequate, and 1 inadequate using both live and recorded examination (Kappa 1.0, 95% CI [1, 1]).

Evaluation of vocal ford motion was similarly identical between evaluators for 14 of the 18 subjects (78%). Nine were interpreted as normal, 3 as paretic, and 2 as paralytic (Kappa 0.69 [0.38, 1]). There was no disagreement on the sidedness of the vocal fold involved (3 left, 1 right, 1 bilateral). There was one 'Paretic'-'Paralytic' and two 'Normal'-'Paretic' discrepancies. There were no 'Normal'-'Paralytic' discrepancies. One response was left blank.

Evaluation of each sub-site showed overall moderate reliability (Kappa 0.51, [0.34, 0.69]). Evaluation of the arytenoids had fair agreement with a Kappa of 0.28 [0.022, 0.53]. Five were scored as 'Normal' for both, and five as 'Edema' for both. The most common discrepancy was 'Normal' on live exam and 'Edema' on recorded exam (n = 7). One 'Lesion' on live and 'Edema' on recorded exam was noted.

Evaluation of the epiglottis showed a Kappa of 0.68 [0.29, 1]. Eleven were 'Normal' and three showed 'Edema' on both evaluations. One subject was rated as 'Malacia' on live exam and 'Normal' on recorded exam, and one as 'Normal' on live exam and 'Edema' on recorded exam. Two subjects were not scored by both methods and were not included.

The aryepiglottic folds showed substantial agreement with a Kappa of 0.85 [0.57, 1]. Thirteen subjects were scored as 'Normal', and 4 as 'Edema' on both. One patient

Nasal Endoscopy Scoring Sheet

Date
Pt Identification Number ___
Attending Reviewer ___
This subject was evaluated: Live ___   By Recording ___

Nasal Cavity:

      Masses: Present___   Absent___
      Abnormality: Left___ Right___ Bilateral/Both___

Nasopharynx
      Masses: Present___   Absent___
      Abnormality: Left___ Right___ Bilateral/Both___

Oropharynx:
      Masses: Present___   Absent___
      Palatine Tonsils: Normal____ Masses___ Lesions___
      Abnormality: Left___ Right___ Bilateral/Both___

Base of Tongue:
      Masses: Present___   Absent___
      Abnormality: Left___ Right___ Bilateral/Both___

Larynx:
      Epiglottis: Normal___ Edematous___ Mass___ Lesion___ Malacia___
      Abnormality: Left___ Right___ Bilateral/Both___

      Arytenoids: Normal___ Edematous___ Mass___ Lesion___ Malacia___
      Abnormality: Left___ Right___ Bilateral/Both___

      AE Folds: Normal__ Edematous___ Mass___ Lesion___ Malacia___
      Abnormality: Left___ Right___ Bilateral/Both___

      False Vocal Cords: Normal__ Edematous___ Mass___ Lesion___ Malacia___
      Abnormality: Left___ Right___ Bilateral/Both___

      True Vocal Cords: Normal__ Edematous___ Mass___ Lesion___ Malacia___
      Abnormality: Left___ Right___ Bilateral/Both___

      Movement: Normal___ Paresis___ Paralysis___
      Abnormality: Left___ Right___ Bilateral/Both___
      Adequacy of airway Y___ N____

Fig. 1   Survey completed by each physician following either live or recorded FF-NPL.

was scored as 'Normal' on live and 'Edema' on recorded exam.

Scoring of the false vocal folds had substantial agreement with a Kappa of 0.68 [0.57, 1]. Thirteen subjects were scored as 'Normal', and 3 as 'Edema' in both circumstances. There was one 'Normal' on live exam and 'Edema' on recorded, and 1 'Edema' on live exam and 'Normal' on recorded.

The true vocal folds showed poor reliability with a Kappa of 0.14 [−0.28, 0.55]. Eleven subjects were scored as 'Normal' on both exams. 'Mass' was identified on both exams for 1 subject, and 1 'Lesion' and 1 'Mass' were each noted on recorded exams that were scored as 'Normal' on live exam. Two subjects were scored as 'Normal' on live exam and 'Edema' on recorded exam, and 1 as 'Edema' on live exam and 'Normal' on recorded exam.

Discussion

The availability of a reliable, secure, portable, and high-quality method for recording laryngoscopic examinations would greatly facilitate patient evaluation and triage. The utility of telemedicine and the application of smartphone technology to its expansion has been previously demonstrated.[2–7] Because there are differences between images captured by consumer level photographic equipment, and those meant for scientific or medical applications, the methods need to be validated in order to ensure diagnostic information is not lost.[8] In this study, a portable, light-weight, and relatively simple system was devised to allow direct viewing and recording of FF-NPL examinations onto a smartphone, which allowed a comparison of the images

Fig. 2 Custom designed smartphone-endoscope adapter used to capture video.

Fig. 3 Example image obtained using coupling device and iPhone 4.

obtained to the live examination directly through the scope.

Utilizing the iPhone 4, a custom adapter, and a commercially available lens system, the ability to reproducibly evaluate FF-NPL examinations via recording on a smartphone was demonstrated. The inter-rater reliability between two laryngologists viewing live and recorded examinations was shown to have complete agreement for airway patency, 'substantial agreement' for paresis/paralysis, and 'moderate agreement' for evaluation of the

mucosa of each sub-site of the larynx.[9] Further, significant correlations for all sites except the true vocal cords even when the physician viewing the recorded exam was not given any historical or contextual information about the patient, was shown.

Although the overall findings support the utility of this method, this study has several limitations. First, there was a limited number of patients evaluated. Secondly, the survey was designed to evaluate the entire aerodigestive tract proximal to the vocal cords; however, the recordings often did not contain adequate recording time of the non-laryngeal portions for evaluation. This was a consequence of adding the device to the endoscope after an adequate live exam was complete, but before removal of the endoscope from the subject. This resulted in most of the recordings being focused primarily on the larynx, with insufficient recording of the other sites, which resulted in their subsequently removal from the final analysis.

Further, there were variations in correlations between reviewers noted for some of the laryngeal sub-sites. This may represent expected variation for this subjective endpoint, or an artifact of the recording that skews interpretation of these attributes of the mucosa. There was lack of a clear deviation towards one finding in the live or recorded situation versus the other, except for a trend towards scoring 'Edema' versus 'Normal' for the arytenoids on recorded exam over live. This study was not designed to test if this was a difference in the judgment of the two reviewers, or an artifact of the recording process.

Specifically, the low correlation found for the true vocal folds may represent a limitation of this method. Although the statistical correlation was low for this sub-site — and the only one for which the confidence interval crossed null — individual analysis of the differences seemed less significant. There were several 'Normal' — 'Edema' discrepancies, but none of which where the edema was judged to be compromising the airway. Additionally, the discrepancies on identification of a 'Mass' or 'Lesion' on one exam and not the other were both 'overcalls' on the recorded exam, and not 'misses'. This study was too small to properly evaluate if this was a consequence of low sample size, or a true limitation of the method.

Finally, during the course of recording and evaluation it became apparent that the brightness of the light source used had a significant impact on the quality of the recorded exams. This, along with proper framing, focusing, and exposure settings on the phone were optimized with experience. Additionally, subsequent testing of the device has shown that using it for the entire exam significantly improves the quality of the recordings, as the exposure and focus settings can be more precisely adjusted before scope placement.

Conclusion

The application of smartphone technology to patient care represents an opportunity to reduce costs, improve communication, and ease accurate documentation. This study supports the diagnostic reliability of a simple device to allow direct recording of flexible fiberoptic nasopharyngolaryngoscopy onto smartphones.

Table 1 Live versus recorded laryngeal evaluation by sub-site.

Adequacy of airway					
Agree 'Yes'	Agree 'No'	Disagree	Missing	Kappa	95% CI
17	1	0	0	1	[1, 1]
Vocal cord motion					
Agree Normal	Agree Paretic/Paralytic	Disagree	Missing	Kappa	95% CI
9	5	3	1	0.69	[0.38, 1]
Epiglottis					
Agree Normal	Agree Abnormal	Disagree	Missing	Kappa	95% CI
11	3	2	2	0.68	[0.29, 1]
Arytenoids					
Agree Normal	Agree Abnormal	Disagree	Missing	Kappa	95% CI
5	5	8	0	0.28	[0.022, 0.53]
AE folds					
Agree Normal	Agree Abnormal	Disagree	Missing	Kappa	95% CI
13	4	1	0	0.85	[0.57, 1]
False vocal cords					
Agree Normal	Agree Abnormal	Disagree	Missing	Kappa	95% CI
13	3	2	0	0.68	[0.57, 1]
True vocal cords					
Agree Normal	Agree Abnormal	Disagree	Missing	Kappa	95% CI
11	1	6	0	0.14	[−0.28, 0.55]
All sub-sites					
Agree Normal	Agree Abnormal	Disagree	Missing	Kappa	95% CI
53	16	19	2	0.51	[0.34, 0.69]

Conflicts of interest

The first and last authors (JAB and NM) on this manuscript hold intellectual property interest in the device used to collect data for this study. The same authors are co-founders of a company whose purpose is to commercialize this technology.

References

1. Franko OI, Tirrell TF. Smartphone app use among medical providers in ACGME training programs. *J Med Syst*. 2012;36:3135−3139.
2. Moumoulidis I, Mani N, Patel H, Leong P. A novel use of photo messaging in the assessment of nasal fractures. *J Telemed Telecare*. 2007;13:387−390.
3. Lam TK, Preketes A, Gates R. Mobile phone photo messaging assisted communication in the assessment of hand trauma. *ANZ J Surg*. 2004;74:598−602.
4. Engel H, Huang JJ, Tsao CK, et al. Remote real-time monitoring of free flaps via smartphone photography and 3G wireless Internet: a prospective study evidencing diagnostic accuracy. *Microsurgery*. 2011;31:589−595.
5. Eze N, Lo S, Bray D, Toma AG. The use of camera mobile phone to assess emergency ENT radiological investigations. *Clin Otolaryngol*. 2005;30:230−233. discussion 233.
6. Garritano FG, Goldenberg D. Successful telemedicine programs in otolaryngology. *Otolaryngol Clin North Am*. 2011;44:1259−1274. vii.
7. Liu H, Akiki S, Barrowman NJ, Bromwich M. Mobile endoscopy vs video tower: a prospective comparison of video quality and diagnostic accuracy. *Otolaryngol Head Neck Surg*. 2016;155:575−580.
8. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977;33:159−174.
9. Skandarajah A, Reber CD, Switz NA, Fletcher DA. Quantitative imaging with a mobile phone microscope. *PLoS One*. 2014;9:e96906.

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