Effect of Chromoendoscopy Filters on Visualization of KTP Laser–Associated Tissue Changes: A Cadaveric Animal Model

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Abstract

Standard KTP laser (potassium titanyl phosphate) wavelength-specific protective eyewear often impairs visualization of tissue changes during laser treatment. This sometimes necessitates eyewear removal to evaluate tissue effects, which wastes time and poses safety concerns. The objective was to determine if “virtual” or “electronic” chromoendoscopy filters, as found on some endoscopy platforms, could alleviate the restricted visualization inherent to protective eyewear. A KTP laser was applied to porcine laryngeal tissue and recorded via video laryngoscopy with 1 optical (Olympus Narrow Band Imaging) and 8 digital (Pentax Medical I-scan) chromoendoscopy filters. Videos were viewed by 11 otolaryngologists wearing protective eyewear. Using a discrete visual analog scale, they rated each filter on its ability to improve visualization. No filter impaired visualization; 5 of 9 improved visualization. Based on statistical significance, the number of positive responses, and the lack of negative responses, narrow band imaging and the I-scan tone enhancement filter for leukoplakia performed best. These filters could shorten procedure time and improve safety; therefore, further clinical evaluation is warranted.

Keywords

KTP laser, in-office surgery, virtual chromoendoscopy, electronic chromoendoscopy, narrow band imaging, i-scan, protective eyewear

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The KTP laser (potassium titanyl phosphate) is a versatile tool that can be used to treat a variety of laryngeal and pharyngeal lesions; however, subtle treatment effects are poorly visualized through standard KTP laser wavelength-specific protective eyewear (KPE). This sometimes necessitates placement of the laser into “stand-by” mode for removal of protective eyewear to evaluate treatment effect, which raises safety concerns and lengthens procedure time. KPE essentially filters all violet, blue, and green light and has been shown to cause blue-yellow and red-green color confusion.1 Color confusion in the operating room that is associated with the use of KPE has been reported in the urology,1 otolaryngology,2 and anesthesiology3 literature. No publications exist reporting color confusion in laryngeal KTP procedures.

Chromoendoscopy filters were designed to enhance the appearance of dysplastic mucosa during screening gastrointestinal endoscopy procedures. These filters are available on several endoscopy platforms and can be turned on and off with the push of a button. Narrow band imaging (NBI; Olympus America, Center Valley, Pennsylvania) is an example of optical chromoendoscopy whereby the wavelength of the light source is modified to enhance the submucosal vasculature.4,5 I-scan (Pentax Medical, Montvale, New Jersey) is an example of digital chromoendoscopy whereby the image is subjected to customizable digital postprocessing.5 I-scan consists of 3 algorithms: surface enhancement...
(SE), contrast enhancement (CE), and tone enhancement (TE). Two preset filters (i-scan 1 and i-scan 2) are combinations of all 3 algorithms. Custom TE filters can be configured to enhance certain mucosal features and include esophageal (TE:e), gastric (TE:g) and colonic mucosa (TE:c), Barrett’s esophagitis (TE:b), hemoglobin (TE:r), and leukoplakia (TE:d).

These filters are not intended for use with KPE; however, enhancement of certain wavelengths could improve the appearance of treatment changes when viewed through KPE. Our hypothesis was that each filter would alter the surgeon’s ability to visualize tissue changes associated with KTP treatment via KPE, in comparison with KPE alone.

**Materials and Methods**

This study was exempt from Institutional Animal Care and Use Committee approval as a laboratory-based study with no living animal contact. Cadaveric porcine larynges were bisected. An AuraXP KTP laser with a 0.4-mm EndoStat Fiber (Boston Scientific, Marlborough, Massachusetts) was used to ablate the laryngeal mucosa to a KTP 1 or 2 tissue effect (superficial tissue blanching with or without epithelial disruption). Settings were 35 W, 15-millisecond pulse width, and 2 pulses per second.

The filters included an optical filter (NBI; Olympus America) and 8 digital filters (i-scan 1, i-scan 2, TE:r, TE:d, TE:b, TE:e, TE:g, TE:c; Pentax Medical). I-scan 1 and i-scan 2 settings were factory programmed and consisted of SE3, CE2, and TE:r for i-scan 1 and SE3, CE2, and TE:d for i-scan 2. The TE filters were used in isolation without SE or CE. For NBI, an Olympus VISERA ELITE processor was used with an ENF-VH video rhinolaryngoscope. For the digital filters, a Pentax Medical EPK-i processor was used with a VLS-1190STK video nasopharyngolaryngoscope.

Ten-second KTP video clips were produced with unfiltered and filtered images side by side, then arranged into 1 video in random order. The raters included 11 otolaryngologists wearing KPE (4 were laryngologists), blinded to the type of filter. Each was given a questionnaire asking to compare one’s ability to visualize treatment-related tissue changes with KPE alone and with each filter, using a 10-point discrete visual analog scale. The scale ranged from 1 ("much worse" visualization with the filter) to 10 ("much better"), with 5 or 6 indicating similar visualization with or without the filter.

A group comparison was made with a Kruskal-Wallis test, and comparisons of each filter were made against a neutral rating with a 2-tailed Wilcoxon signed-rank test. Interrater reliability was assessed with the intraclass correlation coefficient based on a 2-way mixed effects model. Statistical significance was set at $P < .05$.

**Results**

**Figure 1** shows digital photographs taken while a sample video clip was played on a high-definition monitor. This demonstrates KTP laser-related tissue effects consistent with typical ablative KTP procedures and simulates visualization with and without KPE. It also demonstrates subjectively improved visual resolution of the treatment area with the filter with KPE.

**Figure 2** illustrates the number of positive responses for each filter. A Kruskal-Wallis test indicated that a significant difference existed for responses to at least 1 filter ($P = .001$). **Table 1** presents descriptive statistics of pooled responses by the raters for each filter. Responses from 5 of 9 filters were statistically different from neutral. Since all 5 scored higher than the neutral rating, this difference indicates improved visualization with these filters. If statistical
significance is considered in addition to the number of positive ratings and the lack of negative ratings (Table 1), NBI and TE:d performed the best. Additionally, the worst-performing filter (TE:e) was no different from neutral ($P = .271$), indicating that no filter impaired visualization.

Interrater reliability was good, based on an intraclass correlation coefficient of 0.71 (95% CI, 0.32-0.92).

Discussion

NBI has been evaluated in the otolaryngology literature for the detection of laryngeal and pharyngeal cancers and to evaluate laryngeal papillomatosis. I-scan has been used to detect lung cancer and for Barrett’s and reflux esophagitis. Ellis et al described difficulty in discerning active bleeding during KTP nasal procedures due to KPE, then developed and validated a postcapture image enhancement filter with Adobe Photoshop. It is also of interest that chromoendoscopy filters have been used to evaluate the extent of laryngeal papillomatosis during and prior to treatment, however, to our knowledge, no studies attempted to apply these filters during KTP laser treatment to enhance visualization of treatment changes.

These filters are present on most endoscopy platforms and provide a simple and effective way to improve visualization during KTP laser procedures. It makes intuitive sense that a filter designed to enhance leukoplakia (TE:d) would perform well, since tissue blanching was the end point. The benefit of NBI is not as intuitive. Perhaps enhancement of blue/green wavelengths provides greater contrast to wavelengths excluded by KPE. Another important outcome is that no filter inhibited visualization.

This study has limitations. Cadaveric tissue was used, and living tissue may behave differently with chromoendoscopy filters. Also, interrater reliability was good but not excellent. The level of agreement may have been improved if only laryngologists were surveyed.

Conclusions

Several filters improved visualization, and no filter impaired visualization; therefore, optical and digital filters (specifically, NBI and TE:d) are both recommended for clinical use.

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Author Contributions

Christopher M. Johnson, designed study, collected and analyzed data, wrote manuscript, revised manuscript, final approval; Mariah B. Pate, collected and analyzed data, wrote manuscript, final

Table 1. Outcomes for Each Filter.

<table>
<thead>
<tr>
<th>Filter</th>
<th>Responsesa</th>
<th>Mean</th>
<th>Median (IQR)</th>
<th>P Valueb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrow band imaging</td>
<td>8</td>
<td>3</td>
<td>0</td>
<td>7.64</td>
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<tr>
<td>I-scan</td>
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<td>4</td>
<td>1</td>
<td>6.36</td>
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<tr>
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<td>5</td>
<td>5</td>
<td>1</td>
<td>6.27</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>6.59</td>
</tr>
<tr>
<td>Tone enhancement</td>
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<td>4</td>
<td>0</td>
<td>6.91</td>
</tr>
<tr>
<td>Hemoglobin</td>
<td>3</td>
<td>7</td>
<td>1</td>
<td>5.77</td>
</tr>
<tr>
<td>Leukoplakia</td>
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<td>8</td>
<td>3</td>
<td>5.14</td>
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<tr>
<td>Barrett’s esophagitis</td>
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<td>4</td>
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<tr>
<td>Gastric</td>
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</tr>
<tr>
<td>Colonic mucosa</td>
<td>5</td>
<td>6</td>
<td>0</td>
<td>6.41</td>
</tr>
</tbody>
</table>

Abbreviation: IQR, interquartile range.

aBetter, neutral, and worse refer to ratings of 7-10, 5 or 6, and 1-4, respectively.

bP value represents the result of a 2-tailed Wilcoxon signed-rank test, with the null hypothesis being a response of 5.5 (neutral). Bold indicates statistical significance, $P < .05$. 

Figure 2. Number of ratings indicating improved visualization (score $>6$) for each filter. The x-axis is fixed at 11 because there were 11 raters. NBI, narrow band imaging; TE, tone enhancement (TE:b, Barrett’s esophagitis; TE:c, colonic mucosa; TE:d, leukoplakia; TE:e, esophageal; TE:g, gastric; TE:r, hemoglobin).
approval; **Gregory N. Postma**, designed study, revised manuscript, final approval.

**Disclosures**

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**References**