Infrared endoscopic system for bleeding-point detection after flushing with indocyanine green solution (with videos)

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Background: Infrared endoscopy is used to visualize vessels in the GI tract. By applying this system, we developed a new method to visualize a bleeding point during endoscopic resection.

Objective: This study aimed to evaluate the ability of infrared endoscopy to detect a bleeding point during endoscopic resection and to elucidate the mechanism required for clear visualization of a bleeding point by in vitro color analysis.

Design: Observational case series.

Setting: A cancer-referral center.

Patients and Interventions: A total of 10 bleeding sites were observed during endoscopic resection of upper-GI cancers by infrared endoscopy after flushing with indocyanine green (ICG) solution (0.125 mg/mL water).

Main Outcome Measurements: Detection of bleeding points.

Results: Bleeding points were identified in all bleeding sites by infrared endoscopic viewing. Bleeding points were displayed in white, whereas, an ulcer bed was in blue and pooled blood was a blue-to-gray color. By in vitro color analysis, blood was white, blood twice diluted with ICG solution was dark blue, and blood 4-times diluted with ICG solution was light blue on infrared endoscopic views. Color differences with blood dilution were more obvious in an infrared endoscopic view compared with a conventional endoscopic view. Blood thickness, movement, and clotting did not influence the color differences.

Limitations: Uncontrolled study.

Conclusions: We reported a flushing method by which we could detect all bleeding points during endoscopic resection. Clear visualization of bleeding points comes from differences in blood and ICG concentration between spurting and pooled blood.

Endoscopic resection (ER) is a minimally invasive and potentially curative treatment for GI tumors.1-3 During ER, bleeding can sometimes occur from a resected site. Bleeding elongates the time taken for the procedure, which can become more difficult because the view of the operative field is deteriorated. Infrared rays can penetrate deep into tissue because of their limited scattering characteristics and low absorption by water and hemoglobin.

By using these characteristics, infrared endoscopy was developed to visualize vessels in the GI tract. The method has been used to assess the depth of involvement of gastric cancers and other vascular lesions.4-10 We reported the ability of this method to clearly visualize bleeding points during ER.11 For this, we injected indocyanine green (ICG) solution into the submucosal layer (submucosal injection method) for clear visualization of a bleeding point. Because injecting ICG into the submucosal layer is difficult after ER, we had to inject ICG before ER, even for non-bleeders. We recently found that we could also visualize bleeding points after flushing with ICG solution (the “flushing method”), after confirming bleeding. The flushing method is simple and would be applicable to other bleeding situations.

Abbreviations: CCD, charge-coupled device; ER, endoscopic resection; ICG, indocyanine green.

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With both the submucosal injection method and the flushing method, clear visualization of bleeding points comes from color differences between pooled blood (blue to gray) and spurting blood (white). However, there are no reports of the mechanism that leads to this color difference. This study aimed to evaluate the ability of an infrared endoscopic view to detect a bleeding point during ER. We also sought to elucidate the mechanism that facilitates the clear visualization of a bleeding point.

MATERIALS AND METHODS

Infrared electronic endoscopy system and ICG

The infrared electronic endoscopy system we used was made up of a light source, special filters, a distally mounted charge-coupled device (CCD), and a forward-viewing electronic videoendoscope (GIF-Q260 IRZ; Olympus Medical Systems Corp, Ltd, Tokyo, Japan)(Fig. 1). Light produced by a xenon lamp (CIV-260SL; Olympus) first passes through an infrared pass filter, then 2 ranges of infrared rays are emitted through red-green-blue filters. The red and green channels of the endoscope pass the light at 790 to 820 nm, and the blue one at 920 to 960 nm. Emitted infrared light is then reflected from an object and collected by the CCD. The signals are processed by an image processor (CV-260; Olympus) and displayed on a color monitor. An infrared endoscopic view can be switched to a conventional view by pressing a small button on the control head.

ICG is usually used as the contrast medium. ICG absorbs infrared light maximally at a wavelength around 805 nm, which corresponds to the red and green channels of the endoscope, and it reflects infrared light at 920 to 960 nm, which corresponds to the blue channel of the endoscope. Therefore, ICG is displayed in blue on a monitor.

Flushing method

The flushing method was used to detect bleeding points as follows: (1) a forward-viewing endoscope (GIF-Q260 IRZ; Olympus) was introduced; (2) ER was carried out by using this endoscope; (3) when there was bleeding, the ulcer-bleeding site was washed by flushing 20 to 40 mL of ICG solution (0.125 mg/mL water); and (4) infrared observation of the bleeding site was then undertaken. Infrared endoscopic observation with ICG solution was performed from a position above the cups.

Color analysis of conventional and infrared endoscopic view

We conducted an investigation to elucidate the mechanism that facilitates the clear visualization of a bleeding point during infrared endoscopy. Absorbance or reflection of the emitted light was influenced by many factors. From clinical findings, we focused on 3 differences between spurting and pooled blood: blood thickness, blood concentration, and blood movement. In this investigation, concentrated red cells were used as blood. We also compared fresh blood and clots. Whole blood with sodium citrate was used as fresh blood. Whole blood without sodium citrate that coagulated was used as clotting blood.

1. Blood thickness. Three small, cylindrical, translucent, nylon cups, 10 mm in diameter and 11 mm in height, were placed on a board. The first cup was filled with 1 mL blood, the second with 2 mL, and the third with 4 mL, but each cup had a different thickness of blood. Conventional and infrared endoscopic observation was performed from a position above the cups.

2. Blood dilution (with water). Samples of 0.1 mL blood, 0.05 mL blood diluted with 0.05 mL water (twice-diluted blood), and 0.025 mL blood diluted with 0.075 mL water (4-times–diluted blood) were prepared and dripped onto a Petri dish. Conventional and infrared endoscopic observation was then performed as above.

3. Blood dilution (with ICG solution). For the flushing method, we observed bleeding points against a background of blood diluted with ICG solution. To imitate this condition, blood was diluted with ICG solution: 0.1 mL blood, 0.05 mL blood diluted with 0.05 mL ICG solution (0.25 mg/mL) (twice-diluted blood), and 0.025 mL blood diluted with 0.075 mL ICG solution (4-times–diluted blood) were prepared and dripped onto a Petri dish. Conventional and infrared endoscopic observation was then performed as above.

4. Blood movement. Two infusion tubes were filled with blood and were placed parallel to each other on the board. We wanted to see blood in motion in one of the tubes by injecting it through the infusion tube with a 20-mL syringe at speeds of 1 mL/sec to 5 mL/sec.
Conventional and infrared endoscopic observations of the 2 tubes were performed from a vertical angle and from angles of 45° and 135°.

5. Fresh blood and clot. Fresh whole blood 0.1 mL and 0.1-mL clot were prepared and dripped onto a Petri dish. Conventional and infrared endoscopic observation was then performed from a position above the dish.

RESULTS

Flushing method

In the infrared endoscopic system, without ICG injection, the ulcer base and bleeding were displayed in the same gray color. After flushing with ICG, the submucosal connective tissue was displayed in blue on a monitor. If bleeding occurred during the procedure, the bleeding point usually displayed in white, whereas pooled blood was displayed in a blue-to-gray color. Therefore, we were able to clearly recognize the bleeding point, without having to undertake aggressive washing.

A total of 10 bleeding sites in 6 patients who bled during endoscopy were observed by infrared endoscopy after flushing with ICG. Bleeding occurred during EMR for esophageal cancer in 3 cases and during endoscopic submucosal dissection of gastric cancer in 3 cases. Of the 10 bleeding sites, bleeding points were difficult to identify in 2 by conventional endoscopic view. However, the bleeding points of all patients were identified after flushing with ICG.
20 to 40 mL of ICG solution and were successfully treated by endoscopic coagulation. Bleeding points were more clearly displayed in spurting bleeding than oozing bleeding.

Case presentation

Case 1. An esophageal squamous-cell carcinoma in the mid esophagus was treated by EMR by using the transparent distal translucent cap method. Overt bleeding occurred soon after EMR. On a conventional endoscopic view, the bleeding point was not clearly recognized in the pooled blood (Fig. 2A, Videos 1 and 2, available at www.giejournal.org). By infrared endoscopic view, after flushing 20 mL of ICG solution, the bleeding point was clearly visualized in white, whereas the pooled blood and ulcer bed were seen in blue (Fig. 2B, Videos 1 and 2).

Case 2. A gastric adenocarcinoma on the greater curvature of the gastric antrum was treated by the endoscopic submucosal dissection method. During dissection of the submucosal connective tissue, overt bleeding occurred. By conventional endoscopic view, the bleeding point was not clearly recognized (Fig. 3A). On a infrared endoscopic view, after flushing with 40 mL of ICG solution, the bleeding point was clearly visualized in white, whereas the pooled blood and ulcer bed were seen in blue (Fig. 3B).

Color analysis of conventional and infrared endoscopic views

1. Blood thickness. Three different thicknesses of blood were red on a conventional endoscopic view and gray on an infrared endoscopic view. There was no difference in color with regard to blood thickness (Figs. 4 and 5).

2. Blood dilution (diluted with water). On conventional endoscopic views, blood was displayed in red, blood twice-diluted with water was dark red, and blood 4-times-diluted with water was light red (Fig. 4). On infrared endoscopic views, blood was displayed in gray, blood twice-diluted with water was dark gray, and blood 4-times-diluted with water was light gray (Fig. 5). The color contrast was more obvious by infrared endoscopic observation than by conventional endoscopic observation.

3. Blood dilution (diluted with ICG solution). On conventional endoscopic views, blood was displayed in red, blood twice-diluted with ICG solution was dark red, and blood 4-times-diluted with ICG solution was dark red (Fig. 4). On infrared endoscopic views, blood was displayed in white, blood twice-diluted was dark blue, and blood 4-times-diluted was light blue (Fig. 5). The color contrast was more obvious by infrared endoscopic observation than by conventional endoscopic observation.
4. Blood movement. The 2 infusion tubes filled with blood were red on a conventional endoscopic view and gray on an infrared endoscopic view. There was no difference in color between the 2 tubes at all of the injection speeds and angles (Fig. 6).

5. Fresh blood and clot. Fresh blood and clot were dark red on a conventional endoscopic view and dark gray on an infrared endoscopic view. There was no difference with regard to the clotting of blood (Fig. 6).

DISCUSSION

We discuss here a new method that we have called the “flushing method” for clear visualization of bleeding points during ER. We also investigated the possible mechanisms that facilitate clear visualization. Bleeding during ER is a frequently encountered complication, especially when larger lesions are resected. Advances in both endoscopic instrumentation and techniques now mean that it is now not so challenging for experienced endoscopists to control bleeding. However, for trainees, it is still difficult to recognize bleeding points and then to stop the bleeding, especially when it occurs in a narrow space, such as the esophagus, or if the bleeding point is under pooled blood. In such situations, a bleeding point is usually sealed by surrounding blood, which results in the bleeding point being missed because both pooled and spurting blood are displayed in red on conventional endoscopic views. However, the method discussed here displays pooled and spurting blood in different colors and so facilitates the clear visualization of bleeding points without aggressive washing.

The flushing method only requires that the bleeding site be washed with 20 to 40 mL of ICG solution in cases of actual bleeding, whereas the submucosal injection method requires the submucosal injection of ICG before ER, even for nonbleeders, and cannot be applied in other bleeding situations. The flushing method thus is simple and appears applicable to other situations, such as bleeding from a peptic ulcer, varix, or angiodysplasia. We have plans to evaluate its utility in gastric-ulcer bleeding.

Infrared endoscopic observation after intravenous injection of ICG has been used in the diagnosis of gastric cancer. In this method, deep submucosal vessels can be observed within 1 minute of ICG injection. Although we have not evaluated its utility in bleeding cases, this method should help to identify large-diameter blood vessels that might bleed during or after ER.
A limitation of this method would be the visualization of oozing bleeding. For slowly oozing blood, the color contrast of oozing and pooled blood was not obvious, and bleeding points were not clearly displayed as spurting bleeding. Accordingly, spurting bleeding surrounded by pooled blood will be a good indication for infrared endoscopic observation.

From the results of color analyses, the concentration of blood would be one of the main factors that contribute to the color differences, whereas blood thickness, movement, and clotting did not influence color differences. Usually blood is displayed in white by infrared endoscopy. Because infrared rays are characterized by their high-penetration properties, they can penetrate through diluted blood, and the color changes to a translucent one, with the dilution of blood. When blood is diluted with ICG solution, infrared rays at around 805 nm, which correspond to red and green, are absorbed by ICG, and those around 940 nm are reflected. Hence, the color changes to a bluish one with increases in the concentration of ICG solution to blood. The color changes of blood with dilution by an ICG solution were more obvious on infrared endoscopic views than on conventional endoscopic ones.

We introduced our flushing method, which was able to detect bleeding points during ER in all the cases studied for this report. Clear visualization of bleeding points appeared to come from the differences in blood and ICG concentrations between spurting and pooled blood.

DISCLOSURE

The authors report that there are no disclosures relevant to this publication. The authors codeveloped the infrared endoscopic system with Olympus Medical Systems Corp; however, we have no financial or commercial associations that might be a conflict of interest in relation to this article.

REFERENCES

Pancreatic pseudocyst gastrostomy with a peroral, flexible stapler: human natural orifice transluminal endoscopic surgery anastomoses in 2 patients (with videos)

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Background: Complex, symptomatic pancreatic pseudocysts often must be surgically drained. Natural orifice surgery is an emerging field in which surgical procedures are performed by using an endoluminal approach through an existing body orifice.

Patients and Setting: Two patients at our institution, an academic, tertiary care center.

Design: Two patients who underwent a standard, stapled, surgical cystgastrostomy for drainage of a complex, infected pseudocyst by using a flexible stapling device are described. These procedures were performed under endoscopic observation and guidance, all transorally, without the need for laparotomy or laparoscopy.

Results: Both patients had a technically successful outcome, and both did well after surgery, with only mild chest pain and throat discomfort in one, and no adverse sequelae at all in the other patient. Both patients had complete resolution of their complex, debris-filled pseudocysts at 6 weeks when examined by endoscopy and at 3 months when examined by CT.

Conclusions: An entirely endoscopic, peroral, stapled pseudocyst gastrostomy is feasible and can lead to an excellent outcome. For properly selected patients, this may be an alternative to more traditional types of surgical cystgastrostomy.

Abbreviations: ICU, intensive care unit; IRB, institutional review board; NOTES, natural orifice transluminal endoscopic surgery

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Pancreatic pseudocysts are formed as complications of severe pancreatitis, and drainage is needed when they become symptomatic. This is accomplished by endoscopic, percutaneous, or surgical techniques. Surgical drainage may be required when there is solid debris located in the pseudocyst cavity; severe, recurrent infection; or in

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