Construction of a Novel Intraoperative Cerenkov Luminescence Imaging System for Image-Guided Resection of Colorectal Cancer on Patients

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Objectives

Fluorescent molecular imaging (FMI) guided surgery has been actively explored in pre-clinical and clinical research. However, their clinical applications have been severely limited by the low signal to noise ratio (SNR) because of the external excitation and very few fluorescent probes approved by the Food and Drug Administration (FDA). In recent years, Cerenkov luminescence imaging (CLI) has attracted more and more attentions because of its high imaging throughput capability, high superficial resolution, low cost and the wide variety of clinically available probes. This study reports the development and evaluation of a novel intraoperative CLI navigation system for clinical imaging of colorectal cancer patients.

Methods

Firstly, a novel intraoperative CLI navigation system was constructed, which was mainly consisted of a CLI subsystem and a color photograph imaging subsystem. Both of them were fixed on a rotating platform. CLI subsystem was used for acquiring Cerenkov luminescence, which contained a highly sensitive camera (iXon3 888，ANDOR，UK) and a lens (Xenon 0.95/17-0010, Schneider, France). Color photograph was obtained using the color photograph imaging subsystem consisted of a camera (PCO.Edge 5.5, Oxford Instrument, UK) and a lens (Xenon 0.95/17-0010, Schneider, France). Next, a variety of the imaging parameters of the system were tested, including the field of view (FOV), work distance (WD), resolution, and sensibility. Lastly, an EP tube contained ^{18}F-FDG (4 μCi, 1 ml) covered with intestinal mucosa of pig was used in the phantom study in order to simulate the more real experimental environment. Both the Cerenkov luminescence (CL) image and the photographs were acquired (exposure time: 5 mins for CLI; 0.5 s for photograph). The Cerenkov luminescent image was firstly processed using median filtering algorithm to get rid of noise caused by gamma rays and then superimposed on the photograph image. Statistical significance was determined using the Student *t* test (Prism v6.0, GraphPad, La Jolla, CA).

Results

The intraoperative CLI system was constructed [Figure 1A(a)]. The picture of the CLI camera, lens, photograph camera, and rotating platform is shown in Figure A(b)-(e), respectively. The optimized imaging parameters of the system were included in Table 1. 0.53 μCi/ml ^{18}F-FDG could be clearly visualized using this system [Figure 1B(a)]. The photograph, and the overlay image of the same EP tube is shown in Figure 1B(b)-(c), respectively. Figure 1C(a)-(c) represent the photograph, CL image, and overlay of the EP tube contained ^{18}F-FDG (4 μCi, 1 ml) covered with intestinal mucosa of pig. It was obvious that CL could penetrate the intestinal mucosa.

Conclusions

In this study, a novel intraoperative CLI navigation system has been successfully constructed for image-guided resection of colorectal cancer on patients. The specification of the surgical navigation system has been tested and phantom study was conducted. The intraoperative CLI navigation system exhibits the high potential of detecting the very weak signal as low as 0.53 μCi/ml ^{18}F-FDG in an open darkroom and could be used for image-guided resection of colorectal cancer on patients.

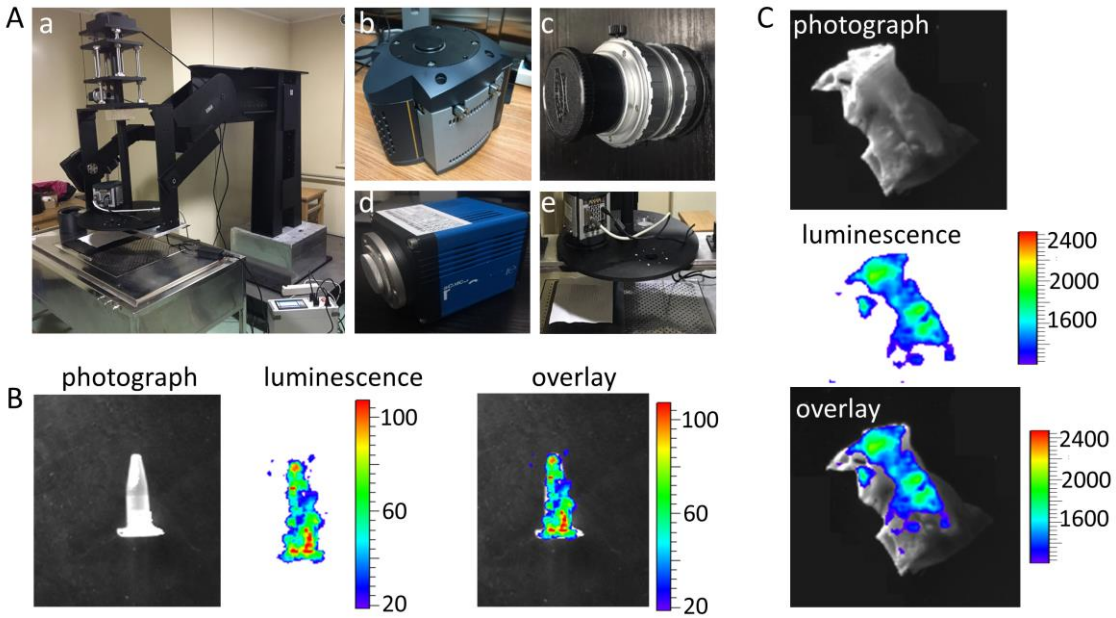

Figure 1. Intraoperative CLI navigation system and the minimum imaging dose experiment. A, (a) Figure of the intraoperative CLI navigation system. (b)-(e) Figure of the CL camera, lens, color photograph camera, and the rotating platform, respectively. B, (a)-(c) The photograph, CI image, and overlay image of the same EP tube contained ^{18}F-FDG (1.5ml) with the activity of 0.8 μCi, respectively. C, (a)-(c) The photograph, CI image and overlay image of the EP tube contained ^{18}F-FDG (4 μCi, 1 ml) covered with intestinal mucosa of pig, respectively.

Table 1 Specification of the surgical navigation system

System Features	Performance parameters
Chip area	CLI CCD 1.1"; Colour CCD
Working distance (mm)	82-550
Surgical field of view (mm)	6.96*6.96-42.33*42.33
Sensor resolution	1024 x 1024 imaging pixels(CLI); 2560 x 2160 imaging pixels(Color photograph)
	13 x 13 μm pixels; 6.5 x 6.5 μm pixels
	13.3 x 13.3 mm imaging area; 16.6 x 14.0 mm imaging area
Sensibility (μCi/ml)	0.53
Image windows	Visible, Cerenkov luminescence, overlay