Title: Indocyanine green fluorescence intraoperative imaging for hepatic hydrothorax with a small diaphragmatic defect

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Conflicts of interest

All authors declare no conflict of interest associated with this manuscript.

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Central message

Indocyanine green fluorescence imaging combined with pneumoperitoneum is sensitive for detecting small diaphragmatic defects.

Central picture

Fluorescence imaging revealed the passage of a small amount of dye through the diaphragm.

Hepatic hydrothorax is defined as a pleural effusion in a patient with cirrhosis who does not have any other detectable cause for the effusion. The most likely etiology is leakage of ascites from the peritoneal cavity into the pleural cavity through diaphragmatic defects.[1] These defects are almost always very small, making them difficult to detect during thoracoscopic surgery.[2] Here we report the use of indocyanine green (ICG) fluorescence imaging combined with pneumoperitoneum for detection of a diaphragmatic defect in a patient with hepatic hydrothorax.

CLINICAL SUMMARY

An 82-year-old man was admitted to our hospital with progressive dyspnea. He had a history of liver cirrhosis (Child-Pugh class C and model for End-Stage Liver Disease score 13) due to hepatitis C virus infection and was on treatment with diuretics and sodium restriction for refractory ascites. The chest X-ray film and computed tomography demonstrated a massive right pleural effusion together with a small volume of ascites (Figure 1A). After thoracentesis was performed, analysis revealed that the pleural fluid was a transudate and cytology was negative. Echocardiography demonstrated normal cardiac function. Technetium-99m scintigraphy showed that radioisotope injected into the peritoneal cavity migrated to the thoracic cavity, suggesting the existence of a diaphragmatic defect around the cardiopulmonary angle (Figure 1B). Based on these findings, hepatic hydrothorax with a diaphragmatic defect was diagnosed and the patient

was scheduled for thoracoscopic repair. Under general anesthesia with differential lung ventilation, he was placed in the left hemi-lateral decubitus position. A 12 mm trocar was inserted through an umbilical incision and pneumoperitoneum was initiated with carbon dioxide (CO_2) at a pressure of 10 mmHg. A 5 mm trocar was inserted in the right subcostal region on the midclavicular line for infradiaphragmatic injection of ICG. Two 15-mm mini-thoracotomy incisions were made in the 9th intercostal space (ICS) and the 8th ICS. First, the thoracic cavity was explored with an endoscopic ICG near-infrared fluorescence (NIF) imaging system (D-LIGHT P, Karl Storz, Germany) in white light mode and no passage through the diaphragm was identified. Next, the pleural cavity was filled with sterile saline, but no bubbles were seen on the diaphragm. Finally, ICG (25 mg diluted with 50 ml of sterile saline) was injected into the peritoneal cavity. Although the dye stained a small bulge of the diaphragm near a tiny reddish area located at the central tendon of the diaphragm, no leakage of dye was identified by examination in white light mode (Figure 2A). However, imaging in ICG fluorescent mode clearly showed blue fluorescence around the tiny reddish area and blue fluorescence was also observed in the saline inside the thoracic cavity (Figure 2B). These findings were considered to reflect the leakage of a small amount of ICG that could not be detected under white light. The probable defect was repaired with a non-absorbable suture, after which the site was reinforced with polyglycolic acid sheet and fibrin glue. The pleural effusion resolved after surgery and the chest

drain tube was removed on postoperative day 7. There was no recurrence of the pleural effusion and the patient was discharged on postoperative day 29. Subsequently, uncontrollable ascites developed and he died of liver failure two months after the operation.

Discussion

Dye or/and pneumoperitoneum have already been used for intraoperative detection of diaphragmatic defects.[2-4]Takayama et al. reported the detection of diaphragmatic defects in 22% (2/9) of patients by pneumoperitoneum [3]. In addition, Huang et al. reported that defects were identified in 91% (10/11) of patients by using methylene blue dye alone [2]. Recently, Yutaka et al. reported that the combination of pneumoperitoneum and ICG (without fluorescence) was useful for detecting diaphragmatic blebs in patients without obvious defects. [4]

Diagnosis of hepatic hydrothorax is confirmed when a communication is identified between the peritoneal and thoracic cavities. One of the methods employed is intraperitoneal injection of a radioisotope, after which its migration into the thoracic cavity confirms the existence of a communication.[1] However, migration of ascites is limited by loss of the pressure gradient when the thoracic cavity is opened during surgery. Although reproducing the pressure gradient with pneumoperitoneum is reasonable, it is not easy to find bubbles from a diaphragmatic defect in the narrow thoracic cavity filled with saline. It has been reported that combining pneumoperitoneum

and dye injection may facilitate detection of diaphragmatic defects[4]. In the present case, ICG fluorescent imaging proved to be sensitive for detection of a small diaphragmatic defect.

ICG emits fluorescence with a peak wavelength of around 830 nm when illuminated with near-infrared light. An in vitro investigation has revealed that ICG fluorescence images can be obtained with very low ICG concentrations of 0.005-0.01 mg/ml.[5] Therefore, ICG fluorescence imaging can contribute to the detection of even very small diaphragmatic defects with minimal flow of ICG into the thoracic cavity.

In conclusion, surgical closure of diaphragmatic defects is effective for patients with hepatic hydrothorax if the site of leakage can be identified. ICG fluorescence imaging combined with pneumoperitoneum is a sensitive method for detecting small diaphragmatic defects.

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Figure legends

Figure 1: (A) The chest X-ray film obtained on admission reveals a large right pleural effusion. (B) Intraperitoneal injection of 99m-technetium (white arrow) demonstrates flow of the tracer

from the peritoneal cavity into the right thoracic cavity (arrowhead).

Figure 2: (A) After intraperitoneal injection of indocyanine green under pneumoperitoneum, a small bulge of the diaphragm was colored near the tiny reddish area, but no obvious dye leakage was identified. (B) Fluorescent mode imaging clearly shows blue fluorescence around the tiny reddish area and blue fluorescence was also observed in saline inside the thoracic cavity.

Figure 1

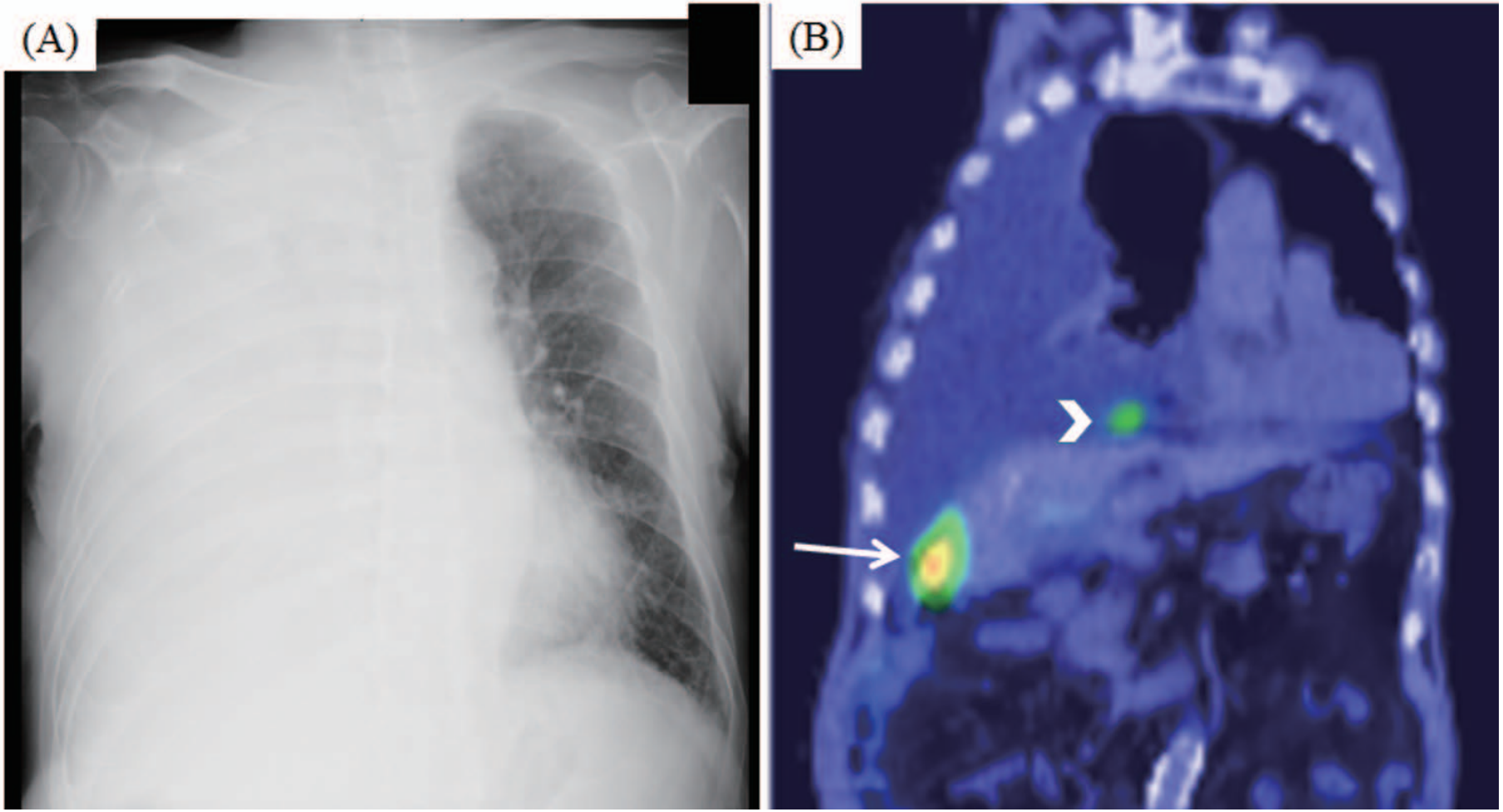

Figure 2