Intramucosal Carbon Dioxide Partial Pressure Measurement Rescued the Reconstructed Gastric Tube

Toru KANEDA[*1], Kiyoshi ISOBE[*2] and Toshiyasu SUZUKI[*1]

[*1]*Department of Anesthesiology, Tokai University School of Medicine*
[*2]*Department of Surgery, Shizuoka Red Cross hospital*

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A 60-year-old male patient with esophageal carcinoma underwent esophagectomy and gastric tube construction with cervical esophagogastrostomy. A tonometer catheter (Tonometrics™ Catheter, TONO-16 F, Datex-Ohmeda, Finland) was placed transnasally into the lumen of the gastric tube just after the gastric tube formation. The catheter was connected to a TONOCAP (Datex Ohmeda) monitor. The intramucosal partial pressure of carbon dioxide ($PiCO_2$) was then measured intermittently. A $PiCO_2$ of 105 mmHg just after the gastric tube formation indicated the possibility of an impaired blood flow in the gastric tube. Reanastomosis of the artery and vein to the gastric tube was performed immediately to improve perfusion. This procedure salvaged the gastric tube and $PiCO_2$ decreased to 43 mmHg at the end of the operation. Subsequently, $PiCO_2$ returned to the normal range. $PiCO_2$ is regularly measured to assess the state of the reconstructed gastric tube during the postoperative period in the intensive care unit (ICU). The clinical course of the patient suggests that measuring $PiCO_2$ using a tonometer catheter is useful to detect any abnormal blood supply to the reconstructed gastric tube not only in the postoperative period in the ICU but also in the intraoperative period.

Key words: esophageal carcinoma, gastric tube, $PiCO_2$, tonometory method, measurement in intraoperative period

INTRODUCTION

Gastric tube formation with cervical esophagogastrostomy via the antesternum is an effective method of reconstruction after esophagectomy to treat esophageal carcinoma. Partial devascularization of the gastric tube resulting in decreased blood flow and oxygenation is one of the major problems associated with gastric tube formation. Therefore, it is important to evaluate the blood supply in the reconstructed gastric tube because an inadequate blood supply is associated with anastomotic leakage after esophagogastrostomy.

Monitoring the intramucosal partial pressure of carbon dioxide ($PiCO_2$) in the gastric tube using a tonometer catheter [1, 2] inserted into the gastric tube is an effective method to evaluate the blood supply. Previous studies [3, 4] evaluated the blood perfusion in the gastric tube after esophagectomy to measure the $PiCO_2$ values. $PiCO_2$ is usually measured to assess the state of the reconstructed gastric tube during the postoperative period in the intensive care unit (ICU). However, inadequate blood supply to the gastric tube was detected immediately after esophagogastrostomy during the surgery in the present case. The $PiCO_2$ value in the gastric tube was abnormally high (105 mmHg). The surgeons performed emergent artery-to-artery and vein-to-vein anastomoses to improve the blood supply to the gastric tube. This report presents a case in which the reconstructed gastric tube was rescued by $PiCO_2$ measurement immediately after it was formed.

CASE REPORT

A 60-year-old male patient was diagnosed with esophageal cancer. His height and body weight were 163 cm and 47 kg. He underwent preoperative chemotherapy and radiotherapy. The patient's medical history included hypertension managed by oral amlodipine and untreated borderline type diabetes mellitus. The patient also had left-side paralysis after cerebral infarction, which was treated with oral administration of ticlopidine. There were no remarkable findings in the patient's family history, and no abnormal laboratory data were obtained preoperatively, except for left ventricular hypertrophy on ECG.

The patient was premedicated with 20 mg famotidine, 0.5 mg atropine sulfate and 25 mg hydroxyzine 30 minutes before he was brought into the operating room. Routine monitoring of ECG, noninvasive blood pressure, and oxygen saturation was initiated in the operating room. An epidural catheter was then inserted into the epidural space from the Th6/7 intervertebral space. Anesthesia was induced with 50 μg fentanyl and 90 mg propofol. The trachea was intubated with 5 mg vecuronium using a Univent tube (Fuji Systems Corporation, Tokyo Japan) because the surgery required one-lung ventilation. Anesthesia was maintained with N_2O, O_2, sevoflurane, fentanyl, vecuronium and epidural anesthesia. The radial artery was cannulated to measure continuous arterial blood pressure during surgery. A catheter was also inserted

Toru KANEDA, Department of Anesthesiology, Tokai University School of Medicine 143 Shimokasuya, Isehara, Kanagawa 259-1193, Japan
Tel: +81-463-93-1211 (ext. 6491) Fax: +81-463-91-9260 E-mail: t-kaneda@is.icc.u-tokai.ac.jp

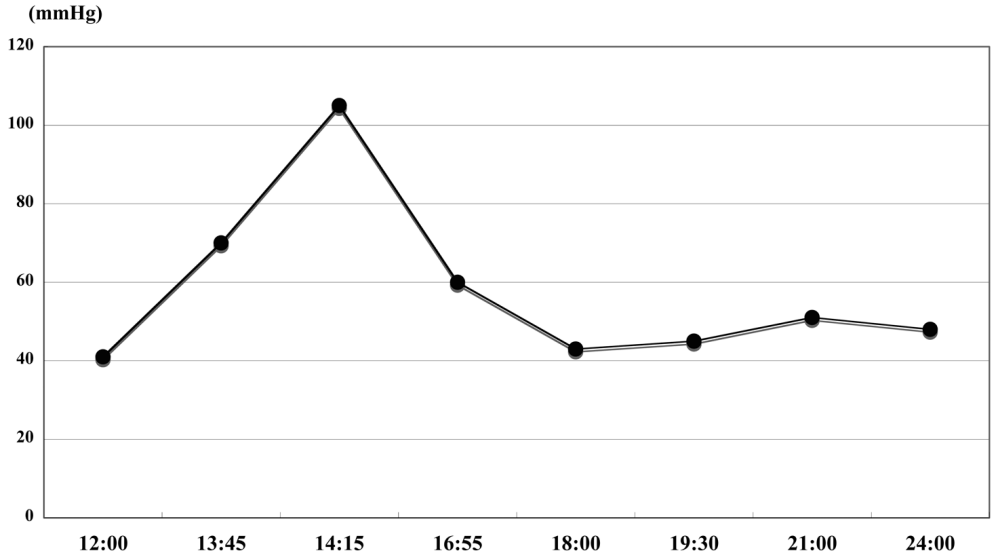

Fig. 1 Operation was performed from at 9:45 to at 19:30, and then this patient entered in intensive care unit (ICU) at 21:00. $PiCO_2$ monitoring was started at 12:00.

from the internal jugular vein to measure the central venous pressure.

There were no abnormal findings in either the circulatory or respiratory conditions, and there were no problems with the surgical procedure. A gastric tube was formed after esophagectomy and esophagogastrostomy was performed. A tonometry catheter (Tonometrics™, TONO-16F) was inserted transnasally into the gastric tube. The catheter was connected to a TONOCAP (Datex-Ohmeda) monitor, which measured $PiCO_2$ in the reconstructed gastric tube. $PiCO_2$ was measured at 10-minute intervals by the air tonometry method.

The baseline $PiCO_2$ value was 41 mmHg at 12:00. But the $PiCO_2$ increased to 70 mmHg at 13:45, and further increased to 105 mmHg at 14:15. Arterial blood gas analysis was performed at the same time but no abnormalities were observed in partial pressure of arterial carbon dioxide ($PaCO_2$) or any other parameters. Blood pressure was also normal. Although no remarkable changes were seen in the reconstructed gastric tube at 13:45, tube discoloration was noticed at 14:00. This suggested impaired blood flow in the gastric tube. Reanastomosis of the artery (from the superficial cervical artery to the short gastric artery) and vein (from the short gastric vein to the external jugular vein) to the gastric tube was performed immediately to improve the perfusion. The $PiCO_2$ value decreased to 60 mmHg after this procedure (16:55), and 45 mmHg at the end of surgery. This indicated that the gastric tube was salvaged. The $PiCO_2$ value was about 40 mmHg after surgery and remained within the normal range throughout the stay in the ICU. The changes in the $PiCO_2$ value from the first measurement during surgery until 24:00 on the first operative day are shown in Fig. 1. After that, the $PiCO_2$ value showed almost normal.

DISCUSSION

Tissue hypoxia is caused by compromised perfusion, which leads to a decreased level of CO_2 washout in the mucosal tissue. The partial pressure of CO_2 in the mucosa can be increased by CO_2 accumulation. Therefore, an increase in $PiCO_2$ can serve as a valid index of tissue perfusion. In addition, $PiCO_2$ can be determined indirectly by measuring the intraluminal PCO_2, since the diffusion of CO_2 results in equilibrium in the mucosa and the lumen of hollow viscous organs [5, 6]. Therefore, $PiCO_2$ may be the only reliable indicator of changes in local perfusion in the reconstructed tissue.

$PiCO_2$ is indirectly measured by tonometry using PCO_2, which diffusely dissolves in saline within the tonometer catheter balloon. This tonometry method was introduced by Fiddian-Green *et al.* in 1982 [1], and it has been conventionally used as an index to detect splanchnic perfusion of critically ill patents in the early stage of disease by measuring $PiCO_2$ in the gastric mucosa, thus providing an index of oxygen metabolism in tissue throughout the body in seriously ill patients [7]. However, $PiCO_2$ is only an index of perfusion evaluation when $PaCO_2$ remains in the normal range because the value of $PiCO_2$ is influenced by $PaCO_2$ and can rise under conditions such as respiratory failure [8].

Imanishi *et al.* [9] measured $PiCO_2$ by tonometer using saline to evaluate the blood perfusion of a transplanted intestinal tract that was reconstructed by transferring the free jejunum in a radical operation for pharyngeal carcinoma. Although it took a relatively long time, 30–60 minutes, for PCO_2 to reach an equilibrium between the intra-balloon saline of the tonometer catheter and the reconstructed tissue, Imanishi *et al.* [9] showed the usefulness of this technique in that the value was objective and easily interpretable. Furthermore, the procedures were simple and comparatively easy to perform, and the method was noninvasive and reproducible. Imanishi *et al.* found that the $PiCO_2$ measurement provided reliable

information to evaluate the blood perfusion of the reconstructed free jejunum transfer. Moriyama [10] reported the usefulness of $PiCO_2$ measurement as a perfusion index of reconstructed tissue because it can detect early disorders in a transplanted intestinal tract by measuring $PiCO_2$ during free jejunum transfer in radical surgery for esophageal carcinoma in the cervix.

A TONOCAP monitor was used to measure $PiCO_2$ in the present case. $PiCO_2$ measurement was performed by measuring carbon dioxide automatically at regular intervals, forming a closed circuit between a tonometer catheter balloon and a measurement device, using infrared sensor technology using air substituted for saline solution. In comparison to conventional $PiCO_2$ measurement using saline, this air tonometry method does not need to consider the time for the PCO_2 value inside and outside of the balloon to reach equilibrium [11, 12] and it enables acute measurements. In addition, a tonometer catheter inserted in the reconstructed gastric tube was connected to the sample line of the TONOCAP, during surgery, and $PiCO_2$ was measured every 10 minutes.

Schroder [13] examined the intraoperative changes in $PiCO_2$ using a TONOCAP during gastric tube formation in 2001, and showed that continuous tonometry is a valid method to detect changes in $PiCO_2$ during gastric tube formation. $PiCO_2$ was measured using air tonometry with a TONOCAP to evaluate the perfusion of the reconstructed gastric tube during the intraoperative period after esophagectomy for esophageal carcinoma. An impaired perfusion in the reconstructed gastric tube was detected at the early stage, thus allowing for prompt treatment. A tonometer catheter is usually inserted to evaluate the blood perfusion of the reconstructed gastric tube during the postoperative period. An abnormally high value of $PiCO_2$ (105 mmHg) was detected before the surgeon noticed the discoloration in the reconstructed gastric tube in the present case because the catheter was inserted immediately after reconstruction. Therefore, prompt action was taken to restore blood perfusion in the gastric tube. Both $PaCO_2$ elevation and the patient's systemic condition were correlated, and it is important to remember that the value of $PiCO_2$ can be affected by defective conditions such as hypotension, serious infectious disease and multiple organ failure. The patient in the present case had no such conditions when the $PiCO_2$ was abnormally high.

Direct monitoring of the color of the tissue has been the only method to detect ischemia with a perfusion disorder in reconstructed tissue during an operation. In addition, there is no established method for evaluation without direct measurement of blood flow using a laser Doppler flow meter. Furthermore, the increased $PiCO_2$ value was detected earlier than discoloration in the reconstructed gastric tube in the present case. Therefore, the $PiCO_2$ immediately after reconstruction during surgery allowed for a prompt response for the treatment of inadequate perfusion of the reconstructed gastric tube, which occurred just after esophagogastrostomy. Therefore, $PiCO_2$ measurement during surgery was useful for evaluating the perfusion of the gastric tube just after its reconstruction.

In conclusion, $PiCO_2$ measurement allowed for the rescue of the gastric tube just after reconstruction. Therefore, the $PiCO_2$ measurement is useful not only during the postoperative period but also during surgery.

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