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ERRATUM

# Erratum to: Thoracic and cardiovascular surgery in Japan during 2013

## Annual report by The Japanese Association for Thoracic Surgery

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### Erratum to: Gen Thorac Cardiovasc Surg (2015) 63:670–701 DOI 10.1007/s11748-015-0590-3

The following errors appeared in the above-cited article. (A) Cardiovascular surgery section: in the 3rd paragraph, on the 4th line, "9168 cases in 2003" should read "9165 cases in 2003"; on the 6th line, "15,757 cases in thoracic aortic aneurysm" should read "15,758 cases in thoracic aortic aneurysm"; on the 8th line, "4.0, 4.6 and 14.6%, respectively" should read "4.0, 4.7 and 14.6%, respectively"; on the 10th line, "16,752 cases" should read "16,560 cases"; and on the 13th line, "83.4% increase" should read "83.8% increase". In the 5th paragraph, on the 14th line, "6.7% in 2003" should read "6.9% in 2003". In the 6th paragraph, on the 2nd line, "83.4%" should read "83.8%"; on the 4th line, "placement" should read "replacement", and "2.2 and 3.7%" should read "2.9 and 5.4%"; on the 6th line, "0.8%" should read "1.1%"; on the 25th line, "38.2%" should read "38.3%"; and on the 26th line, "41.9%" should read "59.4%". In the 7th paragraph, on the 11th line, "23.4%" should read "22.4%". In the 8th paragraph, on the 3rd line, "1.0 and 1.7%" should read "0.8 and 1.4%"; on the 10th line, "5.5%" should read "7.3%"; and on the 14th line, "8.5–6.4%" should read "8.0–6.4%". In the 9th paragraph, on the 2nd line, "414

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**Table 5** Thoracic aortic aneurysm (total; 15,758)
(1) Dissection (total; 6787)

| Replaced site | Stanford type | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acute | | | | | | | | Chronic | | | | | | | | Concomitant operation | | | | | Redo | | | |
| | A | | | | B | | | | A | | | | B | | | | | | | | | | | | |
| | Cases | 30-day mortality | | Hospital mortality | Cases | 30-day mortality | | Hospital mortality | Cases | 30-day mortality | | Hospital mortality | Cases | 30-day mortality | | Hospital mortality | AVP | AVR | MVP | MVR | CABG | Cases | 30-day mortality | | Hospital mortality |
| | | Hospital | After discharge | | | Hospital | After discharge | | | Hospital | After discharge | | | Hospital | After discharge | | | | | | | | Hospital | After discharge | |
| 1. Ascending Ao. | 2608 | 186 (7.1) | 2 (0.1) | 217 (8.3) | 4 | 0 (0.0) | 0 | 1 (25.0) | 186 | 3 (1.6) | 0 | 6 (3.2) | 8 | 0 (0.0) | 0 | 0 (0.0) | 216 | 111 | 17 | 8 | 132 | 51 | 2 (3.9) | 0 | 4 (7.8) |
| 2. Aortic Root | 197 | 34 (17.3) | 0 | 35 (17.8) | 0 | 0 | 0 | 0 | 65 | 6 (9.2) | 0 | 7 (10.8) | 1 | 0 | 0 | 0 | 37 | 185 | 6 | 1 | 42 | 38 | 5 (13.2) | 0 | 5 (13.2) |
| 3. Ascending Ao. + Arch | 1393 | 108 (7.8) | 0 | 124 (8.9) | 32 | 1 (3.1) | 0 | 2 (6.3) | 282 | 6 (2.1) | 0 | 11 (3.9) | 112 | 3 (2.7) | 0 | 4 (3.6) | 106 | 62 | 3 | 4 | 95 | 91 | 4 (4.4) | 0 | 8 (8.8) |
| 4. Arch + descending Ao. | 25 | 1 (4.0) | 0 | 2 (8.0) | 6 | 1 (16.7) | 0 | 2 (33.3) | 31 | 4 (12.9) | 0 | 4 (12.9) | 56 | 4 (7.1) | 0 | 4 (7.1) | 0 | 0 | 0 | 0 | 2 | 17 | 6 (35.3) | 0 | 5 (29.4) |
| 5. Aortic Root + Asc. Ao. + Arch | 86 | 12 (14.0) | 0 | 14 (16.3) | 2 | 0 | 0 | 0 | 33 | 1 (3.0) | 0 | 1 (3.0) | 13 | 0 | 0 | 0 | 22 | 85 | 1 | 0 | 15 | 18 | 0 | 0 | 0 |
| 6. Descending Ao. | 13 | 3 (23.1) | 0 | 3 (23.1) | 37 | 6 (16.2) | 0 | 5 (13.5) | 84 | 2 (2.4) | 0 | 3 (3.6) | 270 | 12 (4.4) | 0 | 17 (6.3) | 0 | 0 | 0 | 0 | 4 | 41 | 1 (2.4) | 0 | 3 (7.3) |
| 7. Thoracoabdominal Ao. | 1 | 0 | 0 | 0 | 11 | 1 (9.1) | 0 | 3 (27.3) | 29 | 4 (13.8) | 0 | 4 (13.8) | 145 | 9 (6.2) | 0 | 12 (8.3) | 0 | 0 | 0 | 0 | 1 | 47 | 5 (10.6) | 0 | 6 (12.8) |
| 8. Extra-anatomical bypass | 14 | 2 | 0 | 2 (14.3) | 24 | 2 (8.3) | 0 | 3 (12.5) | 2 | 0 | 0 | 0 (0.0) | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 (33.3) | 0 | 1 (33.3) |
| 9. Stent graft*[a] | 107 | 9 (8.4) | 0 | 7 (6.5) | 181 | 17 (9.4) | 0 | 21 (11.6) | 139 | 0 | 0 | 1 (0.7) | 587 | 6 (1.0) | 1 (0.2) | 12 (2.0) | 6 | 2 | 0 | 0 | 3 | 70 | 2 (2.9) | 0 | 3 (4.3) |
| 1) TEVAR*[b] | 48 | 7 (14.6) | 0 | 7 (14.6) | 179 | 16 (8.9) | 0 | 20 (11.2) | 119 | 0 | 0 | 1 (0.8) | 556 | 6 (1.1) | 1 (0.2) | 12 (2.2) | 5 | 1 | 0 | 0 | 1 | 68 | 2 (2.9) | 0 | 3 (4.3) |
| 2) Open stent | 59 | 2 (3.4) | 0 | 3 (5.1) | 2 | 1 (50.0) | 0 | 1 (50.0) | 20 | 0 | 0 | 0 | 31 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 2 | 0 | 0 | 0 |
| a) With total arch*[c] | 59 | 2 (3.4) | 0 | 3 (5.1) | 2 | 1 (50.0) | 0 | 1 (50.0) | 20 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 1 | 0 | 0 | 0 |
| b) Without total arch*[d] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 3) Unspecified | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 4444 | 355 (8.0) | 2 (0.05) | 404 (9.1) | 297 | 28 (9.4) | 0 | 37 (12.5) | 851 | 26 (3.1) | 0 | 37 (4.3) | 1195 | 34 (2.8) | 1 (0.1) | 49 (4.1) | 387 | 445 | 27 | 13 | 294 | 376 | 26 (6.9) | 0 | 35 (9.3) |

Values in parenthesis represent mortality %

*Ao* aorta, *AVP* aortic valve repair, *AVR* aortic valve replacement, *MVP* mitral valve repair, *MVR* mitral valve replacement, *CABG* coronary artery bypass grafting, *TEVAR* thoracic endovascular aortic (aneurysm) repair

Acute, within 2 weeks from the onset

*a = *b + *c + *d + unspecified

**Table 5** continued

(2) Non-dissection (total; 8971)

| Replaced site | Unruptured | | | | Ruptured | | | | Concomitant operation | | | | | Redo | | | | CPB (−) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cases | 30-day mortality | | Hospital mortality | Cases | 30-day mortality | | Hospital mortality | AVP | AVR | MVP | MVR | CABG | Cases | 30-day mortality | | Hospital mortality | Cases | 30-day mortality | | Hospital mortality |
| | | Hospital | After discharge | | | Hospital | After discharge | | | | | | | | Hospital | After discharge | | | Hospital | After discharge | |
| 1. Ascending Ao. | 1201 | 25 (2.1) | 0 | 32 (2.7) | 62 | 7 (11.3) | 0 | 9 (14.5) | 40 | 820 | 67 | 39 | 147 | 95 | 7 (7.4) | 0 | 10 (10.5) | 2 | 0 | 0 | 0 |
| 2. Aortic Root | 928 | 16 (1.7) | 1 (0.1) | 24 (2.6) | 31 | 8 (25.8) | 0 | 8 (25.8) | 232 | 631 | 54 | 24 | 95 | 145 | 13 (9.0) | 0 | 14 (9.7) | 1 | 0 | 0 | 0 |
| 3. Ascending Ao. + Arch | 2151 | 44 (2.0) | 0 | 72 (3.3) | 173 | 25 (14.5) | 0 | 37 (21.4) | 33 | 201 | 28 | 8 | 327 | 105 | 8 (7.6) | 0 | 10 (9.5) | 6 | 0 | 0 | 0 |
| 4. Arch + descending Ao. | 104 | 6 (5.8) | 0 | 9 (8.7) | 23 | 3 (13.0) | 0 | 5 (21.7) | 0 | 2 | 0 | 1 | 7 | 11 | 3 (27.3) | 0 | 4 (36.4) | 8 | 0 | 0 | 0 |
| 5. Aortic root + Asc. Ao. + Arch | 109 | 1 (0.9) | 0 | 2 (1.8) | 5 | 2 (40.0) | 0 | 2 (40.0) | 24 | 80 | 5 | 1 | 6 | 20 | 3 (15.0) | 0 | 3 (15.0) | 2 | 0 | 0 | 0 |
| 6. Descending Ao. | 343 | 12 (3.5) | 0 | 18 (5.2) | 84 | 16 (19.0) | 0 | 18 (21.4) | 0 | 0 | 0 | 0 | 4 | 33 | 3 (9.1) | 0 | 6 (18.2) | 26 | 2 (7.7) | 0 | 2 (7.7) |
| 7. Thoracoabdominal Ao. | 372 | 17 (4.6) | 1 (0.3) | 28 (7.5) | 52 | 9 (17.3) | 0 | 15 (28.8) | 0 | 0 | 0 | 0 | 1 | 42 | 1 (2.4) | 0 | 3 (7.1) | 11 | 0 | 0 | 0 |
| 8. Extra-anatomical bypass | 35 | 0 | 0 | 1 (2.9) | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 0 (0.0) | 0 | 0 |
| 9. Stent graft*[a] | 2928 | 43 (1.5) | 1 (0.03) | 73 (2.5) | 368 | 39 (10.6) | 3 (0.8) | 55 (14.9) | 7 | 7 | 1 | 0 | 25 | 122 | 6 (4.9) | 1 (0.8) | 7 (5.7) | 1079 | 19 (1.8) | 3 (0.3) | 28 (2.6) |
| 1) TEVAR*[b] | 2774 | 37 (1.3) | 1 (0.04) | 66 (2.4) | 358 | 38 (10.6) | 3 (0.8) | 53 (14.8) | 3 | 1 | 0 | 0 | 5 | 118 | 5 (4.2) | 1 (0.8) | 6 (5.1) | 1059 | 19 (1.8) | 3 (0.3) | 28 (2.6) |
| 2) Open stent | 154 | 6 (3.9) | 0 | 7 (4.5) | 10 | 1 (10.0) | 0 | 2 (20.0) | 4 | 6 | 1 | 0 | 20 | 4 | 1 (25.0) | 0 | 1 (25.0) | 20 | 0 | 0 | 0 |
| a) With total arch*[c] | 112 | 6 (5.4) | 0 | 7 (6.3) | 10 | 1 (10.0) | 0 | 2 (20.0) | 4 | 5 | 1 | 0 | 16 | 2 | 1 (50.0) | 0 | 1 (50.0) | 0 | 0 | 0 | 0 |
| b) Without total arch*[d] | 42 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 4 | 2 | 0 | 0 | 0 | 20 | 0 | 0 | 0 |
| 3) Unspecified | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 8171 | 164 (2.0) | 3 (0.04) | 259 (3.2) | 800 | 109 (13.6) | 3 (0.4) | 149 (18.6) | 337 | 1741 | 155 | 73 | 613 | 574 | 44 (7.7) | 1 (0.2) | 57 (9.9) | 1137 | 21 (1.8) | 3 (0.3) | 30 (2.6) |

Values in parenthesis represent mortality %

*Ao* aorta, *AVP* aortic valve repair, *AVR* aortic valve replacement, *MVP* mitral valve repair, *MVR* mitral valve replacement, *CABG* coronary artery bypass grafting, *TEVAR* thoracic endovascular aortic (aneurysm) repair

*a = *b + *c + *d + unspecified

**Table 7** Assisted circulation (total; 1713)

| Sites | VAD | | | | | | | | | Heart–lung assist | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Device | | | Results | | | | | | Method | | Results | | | |
| | Centrifugal | VAS | Others | Not weaned | | | Weaned | | | PCPS | Others | Not weaned | | Weaned | |
| | | | | On going | Death | Transplant | Alive | Deaths | Transplant | | | Deaths | Transplant | Deaths | Alive |
| Post cardiotomy | | | | | | | | | | | | | | | |
| Left | 38 | 4 | 7 | 8 | 30 (61.2) | 0 | 3 | 8 (16.3) | 0 | | | | | | |
| Right | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | |
| Biventricle | | | | | | | | | | | | | | | |
| Left | 1 | 3 | 0 | 0 | 3 (75.0) | 0 | 1 | 0 | 0 | 499 | 69 | 274 (48.2) | 0 | 85 (15.0) | 209 |
| Right | 4 | 0 | 0 | | | | | | | | | | | | |
| Congestive heart failure | | | | | | | | | | | | | | | |
| Left | 50 | 41 | 92 | 112 | 38 (20.8) | 7 | 16 | 9 (4.9) | 0 | | | | | | |
| Right | 2 | 1 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | | | | | | |
| Biventricle | | | | | | | | | | | | | | | |
| Left | 5 | 22 | 3 | 5 | 14 (46.7) | 0 | 8 | 3 (10.0) | 0 | 685 | 29 | 360 (50.4) | 0 | 105 (14.7) | 249 |
| Right | 18 | 11 | 1 | | | | | | | | | | | | |
| Respiratory failure | | | | | | | | | | 106 | 22 | 46 (35.9) | 0 | 16 (12.5) | 66 |
| Total | 118 | 82 | 103 | 126 | 85 (28.1) | 7 | 30 | 20 (6.6) | 0 | 1290 | 120 | 680 (48.2) | 2 | 206 (14.6) | 524 |

Values in parenthesis represent mortality %

*VAD* ventricular assist devise, *VAS* ventricular assist system, *PCPS* percutaneous cardiopulmonary support

**Table 33**
14. Combined resection of neighboring organ(s)

| | Cases | 30 day mortality | | Hospital mortality |
|---|---|---|---|---|
| | | Hospital | After discharge | |
| 14. Combined resection of neighboring organ(s) | 1581 | 7 (0.4) | 3 (0.2) | 19 (1.2) |
| (A) Primary lung cancer (organ resected) | | | | |
| Aorta | 16 | 0 | 0 | 0 |
| Superior vena cava | 40 | 0 | 0 | 0 |
| Brachiocephalic vein | 12 | 0 | 0 | 0 |
| Pericardium | 177 | 2 (1.1) | 0 | 3 (1.7) |
| Pulmonary artery | 227 | 1 (0.4) | 0 | 1 (0.4) |
| Left atrium | 45 | 0 | 0 | 1 (2.2) |
| Diaphragm | 98 | 1 (1.0) | 0 | 1 (1.0) |
| Chest wall (including ribs) | 500 | 1 (0.2) | 0 | 9 (1.8) |
| Vertebra | 31 | 0 | 0 | 3 (9.7) |
| Esophagus | 12 | 0 | 0 | 0 |
| Total | 1158 | 5 (0.4) | 0 | 18 (1.6) |
| (B) Mediastinal tumor (organ resected) | | | | |
| Aorta | 3 | 0 | 0 | 0 |
| Superior vena cava | 69 | 0 | 0 | 1 (1.4) |
| Brachiocephalic vein | 93 | 1 (1.1) | 0 | 1 (1.1) |
| Pericardium | 267 | 1 (0.4) | 0 | 2 (0.7) |
| Pulmonary artery | 9 | 0 | 0 | 0 |
| Left atrium | 2 | 0 | 0 | 0 |
| Diaphragm | 16 | 0 | 0 | 0 |
| Chest wall (including ribs) | 20 | 0 | 0 | 0 |
| Vertebra | 7 | 0 | 0 | 0 |
| Esophagus | 1 | 0 | 0 | 0 |
| Lung | 277 | 1 (0.4) | 0 | 1 (0.4) |
| Total | 764 | 3 (0.4) | 0 | 5 (0.7) |

Values in parenthesis represent mortality %

operations" should read "840 operations"; and on the 4th line, "298 operations" should read "371 operations". In the 11th paragraph, on the 6th line, "8171 cases" should read "8971 cases"; and on the 9th line, "2.2%" should read "3.2%". In the 13th paragraph, on the 4th line, "42% increase" should read "4.2% increase".

Additionally, there are some errors in the following tables. Table 3 (3), on the 4th line (4 Damus–Kaye–Stansel operation), values of the columns "Neonate; Hospital mortality", "Infant; 30-day mortality; Hospital", and "Infant; Hospital mortality" should be "1 (33.3)", "4 (8.0)", and "6 (12.0)", not "1", "4", and "6", respectively. The title for Table 9 should read "Pacemaker + ICD (total; 4660)". In (B) General thoracic surgery section, Table 33, the first line of the column "30-day mortality; Hospital" should read "7 (0.4)", not "7 (1.4)". Other tables with errors and their corrections are given below.

In addition, the following error appeared in the above-cited article. (A) Cardiovascular surgery section: in the 2nd paragraph, on the 6th line, "A total of 67,325 cardiovascular operations" should read "A total of 65,312 cardiovascular operations".

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# Restoration of gastrointestinal motility ameliorates nutritional deficiencies and body weight loss of patients who undergo laparoscopy-assisted proximal gastrectomy

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**Abstract**
*Background* Esophagogastrostomy after proximal gastrectomy (PG) is a simple and safe reconstruction, but it leads to a high incidence of reflux esophagitis and impairs postoperative quality of life. We have already reported gastric tube (GT) reconstruction after PG and performed it on more than 100 patients. No studies have reported long-term outcomes after PG–GT. The aim of this study was to investigate long-term outcomes, including nutrition indices, such as body weight, serum albumin, total protein, hemoglobin, and ferritin after PG, and observe recovery of upper gastrointestinal tract motility.
*Methods* We analyzed body weight loss and laboratory findings at our outpatient clinic at 1, 6, 12, 24, 36, 48, and 60 months postoperatively. Manometric recording was carried out at 1, 2, 3, 4, and 5 years after surgery.
*Results* The percentage change in body weight in the PG–GT group was significantly larger than that in the PG–JI and TG–RY groups at 2.5, 3, 4, and 5 years after surgery. The levels of hemoglobin and ferritin in the PG–GT and PG–JI groups were significantly higher than those in the TG–RY group at all time points except 6 months after surgery. In the fasted state, the phase III originated at the gastric tube was propagated to the duodenum 3 years after surgery. In the fed state, phasic contractions of the duodenum were in harmony with gastric tube contractions 3 years after surgery.
*Conclusions* PG–GT is the least invasive procedure, and restoration of gastrointestinal motilities in the gastric tube and duodenum may ameliorate body weight loss and nutritional status, including anemia, in patients after PG.

**Keywords** Early gastric cancer · Laparoscopy-assisted proximal gastrectomy · Manometry

**Abbreviations**

| | |
|---|---|
| TG | Total gastrectomy |
| EGC | Early gastric cancer |
| PG | Proximal gastrectomy |
| QOL | Quality of life |
| GT | Gastric tube |
| LAPG | Laparoscopy-assisted proximal gastrectomy |
| JI | Jejunal interposition |

Gastric cancer remains a global disease with a high mortality rate, especially in East Asian countries, such as Japan, China, and Korea [1]. In recent decades, the worldwide incidence of distal gastric cancers has decreased slightly, whereas that of proximal gastric cancers has increased steadily [2, 3]. In Japan, total gastrectomy (TG) with extensive (D2) lymph node dissection has been considered the standard procedure for the treatment of gastric cancer involving the upper third of the stomach [4]. However, in East Asia, especially in Korea and Japan, nationwide mass screening programs have improved the survival of patients with gastric cancer through early detection [5]. Because the prognosis of early gastric cancer

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(EGC) is excellent, interest has been directed at improving quality of life (QOL) and at the use of minimally invasive treatment, which would appear to favor proximal gastrectomy (PG) in patients with early-stage proximal gastric cancer. However, PG destroys anatomic anti-reflux barriers, including the lower esophageal sphincter and the acute angle of His. It leads to reflux esophagitis through acid reflux and regurgitation. To prevent reflux esophagitis, several reconstructive procedures after PG have been reported. In particular, a high incidence of reflux esophagitis after simple esophagogastrostomy has prompted the development of several novel techniques for reconstruction (e.g., jejunal pouch interposition and double tract reconstruction) that are designed to prevent reflux esophagitis [6]. However, these techniques are complicated, time-consuming, and sometimes unsatisfactory. We introduced gastric tube (GT) reconstruction after PG in 2010 [7] and performed PG on more than 100 patients with EGC. Moreover, we have already reported that the incidence of reflux esophagitis after laparoscopy-assisted proximal gastrectomy (LAPG) decreased with time, in parallel with the recovery of gastrointestinal motility [8]. However, some studies found that PG provided no benefit in terms of postoperative nutritional status and weight loss [9, 10]. Although some patients suffer from stasis 1 year after PG, we suggest that most of them report that their symptoms gradually improve and that the amount of food intake gradually increases after the second year. Thus, we investigated long-term outcomes, including nutrition indices, such as body weight, serum albumin, total protein, hemoglobin, and ferritin. We also observed changes in upper gastrointestinal tract motility, including the gastric tube, to determine whether motility relates to nutritional status.

## Subjects and methods

### Patients

From April 2000 through December 2014, we performed PG on 134 patients with gastric cancer at Gunma University Hospital. The indication for PG at our institute is gastric cancer located in the upper third of the stomach with a clinical stage of T1-2N0M0, based on the Japanese Classification of Gastric Carcinoma [11]. We performed mainly jejunal interposition (JI) reconstruction from 2000 to 2005 and GT reconstruction from 2006 to 2014; we did not change the reconstructive procedure according to the size of the remnant stomach after gastrectomy. From this PG group, we selected the 124 patients who were diagnosed pathologically with T1-2N0M0 gastric cancer (Fig. 1). Patients in the PG group were classified retrospectively based on the surgical method and the reconstructive procedure into a PG–JI group ($n = 40$) and a PG–GT group ($n = 84$). We compared the long-term outcomes after PG to outcomes seen after TG. In the same time period (2000–2014), there were 291 cases of TG performed for gastric cancer at Gunma University Hospital. From this group, we selected the 99 patients who were diagnosed pathologically with T1-2N0M0 gastric cancer and who underwent TG with Roux-en Y reconstruction (TG–RY).

We analyzed patient age and gender, tumor characteristics, duration of surgery, estimated blood loss, postoperative complications, and nutritional parameters. Nutritional parameters after surgery were assessed based on changes in body weight and laboratory findings (total protein, serum albumin, hemoglobin, and ferritin). Following surgery, prophylactic proton pump inhibitor was given to all patients. Endoscopic examinations were performed on all patients 12 months postoperatively to evaluate the condition of the lower esophageal mucosa. The degree of reflux esophagitis was classified according to the Los Angeles Classification of Esophagitis [12]. The median duration of follow-up for all patients was 48 months (range 6–60 months). Patients were routinely followed at our outpatient clinic at 1, 6, 12, 24, 36, 48, and 60 months postoperatively. This study was approved by the Institutional Review Board of the Gunma University Graduate School of Medicine and was in accordance with the ethical guidelines of the Declaration of Helsinki.

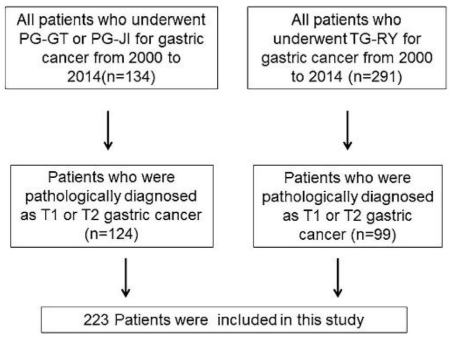



**Fig. 1** Study design. PG–GT proximal gastrectomy followed by gastric tube reconstruction, PG–JI proximal gastrectomy followed by jejunum interposition, TG–RY total gastrectomy followed by Roux-en Y reconstruction. Staging was classified according to the 3rd English edition of the Japanese classification of gastric carcinoma

## Surgical procedure

Proximal gastrectomy was performed with curative intent; vagus nerve preservation was not performed. Gastric tube reconstruction was performed as described previously [7]. In LAPG, five ports were introduced into the right upper quadrant (5 mm), right middle quadrant (12 mm), umbilical region (12 mm), left middle quadrant (5 mm), and left upper quadrant (12 mm). Before reconstruction, PG was completed with dissection of the lymph nodes according to the Japanese gastric cancer treatment guidelines [13]. Reconstruction was done with a gastric tube. Esophagogastrostomy was performed with an Orvil package (Covidien, Dublin, Ireland) consisting of a 25-mm anvil with the head pretilted and the tip attached to an 18-Fr orogastric tube. In preparation for transoral placement of the anvil head, the esophagus was transected with an Endo-GIA 60-3.5 stapler (Covidien). A minilaparotomy (about 4 cm long) was made in the upper abdomen, and the peritoneal cavity was entered. The stomach was exteriorized through this incision. After the vessels of the greater and lesser curvatures were ligated, the gastric body was divided with the Endo-GIA 60-3.5 stapler to create a gastric tube (20 cm long, 3–4 cm wide, Fig. 2A). The cartridge of the circular stapler was introduced through the cut-end of the gastric tube, allowing the tip of the cartridge to exit the anterior wall of the gastric tube. Using the Lig-A-Loops (Cardinal Health Japan, Tokyo, Japan), the gastric tube was pulled toward the main body of the cartridge to prevent the gastric tube from slipping off and being accidentally caught up inside the approximation of the anvil and the cartridge when closing the circular stapler. The cartridge of the circular stapler was introduced into the peritoneal cavity through the minilaparotomy. Docking with the anvil and cartridge was performed under confirmation of appropriate approximation using a fiberscope (Fig. 2B). After anastomosis was performed, the cut-end of the gastric tube was closed using the Endo-GIA 60-3.5 stapler. The diaphragm and gastric tube were sutured to prevent reflex esophagitis (Fig. 2C, D). A pyloroplasty was carefully performed with the finger fracture method.

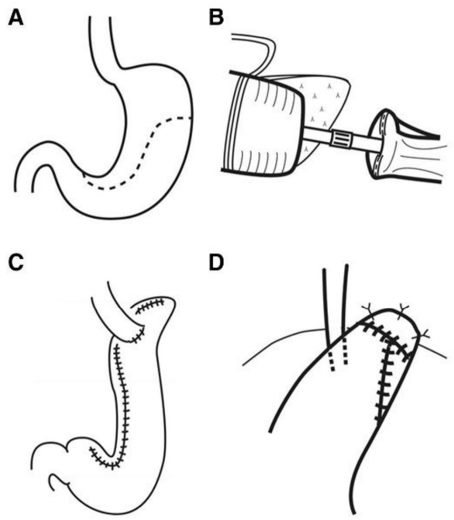



**Fig. 2** Method of gastric tube reconstruction. **A** The upper two-thirds of the stomach were resected with a linear stapler device along a *dashed line*. **B** The cartridge of the circular stapler was introduced into the peritoneal cavity through the minilaparotomy. **C** The anastomosis was made between the esophagus and the anterior wall of the gastric tube with a circular stapler. **D** The tip of the gastric tube and diaphragm were sutured to prevent reflux esophagitis

When we performed JI reconstruction, a 10- to 15-cm-long jejunal limb was brought up via the retrocolic route and anastomosed end-to-side with the esophagus and end-to-side with the remaining stomach [14]. We used a circular stapling device, size 25 mm (CDH or PCEEA), for the esophagojejunostomy and jejunogastrostomy.

Surgical treatment with RY reconstruction after LATG was described previously [15].

## Manometric recording

Manometric recording was carried out at 1, 2, 3, 4, and 5 years after surgery.

A 6-mm-diameter flexible probe containing four strain gauge pressure transducers was used to monitor intestinal motor activity (GMMS-600; Star Medical, Tokyo, Japan). All subjects were required to stop taking medications known to affect gastrointestinal motility for at least 48 h before the study. After the subjects had fasted for at least 12 h overnight, the manometry assembly was inserted through a nostril, and all pressure transducers were positioned in the reconstructed tract under fluoroscopic control as described below. The pressure transducers were positioned to measure intraluminal pressure in the esophagus, gastric tube, and duodenum. The first to the seventh proximal pressure transducers were positioned in the esophagus. The eighth and ninth pressure transducers were positioned in the gastric tube. The 10th transducer was located in the proximal duodenum. Recording was started at 9:00 a.m. in all patients and continued for 4 h—the first 2 h with the patient fasting, and the remaining 2 h after the patient ingested a 400-kcal meal (carbohydrates, 62.4 g; proteins, 17.52 g; lipids, 8.9 g/400 ml). All patients ingested the entire meal.

### Statistical analysis

The statistical significance of the difference between two parameters was determined with Student's *t* test or Fisher's exact test. Statistical significance was set at $p < 0.05$ (two-sided). Statistical analyses were performed with JMP® version 9 (SAS Institute, Inc., Cary, NC, USA).

## Results

### Patient clinical characteristics

The clinicopathological features of the patients who underwent the different surgical approaches are summarized in Table 1. There were 84 cases of PG–GT (which included 69 laparoscopic cases), 40 cases of PG–JI, and 99 cases of TG–RY (which included 33 laparoscopic cases). The average patient age in each surgical group was as follows: PG–GT, 64.6 ± 16.3 years; PG–JI, 66.0 ± 9.1 years; and TG–RY, 68.2 ± 11.2 years. No significant association was found between surgical approach and sex, age, or histologic type. The median tumor size in the PG–GT, PG–JI, and TG–RY groups was 29.6, 29.2, and 46.1 mm, respectively, with a significant difference between the TG–RY and PG–GT groups ($p = 0.0001$) and between the TG–RY and PG–JI groups ($p = 0.0001$).

In terms of the pathological T factor, 58 (69.0 %) of the PG–GT, 29 (72.5 %) of the PG–JI, and 70 (70.7 %) of the TG–RY patients had cancer invasion deeper than the submucosa. In terms of the pathological N factor, 8 (9.5 %) of the PG–GT, 3 (7.5 %) of the PG–JI, and 17 (17.2 %) of the TG–RY patients had localized lymph node metastasis. As for pathological stage, 51 (60.7 %) of the PG–GT, 23 (57.5 %) of the PG–JI, and 58 (58.6 %) of the TG–RY patients were pathological stage IB. There were no significant differences among the three groups with regard to T factor, N factor, and pathological stage.

### Operative results and postoperative complications

The median operating time for the PG–GT, PG–JI, and TG–RY groups was 204, 227, and 242 min, respectively. Although the time for the PG–GT group was shorter than that of the other groups, the difference was not significant. The median operative blood loss was 208, 500, and 484 ml, respectively, with a significant difference between the PG–GT and PG–JI groups ($p = 0.0001$) and the PG–GT and TG–RY groups ($p = 0.0001$; Table 1). Although a less extensive lymphadenectomy was carried out in the PG group, there was no significant difference among the three groups.

There were no postoperative deaths in this 223-patient study population. One patient (2.5 %) in the PG–GT group developed an anastomotic leakage and an intramediastinal abscess that required image-guided drainage.

Eleven patients (13.0 %) in the PG–GT group and five patients (12.5 %) in the PG–JI group experienced anastomotic stenosis (11 patients at the esophagogastrostomy and 5 patients at the esophagojejunostomy) and underwent successful balloon dilatation, while no patients in the TG–RY group suffered from anastomotic stenosis. The findings of endoscopic examinations performed 1 month and 1 year after surgery are shown in Fig. 3. Thirteen patients (15.4 %) in the PG–GT group were confirmed to have reflux esophagitis on endoscopy 1 month after surgery. The severity of esophagitis in these 13 patients was grade A in two, grade B in nine, and grade C in two patients. Eight patients (9.5 %) were confirmed to have reflux esophagitis on endoscopy 1 year after surgery. The severity of esophagitis in these 8 patients was grade A in five and grade B in three patients. Seven patients (17.5 %) in PG–JI group were confirmed to have reflux esophagitis on endoscopy 1 month after surgery. The severity of esophagitis in these 7 patients was grade A in four, grade B in two, and grade C in one patient. Four patients (10.0 %) were confirmed to have reflux esophagitis on endoscopy 1 year after

**Table 1** Characteristics of the patients

| | PG GT($n = 84$) | PG JI ($n = 40$) | TG–RY ($n = 99$) |
|---|---|---|---|
| Age (years) | 64.6 ± 16.3 | 66.0 ± 9.1 | 68.2 ± 11.2 |
| Gender (Male/female) | 62/22 | 30/10 | 72/27 |
| Histologic type (Well/Mod/Por) | 43/19/22 | 18/9/13 | 52/18/29 |
| T factor (1a/1b/2) | 26/48/10 | 11/23/6 | 29/44/26 |
| Tumor size | 29.6 ± 17.9 | 29.2 ± 26.7 | 46.1 ± 27.2 |
| N factor (0/1) | 76/8 | 37/3 | 82/17 |
| Stage (IA/IB) | 33/51 | 17/23 | 41/58 |
| Operation (Laparo/Open) | 69/15 | 0/40 | 33/66 |
| Operation time | 204.2 ± 51.0 | 227.5 ± 41.4 | 242.5 ± 73.7 |
| Blood loss | 208.9 ± 236.9 | 500.3 ± 343.6 | 484.4 ± 529.2 |
| Number of dissected LN | 25.1 ± 11.4 | 20.1 ± 9.3 | 31.2 ± 18.4 |

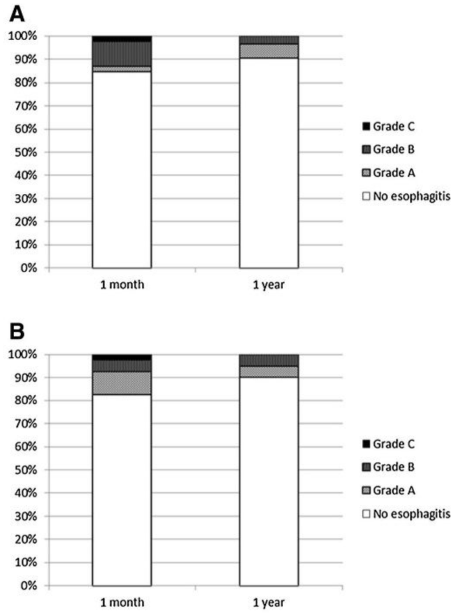



**Fig. 3** Findings of endoscopic examination. Reflux esophagitis was classified according to the Los Angeles classification. **A** At 1 month after surgery, the rate of reflux esophagitis of PG–GT was 15 %. It had decreased to 9 %. **B** At 1 month after surgery, the rate of reflux esophagitis of PG–JI was 17 %. It had decreased to 10 %

surgery. The severity of esophagitis in these 4 patients was grade A in two and grade B in two patients.

### Nutritional status

Nutritional indicators, such as body weight, serum albumin, total protein, ferritin, and hemoglobin levels, were investigated. To determine the percentage change in each nutritional indicator, changes in the values were divided by the preoperative value and multiplied by 100. Body weight steadily declined in all groups until 1.5 years, but after that, it started to increase in the PG–GT and PG–JI groups. The percentage change in body weight in the PG–GT group was significantly larger than that in the PG–JI and TG–RY groups at 2.5, 3, 4, and 5 years after surgery (Fig. 4). Figure 5 shows the results of the blood tests. We used the hemoglobin and ferritin levels as indicators of anemia. The hemoglobin level in the TG–RY group steadily declined, whereas those in the PG–GT and PG–JI groups did not show any decline. The hemoglobin level was significantly lower in the TG–RY group than in the PG–GT and PG–JI groups at all time points except 6 months after surgery. In the PG–GT and PG–JI groups, the ferritin level stabilized 6 months after surgery, but in the TG–RY group, it decreased continuously. Ferritin levels in the PG–GT and PG–JI groups were significantly higher than that of the TG–RY group at all time points except 6 months after surgery.

No significant differences among 3 groups were observed in the levels of total protein and serum albumin at any time point.

### Manometric study

In the fasted state, phase III motility of the gastric tube was observed but not propagated to the duodenum 1 year after surgery. However, the phase III motility that originated at the gastric tube was propagated to the duodenum 3 years after surgery (Fig. 6). In the fed state, nonpropagating clustered contractions of the gastric tube were observed after a meal, but no contractions of the duodenum were observed 1 year after surgery. However, phasic contractions of the duodenum were in harmony with gastric tube contractions 3 years after surgery (Fig. 7).

### Survival

After a median follow-up of 48 months, overall 5-year survival rates in the TG and PG groups were 93.3 % and 92.8 %, respectively ($p = 0.86$).

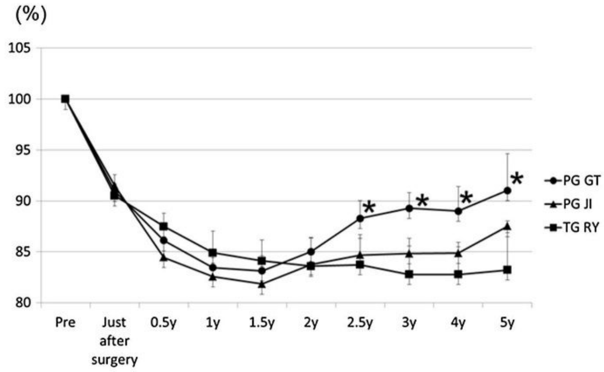
## Discussion

The results of the present study demonstrated that PG–GT has advantages as a surgical procedure compared with PG–JI and TG–RY in terms of its less invasiveness, such as shorter operative time, less intraoperative blood loss, and less body weight loss.

Recently, the use of laparoscopic gastrectomy has increased, and its convenience is essential for performing less invasive operations. Therefore, we consider that the GT reconstruction is the most useful procedure from the viewpoint of surgical safety. The shorter surgical duration and lesser intraoperative blood loss with PG–GT are due to the number of anastomoses and extent of lymph node dissection. The PG–GT involves just one anastomosis and localizes lymph node dissection. Some studies reported that esophagogastrostomy after PG was a better procedure than TG–RY in terms of surgical duration and blood loss [16–19].

Our indication for PG is cT1-2N0M0 gastric cancer, because pT1-2 gastric cancer located in the upper third of the stomach did not show any pathological lymph node

**Fig. 4** Comparison of the rate of body weight loss among the PG–GT, PG–JI, and TG–RY groups. All postoperative data are represented as values (mean ± SD) relative to preoperative data. The percentage increase in body weight of the PG–GT group was significantly larger than those of PG–JI and TG–RY groups at 2.5, 3, 4, and 5 years after surgery. *$p < 0.05$



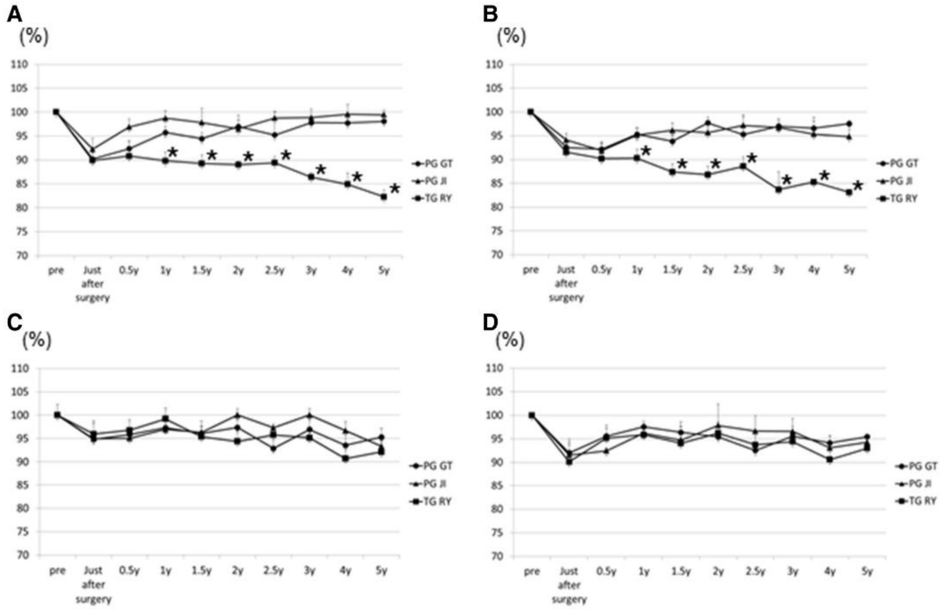




**Fig. 5** Laboratory examinations related to postoperative anemia and nutritional status. All postoperative data are represented as values (mean ± SD) relative to preoperative data. *$p < 0.05$. **A** Hemoglobin (Hb) level. The levels in the PG–GT and PG–JI groups were significantly higher than that in the TG–RY group at all time points except 6 months after surgery. **B** Ferritin level. The levels in the PG–GT and PG–JI groups were significantly higher than that of the TG–RY group at all time points except 6 months after surgery. **C** Total protein (TP). No statistically significant difference was seen among the three groups at any time point. **D** Serum albumin (Alb). No statistically significant difference was seen among the three groups at any time point

metastasis at stations #4d, #5, and #6 [11]. We chose patients with pT1-2N0M0 gastric cancers who underwent TG with Roux-en Y reconstruction during the same period to compare long-term outcomes. None of these TG patients underwent splenectomy, which could have affected the long-term outcome. Some previous reports indicated high

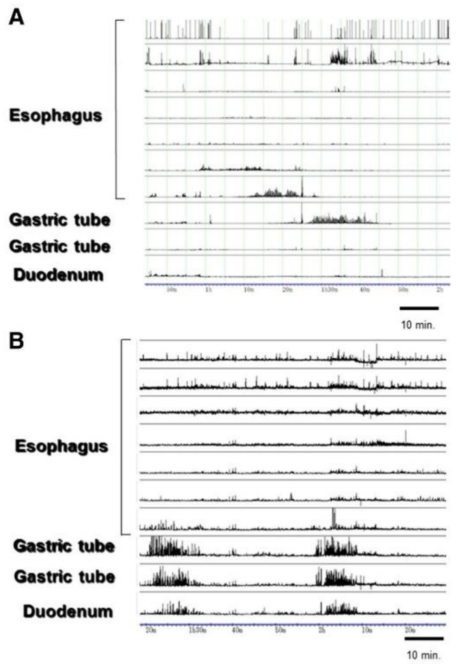



**Fig. 6** Gastrointestinal motor activity in the fasted state 1 year after PG–GT (**A**) and 3 years after PG–GT (**B**)

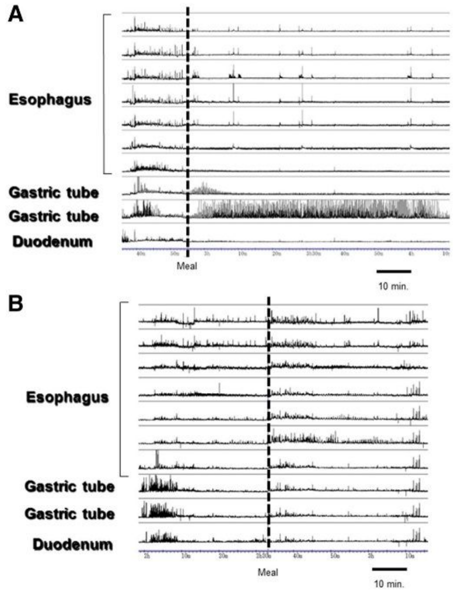



**Fig. 7** Gastrointestinal motor activity in the fed state 1 year after PG–GT (**A**) and 3 years after PG–GT (**B**)

overall 5-year survival rates of approximately 95 %. They reported that the overall survival rate of the PG group was similar to that of TG group [18, 19]. Our survival data align with those data.

Esophagogastrostomy is a simple reconstruction method but often leads to reflux esophagitis and anastomotic stenosis. In the present study, anastomotic stenosis occurred in 13.0, 12.5, and 0 % of PG–GT, PG–JI, and TG–RY patients, respectively. However, balloon dilatation was found to manage anastomotic stenosis effectively in most patients. Our data showed that the number of patients with reflux esophagitis decreased, and the grade of reflux esophagitis got milder with time from gastrectomy in both the PG–GT and PG–JI groups. All patients were treated with proton pump inhibitors. It has been reported that the percentage of reflux esophagitis in patients with esophagogastrostomy was around 20 % [16, 17]. We observed a lower percentage of reflux esophagitis in our study.

Poor postoperative nutritional status has also been one of the main issues for patients who have undergone gastrectomy. Considering our data, PG followed by gastric tube reconstruction could be a better method in terms of preserving QOL after surgery, particularly for preventing weight loss and anemia. In the present study, the hemoglobin level in the PG group was higher than that in the TG–RY group at all time points. This result is consistent with the previous reports [18–20]. Our data also indicated that ferritin levels were significantly higher than that of TG–RY at all time points after first year postsurgery and suggested that proximal gastrectomy prevents iron deficiency anemia after surgery. It has been shown that primary absorption of dietary iron occurs at the duodenal mucosa in mammals. We think duodenal passage plays an important role in the absorption of dietary iron.

Maintaining body weight is one of the most important issues after gastrectomy, but it is controversial whether proximal gastrectomy can prevent weight loss compared with total gastrectomy. Chen et al. [10] and Masuzawa et al. [18] reported that there was no difference in weight loss between patients treated with PG and TG. However, Ichikawa et al. [19] indicated that body weights were significantly lower in the TG group than in the PG group followed by the esophagogastrostomy group through the first to fifth year after surgery. Moreover, Nakamura et al. [17] showed that body weight in patients who underwent esophagogastrostomy following PG was significantly higher than that in patients who underwent jejunum interposition following PG at the third year after surgery. Interestingly, both studies showed no significant difference in nutritional status, such as total protein and serum albumin, regardless of the difference in body weight loss. Our data are in agreement with those results. The physiological function of the residual stomach after proximal gastrectomy has not been clarified in humans. We have already reported that the motilities of the gastric tube recovered with time, and it was associated with reflux esophagitis [8]. In the present study, manometric investigations revealed inadequate restoration of motilities in the gastric tube and duodenum in both the fasted and fed states at the first year after surgery. In the fasted state, phase III motility seems to be the most important motor activity, because indigestible food particles and gastric juice are emptied from the gastric tube into the small intestine during this phase. The paucity of phase III motility seems to result in stasis in the gastric tube. This could be the explanation for the insufficient recovery of dietary intake and of body weight loss. Our study showed that phase III motility did not appear 1 year after surgery, but it regularly appeared 3 years after surgery. We believe this restoration of phase III motility may contribute to food intake and maintenance of body weight. In the fed state, nonpropagated clustered contractions were observed in the gastric tube, but no contractions were observed in the duodenum. It is well known that gastroduodenal coordination plays a major role in the process of gastric emptying and gastrointestinal transit [21]. We hypothesize that uncoordinated motility between the gastric tube and the duodenum contributed to stasis. We did not study gastro-duodenal coordination in any more detail; however, it is assumed that the weak contractile activity of the duodenum contributed to stasis. At 3 years after surgery, clustered contractions in the duodenum appeared on manometry, and body weight recovered close to 90 %. We think this restoration of contractions in the duodenum could result in sufficient food intake and prevention of body weight loss after surgery.

In conclusion, we consider that PG–GT is the least invasive procedure in terms of operating time and blood loss. PG–GT could lead to a similar prognosis in patients with proximal gastric cancer compared with TG–RY, and early complications could be overcome. Probably, preservation of the duodenal passage could contribute to better iron uptake. Restoration of gastrointestinal motilities in the gastric tube and duodenum may ameliorate body weight loss and nutritional status, including anemia, in patients after PG.

#### Compliance with ethical standards

**Disclosures** Drs. Yoshitaka Toyomasu, Kyoichi Ogata, Masaki Suzuki, Toru Yanoma, Akiharu Kimura, Norimichi Kogure, Mitsuhiro Yanai, Tetsuro Ohno, Erito Mochiki, and Hiroyuki Kuwano have no conflicts of interest or financial ties to disclose.

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