Validity and significance of 30-day mortality rate as a quality indicator for gastrointestinal cancer surgeries

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Abstract

Background and Aim: Benchmarking has proven beneficial in improving the quality of surgery. Mortality rate is an objective indicator, of which the 30-day mortality rate is the most widely used. However, as a result of recent advances in medical care, the 30-day mortality rate may not cover overall surgery-related mortalities. We examined the significance and validity of the 30-day mortality rate as a quality indicator.

Methods: The present study was conducted on cancer surgeries of esophagectomy, total gastrectomy, distal gastrectomy, right hemicolectomy, low anterior resection, hepatectomy, and pancreaticoduodenectomy that were registered in the first halves of 2012, 2013 and 2014 in a Japanese nationwide large-scale database. This study examined the mortality curve for each surgical procedure, "sensitivity of surgery-related death" (capture ratio) at each time point between days 30-180, and the association between mortality within 30 days, mortality after 31 days, and preoperative, perioperative, and postoperative factors.

Results: Surgery-related mortality rates of each surgical procedure were 0.6%-3.0%. Regarding 30-day mortality rates, only 38.7% (esophagectomy) to 53.3% (right hemicolectomy) of surgery-related mortalities were captured. The capture ratio of surgery-related deaths reached 90% or higher for 120-day to 150-day mortality rates. Factors associated with mortality rate within 30 days/after the 31st day were different, depending on the type of surgical procedure.

Conclusion: Thirty-day mortality rate is useful as a quality indicator, but is not necessarily sufficient for all surgical procedures. Quality of surgery may require evaluation by combining 30-day mortality rates with other indicators, depending on the surgical procedure.

Keywords
30-day mortality rate, gastrointestinal cancer, hepatobiliary cancer, pancreatic cancer, quality indicator
1 | INTRODUCTION

Benchmarking and evaluations of surgical quality have proven beneficial and indispensable for improving surgical quality.1,2 A technique that focuses on the "structure," "process," "results," and "outcomes" of medical care has been proposed as a method for evaluating the quality of medical care, and a variety of other parameters are also being used as indicators in the assessment of surgical quality.3 For example, number of surgeries has been used as a "structural" indicator, rate of laparoscopic surgeries and length of hospital stay have been used as "process" indicators, and surgery-related mortality rate, as well as the rate of complications, has been used as "outcome" indicators. In recent years, interest has been increasingly shown in, as well as expectations from, outcome-oriented evaluations and measurements of medical care quality.

Mortality is an objective indicator, and assessment methods using overall mortality, surgery-related mortality, in-hospital mortality, 30-day mortality, and 90-day mortality are commonly used. Historically, the 30-day mortality rate has been used to measure performance across a wide range of surgical disciplines, and the American College of Surgeons National Surgical Quality Improvement Program (ACSNSQIP) database, which is widely considered as the gold standard database for surgical quality improvements and future pay-for-performance programs, records 30-day complication and mortality outcomes after surgery.4-6 The 30-day mortality rate, as an objective indicator, may not entirely encompass the overall surgery-related mortality rate.7,8 As a result of recent progress in medical care, especially advances in anaesthesia9 and intensive care,10 early postoperative mortality rates have decreased and survival rates have improved among patients who could have died early after surgery if treated using previous methods. However, this does not necessarily mean that all patients who avoid death during the early postoperative period will continue to survive. Medical circumstances, such as length of hospital stay after surgery, are different in each country, and patients particularly in Europe and the USA are discharged from hospitals during the early postoperative period. As a result, surgery-related complications that occur after discharge might be impossible to determine on the basis of 30-day mortality rates or in-hospital mortality rates. There is an absence of available data pertaining to how much of the surgery-related mortality rate can be determined based on the 30-day mortality rate, although this observation varies depending on situations in each country.

Herein, our study examines the significance and validity of the 30-day mortality rate as a surgery-related quality indicator (QI).

2 | METHODS

2.1 | Data collection

The National Clinical Database (NCD) was established in 2010 as a nationwide database that registers all surgical cases in cooperation with the surgical board certification system. Registrations started in 2011 and, currently, approximately 4300 facilities all over Japan are participating in the registry, and approximately 97% of surgical operations carried out by surgeons have been registered.11 The NCD, a Web-based data management system, continuously involves individuals who approve data, those in charge of annual case reports from various departments, and data entry personnel, thereby assuring data traceability. Among gastrointestinal surgeries registered in the NCD, data on items similar to those of the ACSNSQIP have been collected in regard to esophagectomy, total gastrectomy, distal gastrectomy, right hemicolectomy, low anterior resection, hepatectomy, pancreaticoduodenectomy, and acute diffuse peritonitis. Hepatectomy included only extended lobectomy, lobectomy and segmentectomy other than lateral segmentectomy for primary liver cancer or gallbladder cancer.

NCD records between January 1, 2012 and December 31, 2014 were analyzed for this study. The study was conducted on cases of gastrointestinal cancers, which were treated with esophagectomy, total gastrectomy, distal gastrectomy, right hemicolectomy, low anterior resection, hepatectomy, and pancreaticoduodenectomy. To examine the significance and validity of the 30-day mortality rate as a surgical QI, the study was carried out without including acute diffuse peritonitis, in which the patient’s condition before surgery may have a great influence on the mortality rate. In addition, cases of non-curative resection were excluded to exclude cancer-related deaths. In order to increase the quality of the endpoints, a longer duration was given to the postoperative observation period, and data on surgical cases operated between January and June, which allowed for acquisition of follow-up data from 30 days to 180 days after surgery, were analyzed. Records from patients who refused use of their data were excluded from this analysis. Records with missing data for age, gender, or status at postoperative day 30 were also excluded. Because non-curative resection cases had been excluded, postoperative mortality was equivalent to surgery-related mortality and, therefore, was considered as an endpoint.

2.2 | Mortality curve for each operative procedure

Mortality curves were drawn using death within 30 days or postoperative death as events to visualize when mortality events occurred in the postoperative course.

2.3 | Sensitivity of surgery-related mortality (capture ratio)

In order to assess the mortality at various time points, ranging from 30 days to 180 days, which covers the surgery-related mortality rate, we calculated the sensitivity of mortality at each point (capture ratio) on the basis of the 210-day mortality, and we also calculated respective 95% confidence intervals.

2.4 | Association between mortality within 30 days, mortality after 31 days, and preoperative, perioperative, and postoperative factors

Preoperative, perioperative, and postoperative factors, extracted during the creation of surgery-related mortality models, were used for
examining association of mortality within 30 days and after 31 days. We investigated the distribution of patients who died within 30 days as well as that of patients who died after the 31st day, and the difference between the two was tested using Fisher’s exact test. In both categories, a two-sided P-value of < 0.05 was considered statistically significant. Statistical analyses were carried out using STATA14 (Stata Corp., College Station, TX, USA).

The present study followed the ethical guidelines of human subjects based on the Helsinki Declaration. Review and approval by the ethics committee was not carried out because existing unlinkable, anonymized data were used in the present study.

3 | RESULTS

3.1 | Subjects

Our study included 7448 cases of esophagectomy, 22 453 cases of total gastrectomy, 48 774 cases of distal gastrectomy, 24 260 cases of right hemicolectomy, 27 046 cases of low anterior resection, 7486 cases of hepatectomy, and 10 550 cases of pancreaticoduodenectomy. Among patients with esophagectomies, 39.5% presented a history of smoking tobacco within 1 year before surgery, and 62.0% had an alcohol-consumption habit before surgery. Among patients with hepatectomies and those with pancreaticoduodenectomies, patients who were diagnosed with diabetes mellitus before surgery accounted for 28.1% and 30.2%, respectively, and these rates were higher than those found in patients undergoing other surgical procedures. Patients with intraoperative blood loss of 1000 mL or more accounted for 37.9% of those treated for hepatectomies, and 34.2% of those treated for pancreaticoduodenectomies, and patients with postoperative complications of Clavien-Dindo classification grade III or greater accounted for 16.9% of those treated for esophagectomies and 16.0% of those treated for pancreaticoduodenectomies. Patients with postoperative anastomotic leakage accounted for 11.6% of those treated for esophagectomies, 8.5% of those treated for low anterior resections, and 10.6% of those treated for esophagectomies and 16.0% of those treated for pancreaticoduodenectomies. Finally, 20.7% of patients treated for pancreaticoduodenectomies developed pancreatic fistulas (any grade), 2.3% developed grade C pancreatic fistulas, and bile leakage was present in 6.7% of patients treated for hepatectomies (Table 1).

3.2 | Mortality curves for each surgical procedure

When survival or death at day 210 was used as an endpoint, the surgery-related mortality rate was 3.0% for patients with hepatectomies, 2.5% for patients with pancreaticoduodenectomies, 2.3% for patients with esophagectomies, 1.4% for patients with total gastrectomies, 1.1% for patients with right hemicolectomies, 0.8% for patients with distal gastrectomies, and 0.6% for patients with low anterior resections, respectively, in descending order. All types of surgical procedures showed mortality rates that increased over time.

For right hemicolectomies, low anterior resections, and hepatectomies, the mortality rate nearly reached a plateau between days 90 and 150. For esophagectomies, total gastrectomies, gastrectomies, and pancreaticoduodenectomies, the mortality rate continuously increased until day 210 (Figure 1).

3.3 | Sensitivity of the 30-to-180-day mortality rate (capture ratio for surgery-related mortalities) in comparison with the 210-day mortality rate (surgery-related mortalities)

The 30-day mortality rate captured only 38.7% (esophagectomies) to 53.3% (right hemicolectomies) of surgery-related mortalities. The capture ratio for surgery-related mortalities reached 90% or greater when the 120-day mortality rate was taken into consideration for right hemicolectomy, low anterior resection, hepatectomy, and pancreaticoduodenectomy, as well as when the 150-day mortality rate was taken into account for esophagectomy, total gastrectomy, and distal gastrectomy. The capture ratio for surgery-related mortalities reached 90% or greater when the 120-day mortality rate was taken into consideration for right hemicolectomy, low anterior resection, hepatectomy, and pancreaticoduodenectomy, and when the 150-day mortality rate was taken into consideration for esophagectomy, total gastrectomy and distal gastrectomy. The capture ratio of 90-day mortality rate was 80.3% in esophagectomies, 80.3% in total gastrectomies, 81.6% in distal gastrectomies, 89.0% in right hemicolectomies, 88.5% in low anterior resections, 85.2% in hepatectomies and 81.2% in pancreaticoduodenectomies (Table 2).

3.4 | Association between mortality within 30 days, mortality after 31 days, and preoperative, perioperative and postoperative factors

Among factors that likely affect surgery-related mortality rates, the following showed a significantly higher percentage of deaths within 30 days, irrespective of the type of surgical procedure: postoperative complications of Clavien-Dindo classification grade III or higher (except esophagectomy), postoperative complications of Clavien-Dindo classification grade IV or higher (all surgical procedures), unplanned postoperative intubation (except esophagectomy and hepatectomy), and cardiac complications (all surgical procedures). In addition, the following factors were associated with individual surgical procedures: renal dysfunction (distal gastrectomy, right hemicolectomy), central nervous system disorder (right hemicolectomy), sepsis (right hemicolectomy), and septic shock (total gastrectomy, low anterior resection). Conversely, the following factors displayed significantly lower percentages in terms of mortality within 30 days: reoperation within 30 days (esophagectomy, total gastrectomy, right hemicolectomy, pancreaticoduodenectomy), anastomotic leakage (total gastrectomy, distal gastrectomy), pulmonary embolism (low anterior resection), pneumonia (hepatectomy), and urinary tract infection (total gastrectomy, right hemicolectomy) (Table 3).
TABLE 1  Characteristics of analyzed subjects

|                        | Esophagectomy (n = 7448) | Total gastrectomy (n = 22 453) | Distal gastrectomy (n = 48 774) | Right hemicolecetomy (n = 24 260) | Low anterior resection (n = 27 046) | Hepatectomy (n = 7486) | Pancreaticoduodenectomy (n = 10 550) | Total (n = 148 017) |
|------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------------|-----------------------------------|------------------------|--------------------------------------|-------------------|
| Age (y)                |                           |                               |                                 |                                   |                                   |                        |                                      |                   |
| 59                     | 1387                      | 18.6                          | 3340                            | 14.9                              | 7953                              | 16.3                   | 2569                                 | 10.6              |
| 60-64                  | 1477                      | 19.8                          | 3148                            | 14.0                              | 7005                              | 14.4                   | 3247                                 | 13.4              |
| 65-69                  | 1671                      | 22.4                          | 3652                            | 16.3                              | 7675                              | 15.7                   | 4464                                 | 18.4              |
| 70-74                  | 1586                      | 21.3                          | 4553                            | 20.3                              | 8877                              | 18.2                   | 4732                                 | 19.5              |
| 75-79                  | 947                       | 12.7                          | 4207                            | 18.7                              | 8339                              | 17.1                   | 3607                                 | 13.3              |
| 80+                    | 380                       | 5.1                           | 5535                            | 15.8                              | 8925                              | 18.3                   | 3263                                 | 12.1              |
| Gender                 |                           |                               |                                 |                                   |                                   |                        |                                      |                   |
| Female                 | 1223                      | 16.4                          | 5701                            | 25.4                              | 16 204                            | 33.2                   | 12 450                               | 51.3              |
| Male                   | 6225                      | 83.6                          | 16 752                           | 74.6                              | 32 570                            | 66.8                   | 11 810                               | 48.7              |
| Smoking habits         | (-)                       | 4509                          | 60.5                             | 17 534                             | 78.1                              | 38 700                  | 81.3                                 | 21 378            |
|                        | (+)                       | 2939                          | 39.5                             | 4919                               | 21.9                              | 10 074                  | 11.9                                 | 2882              |
| Drinking habits        | (-)                       | 2830                          | 38.0                             | 16 000                             | 71.3                              | 35 455                  | 72.7                                 | 20 008            |
|                        | (+)                       | 4618                          | 62.0                             | 6453                               | 28.7                              | 13 319                  | 27.3                                 | 4252              |
| Hypertension           | (-)                       | 5033                          | 67.6                             | 14 128                             | 62.9                              | 30 376                  | 62.3                                 | 14 715            |
|                        | (+)                       | 2415                          | 32.4                             | 8325                               | 37.1                              | 18 398                  | 37.7                                 | 9545              |
| Diabetes               | (-)                       | 6507                          | 87.4                             | 18 488                             | 82.3                              | 40 319                  | 82.7                                 | 19 876            |
|                        | (+)                       | 941                           | 12.6                             | 3965                               | 17.7                              | 8 455                   | 17.3                                 | 4384              |
| Chronic obstructive pulmonary disease | (-) | 6945                  | 93.2                             | 21 405                             | 95.3                              | 46 734                  | 95.8                                 | 23 568            |
|                        | (+)                       | 503                           | 6.8                              | 1048                               | 4.7                               | 2040                    | 4.2                                  | 692               |
| Brain disorder         | (-)                       | 7273                          | 97.7                             | 21 610                             | 96.2                              | 46 946                  | 96.3                                 | 23 295            |
|                        | (+)                       | 175                           | 2.3                              | 843                                | 3.8                               | 1828                    | 3.7                                  | 965               |
| ASA 2                  | (-)                       | 2418                          | 32.5                             | 6986                               | 31.1                              | 16 262                  | 33.3                                 | 6649              |
|                        | (+)                       | 5030                          | 67.5                             | 15 467                             | 68.9                              | 32 512                  | 66.7                                 | 17 611            |
| Intraoperative cardiac complications | (-) | 7438                  | 99.9                             | 22 443                             | 100.0                             | 48 755                  | 100.0                                | 24 251            |
|                        | (+)                       | 10                            | 0.1                              | 10                                 | 0.0                               | 19                      | 0.0                                  | 9                 |
| Intraoperative blood loss ≥1000 mL | (-) | 6709                  | 90.1                             | 20 261                             | 90.2                              | 47 436                  | 97.3                                 | 23 718            |
|                        | (+)                       | 739                           | 9.9                              | 2192                               | 9.8                               | 1338                    | 2.7                                  | 542               |
| Postoperative complications Clavien-Dindo classification ≥grade III | (-) | 6188                  | 83.1                             | 20 642                             | 91.9                              | 46 507                  | 95.4                                 | 23 195            |
|                        | (+)                       | 1260                          | 16.9                             | 1811                               | 8.1                               | 2267                    | 4.6                                  | 1065              |
| Procedure                                      | No. (%) | No. (%) | No. (%) | No. (%) | No. (%) | No. (%) | No. (%) | No. (%) |
|-----------------------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|
| Esophagectomy (n = 7448)                      | 7199   | 96.7    | 22 118  | 98.5    | 48 322  | 99.1    | 24 044  | 99.1    |
| Total gastrectomy (n = 22 453)                | 249     | 3.3     | 335     | 1.5     | 452     | 0.9     | 216     | 0.9     |
| Distal gastrectomy (n = 48 774)               | 26 782 | 99.0    | 7268    | 97.1    | 10 251  | 97.2    | 145 984 | 98.6    |
| Right hemicolectomy (n = 24 260)              | 264     | 1.0     | 218     | 2.9     | 299     | 2.8     | 2033    | 1.4     |
| Low anterior resection (n = 27 046)           | 23 991 | 98.9    | 26 844  | 99.3    | 7364    | 98.4    | 10 316  | 97.8    |
| Hepatectomy (n = 7486)                        | 290     | 1.1     | 122     | 1.6     | 234     | 2.2     | 3292    | 2.2     |
| Pancreatectoduodenectomy (n = 10 550)         | 205     | 1.1     | 122     | 1.6     | 234     | 2.2     | 3292    | 2.2     |
| Total (n = 148 017)                           | 145 984 | 98.6   | 146 078 | 98.7   | 146 736 | 99.8   | 146 078 | 98.7   |

Postoperative complications

- Clavien-Dindo classification ≥ grade IV
  - No. % No. % No. % No. % No. % No. % No. % No. %
  - (-) 7199 96.7 22 118 98.5 48 322 99.1 24 044 99.1 26 782 99.0 264 1.0 216 0.9 249 3.3
  - (+) 249 3.3 335 1.5 452 0.9 216 0.9 264 1.0 218 2.9 299 2.8

- Reoperation within 30 days after operation
  - (-) 6768 90.9 21 332 95.0 47 301 97.0 24 044 99.1 26 782 99.0 7268 97.1 10 251 97.2 145 984 98.6
  - (+) 249 3.3 335 1.5 452 0.9 216 0.9 264 1.0 218 2.9 299 2.8

- Surgical site infection other than anastomotic leakage
  - (-) 6828 91.7 21 304 94.9 47 406 97.2 24 044 99.1 26 782 99.0 7268 97.1 10 251 97.2 145 984 98.6
  - (+) 620 8.3 1149 5.1 1368 2.8 216 0.9 264 1.0 218 2.9 299 2.8

- Anastomotic leakage
  - (-) 6584 88.4 21 524 95.9 47 749 97.9 24 044 99.1 26 782 99.0 7268 97.1 10 251 97.2 145 984 98.6
  - (+) 864 11.6 929 4.1 1025 2.1 110 0.5 1211 4.5 444 5.9 1092 10.4

- Transfusion ≥ 5 U
  - (-) 7279 97.7 22 234 99.0 48 502 99.4 24 044 99.1 26 782 99.0 7268 97.1 10 251 97.2 145 984 98.6
  - (+) 169 2.3 219 1.0 272 0.6 116 0.5 122 1.1 262 3.5 444 5.9 1092 10.4

- Postoperative unexpected intubation
  - (-) 7012 94.1 22 165 98.7 47 414 97.9 24 044 99.1 26 782 99.0 7268 97.1 10 251 97.2 145 984 98.6
  - (+) 436 5.9 288 1.3 360 0.7 110 0.5 137 0.5 262 3.5 444 5.9 1092 10.4

- Postoperative mechanical ventilation ≥ 48 h
  - (-) 6881 92.4 22 157 98.7 48 418 99.3 24 044 99.1 26 782 99.0 7268 97.1 10 251 97.2 145 984 98.6
  - (+) 567 7.6 296 1.3 356 0.7 161 0.7 168 0.6 154 2.1 237 2.2 1939 13.1

- Postoperative renal dysfunction
  - (-) 7318 98.3 22 264 99.2 48 493 99.4 24 121 99.4 26 852 99.3 7331 97.9 10 378 98.4 146 517 99.0
  - (+) 130 1.7 189 0.8 281 0.6 139 0.6 194 0.7 155 2.1 172 1.6 1260 0.9

- Postoperative central nervous system disorder
  - (-) 7430 99.8 22 400 99.8 48 897 99.8 24 211 99.8 26 998 99.8 7327 98.9 10 528 99.8 147 736 99.8
  - (+) 18 0.2 53 0.2 85 0.2 45 0.2 48 0.2 10 0.1 22 0.2 281 0.2

- Postoperative cardiac complications
  - (-) 7388 99.2 22 360 99.6 48 653 99.8 24 203 99.8 26 981 99.8 7445 99.5 10 478 99.3 147 509 99.7
  - (+) 59 0.8 93 0.4 121 0.5 57 0.2 65 0.2 41 0.5 72 0.7 508 0.3

- Postoperative sepsis
  - (-) 7066 94.9 21 954 97.8 48 198 98.8 23 978 98.8 26 509 98.0 7299 98.8 10 096 95.7 145 100 98.0
  - (+) 382 5.1 499 2.2 576 1.2 282 1.2 537 2.0 187 2.5 454 4.3 2917 2.0

- Postoperative septic shock
  - (-) 7364 98.9 22 324 99.4 48 618 99.7 24 156 99.6 26 921 99.5 7438 99.4 10 447 99.0 147 268 99.5
  - (+) 84 1.1 129 0.6 156 0.3 104 0.4 125 0.5 48 0.6 108 1.0 749 0.5

- Postoperative pneumonia
  - (-) 6543 87.8 21 783 97.0 47 884 98.2 23 991 98.9 26 844 99.3 7364 98.4 10 316 97.8 144 725 97.8
  - (+) 905 12.2 670 3.0 890 1.8 269 1.1 202 0.7 122 1.6 234 2.2 3292 2.2

(Continues)
DISCUSSION

We found that the 30-day mortality, which was a standard QI for international comparisons, was not sufficient as a QI for all gastrointestinal cancer surgeries. Surgical stress, risk of complications, surgery-related mortality rate, and the 30-day mortality differ depending on the type of surgical procedure. Even when the type of surgical procedure was identical, the risk of surgery-related deaths and complications varied depending on patient-related risks, such as age and comorbidities. However, from an overall perspective, the risk roughly reflects the difference associated with the type of surgical procedure. Also, in our data, surgery-related mortality rates varied depending on the type of surgical procedure, where highest values were found in hepatectomies and lowest in low anterior resections. Previous reports, based on a comparison of 30-day mortality rates, have shown that surgical outcomes were more favorable in Japan than in Europe and the USA.

The number of surgeries carried out, rate of laparoscopic surgeries, length of hospital stay, surgery-related mortality rates, and rate of complications among in-hospital deaths are difficult to determine. Similarly, 30-day mortality rates do not reflect all aspects of surgical outcomes or qualities. The findings of the present study show that postoperative complications categorized as Clavien-Dindo classification grade II or greater, postoperative complications categorized as Clavien-Dindo classification grade III or IV, and postoperative complications categorized as Clavien-Dindo classification grade III or IV are very high. In our study, surgical complications, including those that are minor and delayed, cases of hospital transfer or hospital discharge without alleviation of complications and atypical postoperative care systems, were evaluated. From our perspective, surgery-related mortality rates are believed to be of utmost importance as indicators for the evaluation of surgical outcomes, such as postoperative surgical site infections and anastomotic leakage. The capture ratio may differ depending on diagnostic criteria and postoperative care systems, which makes it difficult to carry out a postoperative care system. Safety is the most basic requirement for carrying out surgery, and treatment outcome should be evaluated on an individual basis.

In Japan, the length of postoperative hospital stays are relatively short, and surgery-related deaths among in-hospital deaths are difficult to determine. Similarly, 30-day mortality rates do not reflect all aspects of surgical outcomes or qualities. The findings of the present study show that postoperative complications categorized as Clavien-Dindo classification grade II or greater, postoperative complications categorized as Clavien-Dindo classification grade III or IV, and postoperative complications categorized as Clavien-Dindo classification grade III or IV are very high. In our study, surgical complications, including those that are minor and delayed, cases of hospital transfer or hospital discharge without alleviation of complications and atypical postoperative care systems, were evaluated. From our perspective, surgery-related mortality rates are believed to be of utmost importance as indicators for the evaluation of surgical outcomes, such as postoperative surgical site infections and anastomotic leakage. The capture ratio may differ depending on diagnostic criteria and postoperative care systems, which makes it difficult to carry out a postoperative care system. Safety is the most basic requirement for carrying out surgery, and treatment outcome should be evaluated on an individual basis.

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hemicolectomy), central nervous system disorder (right hemicolectomy), sepsis (right hemicolectomy), and septic shock (total gastrectomy, low anterior resection) were also extracted. In contrast, our results also indicated that factors highly associated with the type of surgical procedure, such as reoperation within 30 days and anastomotic leakage, had significantly lower percentages of deaths occurring within 30 days after surgery. Our data show that factors linked to surgery-related deaths differ depending on the type of surgical procedure, and that when the 30-day mortality rate was used as a QI for an evaluation of surgery outcome or quality, the capture ratio for the determination of deaths associated with surgical technique-related complications may be low or otherwise useless, depending on the respective surgical procedure. Furthermore, our data suggest that when the rate of surgical site infections (except those as a result of anastomotic leakage) is high in surgeries other than low anterior resection, the surgery-related mortality rate is likely to be high even when the 30-day mortality rate is low. Also, when the rate of anastomotic leakage is high in esophagectomy, total gastrectomy, and distal gastrectomy, the surgery-related mortality rate is likely to be high, even when the 30-day mortality rate is low. Similarly, in esophagectomy, right hemicolectomy, pancreaticoduodenectomy, the surgery-related mortality rate is likely to be high when the rate of reoperation within 30 days is high, even when the 30-day mortality rate is low and, as a result, surgery-related mortality may be difficult to evaluate properly.

Meanwhile, in low anterior resections, surgery-related mortalities can be evaluated properly through evaluation of the 30-day mortality rate. Thus, in order to evaluate the outcomes or qualities of surgery, the 30-day mortality rate and other indicators, such as complications, will need to be assessed in combination with outcomes or qualities of surgery. For example, the incidence of anastomotic leakage in total gastrectomy and distal gastrectomy or bile leakage in hepatectomy may be useful. And to use these indicators could fit the actual clinical feelings of surgeons. A comparison with worldwide outcomes or qualities of surgery, or benchmarking, will be necessary to improve the outcomes or qualities of surgery in Japan. However, data regarding Japan, in which surgery-related mortality is well determined, were based on the Japanese health-care system, and it remains unknown whether these observations are unique to Japan or are universal and shared worldwide. Our results, which were derived from data collected in Japan, could be used to guide an evaluation of their association with medical circumstances in all countries worldwide, through an international endeavor.

**5 | CONCLUSION**

The 30-day mortality rate is definitely useful as a QI for the evaluation of the outcomes or qualities of gastrointestinal cancer surgeries,
| TABLE 3 Association between mortality within 30 d, mortality after 31 d, and preoperative, perioperative and postoperative factors |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
|                                | Esophagectomy                   | Total gastrectomy               | Distal gastrectomy              |
|                                | Postoperative death within 30 d | Postoperative death after 31st day | Postoperative death within 30 d | Postoperative death after 31st day |
|                                | (n = 67)                        | (n = 106)                       | (n = 152)                       | (n = 169)                       |
| Age (<59/60-64/65-69/70-74-75-79/80-) | 4/14/8/17/11/6/25/44/11        | .763                           | 4/11/13/21/48/55/20/47/65      | .811                           |
| Gender (F/M)                   | 6/61                            | 7/99                            | 52/148                         | 56/156                         | 1.000                          |
| Smoking habits (-)             | 36 (53.7%)                      | 48 (45.3%)                     | 31 (15.5%)                     | 29 (13.6%)                     | .580                           |
| Drinking habits (-)            | 39 (58.2%)                      | 67 (62.3%)                     | 31 (15.5%)                     | 47 (22.0%)                     | .103                           |
| Hypertension (-)               | 32 (47.8%)                      | 41 (38.7%)                     | 97 (48.5%)                     | 88 (41.1%)                     | .139                           |
| Diabetes (-)                   | 16 (23.9%)                      | 20 (18.9%)                     | 49 (24.3%)                     | 52 (24.3%)                     | 1.000                           |
| Chronic obstructive pulmonary disease (-) | 8 (11.9%)                      | 13 (12.2%)                    | 21 (10.5%)                     | 21 (9.8%)                      | .871                           |
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| Chronic obstructive pulmonary disease (-) | 8 (11.9%)                      | 13 (12.2%)                    | 21 (10.5%)                     | 21 (9.8%)                      | .871                           |
| Brain disorder (-)             | 3 (4.5%)                        | 4 (3.8%)                       | 21 (10.5%)                     | 19 (9.8%)                      | .620                           |
| Intraoperative cardiac complications (-) | 2 (3.0%)                        | 0 (0.0%)                      | 26/126                         | 31/138                         | .884                           |
| Intraoperative blood loss ≥1000 mL | 18 (26.9%)                      | 27 (25.5%)                     | 8/17                           | 18/18                          | .763                           |
| Postoperative complications Clavien-Dindo classification ≥grade III (-) | 55 (82.1%)                      | 79 (74.5%)                     | 55 (82.1%)                     | 51 (48.1%)                     | <.001                           |
| Postoperative complications Clavien-Dindo classification ≥grade IV (-) | 55 (82.1%)                      | 51 (48.1%)                     | 55 (82.1%)                     | 51 (48.1%)                     | <.001                           |
| Reoperation within 30 days after operation (-) | 19 (28.4%)                      | 48 (45.3%)                     | 19 (28.4%)                     | 48 (45.3%)                     | <.001                           |
| Surgical site infection other than anastomotic leakage (-) | 6 (9.0 %)                       | 31 (29.2%)                     | 6 (9.0 %)                       | 31 (29.2%)                     | 1.000                           |
| Anastomotic leakage (-)        | 15 (22.4%)                      | 38 (35.8%)                     | 15 (22.4%)                      | 38 (35.8%)                     | <.001                           |
| Transfusion ≥5 U (-)           | 17 (25.4%)                      | 29 (27.4%)                     | 17 (25.4%)                      | 29 (27.4%)                     | <.001                           |
| Postoperative unexplained intubation (-) | 33 (49.3%)                      | 52 (49.1%)                     | 33 (49.3%)                      | 52 (49.1%)                     | <.001                           |
| Postoperative mechanical ventilation ≥48 h (-) | 35 (52.2%)                      | 62 (58.5%)                     | 35 (52.2%)                      | 62 (58.5%)                     | <.001                           |
| Postoperative renal dysfunction (-) | 22 (32.8%)                      | 28 (26.4%)                     | 22 (32.8%)                      | 28 (26.4%)                     | <.001                           |
| Postoperative central nervous system disorder (-) | 0 (0.0%)                        | 1 (0.9%)                       | 0 (0.0%)                        | 1 (0.9%)                       | .465                            |
| Postoperative cardiac complications (-) | 33 (49.3%)                      | 11 (10.4%)                     | 33 (49.3%)                      | 11 (10.4%)                     | <.001                           |
| Postoperative sepsis (-)       | 34 (50.7%)                      | 47 (44.3%)                     | 34 (50.7%)                      | 47 (44.3%)                     | <.001                           |
| Postoperative septic shock (-)  | 24 (35.8%)                      | 26 (24.5%)                     | 24 (35.8%)                      | 26 (24.5%)                     | <.001                           |
| Postoperative pneumonia (-)    | 34 (50.7%)                      | 55 (51.9%)                     | 34 (50.7%)                      | 55 (51.9%)                     | .662                           |
| Postoperative deep vein thrombosis (-) | 0 (0.0%)                        | 0 (0.0%)                       | 3 (2.0%)                        | 5 (3.0%)                       | .726                            |
| Postoperative pulmonary embolism (-) | 0 (0.0%)                        | 0 (0.0%)                       | 2 (1.3%)                        | 3 (1.8%)                       | .726                            |
| Postoperative urinary tract infection (-) | 1 (1.5%)                        | 8 (7.5%)                       | 1 (1.5%)                        | 8 (7.5%)                       | .156                            |
| Postoperative pancreatic fistula (-) | 4 (6.2%)                        | 10 (5.9%)                      | 4 (6.2%)                        | 10 (5.9%)                      | .179                            |
| Postoperative pancreatic fistula ≥grade C (-) | 4 (6.2%)                        | 10 (5.9%)                      | 4 (6.2%)                        | 10 (5.9%)                      | .179                            |
| ASA2. American Society of Anesthesiologists Classification 2. The significance of bolded terms was “P < 0.05.” | ASA2. American Society of Anesthesiologists Classification 2. The significance of bolded terms was “P < 0.05.” | ASA2. American Society of Anesthesiologists Classification 2. The significance of bolded terms was “P < 0.05.” | ASA2. American Society of Anesthesiologists Classification 2. The significance of bolded terms was “P < 0.05.” |
| Right colectomy | Low anterior resection | Hepatectomy | Pancreatecoduodenectomy |
|-----------------|-----------------------|------------|-------------------------|
| **Postoperative death within 30 days** | **Postoperative death after 31st day** | **Postoperative death within 30 days** | **Postoperative death after 31st day** | **Postoperative death within 30 days** | **Postoperative death after 31st day** |
| (n = 152)      | (n = 169)             | (n = 152)  | (n = 169)              | (n = 152)       | (n = 169)       |
| P-value        | P-value               | P-value    | P-value                | P-value         | P-value         |
| 7/6/10/16/25/78| 2/3/5/9/19/66        | 7/9/11/13/12/28 | 1/9/7/7/16/37         | 3/14/14/29/24/11 | 8/21/19/24/36/20 |
| 63/79          | 60/64                 | 17/63      | 15/62                  | 21/74           | 30/98           | .844 |
| 9 (6.3%)       | 14 (11.3%)            | 19 (23.8%) | 13 (16.9%)            | 20 (21.1%)      | 32 (25.0%)      | .325 |
| 17 (12.0%)     | 16 (12.9%)            | 17 (21.3%) | 14 (18.2%)            | 22 (23.2%)      | 39 (30.5%)      | .288 |
| 60 (42.3%)     | 61 (49.2%)            | 31 (38.8%) | 30 (39.0%)            | 42 (44.2%)      | 61 (47.7%)      | .684 |
| 26 (18.3%)     | 28 (22.6%)            | 20 (25.0%) | 21.0 (27.3%)          | 26 (27.4%)      | 43 (33.6%)      | .380 |
| 9 (6.3%)       | 10 (8.1%)             | 5 (6.3%)   | 3 (3.9%)               | 4 (4.2%)        | 7 (5.5%)        | .762 |
| 14 (9.9%)      | 9 (7.3%)              | 12 (15.0%) | 9 (11.7%)              | 5 (5.3%)        | 7 (5.5%)        | 1.000 |
| 131 (92.3%)    | 119 (96.0%)           | 68 (85.0%) | 65 (84.4%)             | 84 (88.4%)      | 109 (85.2%)     | .554 |
| 3 (2.1%)       | 0 (0.0%)              | 1 (1.3%)   | 0 (0.0%)               | 1 (1.1%)        | 0 (0.0%)        | .426 |
| 11 (7.7%)      | 17 (13.7%)            | 12 (15.0%) | 12 (15.6%)             | 65 (68.4%)      | 88 (68.8%)      | 1.000 |
| 113 (79.6%)    | 57 (46.0%)            | <.001      | 66 (82.5%)             | <.001           | 88 (92.6%)      | 90 (70.3%) |
| 108 (76.1%)    | 29 (23.4%)            | <.001      | 63 (78.8%)             | <.001           | 87 (91.6%)      | 63 (49.2%) |
| 20 (14.1%)     | 35 (28.2%)            | .006       | 34 (42.5%)             | 32 (41.6%)      | 21 (22.1%)      | .637 |
| 19 (13.4%)     | 31 (25.0%)            | .018       | 14 (17.5%)             | 18 (23.4%)      | 4.30           | <.001 |
| 19 (13.4%)     | 20 (16.1%)            | .603       | 30 (37.5%)             | 27 (35.1%)      | .868           | 4 (4.2%) |
| 18 (12.7%)     | 13 (10.5%)            | .702       | 15 (18.8%)             | 16 (20.8%)      | .842           | 47 (49.5%) |
| 32 (22.5%)     | 14 (11.3%)            | .022       | 34 (42.5%)             | 20 (26.0%)      | .043           | 42 (44.2%) |
| 39 (27.5%)     | 28 (22.6%)            | .397       | 29 (36.3%)             | 21 (27.3%)      | .237           | 41 (43.2%) |
| 35 (24.6%)     | 17 (13.7%)            | .030       | 27 (33.8%)             | 16 (20.8%)      | .076           | 41 (43.2%) |
| 9 (6.3%)       | 1 (0.8%)              | .022       | 7 (8.8%)               | 2 (2.6%)        | .168           | 1 (1.1%) |
| 41 (28.9%)     | 2 (1.6%)              | <.001      | 38 (47.5%)             | 11 (14.3%)      | <.001          | 29 (30.5%) |
| 46 (32.4%)     | 26 (21.0%)            | .039       | 33 (41.3%)             | 22 (28.6%)      | .132           | 25 (26.3%) |
| 34 (23.9%)     | 19 (15.3%)            | .091       | 29 (36.3%)             | 9 (11.7%)       | <.001          | 11 (11.6%) |
| 25 (17.6%)     | 32 (25.8%)            | .134       | 16 (20.0%)             | 22 (28.6%)      | .264           | 9 (9.5%) |
| 5 (3.5%)       | 0 (0.0%)              | .063       | 4 (5.0%)               | 1 (1.3%)        | .367           | 3 (3.2%) |
| 2 (1.4%)       | 0 (0.0%)              | .500       | 6 (7.5%)               | 0 (0.0%)        | .028           | 0 (0.0%) |
| 4 (2.8%)       | 12 (9.7%)             | .021       | 2 (2.5%)               | 8 (10.4%)       | .053           | 5 (5.3%) |
| 8 (8.4%)       | 34 (26.6%)            | .001       |                      |                |               |                 |
but it is not necessarily sufficient to cover all types of surgical procedures. Depending on the type of surgical procedure, evaluations of surgical outcome (or qualities) may need to be carried out in combination with the use of the 30-day mortality rate and other indicators, such as complications.

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DISCLOSURE

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