Laparoscopic Surgery for Acute Diffuse Peritonitis Due to Gastrointestinal Perforation: A Nationwide Epidemiologic Study Using the National Clinical Database

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Abstract
Background: Elective laparoscopic surgery is now widely accepted in the treatment of abdominal diseases because of its minimal invasiveness and rapid postoperative recovery. It is also used in the emergency setting for the diagnosis and treatment of acute diffuse peritonitis regardless of the causative disease. However, the value of laparoscopy in acute diffuse peritonitis remains unclear. In this study we aimed to show trends in the use of laparoscopy over time and compare the real-world performance of laparoscopic surgery with that of open surgery for acute diffuse peritonitis due to gastrointestinal perforation.

Methods: We extracted data from the National Clinical Database, a nationwide surgery registration system in Japan, for patients with a diagnosis of acute diffuse peritonitis due to gastroduodenal or colorectal perforation between 2016 and 2019. Trends in the use of laparoscopy over time were identified. Patient characteristics, laboratory findings, surgical findings, and postoperative complications were compared between laparoscopic surgery and open surgery.

Results: Patients in poor condition and those with abnormal laboratory findings tended to undergo open surgery. Anesthesia time and operating time were longer for laparoscopic surgery in patients with gastroduodenal perforation but shorter in those with colorectal perforation. Fewer complications occurred in patients who underwent laparoscopic surgery and open surgery.

Conclusion: The use of laparoscopy is becoming common in surgery for acute diffuse peritonitis due to gastrointestinal perforation. This approach may be a useful option for acute diffuse peritonitis.

KEYWORDS
emergency surgery, gastrointestinal perforation, laparoscopic surgery, peritonitis
1 | INTRODUCTION

Elective laparoscopic surgery is now widely performed for both benign and malignant disease because it is less invasive than open surgery and postoperative recovery is more rapid. Laparoscopy has been reported to be useful in various surgical procedures, including gastrectomy and colectomy. However, its usefulness in the emergency setting is still unclear. Laparoscopic surgery requires an experienced surgeon, a patient in stable condition, and appropriate equipment, not all of which are possible when emergency surgery is required.

Acute diffuse peritonitis is a critical condition that warrants emergency surgery regardless of the causative disease, which is often gastrointestinal perforation. Although laparoscopic surgery would not alter the outcome of acute diffuse peritonitis, its minimal invasiveness might aid the patient’s ability to recover in the emergency setting if they are stable enough to tolerate it. Acute diffuse peritonitis is a common critical disease, but the number of patients treated with the disease at a given institution is limited. Therefore, in this study we aimed to demonstrate trends in the use of laparoscopy over time and compare the real-world performance of laparoscopic surgery with that of open surgery in patients with acute diffuse peritonitis due to gastroduodenal or colorectal perforation using a nationwide surgical database in Japan.

2 | PATIENTS AND METHODS

2.1 | Study design and setting

This retrospective observational study was performed using data from the National Clinical Database (NCD). The NCD is a nationwide surgical registration system in Japan that is linked to the Japanese Society of Gastrointestinal Surgery board certification system and covers almost all surgical cases in Japan. The database contains detailed data for patients with acute diffuse peritonitis, including demographic characteristics, laboratory findings, surgical findings, and postoperative complications. Several reports on emergency surgery have been published using data from the NCD.

We extracted data from this database for patients aged ≥18 years who underwent surgery for acute diffuse peritonitis due to gastroduodenal or colorectal perforation between 2016 and 2019. The study was approved by the Ethics Committee of Kyoto University (approval number R2777).

2.2 | Statistical analysis

Categorical variables are shown as the number and percentage and continuous variables as the median and interquartile range. Patient characteristics, laboratory findings, surgical findings, postoperative complications, and time trends were compared between patients with gastroduodenal or colorectal perforation according to whether they were treated by laparoscopic surgery or open surgery.

3 | RESULTS

3.1 | Gastroduodenal perforation

3.1.1 | Patient characteristics

In total, 7898 patients (71.9%) with gastroduodenal perforation underwent open surgery for acute diffuse peritonitis and 3094 (28.1%) underwent laparoscopic surgery during the study period. The patient characteristics are shown in Table 1. There were fewer elderly patients and women in the laparoscopy surgery group than in the open surgery group. The proportion of elderly patients increased year by year in both groups. Body mass index was similar between the two groups. Laparoscopic surgery was performed less often in patients with diabetes or dyspnea, those who were not independent in activities of daily living, those requiring a ventilator, and those with chronic obstructive pulmonary disease, pneumonia, hypertension, history of myocardial infarction, angina, acute renal failure, dialysis, history of cerebral infarction, bleeding tendency, or sepsis.

3.1.2 | Laboratory findings

Laboratory findings in patients who underwent surgery for acute diffuse peritonitis are summarized in Table S1. Patients who underwent open surgery tended to have abnormal values, including a markedly low white blood cell count (WBC; <3500/μL), low hemoglobin (Hb; male, <13.5 g/dL; female, <11.5 g/dL) low platelets (Plt; <150,000/μL), low albumin (<35 mg/dL), high C-reactive protein (CRP; >1 mg/dL), high activated partial thromboplastin time (APTT; >40 sec), and high prothrombin time-international normalized ratio (PT-INR; >1.1).

3.1.3 | Surgical findings

Surgical findings in patients who underwent surgery for acute diffuse peritonitis caused by gastroduodenal perforation are summarized in Table 2. Anesthesia time and operating time were longer in the laparoscopic surgery group than in the open surgery group. Estimated blood loss and transfusion requirements were smaller and the length of hospital stay was shorter in the laparoscopic surgery group. The proportion of patients who underwent concurrent surgery with abdominal drainage was similar between the laparoscopic surgery group and open surgery group (Table 2). Surgical findings in 2016 were similar to those in 2019.
| TABLE 1 Demographic and clinical characteristics of patients with gastroduodenal perforation |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
|                                               | Open                                          | Laparoscopy                                    |                                              |                                              |
|                                               | 2016: n = 1925                               | 2016: n = 649                                 | 2017: n = 1905                               | 2017: n = 704                                 |
|                                               | 2018: n = 2042                               | 2018: n = 2026                                 | 2019: n = 2019                               | 2019: n = 855                                 |
|                                               | 2019: n = 2019                               | 2019: n = 886                                 |                                              |                                              |
| Age (y)                                        |                                               |                                               |                                               |                                               |
| <70                                           | 990 51.4                                      | 463 67.2                                      | 1227 64.4                                    | 1215 71.6                                    |
| ≥70                                           | 935 48.6                                      | 213 32.8                                      | 1084 53.1                                    | 249 35.4                                      |
| Sex                                            |                                               |                                               |                                               |                                               |
| Male                                          | 1279 66.4                                    | 159 24.5                                      | 1318 64.5                                    | 1199 59.2                                    |
| Female                                        | 646 33.6                                     | 413 63.6                                      | 724 35.5                                     | 387 64.4                                     |
| Body mass index                               |                                               |                                               |                                               |                                               |
| <18.5                                         | 494 25.7                                      | 1175 61.0                                     | 548 26.8                                     | 1203 58.9                                    |
| ≥18.5, <25                                    | 1175 61.0                                     | 548 26.8                                      | 1203 58.9                                    | 1199 59.2                                    |
| ≥25                                           | 250 13.0                                      | 250 13.0                                      | 268 13.1                                     | 262 12.9                                     |
| Unknown                                       | 6 0.3                                         | 6 0.3                                         | 23 1.1                                       | 11 0.5                                       |
| Diabetes mellitus                             |                                               |                                               |                                               |                                               |
| +                                             | 298 15.5                                      | 298 15.5                                      | 343 16.8                                     | 311 15.4                                     |
| Smoking                                       |                                               |                                               |                                               |                                               |
| +                                             | 642 33.4                                      | 642 33.4                                      | 631 30.9                                     | 655 32.3                                     |
| Habitual alcohol consumption                   |                                               |                                               |                                               |                                               |
| +                                             | 506 26.3                                      | 506 26.3                                      | 565 27.7                                     | 515 25.4                                     |
| Dyspnea                                       |                                               |                                               |                                               |                                               |
| +                                             | 130 6.8                                       | 130 6.8                                       | 105 5.1                                      | 113 5.6                                      |
| Independence in ADL                           |                                               |                                               |                                               |                                               |
| +                                             | 540 28.1                                      | 540 28.1                                      | 571 28.0                                     | 544 26.9                                     |
| Mechanical ventilation                        |                                               |                                               |                                               |                                               |
| +                                             | 64 3.3                                        | 64 3.3                                        | 63 3.1                                       | 58 2.9                                       |
| COPD                                          |                                               |                                               |                                               |                                               |
| +                                             | 62 3.2                                        | 62 3.2                                        | 63 3.1                                       | 75 3.7                                       |
| Pneumonia                                     |                                               |                                               |                                               |                                               |
| +                                             | 64 3.3                                        | 64 3.3                                        | 51 2.7                                       | 42 2.1                                       |
| Ascites                                       |                                               |                                               |                                               |                                               |
|                    | Open                  |                 |                 |                 | Laparoscopy          |                 |                 |                 |
|--------------------|-----------------------|-----------------|-----------------|-----------------|----------------------|-----------------|-----------------|-----------------|
|                    | 2016                  | 2017            | 2018            | 2019            | 2016                 | 2017            | 2018            | 2019            |
|                    | n = 1925              | n = 1905        | n = 2042        | n = 2026        | n = 649              | n = 704         | n = 855         | n = 886         |
| n                  | %                     | n %             | n %             | n %             | n %                 | n %             | n %             | n %             |
| +                  | 502                   | 26.1            | 431             | 22.6            | 467                  | 22.9            | 436             | 21.5            |
| + Hypertension     | 634                   | 32.9            | 635             | 33.3            | 697                  | 34.1            | 651             | 32.1            |
| + Congestive heart failure | 39                    | 2.0             | 32              | 1.7             | 39                   | 1.9             | 33              | 1.6             |
| + History of CI    | 15                    | 0.8             | 9               | 0.5             | 7                    | 0.3             | 10              | 0.5             |
| + Angina pectoris  | 25                    | 1.3             | 13              | 0.7             | 14                   | 0.7             | 16              | 0.8             |
| + Acute renal failure | 84                    | 4.4             | 78              | 4.1             | 83                   | 4.1             | 72              | 3.6             |
| + Dialysis         | 45                    | 2.3             | 48              | 2.5             | 53                   | 2.6             | 44              | 2.2             |
| + History of CVD   | 66                    | 3.4             | 81              | 4.3             | 89                   | 4.4             | 84              | 4.1             |
| + Long-term steroid use | 62                  | 3.2             | 58              | 3.0             | 68                   | 3.3             | 49              | 2.4             |
| + Risk of hemorrhage | 167                  | 8.7             | 150             | 7.9             | 134                  | 6.6             | 135             | 6.7             |
| + Blood transfusion | 82                    | 4.3             | 80              | 4.2             | 101                  | 4.9             | 89              | 4.4             |
| + Sepsis           | 147                   | 7.6             | 164             | 8.6             | 301                  | 14.7            | 279             | 13.8            |
| + Malignancy       | 154                   | 8.0             | 141             | 7.4             | 145                  | 7.1             | 126             | 6.2             |

**Abbreviations:** ADL, activities of daily living; CI, cardiac infarction; COPD, chronic obstructive pulmonary disease; CVD, cerebrovascular disease.
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3.1.4 Postoperative complications

Postoperative complications are summarized in Table 3. Most complications were less common in the laparoscopic surgery group than in the open surgery group, other than rare events such as pulmonary embolism and myocardial infarction. The incidence of sepsis increased year by year in both groups. The incidence of other complications did not change over time. The 30-day mortality was higher in patients with malignancy than in those without malignancy in both groups in 2016. However, the difference between them in 30-day mortality decreased over time in both groups.

3.1.5 Time trend for the use of laparoscopy

The proportion of patients who underwent laparoscopic surgery for acute diffuse peritonitis increased slightly from 25.2% in 2016 to 30.4% in 2019 (Figure 1). The incidence of laparoscopic surgery for acute diffuse peritonitis per year and rate of laparoscopic surgery for acute diffuse peritonitis due to gastroesophageal reflux disease increased from 25.2% in 2016 to 30.4% in 2019 (Figure 1).

3.2 Colorectal perforation

3.2.1 Patient characteristics

During the study period, 15,545 patients (90.6%) underwent open surgery for acute diffuse peritonitis as a result of colorectal perforation, and 1,605 (9.4%) underwent laparoscopic surgery. The patient characteristics are shown in Table 4. There were fewer elderly and female patients in the laparoscopy surgery group than in the open surgery group. The body mass index was higher in the laparoscopy surgery group. Laparoscopic surgery was performed less often in patients with dyspnea, pneumonia, ascites, hypertension, congestive heart failure, history of myocardial infarction, angina, acute renal failure, diabetes, history of cerebral infarction, bleeding, and high C-reactive protein level in patients with dyspnea, pneumonia, ascites, hypertension, congestive heart failure, history of myocardial infarction, angina, acute renal failure, diabetes, history of cerebral infarction, bleeding, and high C-reactive protein level.

3.2.2 Laboratory findings

Laboratory findings for patients who underwent surgery for acute diffuse peritonitis are summarized in Table S2. Patients who underwent open surgery tended to have abnormal values, including a markedly low WBC, low Hb, low platelet, low albumin, high BUN, high Cr, and high C-reactive protein level.
### Table 3: Postoperative complications in patients with gastroduodenal perforation

|                      | Open 2016 | Open 2017 | Open 2018 | Open 2019 | Laparoscopy 2016 | Laparoscopy 2017 | Laparoscopy 2018 | Laparoscopy 2019 |
|----------------------|-----------|-----------|-----------|-----------|------------------|------------------|------------------|------------------|
|                      | n  | %   | n  | %   | n  | %   | n  | %   | n  | %   | n  | %   | n  | %   | n  | %   |
| **30-day mortality**|    |      |    |      |    |      |    |      |    |      |    |      |    |      |    |      |
| Total                | 165 | 8.6  | 141 | 7.4  | 191 | 9.4  | 169 | 8.3  | 11  | 1.7  | 24  | 3.4  | 20  | 2.3  | 23  | 2.6  |
| Malignancy           | 25  | 16.2 | 19  | 13.5 | 30  | 20.7 | 12  | 9.5  | 2   | 10.0 | 1   | 4.3  | 2   | 8.0  | 1   | 3.3  |
| Nonmalignancy        | 140 | 7.9  | 122 | 6.9  | 161 | 8.5  | 157 | 8.3  | 9   | 1.4  | 23  | 3.4  | 18  | 2.2  | 22  | 2.6  |
| **Overall complications** |    |      |    |      |    |      |    |      |    |      |    |      |    |      |    |      |
| Grade I              | 174 | 9.0  | 188 | 9.9  | 188 | 9.2  | 183 | 9.0  | 38  | 5.9  | 55  | 7.8  | 62  | 7.3  | 57  | 6.4  |
| Grade II             | 335 | 17.4 | 299 | 15.7 | 335 | 16.4 | 319 | 15.7 | 66  | 10.2 | 78  | 11.1 | 97  | 11.3 | 96  | 10.8 |
| Grade III            | 166 | 8.6  | 256 | 13.4 | 252 | 12.3 | 273 | 13.5 | 35  | 5.4  | 53  | 7.5  | 71  | 8.3  | 66  | 7.4  |
| Grade IV             | 76  | 3.9  | 84  | 4.4  | 62  | 3.0  | 93  | 4.6  | 9   | 1.4  | 11  | 1.6  | 10  | 1.2  | 16  | 1.8  |
| Grade V              | 132 | 6.9  | 123 | 6.5  | 170 | 8.3  | 152 | 7.5  | 8   | 1.2  | 20  | 2.8  | 16  | 1.9  | 19  | 2.1  |
| **Indications for repeat surgery** |    |      |    |      |    |      |    |      |    |      |    |      |    |      |    |      |
| Bleeding             | 19  | 1.0  | 12  | 0.6  | 16  | 0.8  | 12  | 0.6  | 2   | 0.3  | 0   | 0.0  | 1   | 0.1  | 1   | 0.1  |
| Drainage             | 59  | 3.1  | 61  | 3.2  | 45  | 2.2  | 60  | 3.0  | 12  | 1.8  | 11  | 1.6  | 9   | 1.1  | 12  | 1.4  |
| Ileus                | 4   | 0.2  | 5   | 0.3  | 4   | 0.2  | 5   | 0.2  | 1   | 0.2  | 1   | 0.1  | 2   | 0.2  | 1   | 0.1  |
| Other                | 58  | 3.0  | 70  | 3.7  | 61  | 3.0  | 65  | 3.2  | 12  | 1.8  | 17  | 2.4  | 14  | 1.6  | 20  | 2.3  |
| **Superficial incisional SSI** |    |      |    |      |    |      |    |      |    |      |    |      |    |      |    |      |
| +                    | 222 | 11.5 | 301 | 15.8 | 309 | 15.1 | 265 | 13.1 | 15  | 2.3  | 22  | 3.1  | 27  | 3.2  | 36  | 4.1  |
| **Deep incisional SSI** |    |      |    |      |    |      |    |      |    |      |    |      |    |      |    |      |
| +                    | 96  | 5.0  | 140 | 7.3  | 126 | 6.2  | 116 | 5.7  | 10  | 1.5  | 14  | 2.0  | 9   | 1.1  | 12  | 1.4  |
| **Organ/Space SSI**  |    |      |    |      |    |      |    |      |    |      |    |      |    |      |    |      |
| +                    | 159 | 8.3  | 184 | 9.7  | 208 | 10.2 | 187 | 9.2  | 24  | 3.7  | 39  | 5.5  | 37  | 4.3  | 42  | 4.7  |
| **Wound disruption** |    |      |    |      |    |      |    |      |    |      |    |      |    |      |    |      |
| +                    | 68  | 3.5  | 87  | 4.6  | 102 | 5.0  | 83  | 4.1  | 2   | 0.3  | 7   | 1.0  | 6   | 0.7  | 8   | 0.9  |
| **Pneumonia**        |    |      |    |      |    |      |    |      |    |      |    |      |    |      |    |      |
| +                    | 127 | 6.6  | 132 | 6.9  | 143 | 7.0  | 165 | 8.1  | 16  | 2.5  | 29  | 4.1  | 24  | 2.8  | 45  | 5.1  |
| **Unscheduled intratracheal intubation** |    |      |    |      |    |      |    |      |    |      |    |      |    |      |    |      |
| +                    | 77  | 4.0  | 78  | 4.1  | 90  | 4.4  | 84  | 4.1  | 9   | 1.4  | 8   | 1.1  | 12  | 1.4  | 13  | 1.5  |
| **Pulmonary embolism** |    |      |    |      |    |      |    |      |    |      |    |      |    |      |    |      |
| +                    | 5   | 0.3  | 3   | 0.2  | 8   | 0.4  | 5   | 0.2  | 1   | 0.2  | 2   | 0.3  | 3   | 0.4  | 0   | 0.0  |
| Condition                        | Open 2016 | Open 2017 | Open 2018 | Open 2019 | Laparoscopy 2016 | Laparoscopy 2017 | Laparoscopy 2018 | Laparoscopy 2019 |
|---------------------------------|-----------|-----------|-----------|-----------|------------------|------------------|------------------|------------------|
|                                 | n %       | n %       | n %       | n %       | n %              | n %              | n %              | n %              |
| **Mechanical ventilation**      |           |           |           |           |                  |                  |                  |                  |
| +                               | 196 10.2  | 238 12.5  | 253 12.4  | 230 11.4  | 14 2.2           | 35 5.0           | 30 3.5           | 28 3.2           |
| **Renal dysfunction**           |           |           |           |           |                  |                  |                  |                  |
| +                               | 43 2.2    | 72 3.8    | 82 4.0    | 61 3.0    | 10 1.5           | 12 1.7           | 12 1.4           | 19 2.1           |
| **Acute renal failure**         |           |           |           |           |                  |                  |                  |                  |
| +                               | 90 4.7    | 126 6.6   | 117 5.7   | 97 4.8    | 6 0.9            | 18 2.6           | 17 2.0           | 19 2.1           |
| **Urinary infection**           |           |           |           |           |                  |                  |                  |                  |
| +                               | 30 1.6    | 35 1.8    | 22 1.1    | 35 1.7    | 2 0.3            | 10 1.4           | 3 0.4            | 10 1.1           |
| **CNS dysfunction**             |           |           |           |           |                  |                  |                  |                  |
| +                               | 17 0.9    | 16 0.8    | 15 0.7    | 19 0.9    | 7 1.1            | 3 0.4            | 2 0.2            | 1 0.1            |
| **Cardiac arrest**              |           |           |           |           |                  |                  |                  |                  |
| +                               | 36 1.9    | 24 1.3    | 48 2.4    | 44 2.2    | 3 0.5            | 6 0.9            | 3 0.4            | 3 0.3            |
| **Myocardial infarction**       |           |           |           |           |                  |                  |                  |                  |
| +                               | 5 0.3     | 4 0.2     | 2 0.1     | 2 0.1     | 0 0.0            | 2 0.3            | 0 0.0            | 0 0.0            |
| **Blood transfusion**           |           |           |           |           |                  |                  |                  |                  |
| +                               | 214 11.1  | 259 13.6  | 289 14.2  | 300 14.8  | 26 4.0           | 50 7.1           | 40 4.7           | 52 5.9           |
| **Deep vein thrombosis**        |           |           |           |           |                  |                  |                  |                  |
| +                               | 15 0.8    | 18 0.9    | 23 1.1    | 27 1.3    | 2 0.3            | 5 0.7            | 6 0.7            | 1 0.1            |
| **Sepsis**                      |           |           |           |           |                  |                  |                  |                  |
| +                               | 118 6.1   | 175 9.2   | 276 13.5  | 261 12.9  | 10 1.5           | 18 2.6           | 38 4.4           | 34 3.8           |

Abbreviations: CNS, central nervous system; SSI, surgical site infection.
high APTT, and high PT-INR. The proportion of patients with high C-reactive protein was similar between the two groups.

3.2.3 | Surgical findings

Surgical findings in patients who underwent surgery for acute diffuse peritonitis are summarized in Table 5. Anesthesia and operating times were similar between the laparoscopic surgery group and the open surgery group in 2016. The operating time became shorter in the laparoscopic surgery group but remained unchanged in the open surgery group through to 2019. Estimated blood loss and the transfusion requirements were smaller and the length of hospital stay was shorter in the laparoscopic surgery group. The proportion of patients who underwent concurrent surgery with abdominal drainage was higher in the open surgery group than in the laparoscopic surgery group and increased over time in both groups (Table 5).

3.2.4 | Postoperative complications

Postoperative complications are summarized in Table 6. Complications were less common in the laparoscopic surgery group than in the open surgery group. The frequency of infectious complications, such as deep surgical site infection and sepsis, increased year by year in both groups. There was a decrease in the incidence of pneumonia and acute renal failure in the laparoscopic surgery group and increased urinary tract infection, cardiac arrest, and deep vein thrombosis rates in the open surgery group. The 30-day mortality was similar between patients with malignancy and those without malignancy in the open surgery group, while it was higher in patients
| TABLE 4  Demographic and clinical characteristics of patients with colorectal perforation |
|---------------------------------------------------------------|
| **Open** | **Laparoscopy** |
| 2016 n = 3720 | 2016 n = 309 |
| 2017 n = 3782 | 2017 n = 386 |
| 2018 n = 3826 | 2018 n = 416 |
| 2019 n = 4217 | 2019 n = 494 |
| n % | n % | n % | n % | n % | n % | n % | n % |
|---|---|---|---|---|---|---|---|
| **Age (y)** | | | | | | | |
| <70 | 1407 | 37.8 | 1383 | 36.6 | 1353 | 35.4 | 1418 | 33.6 | 161 | 52.1 | 187 | 48.4 | 205 | 49.3 | 238 | 48.2 |
| ≥70 | 2313 | 62.2 | 2399 | 63.4 | 2473 | 64.6 | 2799 | 66.4 | 148 | 47.9 | 199 | 51.6 | 211 | 50.7 | 256 | 51.8 |
| **Sex** | | | | | | | |
| Male | 1966 | 52.8 | 1984 | 52.5 | 1955 | 51.1 | 2203 | 52.2 | 202 | 65.4 | 222 | 57.5 | 237 | 57.0 | 292 | 59.1 |
| Female | 1754 | 47.2 | 1798 | 47.5 | 1871 | 48.9 | 2014 | 47.8 | 107 | 34.6 | 164 | 42.5 | 179 | 43.0 | 202 | 40.9 |
| **Body mass index** | | | | | | | |
| <18.5 | 804 | 21.6 | 849 | 22.4 | 872 | 22.8 | 954 | 22.6 | 54 | 17.5 | 65 | 16.8 | 80 | 19.2 | 92 | 18.6 |
| ≥18.5, <25 | 2276 | 61.2 | 2260 | 59.8 | 2279 | 59.6 | 2462 | 58.4 | 201 | 65.0 | 241 | 62.4 | 253 | 60.8 | 299 | 60.5 |
| ≥25 | 619 | 16.6 | 656 | 17.3 | 659 | 17.2 | 768 | 18.2 | 54 | 17.5 | 80 | 20.7 | 83 | 20.0 | 103 | 20.9 |
| Unknown | 21 | 0.6 | 17 | 0.4 | 16 | 0.4 | 33 | 0.8 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| **Diabetes mellitus** | | | | | | | |
| + | 524 | 14.1 | 557 | 14.7 | 534 | 14.0 | 651 | 15.4 | 44 | 14.2 | 68 | 17.6 | 64 | 15.4 | 74 | 15.0 |
| **Smoking** | | | | | | | |
| + | 596 | 16.0 | 611 | 16.2 | 646 | 16.9 | 674 | 16.0 | 85 | 27.5 | 67 | 17.4 | 82 | 19.7 | 109 | 22.1 |
| **Habitual alcohol consumption** | | | | | | | |
| + | 783 | 21.0 | 773 | 20.4 | 778 | 20.3 | 890 | 21.1 | 94 | 30.4 | 92 | 23.8 | 109 | 26.2 | 133 | 26.9 |
| **Dyspnea** | | | | | | | |
| + | 225 | 6.0 | 207 | 5.5 | 177 | 4.6 | 199 | 4.7 | 14 | 4.5 | 11 | 2.8 | 11 | 2.6 | 12 | 2.4 |
| **Independence in ADL** | | | | | | | |
| + | 1092 | 29.4 | 1126 | 29.8 | 1146 | 30.0 | 1232 | 29.2 | 66 | 21.4 | 87 | 22.5 | 80 | 19.2 | 94 | 19.0 |
| **Mechanical ventilation** | | | | | | | |
| + | 104 | 2.8 | 123 | 3.3 | 133 | 3.5 | 130 | 3.1 | 5 | 1.6 | 7 | 1.8 | 1 | 0.2 | 3 | 0.6 |
| **COPD** | | | | | | | |
| + | 129 | 3.5 | 111 | 2.9 | 136 | 3.6 | 145 | 3.4 | 15 | 4.9 | 10 | 2.6 | 17 | 4.1 | 24 | 4.9 |
| **Pneumonia** | | | | | | | |
| + | 85 | 2.3 | 89 | 2.4 | 76 | 2.0 | 103 | 2.4 | 5 | 1.6 | 4 | 1.0 | 3 | 0.7 | 7 | 1.4 |
| **Ascites** | | | | | | | |
| + | | | | | | | |

**TABLE 4 continued**
| Open | 2016 | 2017 | 2018 | 2019 | Laparoscopy | 2016 | 2017 | 2018 | 2019 |
|------|------|------|------|------|------------|------|------|------|------|
|      | n = 3720 | n = 3782 | n = 3826 | n = 4217 | n = 309 | n = 386 | n = 416 | n = 494 |
| %    | n | % | n | % | n | % | n | % |
| Hypertension | 787 | 21.2 | 727 | 19.2 | 648 | 16.9 | 811 | 19.2 |
| Congestive heart failure | 1536 | 41.3 | 1567 | 41.4 | 1989 | 41.5 | 1849 | 43.8 |
| History of CI | 88 | 2.4 | 63 | 1.7 | 78 | 2.0 | 98 | 2.3 |
| Angina pectoris | 19 | 0.5 | 23 | 0.6 | 22 | 0.6 | 20 | 0.5 |
| Acute renal failure | 122 | 3.3 | 127 | 3.4 | 130 | 3.4 | 146 | 3.5 |
| Dialysis | 167 | 4.5 | 145 | 3.8 | 197 | 5.1 | 191 | 4.5 |
| History of CVD | 137 | 3.7 | 228 | 6.0 | 256 | 6.7 | 266 | 6.3 |
| Long-term steroid use | 222 | 6.0 | 222 | 5.9 | 264 | 6.9 | 286 | 6.8 |
| Risk of hemorrhage | 418 | 11.2 | 372 | 9.8 | 407 | 10.6 | 485 | 11.5 |
| Blood transfusion | 117 | 3.1 | 108 | 2.9 | 126 | 3.3 | 116 | 2.8 |
| Sepsis | 478 | 12.8 | 495 | 13.1 | 921 | 24.1 | 1046 | 24.8 |
| Malignancy | 775 | 20.8 | 840 | 22.2 | 837 | 21.9 | 940 | 22.3 |

Abbreviations: ADL, activities of daily living; CI, cardiac infarction; COPD, chronic obstructive pulmonary disease; CVD, cerebrovascular disease.
with malignancy than in those without malignancy in the laparoscopic surgery group.

### 3.2.5 | Time trend in the use of laparoscopy

The proportion of patients with acute diffuse peritonitis due to colorectal perforation who were treated laparoscopically increased slightly from 7.7% in 2016 to 10.5% in 2019 (Figure 1). There was also an increase in the proportion of institutions that used laparoscopy to treat acute diffuse peritonitis from 18.0% in 2016 to 25.4% in 2019 (Figure 1). The relationship between number of cases per year and rate of laparoscopic surgery for acute diffuse peritonitis due to colorectal perforation in each hospital is shown in Figure S2.

### 4 | DISCUSSION

In this study we investigated the real-world performance of laparoscopy in patients who underwent surgery for acute diffuse peritonitis due to gastroduodenal or colorectal perforation. Patients whose overall health was poor and those with abnormal laboratory findings tended to undergo open surgery regardless of whether the perforation was gastroduodenal or colorectal. For gastroduodenal perforation, anesthesia and operating times were longer in the laparoscopic surgery group than in the open surgery group and did not change over time. There was a decrease in both anesthesia and operating times year by year in patients who underwent laparoscopic surgery for colorectal perforation. Complications were less common in the laparoscopic surgery group than in the open surgery group whether the perforation was gastroduodenal or colorectal. Regardless of site of perforation, the proportion of surgeries that were performed laparoscopically and the numbers of institutions where laparoscopic surgery was performed increased over time.

Many studies, including ones that have used data from the NCD, have demonstrated the effectiveness of laparoscopy in the elective treatment of abdominal disease. Laparoscopy is occasionally used for both diagnosis and treatment of abdominal disease in the emergency setting. Diagnostic laparoscopy has been reported to be useful in the emergency setting because it can overcome the difficulty sometimes encountered in identification of the cause of acute abdomen by preoperative assessment using abdominal imaging methods such as ultrasound and computed tomography. Patients with acute abdomen who cannot be diagnosed accurately often need exploratory surgery, which is invasive and may worsen their physical condition. An inappropriately positioned or wide skin incision may be harmful for patients. Exploratory laparoscopy can facilitate accurate diagnosis of the causative disease in patients with acute abdomen and result in adequate treatment with minimal invasiveness. Furthermore, conversion from laparoscopic surgery to open surgery is considered a useful option in emergency surgery.

It has also been reported that therapeutic laparoscopy may be useful in the emergency setting. However, the studies were
| TABLE 6  Postoperative complications in patients with colorectal perforation |
|---------------------------------------------|---------------------------------------------|
| **Open** | **Laparoscopy** |
|          | 2016 | 2017 | 2018 | 2019 | n | % | n | % | n | % | n | % | n | % |
| 30-day mortality | | | | | | | | | | | | | | | |
| Total | 391 | 10.5 | 422 | 11.2 | 409 | 10.7 | 472 | 11.2 | 15 | 4.9 | 16 | 4.1 | 13 | 3.1 | 20 | 4.0 |
| Malignancy | 88 | 11.4 | 117 | 13.9 | 81 | 9.7 | 114 | 12.1 | 3 | 9.4 | 4 | 8.0 | 4 | 7.5 | 5 | 6.9 |
| Non-malignancy | 303 | 10.3 | 305 | 10.4 | 328 | 11.0 | 358 | 10.9 | 12 | 4.3 | 12 | 3.6 | 9 | 2.5 | 15 | 3.6 |
| Overall complications | | | | | | | | | | | | | | | |
| Grade I | 367 | 9.9 | 389 | 10.3 | 388 | 10.1 | 462 | 11.0 | 26 | 8.4 | 29 | 7.5 | 42 | 10.1 | 41 | 8.3 |
| Grade II | 761 | 20.5 | 823 | 21.8 | 783 | 20.5 | 914 | 21.7 | 62 | 20.1 | 57 | 14.8 | 74 | 17.8 | 82 | 16.6 |
| Grade III | 483 | 13.0 | 553 | 14.6 | 604 | 15.8 | 675 | 16.0 | 40 | 12.9 | 49 | 12.7 | 49 | 11.8 | 79 | 16.0 |
| Grade IV | 200 | 5.4 | 224 | 5.9 | 207 | 5.4 | 246 | 5.8 | 10 | 3.2 | 11 | 2.8 | 10 | 2.4 | 11 | 2.2 |
| Grade V | 316 | 8.5 | 351 | 9.3 | 351 | 9.2 | 419 | 9.9 | 15 | 4.9 | 10 | 2.6 | 12 | 2.9 | 15 | 3.0 |
| Indications for repeat surgery | | | | | | | | | | | | | | | |
| Bleeding | 27 | 0.7 | 24 | 0.6 | 24 | 0.6 | 15 | 0.4 | 2 | 0.6 | 1 | 0.3 | 1 | 0.2 | 6 | 1.2 |
| Drainage | 92 | 2.5 | 74 | 2.0 | 96 | 2.5 | 108 | 2.6 | 8 | 2.6 | 6 | 1.6 | 9 | 2.2 | 9 | 1.8 |
| Ileus | 16 | 0.4 | 8 | 0.2 | 10 | 0.3 | 14 | 0.3 | 3 | 1.0 | 0 | 0.0 | 1 | 0.2 | 2 | 0.4 |
| Other | 199 | 5.3 | 230 | 6.1 | 210 | 5.5 | 267 | 6.3 | 11 | 3.6 | 19 | 4.9 | 18 | 4.3 | 22 | 4.5 |
| Superficial incisional SSI | + | 631 | 17.0 | 932 | 24.6 | 901 | 23.5 | 924 | 21.9 | 29 | 9.4 | 34 | 8.8 | 39 | 9.4 | 50 | 10.1 |
| Deep incisional SSI | + | 342 | 9.2 | 454 | 12.0 | 429 | 11.2 | 428 | 10.1 | 13 | 4.2 | 18 | 4.7 | 15 | 3.6 | 24 | 4.9 |
| Organ/Space SSI | + | 355 | 9.5 | 411 | 10.9 | 436 | 11.4 | 483 | 11.5 | 20 | 6.5 | 42 | 10.9 | 31 | 7.5 | 39 | 7.9 |
| Wound disruption | + | 249 | 6.7 | 312 | 8.2 | 311 | 8.1 | 318 | 7.5 | 5 | 1.6 | 11 | 2.8 | 7 | 1.7 | 13 | 2.6 |
| Pneumonia | + | 292 | 7.8 | 316 | 8.4 | 325 | 8.5 | 336 | 8.0 | 19 | 6.1 | 10 | 2.6 | 16 | 3.8 | 19 | 3.8 |
| Unscheduled intratracheal intubation | + | 133 | 3.6 | 182 | 4.8 | 198 | 5.2 | 187 | 4.4 | 3 | 1.0 | 7 | 1.8 | 7 | 1.7 | 9 | 1.8 |
| Pulmonary embolism | + | 16 | 0.4 | 20 | 0.5 | 20 | 0.5 | 14 | 0.3 | 1 | 0.3 | 0 | 0.0 | 3 | 0.7 | 1 | 0.2 |

(Continues)
| Condition                      | Open 2016 | Open 2017 | Open 2018 | Open 2019 | Laparoscopy 2016 | Laparoscopy 2017 | Laparoscopy 2018 | Laparoscopy 2019 |
|--------------------------------|-----------|-----------|-----------|-----------|-----------------|-----------------|-----------------|-----------------|
|                                | n   | %  | n   | %  | n   | %  | n   | %  | n   | %  | n   | %  | n   | %  | n   | %  |
| Mechanical ventilation         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| +                              | 588 | 15.8| 798 | 21.1| 802 | 19.0| 20  | 6.5 | 29  | 7.5 | 21  | 5.0 | 31  | 6.3 |
| Renal dysfunction              |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| +                              | 248 | 6.7 | 320 | 8.5 | 307 | 8.0 | 20  | 3.6 | 10  | 6.7 | 10  | 4.0 | 12  | 6.3 |
| Acute renal failure            |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| +                              | 248 | 6.7 | 320 | 8.5 | 307 | 8.0 | 20  | 3.6 | 10  | 6.7 | 10  | 4.0 | 12  | 6.3 |
| Urinary infection              |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| +                              | 84  | 2.3 | 92  | 2.4 | 124 | 3.2 | 116 | 2.8 | 4   | 1.3 | 6   | 1.6 | 2   | 0.5 | 7   | 1.4 |
| CNS dysfunction                |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| +                              | 42  | 1.1 | 46  | 1.2 | 52  | 1.4 | 60  | 1.4 | 1   | 0.3 | 4   | 1.0 | 3   | 0.7 | 2   | 0.4 |
| Cardiac arrest                 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| +                              | 61  | 1.6 | 96  | 2.5 | 95  | 2.5 | 122 | 2.9 | 1   | 0.3 | 1   | 0.3 | 0   | 0.0 | 4   | 0.8 |
| Myocardial infarction          |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| +                              | 12  | 0.3 | 7   | 0.2 | 11  | 0.3 | 10  | 0.2 | 0   | 0.0 | 0   | 0.0 | 1   | 0.2 | 1   | 0.2 |
| Blood transfusion              |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| +                              | 554 | 14.9| 654 | 17.3| 695 | 18.2| 703 | 16.7| 21  | 6.8 | 32  | 8.3 | 24  | 5.8 | 30  | 6.1 |
| Deep vein thrombosis           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| +                              | 33  | 0.9 | 54  | 1.4 | 56  | 1.5 | 72  | 1.7 | 2   | 0.6 | 3   | 0.8 | 5   | 1.2 | 2   | 0.4 |
| Sepsis                         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| +                              | 503 | 13.5| 727 | 19.2| 996 | 26.0| 1019| 24.2| 17  | 5.5 | 30  | 7.8 | 42  | 10.1| 45  | 9.1 |

Abbreviations: CNS, central nerve system; SSI, surgical site infection.
observational and the possibility of patient selection bias stemming from the severity of disease cannot be excluded. Most of the studies that have investigated the usefulness of therapeutic laparoscopy have acknowledged the need for both a stable patient and an experienced laparoscopic surgeon as limitations of laparoscopic surgery.

In the present study, we used acute diffuse peritonitis due to gastrointestinal perforation as an example of a disease that typically needs emergency surgery and found that the mortality and complication rates were lower in patients who underwent laparoscopic surgery than in those who underwent open surgery. However, it was not our intention to demonstrate the superiority of laparoscopic surgery for acute diffuse peritonitis due to gastrointestinal perforation; we merely wanted to show the current status of laparoscopic surgery and open surgery for acute diffuse peritonitis. Laparoscopic surgery cannot be performed in patients who are in an extremely poor condition, and there is nothing unusual about the longer length of hospital stay and the higher complication rate in our open surgery group. Acute diffuse peritonitis is common but not a condition that would cause many patients to present at each institution. Therefore, we demonstrated the real-world performance of laparoscopic surgery in this disease using data from a nationwide database.

We found that laparoscopic surgery was more common in patients with acute diffuse peritonitis as a result of gastroduodenal perforation than in those in whom the cause was colorectal perforation. There was an increase in both the proportion of institutions where laparoscopic surgery was performed and the proportion of laparoscopic surgeries performed at each institution over time. The proportion of concurrent surgeries performed for abdominal drainage did not change over time in patients with gastroduodenal perforation but increased in those with colorectal perforation. These findings indicate that emergency laparoscopic surgery for acute diffuse peritonitis is gradually becoming more common even though the proportion remains low, particularly in colorectal surgery.

We exploratorily compared the laparoscopic surgery and open surgery regarding mortality and morbidities and the results showed the superiority of laparoscopic surgery after adjusting for potential confounding factors available in the database. However, we did not present the analysis because we believe that the selection bias between laparoscopic surgery and open surgery could not be reasonably resolved and the results may mislead surgeons regarding the choice of surgical approach in surgery for acute diffuse peritonitis.

The strength of this study is that it used a nationwide surgical database in Japan. The NCD database covers almost all surgeries performed in the country. Moreover, it included data for the two main types of causes of acute diffuse peritonitis. However, the study also has some limitations, which stem mainly from its retrospective design. For example, the accuracy of the data collected relied on the accuracy of data input at each institution and whether data were entered into the NCD on an annual basis. Although there might be an effect of recall bias and transcription errors during the input procedure on the quality of data in the NCD, the quality of these data has been reported to be high. Patient selection bias was inevitable, and we did not investigate for this according to whether surgery was laparoscopic or open. However, the trend observed over time suggests the increased use of laparoscopic surgery for acute diffuse peritonitis over time and its potential usefulness in the emergency setting.

In conclusion, laparoscopic surgery is becoming common for acute diffuse peritonitis due to gastrointestinal perforation. Although the number of candidates for emergency laparoscopic surgery might be limited, laparoscopic surgery may be a useful option for acute diffuse peritonitis.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher’s website.

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