INTRODUCTION

Fatigue is a complex and multicausal phenomenon, which is the sum of physical, mental, and other miscellaneous fatigue from vari-

ous activities. Fatigue has been shown to adversely affect various situations and various fields. Especially, surgeons are easily exposed to massive and intense stress from extended working hours. There is a growing concern that accumulated fatigue due to extended working hours may contribute to poor surgical outcomes.

Despite a declining incidence, gastric cancer still remains the fourth most common type of cancer and the second leading cause of cancer-related deaths worldwide [1,2]. Notably, gastric cancer is the second most common malignant neoplasm and third leading cause of cancer-related death in South Korea [3-5]. There are six institutions in which more than 500 operations are performed annually in South Korea, and indeed, 44.8% of all survey-participated gastric cancer surgeries were conducted at these 6 hospitals among 59 institutions in 2009 [6].

Does operation order has impacts on postoperative complications in gastric cancer patients? A study of surgeon fatigue

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Purpose: There is a growing concern that accumulated fatigue due to extended working hours may contribute to poor surgical outcomes. This study aimed to compare postoperative complications of gastric cancer patients according to operation chronology in a given day as a yardstick of a surgeon’s fatigue.

Methods: The clinicopathologic data of gastric cancer patients who underwent a curative gastrectomy by one surgeon in Asan Medical Center from August 2012 to August 2014 were analyzed retrospectively. The patients were divided into 3 groups according to operation chronology in a given day. Perioperative data were collected by electronic medical records. Comorbidities were assessed using the Charlson comorbidity index. Postoperative complications were categorized according to the Clavien-Dindo classification.

Results: A total of 517 patients were divided into three groups according to chronological order of the surgery in one day. Each group exhibited similar characteristics except for operation time (P = 0.001) and the America Society of Anesthesiologists score (P = 0.01). Operations conducted late in the day tended to require more time and were associated with more comorbidities. However, no significant differences were detected between the chronological order of operation in a given day and postoperative complications.

Conclusion: The chronological order of three gastrectomies performed by one surgeon in a day was not associated with postoperative complications rate.

Keywords: Stomach neoplasm, gastrectomy, Work schedule tolerance
cancer surgery in Korea, one surgeon usually performs three gastrectomies per day. Surgeons will likely experience fatigue throughout the course of a workday; this phenomenon might be related to extended working hours and also can increase the rate of postoperative complications.

An operation carried out earlier in the day might have a lower risk of adverse events than later surgeries that day. Although various risk factors can affect postoperative complications other than surgeon fatigue, such as age, comorbidity, extent of resection, operation time, and combined resection, some studies have shown a relationship between surgeon fatigue and the rate of postoperative complications, and have focused on sleep deprivation, muscle exhaustion, and mental fatigue. Throughout the course of one or more surgeries in a given day, the frequency of muscle contracture has been found to decrease, as assessed by electromyography on the ear, nose, and throat of the surgeon. Slack et al. [7] investigated the relationship between a longer operating time and muscle fatigue of the surgeon by taking an electromyography from the mid-deltoid and brachioradialis muscles. Mental fatigue can also occur during an operation because of the need for a surgeon to intensely focus on the surgical field. Engelmann et al. [8] suggested that taking a break between operations could improve the concentration ability of a surgeon.

Over the course of a day in which a surgeon conducts multiple sequential operations, physical and mental fatigue can accumulate, the sum of which can be considered as overall surgeon fatigue. In the aspect of patient safety and health care policy, it is important to decide how many operations can be safely performed by one surgeon in a day. We aimed in our current study to investigate the relationship between postoperative complications and operation chronology in a single day on the assumption that surgeon fatigue increased with sequential operations.

**METHODS**

Clinicopathological data from gastric cancer patients who received curative gastrectomy from the same surgeon at Asan Medical Center between August 2012 and August 2014 were analyzed retrospectively after Institutional Review Board (IRB) approval (#2015-1075). The surgeon was early forty-something and had performed more than 100 cases of conventional open gastrectomy and 50 cases of laparoscopic gastrectomy as an operator before the present study began. Japanese gastric cancer treatment guidelines 2010 (ver. 3) were used to treat gastric cancer patients and also to classify the extent of lymph node dissection [9]. The complications from combined surgery versus single organ surgery are different and patients who underwent combined resection of an adjacent organ were therefore excluded from our present analyses. Patients were divided into first, second, and third operation groups according to the time of their procedure within a day.

Patient characteristics, including demographic data such as age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) score, and previous surgery were collected via a systematic review of the electronic medical records. The Charlson co-morbidity index was used for comparisons of preoperative comorbidity [10].

Postoperative data included tumor location, extent of lymph node dissection, reconstruction method, TNM stage, operation time, start day for a liquid diet, and hospital day. Postoperative complications were classified into 12 groups and these are listed in Table 1 [11]. In-hospital mortality and postoperative complications were compared using the Clavien-Dindo classification [12].

### Table 1. Postoperative complications

| Complications          | First (181) | Second (171) | Third (165) | Total | P-value |
|------------------------|-------------|--------------|-------------|-------|---------|
| Wound                  | 15 (8.28)   | 21 (12.28)   | 13 (7.87)   | 49    | 0.308   |
| Fluid collection or abscess | 7 (3.86)   | 6 (3.51)     | 4 (2.42)    | 17    | 0.739   |
| Bleeding, intra-abdominal | 1 (0.55)   | 0            | 0           | 1     | 0.395   |
| Bleeding, intra-luminal | 1 (0.55)    | 3 (1.75)     | 1 (0.60)    | 5     | 0.473   |
| Leakage                | 1 (0.55)    | 2 (1.16)     | 2 (1.21)    | 5     | 0.778   |
| Intestinal obstruction | 3 (1.65)    | 3 (1.75)     | 2 (1.21)    | 8     | 0.912   |
| Pancreatitis           | 0           | 0            | 0           | 0     | -       |
| Pulmonary              | 8 (4.41)    | 3 (1.75)     | 3 (1.81)    | 14    | 0.212   |
| Urinary                | 1 (0.55)    | 0            | 2 (1.21)    | 3     | 0.343   |
| Hepatic                | 0           | 0            | 0           | 0     | -       |
| Cardiac                | 0           | 1 (0.58)     | 0           | 1     | 0.363   |
| Others                 | 3 (1.65)    | 5 (2.92)     | 1 (0.60)    | 9     | 0.256   |
| Total                  | 40 (22.09)  | 44 (25.73)   | 28 (17.57)  | 112   | -       |

Values are presented as number (%).
High-grade complications were evaluated when a patient had multiple complications. Tumors were graded in accordance with the seventh edition of the AJCC manual.

Categorical variables are presented as totals and percentages, while continuous variables are shown as median values and interquartile ranges. The χ² test and one-way ANOVA were used and P-values less than 0.05 were considered to indicate statistically significant differences. The Fisher’s exact test was used to calculate P-values for comparisons of each subgroup. Statistical analyses were carried out using PASW software (release 18.0.0, SPSS Inc., Chicago, IL, USA). All statistical analyses are reviewed and confirmed by the medical statistical team of AMC.

Table 2. Demographic characteristics of the 517 study patients

| Characteristic          | First (181)       | Second (171)      | Third (165) | P-value |
|------------------------|-------------------|-------------------|-------------|---------|
| Age (yr)               | 61 ± 11.18        | 58 ± 11.4         | 59 ± 11.7   | 0.126   |
| Sex (male)             | 124 (68.5)        | 108 (63.2)        | 120 (72.7)  | 0.168   |
| BMI (kg/m²)            | 23.5 ± 2.9        | 24.4 ± 3.2        | 23.7 ± 3.8  | 0.052   |
| Previous surgery (none/presence) | 139 (76.8)/42 (23.2) | 134 (78.4)/37 (21.6) | 123 (74.5)/42 (25.5) | 0.709   |
| CCI                    | 2.9 ± 1.4         | 2.8 ± 1.5         | 3.2 ± 1.6   | 0.052   |
| ASA score              | 1.82 ± 0.44       | 1.86 ± 0.39       | 1.96 ± 0.47 | 0.01    |
| Tumor location         |                   |                   |             | 0.433   |
| Upper                  | 36 (19.8)         | 20 (11.6)         | 26 (15.7)   |         |
| Middle                 | 36 (19.8)         | 44 (25.7)         | 35 (21.2)   |         |
| Lower                  | 105 (58.0)        | 104 (60.8)        | 102 (61.8)  |         |
| Entire                 | 4 (2.2)           | 3 (1.7)           | 2 (1.2)     |         |
| Extent of resection    |                   |                   |             | 0.053   |
| Distal gastrectomy     | 127 (70.2)        | 139 (81.3)        | 124 (75.2)  |         |
| Total gastrectomy      | 54 (29.8)         | 32 (18.7)         | 41 (24.8)   |         |
| Operative methods      |                   |                   |             | 0.001   |
| Open                   | 131 (72.4)        | 91 (53.2)         | 109 (66.1)  |         |
| Laparoscopic           | 50 (27.6)         | 80 (46.8)         | 56 (33.9)   |         |
| Reconstruction         |                   |                   |             | 0.097   |
| Billroth I             | 122 (67.4)        | 131 (76.6)        | 112 (67.9)  |         |
| Billroth II            | 4 (2.2)           | 5 (2.9)           | 10 (6.1)    |         |
| RY GJ                  | 1 (0.6)           | 3 (1.8)           | 2 (1.2)     |         |
| RY EJ                  | 54 (29.8)         | 32 (18.7)         | 41 (24.8)   |         |
| Extent of LN dissection|                   |                   |             | 0.104   |
| D1                     | 0                 | 0                 | 1 (0.6)     |         |
| D1+                    | 16 (8.8)          | 14 (8.1)          | 28 (16.9)   |         |
| D2                     | 163 (90.1)        | 157 (91.8)        | 135 (81.8)  |         |
| Others                 | 2 (1.1)           | 0                 | 1 (0.6)     |         |
| TNM stage              |                   |                   |             | 0.638   |
| IA                     | 91 (50.3)         | 102 (59.6)        | 88 (53.3)   |         |
| IB                     | 29 (16.0)         | 20 (11.6)         | 18 (10.9)   |         |
| IIA                    | 13 (7.1)          | 15 (8.7)          | 11 (6.6)    |         |
| IIB                    | 12 (6.6)          | 13 (7.6)          | 12 (7.2)    |         |
| IIIA                   | 15 (8.2)          | 7 (4.0)           | 11 (6.6)    |         |
| IIIB                   | 7 (3.8)           | 6 (3.5)           | 10 (6.0)    |         |
| IIIC                   | 13 (7.1)          | 6 (3.5)           | 13 (7.8)    |         |
| IV                     | 1 (0.5)           | 2 (1.1)           | 2 (1.2)     |         |
| LD start (day)         | 43 ± 1.1          | 44 ± 1.7          | 45 ± 1.6    | 0.506   |
| Hospital stay (day)    | 7.97 ± 4.7        | 8.2 ± 5.9         | 8.1 ± 4.5   | 0.913   |
| Op time (min)          | 154 ± 38.7        | 160 ± 31.7        | 165 ± 40.9  | 0.001   |

Values are presented as mean ± standard deviation or number (%).
BMI, body mass index; CCI, charlson comorbidity index; ASA, American Society of Anesthesiologists; RY GJ, Roux-en-Y gastrojejunostomy; RY EJ, Roux-en-Y esophagojejunostomy; LN, lymph node; LD, liquid diet; OP, operation.
RESULTS

A total of 517 patients were enrolled (male:female = 352:165) comprising 181, 171, and 165 patients in the first, second, and third operation of the day groups, respectively. There were no significant differences in mean patient age, sex, mean BMI, history of previous abdominal surgery, Charlson comorbidity index, tumor location, extent of resection and lymph node dissection, reconstruction methods, or TNM stage. These characteristics are listed in Table 1. The mean operation time and ASA score were significantly increased in the second and third operation of the day groups (P = 0.001, 1.54/160/169; and P = 0.01, 1.82/1.86/1.96; respectively). Postoperative complications for each operation of the day group were categorized into 12 subgroups and these are listed in Table 1.

Overall, the total number of postoperative complications was 121, an overall complication rate of 23.4%. There were no differences among patient subgroups and no significant associations between the postoperative complication rate and operation chronology.

DISCUSSION

The incidence of gastric cancer in Korea is high, and has resulted in surgeons performing three gastrectomy procedures per day at high volume centers, including our institution, Asan Medical Center. In addition to institutional concerns about surgeon fatigue, patients also worry about this issue because of the risk of surgical complications, especially for a surgeon’s last operation in a given day. Many studies have assessed the relationship between sleep deprivation and medical errors, but the effects of daytime workloads are less well characterized.

Sanaka et al. [13,14] suggested that afternoon colonoscopies are associated with a higher failure rate and lower lesion detection rate compared with morning colonoscopies. Thomas et al. [15] reported an adverse relationship between longer operating days and surgical complications for pulmonary lobectomy procedures, but they did not evaluate the pulmonary lobectomies according to their chronological order in a given day. In a previous urology study, Bagrodia et al. [16] reported no difference between two procedures of the same type carried out on the same day by the same surgeon. In another earlier study, it was reported that a laparoscopic prostatectomy, robot-assisted laparoscopic prostatectomy, and percutaneous nephrolithotomy showed differences in the rates of complications [17].

Schieman et al. [18] have previously compared fatigued and non-fatigued surgeons who performed anterior resections for rectal cancer. The term “Fatigued” was applied if a surgeon billed for clinical work after 10 P.M. on the night before performing an anterior resection. However, these authors reported no significant differences in perioperative or long-term complications. Halldorson et al. [19] found that 1-year graft survival was significantly greater if the primary surgeon had more than a two-day interval between transplant procedures. That study reported that patient survival was also improved if a surgeon performed less than three liver transplantations in one week versus more than four procedures (90.4% vs. 80.0%, P < 0.026).

In our present study, each of the three groups had the same complication risk, according to the Charlson comorbidity index (Table 2). The statistical analysis shows that there were no differences between the groups in all categories except ASA score, operation method, and operation time.

The chronology of the gastrectomies in a single day had no significant effect on the postoperative complications in these patients according to the Clavien-Dindo classification (Table 3). The mean operation time increased for second and third groups. To carry out three gastrectomies in a day, a surgeon tends to perform earlier operations quickly in order to finish three operations within anesthesiologists’ regulation time. Thus, an operation time discrepancy might develop. The ASA score also increased in procedures carried out later in a given day in our current series. As mentioned above, to complete three gastrectomies per day, the most difficult cases are often scheduled later in that same day. These later cases tend to be more challenging and require more time to complete; however, we found no significant difference in postoperative complications that arose between our early and late cases. Notably, in the case of severe postoperative complications (Clavien-Dindo grade III to IV), we also found no significant differences between our three study groups. This suggests that a single surgeon can safely carry out three gastrectomies on the same day.

There were some limitations of note to our current study. First, because each group did not have the same ratio of laparoscopic and open methods, the result could be biased. However, there were no statistical differences even though the ratio of laparoscopic sur-

| Clavien-Dindo classification | First (181) | Second (171) | Third (165) | Total |
|-----------------------------|------------|-------------|-------------|-------|
| I                           | 20 (51.3)  | 22 (46.3)   | 17 (55.6)   | 54    |
| II                          | 14 (33.3)  | 17 (41.5)   | 8 (29.6)    | 39    |
| III                         | 4 (10.3)   | 5 (12.2)    | 4 (14.8)    | 13    |
| IV                          | 2 (5.1)    | 0           | 0           | 2     |
| V                           | 0          | 0           | 0           | 0     |
| Sum                         | 40         | 44          | 29          | 113   |

Values are presented as number (%).
surgery, which requires more intricate skills, was higher in groups two and three. We assume that the ratio of laparoscopic and open method has little influence on results. Second, we collected data from a single surgeon to control other confounding factors. Other data sets from different surgeons will need to be evaluated in future studies. Third, there is not much information regarding calculating surgeon’s fatigue objectively. We simply presumed that surgeon’s fatigue will accumulate as operations proceed, and we used chronologic order of operation as yardstick of surgeon fatigue.

The chronologic order of three gastrectomies performed by one surgeon in a day was not associated with postoperative complications rate.

CONFLICT OF INTEREST
No potential conflict of interest relevant to this article was reported.

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