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ORIGINAL RESEARCH

Impact of Enhanced in-Hospital Infection Prevention During the COVID-19 Pandemic on Postoperative Pneumonia in Older Surgical Patients

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Purpose: We aimed to investigate the impact of enhanced in-hospital infection prevention during the coronavirus disease 2019 (COVID-19) pandemic on postoperative pneumonia in older surgical patients.

Patients and Methods: We retrospectively reviewed the electronic medical records of consecutive patients ≥70 years who underwent elective surgery between 2017 and 2021 at our institution. All perioperative variables were retrieved from the electronic medical records. The primary outcome was new-onset postoperative pneumonia during the hospitalization period. Since February 2020, our institution implemented a series of policies to enhance infection prevention, hence patients were divided into groups according to whether they underwent surgery before or during the COVID-19 pandemic. An interrupted time series analysis was performed to evaluate the difference between pre- and post-intervention slopes of the primary outcome.

Results: Among the 29,387 patients included in the study, 10,547 patients underwent surgery during the COVID-19 pandemic. Although there was a decreasing trend of the monthly incidence rate of postoperative pneumonia compared to before the COVID-19 pandemic, there was no statistical significance in the trend (slope before COVID-19 period: β-coefficient, −0.007; 95% CI, −0.022 to 0.007).

Conclusion: Our study revealed that enhanced in-hospital infection prevention implemented to manage the COVID-19 pandemic did not significantly affect the decreasing trend of postoperative pneumonia at our institution.

Keywords: coronavirus, COVID-19, healthcare-associated pneumonia, pandemic, pneumonia, severe acute respiratory syndrome coronavirus 2

Introduction

Coronavirus disease 2019 (COVID-19) had a great impact on the daily lives of individuals globally. Among several changes, enhanced personal hygiene behavior was probably one of the most prominent changes, compared to before the COVID-19 pandemic. The wearing of face masks and the frequent use of alcohol-based hand rubs have become part of our familiar daily routine. Even though these changes caused discomfort, they also had unexpected benefits, such as a resultant decrease in infectious diseases other than COVID-19.[1–6] According to the Healthcare Bigdata Hub released by the Health Insurance Review and Assessment (HIRA) service in South Korea,[7] the number of patients with pneumonia (Korean Classification of Disease code: J12–18) in South Korea has decreased sharply since 2020 (Figure 1) and it has been speculated that this reduction might be related to the enhanced hygiene routines implemented during the COVID-19 pandemic. The COVID-19 pandemic thus provides a valuable opportunity to evaluate the impact of hospital environmental hygiene practices in preventing hospital-acquired infection.[8–11]

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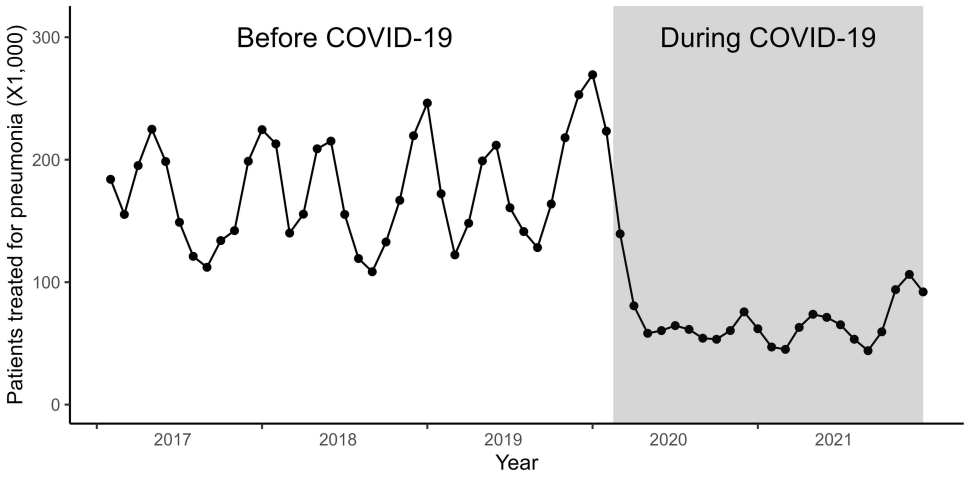

Figure 1 The number of patients treated monthly for all types of pneumonia in South Korea.

Postoperative pneumonia is considered one of the major postoperative complications, which is associated with significant medical and economic burdens.[12] In a large, prospective international observational study, the incidence rate of pneumonia in adult surgical patients was reported as 0.4%,[13] and higher incidence rates have been reported in older adults.[14,15] Postoperative pneumonia is a type of hospital-acquired pneumonia (HAP), which is defined as pneumonia that occurs at least 48 hours after admission,[16] and has been reported to account for about a fifth of overall HAP cases.[17,18]

Considering the association between HAP and hospital environmental-related factors,[17,19] we hypothesized that enhanced in-hospital infection prevention, which was implemented to manage the COVID-19 pandemic, would be associated with a decrease in the incidence of postoperative pneumonia. Several relevant guidelines[19] have consistently recommended hand hygiene as one of the most effective methods to prevent HAP. Wearing a face mask can effectively prevent viral pneumonia, which accounts for about 20–30% of HAP.[19,20] In addition, visitor restrictions during the COVID-19 pandemic were recently reported to be associated with a significant drop in hospital-acquired viral infections.[21] In a study using the Taiwan nationwide database, it was reported that enhanced personal hygiene behavior, including wearing masks, hand hygiene, and social distancing, during the COVID-19 pandemic not only prevented COVID-19, but also reduced all-cause pneumonia.[5] Therefore, we conducted this retrospective study to investigate the association between enhanced in-hospital infection prevention during the COVID-19 pandemic and postoperative pneumonia using interrupted time series analysis.

Materials and Methods

Study Design and Population

The Institutional Review Board of the Seoul National University Hospital approved this single-center, retrospective observational study and waived the requirement for informed consent since the data were de-identified (approval No. H-2203-135-1309). This study adhered to the principles of the Declaration of Helsinki, ensuring the anonymity and confidentiality of all participant data, as well as complying with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.[22]

We reviewed the electronic medical records of all consecutive patients ≥70 years who underwent elective surgery under general or spinal anesthesia between 2017 and 2021 at our institution. The exclusion criteria were as follows: (1) ambulatory surgery; (2) emergent surgery; (3) history of pneumonia; (4) history of COVID-19 infection; (5) perioperative COVID-19 infection; (6) missing covariates for the ARISCAT score;[23] (7) tracheostomy; (8) and subsequent surgery during the same admission period.

Intervention

The first case of COVID-19 infection was confirmed in South Korea on 20 January, 2020. Since the end of January 2020, our institution implemented a series of policies to better prevent and control infection, which were as follows: 1) hospital

access was limited to individuals with daily permission, and body temperature was measured when entering the hospital. 2) Visiting of inpatients was prohibited, and the number of patient guardians was limited to one per inpatient. 3) Wearing of face masks was required of all personnel, and the use of alcohol-based hand sanitizers upon entering was heightened. Although the executive order for mandatory mask-wearing in South Korea came into effect in August 2020, the Government of South Korea had strongly recommended wearing masks since the beginning of the COVID-19 pandemic.[24] In addition, since April 5, 2020, Reverse Transcription-Polymerase Chain Reaction (RT-PCR) testing for the screening of COVID-19 infection was conducted on all patients scheduled to be hospitalized.

The time of the intervention related to enhanced in-hospital infection prevention was set to the end of January 2020, and we defined the two groups as patients who underwent surgery before and during the intervention.

Data Collection and Primary Outcome

We used the electronic medical records contained in our institution's clinical data warehouse to retrieve the perioperative variables used in this study. The following variables were collected: age, sex, body mass index, current smoking, American Society of Anesthesiologists (ASA) physical status, preoperative oxygen saturation value (%) using pulse oximetry, preoperative hemoglobin (g/dL), surgical incision (peripheral, upper abdominal, intrathoracic),[23] type of anesthesia (general or spinal anesthesia), duration of surgery (hours), duration of anesthesia (hours), intraoperative transfusion, postoperative intensive care unit stay, postoperative length of hospital stay (days), and postoperative mechanical ventilation within 24 hours.

The ARISCAT score was calculated for each patient to estimate the baseline risk of postoperative pulmonary complications using the following variables:[23] age, preoperative oxygen saturation, preoperative serum hemoglobin, surgical incision, and duration of surgery. We calculated respiratory infection within a month before surgery, and emergency procedure as 0, because only patients who were admitted for elective surgery with no history of respiratory infections within a month before surgery were included in the study.[23]

The primary outcome was the incidence of new-onset postoperative pneumonia during the index hospitalization period, without considering a specific time window. Pneumonia was defined as the combination of new-onset radiologic infiltration, purulent secretion (except in neutropenia), and one or more of the following criteria: fever, hypoxemia, or leukocytosis.[25] To retrospectively identify postoperative pneumonia, the diagnostic codes,[26] laboratory results, radiology reports, and medical records of postoperative patients were systematically screened, followed by a manual review conducted by the research team.

Statistical Analysis

The baseline characteristics of the patients who underwent surgery before and during the COVID-19 pandemic are summarized using descriptive statistics. The inter-group differences were compared based on the absolute standardized mean difference, and an absolute standardized mean difference (ASD) ≥ 0.1 was considered statistically significant.

To assess the extent to which the intervention was associated with changes in the incidence of postoperative pneumonia, the number of monthly postoperative pneumonia cases per 1000 patients during the study period was plotted, and an interrupted time series analysis was performed (model 0).[27] In the analysis, two periods (before or during COVID-19) were included as two segments, and changes in baseline level (intercepts) and trends (slopes) between the two segments were estimated after controlling for time trends. In addition, considering previous reports on seasonal variation of postoperative pneumonia,[28] within-year seasonality was also adjusted if the model with seasonality showed better accuracy than that without it. A Poisson model with log link was used, and Newey-West standard errors were estimated to account for possible residual autocorrelation and heteroscedasticity.[29]

To account for the baseline risk of postoperative pulmonary complications, we performed two additional interrupted time series analyses. In models 1 and 2, we additionally adjusted for the median value of the monthly ARISCAT score and the monthly proportion of patients with low-risk ARISCAT score, respectively.

All analyses were conducted using tsModel, Imtest, and sandwich packages in R version 4.1.2 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Between 2017 and 2021, 29,387 older adults underwent elective surgery under general or spinal anesthesia at our institution. A total of eight patients were diagnosed with COVID-19 infection during their hospitalization period (all diagnosed postoperatively). After excluding 4193 patients according to the study protocol, the data of the remaining 25,194 patients were analyzed (Figure 2). Among them, 14,647 and 10,547 patients underwent surgery before and during the COVID-19 pandemic, respectively. The comparison of the baseline characteristics of the two groups is summarized in Table 1. Generally, patients who underwent surgery during the COVID-19 pandemic had higher ASA physical status (ASD=0.32), higher preoperative SpO_2 (mean±SD, 97.1% ±2.4% vs 96.6% ±2.6%; ASD = 0.17), and lower proportion of intensive care unit stay (11.3% vs 15.1%, ASD = 0.11).

The overall incidence rate of postoperative pneumonia during the study period was 1.5% (n=366/25,194). The median time interval from surgery to diagnosis of pneumonia was 4 days (interquartile range: 2–8 days, minimum: 1 day, maximum: 74 days) in 366 patients diagnosed with postoperative pneumonia. Among them, a total of 8 patients were diagnosed with pneumonia more than 30 days after surgery. The incidence rate of postoperative pneumonia was significantly lower during the COVID-19 pandemic (1.2%, 127/10,547) than before the COVID-19 pandemic (1.6%, 239/14,647; P = 0.006), and showed a visually decreasing trend during the study period (Figure 3).

The results of interrupted time series analyses are summarized in Table 2. Within-year seasonality was adjusted in the analysis as it showed better performance (P=0.049). Although there was a visually decreasing trend of the monthly incidence rate of postoperative pneumonia before the COVID-19 pandemic in the unadjusted model (model 0), there was no statistical significance in its trend (slope before COVID-19 period: β-coefficient, −0.007; 95% confidence interval [CI], −0.022 to 0.007). Moreover, the intercept and slope of the monthly trend did not differ significantly before and during the COVID-19 pandemic (model 0. Intercept change during COVID-19 period: β-coefficient, −0.012; 95% CI, −0.042 to 0.417. Slope change during COVID-19 period: β-coefficient, −0.007; 95% CI, −0.029 to 0.015). The results

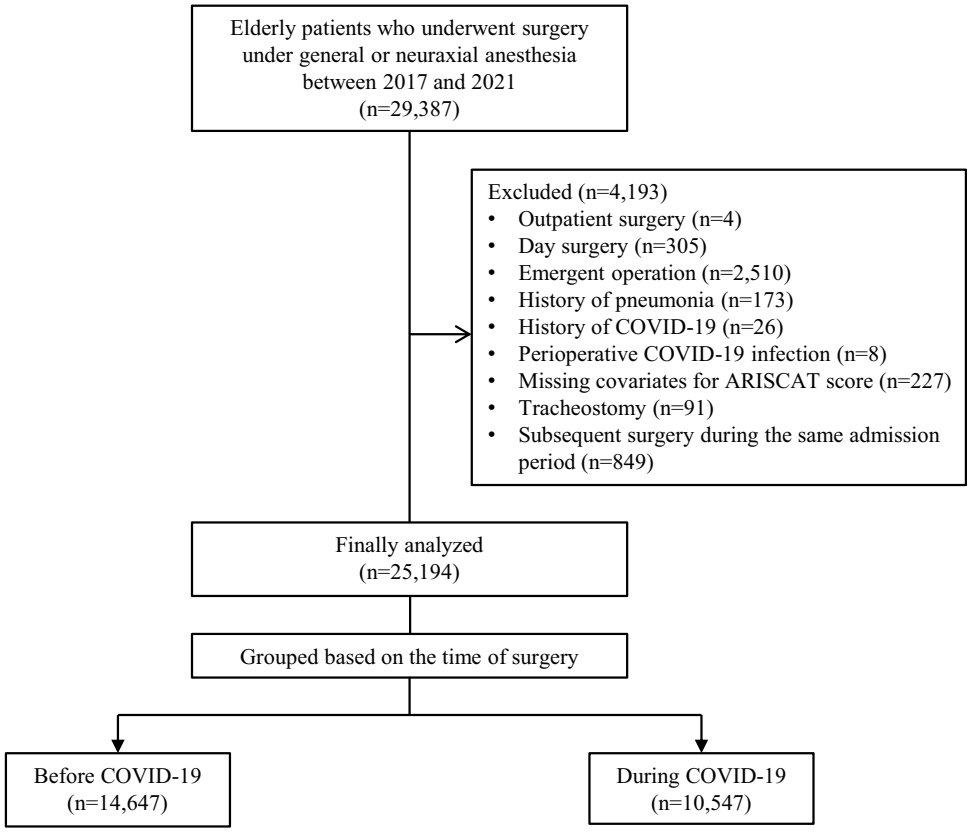

Figure 2 Flowchart of the study. ARISCAT: Assess Respiratory Risk in Surgical Patients in Catalonia.

Table 1 Baseline Characteristics Before and During the COVID-19 Pandemic

	Before COVID-19 (N=14,647)		During COVID-19 (N=10,547)		ASD
	n	Mean ± SD or (%)	n	Mean ± SD or (%)	
Age (years)	14,647	75.6 ±4.5	10,547	75.9 ±4.6	0.06
Female	6872	(46.9)	4955	(47.0)	0.00
Body mass index (kg/m^2)	14,492	24.5 ±3.2	10,427	24.6 ±3.2	0.04
Smoker	579	(4.0)	366	(3.5)	0.03
ASA physical status					0.32
1	1695	(11.6)	365	(3.5)	
2	10,237	(69.9)	7844	(74.4)	
3	2603	(17.8)	2243	(21.3)	
4	112	(0.8)	95	(0.9)	
Preoperative SpO_2 (%)	14,647	96.6 ±2.6	10,547	97.1 ±2.4	0.17
Hemoglobin (g/dl)	14,647	12.7 ±1.5	10,547	12.8 ±1.6	0.02
Surgical incision					0.01
Peripheral	6165	(42.1)	4438	(42.1)	
Upper abdominal	6802	(46.4)	4924	(46.7)	
Intrathoracic	1680	(11.5)	1185	(11.2)	
Type of anesthesia					0.02
General	12,519	(85.5)	9083	(86.1)	
Spinal	2128	(14.5)	1464	(13.8)	
Duration of surgery (hours)	14,647	2.1 ±1.7	10,547	2.0 ±1.7	0.04
Duration of anesthesia (hours)	14,647	3.0 ±2.0	10,547	2.8 ±1.8	0.09
Intraoperative transfusion	1030	(7.0)	696	(6.6)	0.02
Postoperative ICU stay	2209	(15.1)	1195	(11.3)	0.11
Postoperative length of hospital stay (days)	14,647	7.2 ±22.9	10,547	6.4 ±10.9	0.05
Postoperative mechanical ventilation within 24 hours	800	(5.5)	481	(5.0)	0.02
ARISCAT score	14,647	25.4 ±16.4	10,547	24.6 ±16.1	0.05
ARISCAT risk					0.06
Low	7150	(48.8)	5417	(51.4)	
Intermediate	5562	(38.0)	3903	(37.0)	
High	1935	(13.2)	1227	(11.6)	

Abbreviations: ASA, American Society of Anesthesiologists; SpO_2, oxygen saturation measured by pulse oximetry; ICU, intensive care unit; ARISCAT, Assess Respiratory Risk in Surgical Patients in Catalonia; ASD, absolute standardized mean difference; SD, standard deviation.

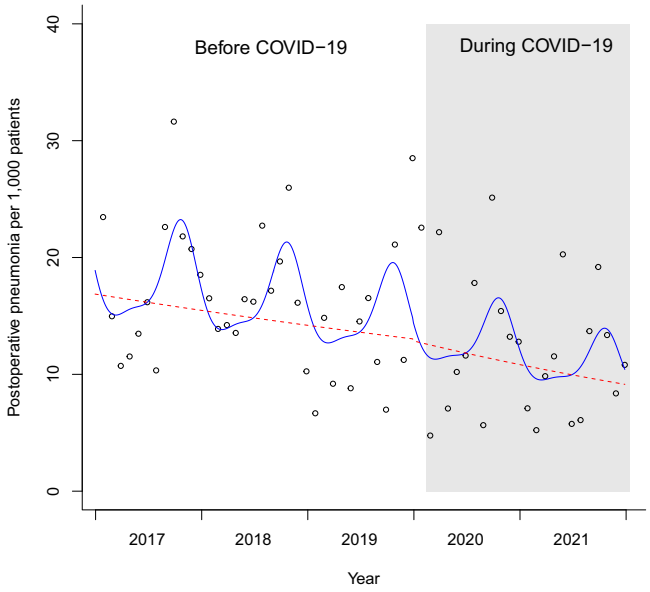

Figure 3 The number of monthly postoperative pneumonia cases per 1000 patients. The blue solid line represents the expected number of pneumonia and the red dashed line indicates the de-seasonalized expected number of pneumonia cases in model 0.

were similar when monthly median values of the Assess Respiratory Risk in Surgical Patients in Catalonia (ARISCAT) score (model 1) or monthly proportion of patients with low ARISCAT risk (model 2) were adjusted for.

Discussion

During the last 5 years, the incidence of postoperative pneumonia steadily decreased at our institution, and there was no significant change in this trend, even after the introduction of enhanced in-hospital infection prevention during the COVID-19 pandemic. In addition, we were able to identify the seasonal variation of postoperative pneumonia during the study period, which has rarely been reported.[28]

The association between enhanced in-hospital infection prevention during the COVID-19 pandemic and reduced hospital-acquired infection has been previously reported, but the results for postoperative infection were contradictory. It seems like the effect of the enhanced infection prevention during the COVID-19 pandemic on surgical site infection is the topic most frequently reported on, with conflicting results.[30–33] The difference in the levels of infection control

Table 2 Interrupted Time Series Analysis for the Monthly Incidence Rate of Postoperative Pneumonia

	Model 0: Before Covariate Adjustment	**Model 1: After Adjustment of Monthly ARISCAT Score Median**	**Model 2: After Adjustment of Monthly Proportion of Patients with ARISCAT Low Risk**
	***β*-Coefficient [95% CI]**	***β*-Coefficient [95% CI]**	***β*-Coefficient [95% CI]**
Slope before COVID-19 period	−0.007 [−0.022, 0.007]	−0.008 [−0.022, 0.007]	−0.009 [−0.023, 0.006]
Intercept change during COVID-19 period	−0.012 [−0.442, 0.417]	−0.012 [−0.446, 0.422]	−0.022 [−0.462, 0.417]
Slope change during COVID-19 period	−0.007 [−0.029, 0.015]	−0.005 [−0.031, 0.022]	0.001 [−0.028, 0.030]
Monthly median of ARISCAT score		0.007 [−0.021, 0.034]	
Monthly ARISCAT low risk proportion			−0.019 [−0.055, 0.016]

Abbreviations: ARISCAT, Assess Respiratory Risk in Surgical Patients in Catalonia; CI, confidence interval.

between institutions before the COVID-19 pandemic and the availability of medical resources during the pandemic could explain these inconsistent results.

However, unlike surgical site infection, there have been few reports on the impact of enhanced in-hospital infection prevention during the COVID-19 pandemic on postoperative pneumonia. In a retrospective cohort study by an Australian tertiary institution, the COVID-19 pandemic-related enhanced infection prevention was not associated with the incidence of hospital-acquired infection, including postoperative pneumonia in surgical patients.[34] In contrast, another retrospective study using the American College of Surgeons National Surgical Quality Improvement Project database reported a significant increase in postoperative pneumonia occurrence during the COVID-19 pandemic compared to before the pandemic.[35] In another study, the authors described the lack of medical resources during the early COVID-19 pandemic in the US and the possibility of perioperative COVID-19 infection as the possible reasons for these results.[29] However, the shortage of medical resources seemed to be less severe in South Korea because the number of COVID-19 infections did not increase as rapidly as in the US.[36] In addition, we excluded patients with perioperative COVID-19 infection to exclude its significant impact on postoperative pneumonia.[37]

In our study, the enhancement of in-hospital infection prevention did not significantly affect the decreasing trend in postoperative pneumonia incidence at our institution. Since the significant medical and economic burdens of post-operative infection, including postoperative pneumonia, have been acknowledged, several efforts have been made to reduce them,[38,39] and there is a possibility that these efforts were continued at our hospital. Therefore, we performed an interrupted time series analysis rather than a simple comparison of the two periods, taking into account the decreasing trend of postoperative pneumonia even before the COVID-19 pandemic. The high level of in-hospital infection prevention practices before the COVID-19 pandemic at our institution possibly affected our negative results. According to our institution's outcomes published in 2021, the proportion of hand hygiene compliance from 2016 to 2020 increased from 92.9% to 95.3%.[40] In addition, standardized incidence ratios of other hospital-acquired infections, such as central line-associated bloodstream infection and ventilator-associated pneumonia, have been on the decline,[40] which could also reflect our institution's effort to prevent hospital-acquired infection. The standardized incidence ratios of central line-associated bloodstream infection and ventilator-associated pneumonia in 2019 were 0.47 and 0.77, respectively.[38] After the Middle East respiratory syndrome coronavirus outbreak in 2015, several organizational policies have been reconsidered to prevent in-hospital infection in South Korea.[41] Considering this, it would have been difficult for the enhanced in-hospital infection prevention efforts during the COVID-19 pandemic to have a notable effect on the incidence of postoperative pneumonia at our institution. Also, the incidence of postoperative pneumonia had continued to decrease during the pre-COVID pandemic period, and it would have been difficult for enhanced in-hospital infection prevention to make the slope of this decreasing trend steeper.

In addition, to the best of our knowledge, our study is the first to report within-year seasonal variability in postoperative pneumonia incidence after all types of elective surgeries. Our result was consistent with that of a retrospective study of patients undergoing coronary artery bypass grafting, in which the risk of postoperative pneumonia was higher during fall/winter than in spring/summer.[28] Similarly, our study showed that the incidence rate of pneumonia was highest during the fall season. The seasonality of postoperative pneumonia could reflect the contribution of common seasonal pathogens, such as influenza and S. pneumoniae.[28] Considering that these pathogens can be transmitted from person to person through respiratory droplets, enhanced infection prevention, such as face masks and hand hygiene, can prevent postoperative pneumonia. However, the seasonal pattern of postoperative pneumonia in our study was inconsistent with that of the combination of all types of pneumonia in South Korea, which showed two annual peaks during spring and winter (Figure 1). This discrepancy may be due to the differences in the population and composition of pathogens during different seasons. Further investigations regarding the seasonality of postoperative pneumonia are warranted to prevent it more effectively.

We acknowledge several limitations to our study. First, although our results were consistent after adjusting for baseline risk for postoperative pneumonia using several risk factors, unadjusted confounding may remain. Second, the study was conducted in a single tertiary teaching hospital in South Korea. The impact of change during the COVID-19 pandemic may vary depending on the institution's implemented infection control protocol, and adherence thereto, before the pandemic. Third, since February 2020, there have been several serial changes to our institution's infection prevention

policies, but we arbitrarily set February 2020 as the time of intervention. In addition, it was difficult to quantify the changes in infection prevention before and after the pandemic at our institutions. Last, we could not obtain data relating to the etiologic pathogen of pneumonia. Further research analyzing the monthly distribution of pathogens associated with postoperative pneumonia may provide an explanation for its seasonality.

Conclusion

In conclusion, the enhanced in-hospital infection prevention practices implemented to manage the COVID-19 pandemic did not significantly affect the decreasing trend of postoperative pneumonia at our institution. Considering the high level of infection control before the COVID-19 pandemic, these enhancements were unable to have an effect on the existing trend. However, to prepare for the post-pandemic era, we should use this rare opportunity provided by the COVID-19 pandemic to further research the impact of intensifying in-hospital infection prevention control on postoperative outcomes.

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Non declared.

Disclosure

The authors declare that they have no competing interests.

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