Public reporting of hospital-level surgical volume and its influence on patient and hospital behavior

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Public reporting of hospital-level surgical volume and its influence on patient and hospital behavior

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Acknowledgements

Sow a thought, and you reap an act; Sow an act, and you reap a habit; Sow a habit, and you reap a character; Sow a character, and you reap a destiny.

Charles Reade (1814-1884)

I cited this quote at my graduate school interview, about 4 years ago. When I entered the university in 2007, I did not know what to do. Times had changed when I returned to my university after being released from my military duty. I was inspired by professors who were newly appointed in my university, and my attitude toward university life had also changed. Thanks to their teachings, I set my goal on reaching their levels of personal and academic achievement. This is how my second life started, and the “thought” regarding my long-term goal was also sown. After many efforts to achieve my goals, I decided to go to graduate school to transform my dream into an “act.” During graduate school life, I had diverse experiences and was able to develop my knowledge and wisdom, thanks to many professors in Yonsei University. With passion and effort, my time in graduate school passed as a “habit.” Now it is time to take my goals to the next level, and to make it my “destiny.” I would like to thank many people who helped me during my academic life, and I dedicate this dissertation to them.

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Kyu-Tae Han

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract

Public reporting of hospital-level surgical volume and its influence on patient and hospital behavior

Background: In Dec 2007, the South Korean government introduced public reporting of hospital-level surgical volume for major surgeries, including gastrectomy in gastric cancer. It aimed to improve options available to patients and the overall quality of hospitals through informing quality indicators and leading benchmarking between hospitals. The purpose of this study was to investigate the changes in patient and hospital behavior after introducing the public reporting of hospital-level surgical volume among gastric cancer patients who underwent gastrectomy.

Materials and Methods: We used the National Health Insurance (NHI) national sampling cohort data on 2,214 patients who were diagnosed with gastric cancer based on the International Classification of Diseases (ICD)-10 (ICD-10: C16) and underwent gastrectomy in 105 hospitals during 2004–2012. We performed an interrupted time series analysis using generalized estimated equation (GEE) models with Poisson distribution and log link function to examine the impact of public reporting on patients' choice of hospital as an influence on patient behavior. Subsequently, to measure the impact of public reporting on the volume-outcome relationship in length of stay (LOS), inpatient cost, and 1-year mortality as changes in hospital behavior, we performed a linear regression analysis using the GEE model with gamma distribution and log link or survival analysis using Cox proportional hazard model adopting Difference In Difference (DID) methods. Finally, we suggest new optimal surgical volume criteria for achieving a more effective volume-outcome relationship.

Results: In total, 79.27% patients visited a hospital with a higher surgical volume based on first quartile during study period, and this percentage decreased after public reporting, although it was not statistically significant (80.66% to 78.36%, P=0.1909). The averages of LOS and inpatient costs were 15.03 days and 5.51 million KRW, respectively. The LOS decreased after public reporting, but inpatient cost increased, although the difference was not statistically significant (LOS: 16.15 days to 14.31 days, P<0.05; inpatient cost: 4.75 million KRW to 6.02 million KRW, P=0.084). Further, 5.87% of patients died within 1 year after undergoing gastrectomy, and this proportion increased after public reporting, although not significantly (5.17% to 6.34%, P=0.2529). According to the interrupted time series analysis, the time trends after public reporting seemed to be associated with patient's choice, but this association was not significant considering the policy about reducing copayment in cancer care. According to the results of multiple analyses for LOS, inpatient cost, and 1-year mortality, there were volume-outcome relationships (for LOS, Q2 ratio of LOS [RL]: 0.901, P<0.05; Q3 RL: 0.886, P<0.001; and Q4 RL: 0.785, P<0.001; for inpatient cost, Q2 ratio of cost [RC]: 0.963, P=0.2143; Q3 RC: 0.927, P<0.05; Q4 RC: 0.817, P<0.001; and for 1-year mortality, Q2 hazard ratio [HR]: 0.876, p=0.6013; Q3 HR: 0.937, P=0.7975; Q4 HR: 0.334, P<0.05). Based on the DID methods, such volume-outcome relationships for LOS and inpatient cost were found greater after public reporting. However, for 1-year mortality, this association disappeared after public reporting. On applying the new criteria for surgical volume identified in the present study, the impact of public reporting of the volume-outcome relationships was more significant for LOS and inpatient cost.

Discussion and Conclusion: This study suggested that public reporting about surgical volume in gastric cancer was not associated with patients' choice of hospital. Patients were more affected by policies on economic support rather than public reporting, and the changes in treatment options may have been affected by an increasing preference for large size hospitals. Thus, public reporting did not operate effectively for improving the options available for patients and their decision making on health care utilization. On the other hand, public reporting affected efficiency in cancer care through informing quality indicators and leading benchmarking between hospitals. Despite some problems pertaining to evaluation criteria and the policy streams, which are changing into informing surgical outcomes, the introduction of public reporting had a positive impact on hospital behavior rather than on patient aspects. This study revealed the need for health policy makers and decision makers to review the optimal evaluation criteria for quality of care in cancer patients, and to accordingly reform public reporting. In particular, efforts are needed to improve the perceptions of patients on public reporting and to motivate the effective use of public reporting in both patients and hospitals from a long-term perspective.

Key words: Gastric cancer, Surgical volume, Public reporting, Quality of care

I. Introduction

1. Study Background

South Korea has experienced rapid social and economic development during the last few decades. In 1989, the South Korean government introduced the National Health Insurance (NHI). Since then, the overall health status and life expectancy of South Koreans has improved (life expectancy: from 65.7 years in 1980 to 82.4 years in 2014).[1] However, these improvements have led to the aging of the South Korean society (proportion of individuals aged above 65 years: from 3.9% in 1980 to 11.3% in 2010). Further, the major health issues in South Koreans have changed from acute to chronic diseases as compared to that in the past.[2]

Cancer is the most common chronic disease, with a rapidly increasing incidence, according to Cancer Registration Statistics (from 214.2 per 100,000 people in 1999 to 415.7 per 100,000 people in 2010).[3] With this remarkable increase, the proportion of mortality due to cancer has also doubled. According to recent statistics, cancer still ranks as the most common cause of death in South Korea (28.6% in 2014), even though many treatment strategies related to cancer, including surgical treatment or chemotherapy have been developed to improve survival rates in cancer patients.[3,4] In addition, the economic burden due to cancer has been increasing continuously, and it was estimated at about 2.11 billion dollars in 2014; which is about 5% of the total healthcare expenditure in 2014.[5]

As cancer was considered one of the major causes of death among South Koreans, the government introduced various policies and programs to address the problems related to cancer. Since 1996, the South Korean government has been developing a 10-year plan for cancer control, to reduce the problems related to caner, and to establish the infrastructure required for managing cancer patients.[6] Since then, the government has established the National Cancer Center in 2000, and has introduced the Cancer Control Act in 2003, to relieve the burden cause by cancer and to contribute to the promotion of national health.[7] Based on these changes in policies for cancer patients, the infrastructure related to cancer has improved remarkably. However, there still remain some concerns about increasing issues related to cancer, such as cost burden or mortality, as South Korea faces an aging society.

In 2006, the second 10-year plan for cancer control was established for reducing the disease burden by minimizing the disease incidence and mortality through comprehensive management for cancer patients.[6] It has led to positive effects on health outcomes in cancer patients so far. Nevertheless, some public issues related to cancer patients persist. Although the NHI was introduced about 20 years ago, the cost burden of cancer patients continues to surpass that of other diseases. Therefore, the South Korean government decided to expand the insurance coverage for severe patients including cancer patients, and a program for reducing copayment of cancer patients was introduced since Jan 2004. This program was expanded in phases (from 30% to 20% copayment in outpatient care in Jan 2004, from 20% to 10% total copayment in Sep 2005, and from 10% to 5% total copayment in Dec 2009).[7] Although there are controversies about the levels of optimal coverage for cancer patients, the positive impact of such policies for cancer patients have been analyzed in previous studies.

The policies for cancer patients in South Korea have also changed from another point of view. According to the framework of health policy by Park et al., the health policy has been introduced based on the health care demand and supply, and it could achieve an improvement in the quality of life (QOL) of people by improving access, quality, and cost aspects of health care through support and regulation.[8] Up until the mid-2000s, the health policies for cancer patients mainly focused on improving the level of structure and environment in cancer care access and cost. Thus, the focus of health policies for cancer has turned towards quality aspects since the mid-2000s.

In 2007, the South Korean government introduced public reporting in cancer care, as part of the Healthcare Quality Assessment that was implemented in 2000, to evaluate whether optimal benefits coverage was provided to patients. This program mandates public reporting of hospital-level surgical volume for 7 types of surgery including gastrectomy in patients with gastric cancer. If hospital-level surgical volume met the criterion for optimal volume, the hospital was considered a better grade hospital. It had substantial meaning in cancer care because this was the first program that evaluated the quality of care and informed cancer patients about the results, which in turn helped improve their informed choice of hospitals for seeking surgical treatment. In general, patients who were newly diagnosed with cancer tend to visit a hospital with better quality of care for cancer patients, because diseases like cancer deal with life or death. However, in the healthcare area, there still remain information gaps between healthcare providers and patients despite the availability of information from several sources such as the Internet. Thus, they could not select a hospital where they wished to receive treatment, including surgical treatment, and they usually selected medical institutions based on factors such as accessibility, reputation, and doctor on staff.[9,10] However, public reporting about hospital performance, such as hospital-level surgical volume, might affect patient's criteria for choosing a hospital, because patients could get more information and make an informed choice by using a public report rather than basing it on reputation or experience. In addition, the introduction of public reporting could help improve hospital performance through benchmarking between hospitals. Therefore, by the introduction of public reporting, the policy on cancer has moved beyond quantitative growth, to qualitative growth.

Gastric cancer has a higher incidence and mortality rate worldwide. According to the GLOBOCAN, South Korea ranked 1st in the incidence of gastric cancer worldwide (age-standardized incidence rate: 41.8 per 100,000 people).[11] In addition, South Korea has a high incidence and mortality rate for gastric cancer (crude incidence in 2013: 59.7 per 100,000 people, ranking second among all forms of cancer: 13.4%; crude mortality in 2014: 17.6 deaths per 100,000 people, ranking third among all forms of cancer: 17.6%).[12] Gastric cancer is one of the types of cancer in which different surgical outcomes have been reported. Although, in the early stages, gastric cancer is generally treated by endoscopic procedures, most other cases are treated through surgical procedures.[13] Birkmeyer et al. and Hannan et al. suggested that hospitals with higher volume for cancer resection are associated with better outcomes based on the "Practice makes perfect" principle.[14,15] Considering such relationships, during the past decade, public reporting of hospital-level surgical volume may have had a positive effect on patient and hospital behaviors in cancer care, and it may have contributed to the improvement of health outcomes among gastric cancer patients in South Korea.

2. Study Objectives

The purpose of this study was to investigate the changes in patient and hospital behaviors after the introduction of public reporting of hospital-level surgical volume as part of Healthcare Quality Assessments among patients who received gastrectomy. This study first identified the association between patients' choice of hospital, as an indicator of patient behavior, and introduction of public reporting. Next, it compared the volume-outcome relationship for length of stay (LOS), inpatient cost, and mortality, as indicators of changing hospital behavior, with reference to public reporting. Additionally, regarding the current criteria for optimal surgical volume, this study estimated the optimal cut-off value that is required to achieve an effective volume-outcome relationship.

The detailed objectives of this study were as follows:

(1) To identify whether gastric cancer patients who underwent gastrectomy were more likely to choose high surgical volume hospitals after the introduction of public reporting of hospital-level surgical volume related to gastrectomy.

(2) To compare if the volume-outcome relationship differed in patients with gastrectomy based on the public reporting of surgical volume.

(3) To suggest an optimal cut-off volume for achieving a better volume-outcome relationship than that offered by the current criterion.

II. Literature Review

1. Factors associated with hospital choice

Based on Anderson's most widely used conceptual model in health service research, health service utilization is determined based on three factors, medical need factors, predisposing factors, and enabling factors.[16] According to this model, patients perceive the need for medical services, and then they make a decision on medical utilization if the other two factors are achieved. Likewise, medical utilization was originally determined by the medical need of each patient. Thus, patients primarily chose the hospital based on these factors alone. However, such patient behaviors changed with social and economic development, and patient outcomes improved remarkably. It naturally continued to change both needs and demands of patients, which expanded and diversified. In addition, the soaring the patient needs and demands for healthcare led to intense hospital competition over the past few decades. To meet these changes, healthcare professionals' and health policy makers' interest in the factors associated with the hospital choice of patients increased.[17]

Although many factors associated with hospital choice have been examined, the major focus of the earliest research on hospital choice was on convenience, such as distance to the hospital. Previous studies have found that patients preferred hospitals that were convenient to access. In a study using data on 1,965 hospitals in Chicago, it was found that most patients tended to visit the closest hospital based on the relationship between physicians and patients.[18] A study conducted in Michigan revealed that the choice of hospital was associated with distance because the diagnosis of patients affected the travel time to the hospital. But such associations were less sensitive towards patients who needed specialized care or those with severe diseases.[19]

The criteria for hospital choice moved toward aspects of economics or quality of care since the 1980's. The importance of other factors such as patient and hospital characteristics was raised because patients were ignorant about the perspectives of economics and quality of care while making decisions pertaining to choice of hospital before the 1980's. Previous studies identified several patient factors, including age, sex, and socio-economic status, that were found associated with hospital choice. For instance, a study by Cohen and Lee showed that the younger and male patients were less affected by the distance to the hospital.[20] In a study that used data on maternal deliveries in San Francisco, patients with a low socio-economic status were found more likely to visit a public hospital than a private one, and patients with severe clinical conditions were found more sensitive about hospital outcomes while choosing a hospital.[21] Further, hospital size was another hospital characteristic related to hospital choice.[22] Burns and Wholey suggested that hospital volume led to an increase in patient visits.[23] In addition, the previous experience of using hospital affected hospital choice.[24] The preference for doctors was an important factor in hospital choice according to Margoles et al.[25] Based on the results from a study conducted across 5 states in the US, Lane et al. suggested that the criteria of hospital choice differed by types of care; convenience in general care, quality of staff in specialty care, and convenience in emergency care.[10] Further, previous studies have reported that hospital reputation was one of main criteria for choosing a hospital.[26,27] As already described, earlier, patients depended only on subjective criteria rather than objective or quantitative indicators while choosing a hospital. Therefore, hospital reputation and patients' socio-economic status were the key factors that affected healthcare utilization and hospital choice in patients.

However, the patterns in hospital choice have changed since then. In the framework for a study on health care access conducted by Aday and Anderson, it was reported that healthcare utilization and consumer satisfaction are decided based on the impact of both health policies and health delivery systems (Figure 1).[28]

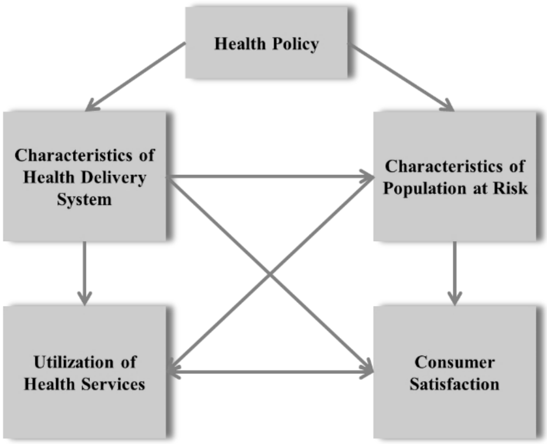


Figure 1. The framework for the study on health care access

In many countries, healthcare information is being collected and shared with the public. This increasing accessibility to health information enables patients to navigate for healthcare systems more knowledgeably.[29-31] Further, patient outcomes have improved as compared to those before the reporting quality of care was introduced.[32] As a result, in recent times, patients can easily access healthcare information and choose a hospital where they wish to receive care for specific diseases.

2. The informed patient choice

Hospital choice traditionally depended on the relationship between doctors and patients.[30] In such cases, physicians played the role of an agent for the patients, and they assisted them to choose an appropriate hospital.[33] However, this relationship has changed owing to the development of healthcare technology and systems, and the patient's role in healthcare decision making has expanded.[34] A study conducted in Minnesota reported that the traditional relationship had begun to change with the involvement of patients in several aspects of healthcare decision making.[35] Over the past few decades, with the introduction of public reporting, patients have been able to access healthcare information easily. As compared to the past, patients can now make decisions in the process of their treatment based on their knowledge about healthcare.[36] This reflects informed patient choice.

The informed patient choice is defined as the decision making in the patient's healthcare utilization after he/she has acquired healthcare information about the quality performance of healthcare providers or hospitals. Many studies have examined the impact of the increasing access to information, such as benefits and risks of treatment options, on decision making.[37,38] Findings of a study conducted in a London hospital revealed that about 50% of all patients made an informed choice, and that the informed patient choice improved their recognition of the treatment process and patient outcomes.[39] Additionally, psychological preparation by informed choice was associated with better psychological and physical outcomes.[40] A meta-analysis on surgical treatment in Scotland revealed that the informed choice of patients could have a positive role in their belief on healthcare outcomes.[41] Previous studies on informed choice showed that it differed in terms of patients' socio-economic status or age.[42,43] In addition, policy intervention related to healthcare information could play a positive role in informed patient choice.[44,45]

Further, some studies have explored patients' attitudes on the availability of opportunities to exercise their informed choice. In a study conducted in Taiwan, it was found that. With reference to physician performance information, more than 70% of the patients responded that they were willing to use a better hospital if they had access to data.[46] Schneider et al. also reported that about 58% patients would visit physicians with better outcomes if they could assess the evaluation results before surgical treatment.[47]

With reference to studies conducted in South Korea, Park et al. showed that patients tend to choose therapeutic options based on their related information.[48] Further, Kim et al. reported that informed patients choice was less associated with the use of antibiotics.[49] However, only one study investigated patient attitudes on public reporting under the Hospital Evaluation Program that was introduced in 2004. In this study, Kang et al. revealed that patients with trust on public evaluation information showed the willingness to use data from hospital evaluation reports.[50] However, there are no studies on the changes of patients' behavior after the introduction of informed quality indicators in South Korea, particular with reference to cancer care.

3. The impact of public reporting on healthcare

The healthcare environment has rapidly changed over the few decades, with increasing focus of major healthcare strategies on improving the quality of care or preventive behavior for diseases. In this changing healthcare environment, health policy makers introduced the public reporting of healthcare information to help markets function more effectively or to meet the demands of patients.[51] Since then, substantial amounts of healthcare information has been released to the public for supporting their healthcare utilization.[52,53] The quality of providers is one key aspects of this information because it help improve patient safety and encourages optimal decision making in healthcare.[29] Based on the conceptual model of the effects of increased health information by Bloom et al. (presented in Figure 2), patients' increasing access to information could lead to more informed and satisfied choices in the process of treatment, and could motivate healthy behaviors.[54]

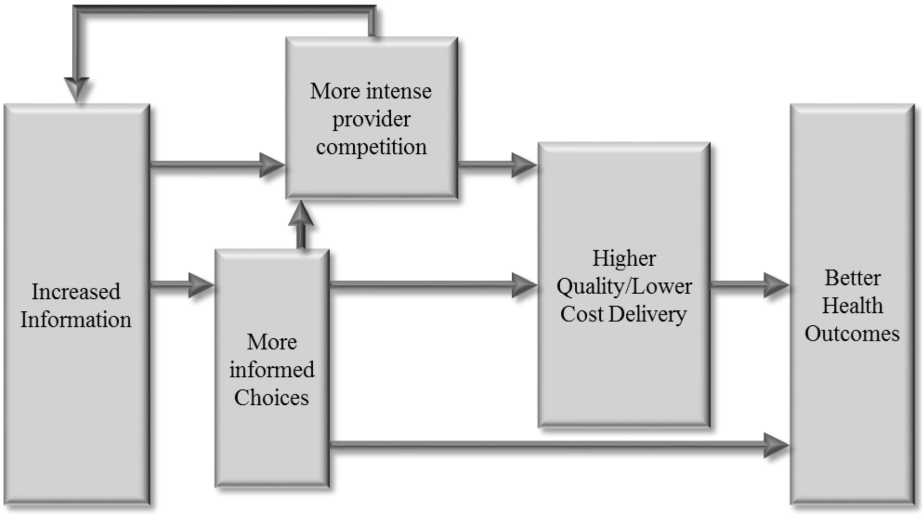


Figure 2. The conceptual model of the effects of increased health information

In addition, increased information could potentially cause other positive effects on patients. First, it could help develop a better relationship between physician and patients, and more complied for doctor's recommendation.[55] Further, it could reduce adverse selection problems and supplier induced demand due to the inequality of information.[56,57] Greenburg suggested that the public reporting of quality performance had positive effect on both patients and hospitals.[58] Informed patients would play a key role in the competition in the healthcare market, which could affect the aspects of price or quality of care.[59]

However, some concerns and issues have been raised about the public reporting of health information. Generally, patients seek health information to understand their condition and to promote social support.[60] Traditionally, patients collected healthcare information from health professionals and their friends or families.[61] Such patterns changed with the development of technologies, through which patients could access health information at anytime, from anywhere, using various sources of information such as the Internet or mass media.[62,63]

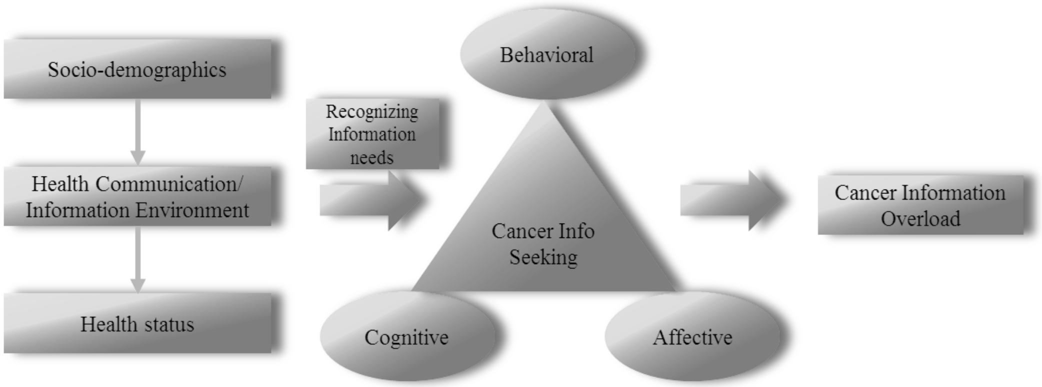


Figure 3. The potential predictors of cancer information overload

Although patients' access to information has improved rapidly, it could cause them to miss critical information or could lead them to not trust important information due to the availability of diverse information.[64] In addition, patients are unable to assess the real utility of various options, and soaring information sometimes leads to less competitiveness in healthcare.[54]

Nevertheless, many previous studies have examined the impact of public reporting on quality performance. Epstein suggested that public reporting of healthcare information had a positive role in the improvement of patients' choice.[65] Effective regionalization was another effect of public reporting.[66] Goodney et al. conducted a study on the beneficiaries of Medicare, and they argued that there was an improvement in the quality of care.[67] A report by the Institute of Medicine (IOM) revealed that the introduction of public reporting could have a positive impact on patient outcomes and quality of care.[68,69] Chassin studied the impact of informing patients about the annual data on risk-adjusted mortality after coronary artery bypass graft surgery in New York. It was found that hospital and physician report card information attributed to about 40% reduction in risk-adjusted mortality after surgery.[70] Data another survey conducted in Denver and St Louis revealed that public reporting improved about 60% of patients' decision making on other health plans .[71] Casalino et al. argued that the impact of the quality reporting program differed by patients' characteristics such as socio-economic status.[72] Béhague et al. emphasized on the importance of educational level on patients' informed choice.[73] In a study on Medicaid beneficiaries in New Jersey, public reporting of health plan performance influenced patients' choices pertaining to their health plan, and it was greater in older groups.[74] Davies et al. also suggested that the impact of quality reporting differed among the vulnerable population.[75] However, public reporting of the quality of care in each hospital might be helpful in improving the overall quality of care and patient choice.[76] Hibbard et al. revealed that public reporting had a positive role in stimulating quality improvement activities in areas with relative lower performance.[77] In addition, a study on the reporting of hospital-level cancer surgical volumes in California found that increasing the availability of information about hospital volumes helped patients, providers, and payers to appropriately choose cancer surgery hospitals.[78]

Expecting such positive impacts, the South Korean government introduced the public reporting of quality performance. In 2000, the Healthcare Quality Assessment was introduced to evaluate whether the optimal benefits coverage was provided to patients in the process of medical treatment, including diagnosis, procedure, prescription, and tests. The objective of this program was strengthen patients' informed choice as well as to improve the quality of care.[79] It was started with the evaluation of pharmaceutical aspects, and gradually expanded to other parts of treatment. It informed the public about results of the evaluation since 2005. In 2007, the South Korean government expanded the Healthcare Quality Assessment to cover cancer care. This involves the public reporting of hospital-level surgical volume for 7 types of surgeries such as gastrectomy, hip replacement, percutaneous coronary intervention, esophagectomy, pancreatectomy, hematopoietic stem cell transplantation, and coronary artery bypass graft.[80] Since then, this policy has been continuously reformed, and the public reporting of surgical volume for 7 types of surgery was conducted in 2016. This public reporting was based on the theory of "practice makes perfect" with reference to the volume-outcome relationship. Thus, it is believed that hospitals or physicians with a high patient volume could improve their practice skills. Since Luft el al. first suggested the impact of the volume-outcome relationship on various aspects of treatment in 1987, it was usually used to proxy indicators that could reflect the hospital's or physician's quality performance.[81,82] In this public reporting, hospital-level surgical volume was evaluated based on performance in the previous year, and a hospital was considered to have a better grade if it met a certain criterion for surgical volume. This criterion was mostly evaluated based on the first quartile data.

Table 1. The items of public reporting of surgical volumes by year

Types of surgery	Year							
	2007	2008	2009	2010	2011	2012	2013	2014
Gastric cancer surgery	O	O	O	O				O
Hip replacement	O	O	O	O	O	O	O	O
Percutaneous coronary intervention	O	O	O	O	O	O	O	
Esophageal cancer surgery	O		O		O	O		O
Pancreatic cancer surgery	O		O		O	O		O
Hematopoietic stem cell transplantation	O		O		O	O		O
Coronary artery bypass graft	O		O		O	O		O
Colon cancer surgery		O	O	O				
Liver cancer surgery		O		O				O

In South Korea, public reporting of quality indicators may have led to some improvements; however, most studies have been conducted from the perspective of physician rather than of patients.[83] For patients, one study suggested that, after the introduction of public reporting, the perceived the quality of hospitals could affect patients' satisfaction and wiliness to re-visit the hospital in which they had already received treatment.[84] However, no study has examined the public reporting of hospital-level surgical volume and its impact on cancer care.

III. Material and Methods

1. Study Population and Design

The data used in this study was derived from the National Health Insurance Service National Sample Cohort 2002–2013, which was released by the Korean National Health Insurance Service (KNHIS) in 2014. The data comprise a nationally representative random sample of 1,025,340 individuals, approximately 2.2% of the entire population covered by the KNHIS in 2002. The data was produced by probabilistic sampling, to represent an individual's total annual medical expenses within each of the 1,476 strata defined by age, sex, eligibility status (employed or self-employed), and income level (20 quantiles for each eligibility status plus medical aid beneficiary) combinations through proportional allocation of the 46,605,433 Korean residents recorded in 2002. The database includes all medical claims filed from January 2002 to December 2013. In addition, the data used in this study included information about the hospital in which each patient received treatment during the study period. To analyze the association between the patients' choice of hospital with high surgical volumes and the introduction of public reporting about hospital-level surgical volumes in patients with gastric cancer and to examine the changes in the volume-outcome relationship in LOS, inpatient cost, and mortality after public reporting, we included the patients who were diagnosed with gastric cancer based on the International Classification of Diseases (ICD)-10 code (ICD-10:

C16, 8,420 patients with gastric cancer). Considering public reporting in this study, we included the patients who underwent gastrectomy due to gastric cancer (3,314 patients with gastrectomy). Subsequently, to assume the new diagnosis reflecting the medical claim data, we excluded the patients who were diagnosed with gastric cancer before 2004, and only included the patients who were diagnosed during 2004–2013 (2,358 gastric cancer patients with gastrectomy during 2004–2013). Additionally, the public reporting about surgical volumes reflected the results of the evaluation for surgical volume based on hospital performance in the previous period (about 1–2 years). Therefore, to satisfy such evaluation criteria, we excluded the patients at hospitals which had no details about surgical treatment provided in the previous year. Further, to analyze patient outcomes after gastrectomy, we excluded the patients with a follow-up period of less than 1 year. Finally, the data used in this study comprised information pertaining to 2,214 patients who were diagnosed with gastric cancer and underwent gastrectomy in 105 hospitals during 2004–2012 (Figure 4).

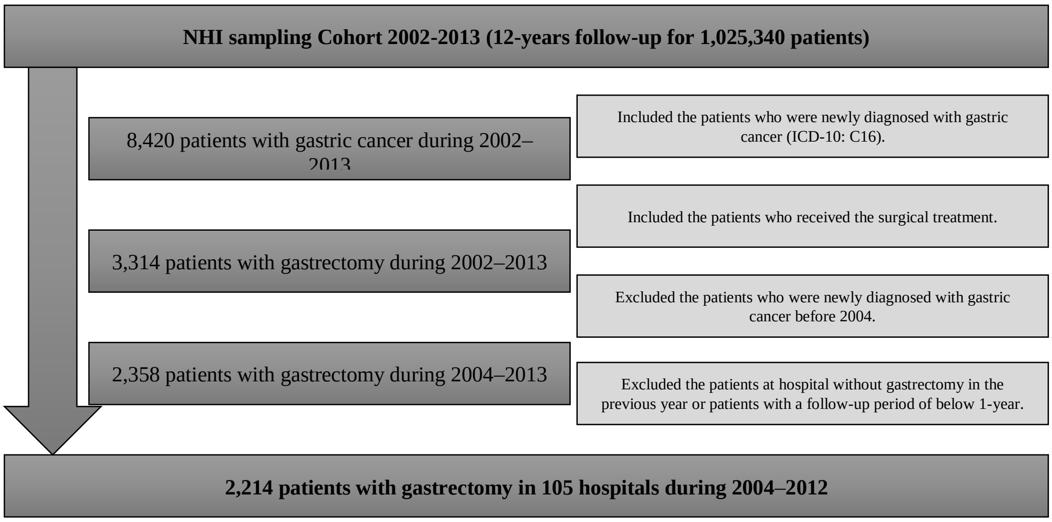


Figure 4. Flow chart of subject selection

Using the above data on 2,214 patients with gastrectomy, we analyzed the impact on patients' choice of hospital and volume-outcome relationship in LOS, inpatient cost, and mortality by introduction of the public reporting of hospital-level surgical volume according to the following study design, which was designed based on the conceptual framework proposed by Bloom et al (Figure 5).[54] First, we analyzed whether the patients with gastric cancer visited a hospital with high volumes of gastrectomy more or less often owing to the introduction of public reporting considering patient factors. Next, we analyzed whether there were changes in the volume-outcome relationship for LOS, inpatient cost, and 1-year mortality after the introduction of public reporting considering both patient factors and hospital factors.

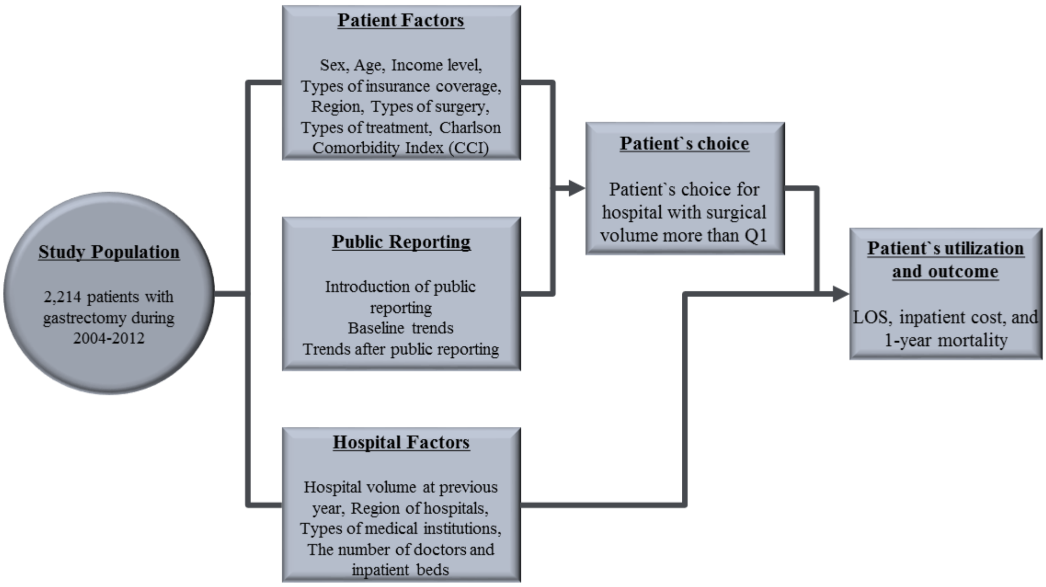


Figure 5. The conceptual framework of the study design

2. Variables

To analyze the impact of public reporting about surgical volumes of gastrectomy on patients and hospital behavior among patients with gastric cancer, we considered the following outcome variables as indicators of patients' choice: LOS, inpatient cost, and mortality (Table 2). Patients' choice of a hospital was defined based on whether patients with gastric cancer visited a hospital with high surgical volume to receive the surgical treatment due to gastric cancer. The hospitals which the patient visited were classified as "high" and "low" based on surgical volume in the first quartile of the previous year, with reference to the current criterion of public reporting. Next, we considered other outcome variables on hospital behavior. The LOS was calculated based on inpatient cases of gastrectomy. Inpatient cost was defined as the total cost incurred in the inpatient case with gastrectomy, and it reflected the conversion factors by year. We identified the first date of hospitalization due to gastrectomy in the calendar year during study period as the index date. If the date of death for each inpatient case was within 365 calendar days after the index date, the inpatient case was defined as "dead".

Table 2. The outcome variables in this study

Category	Outcome variables
Patient behavior	• Whether patients visited to hospital with high surgical volume (above surgical volume in the first quartile of the previous year)
Hospital behavior	• LOS of inpatient case with gastrectomy • Total inpatient cost per case with gastrectomy • 1-year mortality after gastrectomy

The independent variables used in this study included the patient, public reporting, and hospital variables, and it was little differed by analysis of this study. The list of independent variables used in this study has been described in Table 3.

Table 3. List of independent variables

Variables		Definition
Public reporting variables	**Introduction of public reporting**	(1) Before (2) After
	Baseline trends	The time as unit of month during study period
	Trends after public reporting	The time after introducing public reporting as unit of month
Patient variables	**Sex**	(1) Male (2) Female
	Age	(1) Less than 39 years (2) 40-49 years (3) 50-59 years (4) 60-69 years (5) More than 70 years
	Income level	(1) Less than 30 percentile (2) 31-60 percentile (3) 61-80 percentile (4) 81-100 percentile
	Types of insurance coverage	(1) Medical-Aid (2) NHI, self-employed (3) NHI, employed
	Region	(1) Capital area (2) Metropolitan (3) Others
	Types of surgery	(1) Total gastrectomy (2) Subtotal gastrectomy
	Types of treatment	(1) Surgery with chemotherapy or radiotherapy (2) Only surgery
	CCI	(1) 0-1 (2) 2 (3) More than 3
Hospital variables	**Hospital-level surgical volume in the previous year**	(1) First quartile (2) Second quartile (3) Third quartile (4) Fourth quartile
	Region of hospital	(1) Capital area (2) Metropolitan (3) Others
	Types of medical institution	(1) Tertiary hospital (2) General hospital
	The number of doctors	The number of doctors in each hospital
	The number of inpatient beds	The number of inpatient beds in each hospital

In the analysis of patient choice, the interesting variable was the introduction of public reporting about surgical volumes for gastrectomy, trends after introduction of public reporting, and baseline trends. As we already noted, the public reporting about surgical volumes was introduced in Dec 2007, the introduction of public reporting was defined as “before” and “after” using Dec 2007 as a reference point; the time before the policy was introduced was defined as 0, and the time after the public reporting concluded was defined as 1 in order to investigate the changes in patients’ choice of hospitals. Trends after the introduction of public reporting were used to analyze the linear changes in the trend after introducing the public reporting, it was coded as “0” before public reporting and as “0, 1, 2 ...” on a monthly basis during the period after public reporting. The baseline trends were stratified by month from 2004 to 2012. Next, in the analysis of LOS, inpatient cost, and mortality, the variable of interest was the hospital-level surgical volume for gastrectomy in the previous year, which was categorized into quartiles, as “first quartile,” “second quartile,” “third quartile,” and “fourth quartile.”

The other independent variables were also used in this study. First, to analyze the association between the introduction of public reporting and the patients’ choice of hospitals, adjusting the differences in patient’s choice by their characteristics, we considered patients variables such as sex, age, income level, types of insurance coverage, region, types of surgery, types of treatment, and Charlson comorbidity index (CCI). Age was categorized into five groups, as follows: “less than 39 years,” “40–49 years,” “50–59 years,” “60–69 years,” and “more than 70 years,” to reflect the variation in selecting hospitals by age. Income level was categorized into deciles based on mean household income, as follows: ≤10 percentile, 11–20 percentile, 21–30 percentile, 31–40 percentile, 41–50 percentile, 51–60 percentile, 61–70 percentile, 71–80 percentile, 81–90 percentile, and ≥91 percentile. We re-categorized them into four groups, "less than 30th percentile," "31st–60th percentile," "61st–80th percentile," and "81st–100th percentile." The types of insurance coverage were categorized as medical aid, National Health Insurance (NHI) employed, or NHI self-employed based on the NHI criteria. Those under the NHI employed category workers and employers in all workplaces, public officials, private school employees, continuously insured persons, and daily paid workers at construction sites. Beneficiaries of NHI employed also included spouses, descendants, siblings, and parents. People in this category paid a regular portion of their average salary in contribution payments, and the rates changed every year. The NHI self-employed category included people who did not fall into the above-described group. Their contribution amount was set by taking into account their income, property, living standard, and rate of participation in economic activities. Medical aid beneficiaries were defined as patients with an income below the government-defined poverty level or those with a disability, who were provided with free inpatient and outpatient care paid with government funds. Therefore, the type of insurance coverage represented each patient's socioeconomic status. The region of patients was defined as "capital area," "metropolitan," and "others." Due to limitation of the healthcare claim data, we could not consider the cancer staging such as TNM or SEER summary staging, which could reflect the severity of cancer patients. Alternatively, to minimize the limitations of the absence of data on cancer staging, we considered the types of surgery and types of treatment during the treatment period of each patient as independent variables in this study. These variables were defined as "total gastrectomy" and "subtotal gastrectomy" or "surgery with chemotherapy or radio therapy" and "only surgery," respectively. The CCI was calculated by weighting and scoring other comorbid conditions with additional points added to consider comorbidities that could affect health outcomes, and it was categorized into “0–1,” “2,” and “more than 3.”

Next, to investigate the changes in the volume-outcome relationship by the introduction of public reporting about surgical volume in each hospital, we included the independent variables, including patient variables used in the previous analysis, introduction of public reporting, and hospital variables. The hospital variables were region of hospital, types of medical institution, the number of doctors, and the number of inpatient beds. The region of hospital defined as “capital area,” “metropolitan,” and “others.” The types of medical institution were categorized into “tertiary hospital” and “general hospital” to reflect the hospital variation caused by hospital’s structure. In addition, we also adjusted the variables with reference to the number of doctors or inpatient beds for reflecting the characteristics of hospital resources in each hospital.

Therefore, we first analyzed the relationship between patient’s choice of hospital and introduction of public reporting for surgical volumes by the introduction of public reporting for surgical volume among gastric cancer, adjusting for sex, age, income level, types of insurance coverage, region, types of surgery, types of treatment, and CCI. Then we analyzed the changes in the relationship between hospital surgical volume and LOS, inpatient cost, and mortality, adjusting for sex, age, income level, types of insurance coverage, region, types of surgery, types of treatment, CCI, region of hospital, types of medical institution, the number of doctors, and the number of inpatient beds.

3. Statistical analysis

1) Introduction of public reporting and patients' choice of hospital

In the analysis on patients' choice as an indicator of patient behavior, we first examined the frequencies and percentages of each categorical variable among patients who underwent gastrectomy after diagnosis for gastric cancer by whether patients visited the hospital with surgical volume above that of the first quartile of the previous year, and performed the chi-square test to examine the distribution of visits to a hospital with high volume according to each categorical variable. We then showed the monthly distribution of patients who visited a hospital with high volume over the study period, and compared trends before and after the introduction of public reporting.

Next, we performed the interrupted time series analysis using the Generalized Estimated Equation (GEE) model with Poisson distribution and log link function adjusting patient-level variables to investigate the association between patients' choice of hospitals where they underwent the gastrectomy and the introduction of public reporting about surgical volume among patients with gastrectomy.[85] This analysis was performed through three models by adjusting for covariates to compare the model fit and results; Model 1=Public reporting variables, Model 2=Model 1+Patient's socio-economic status, and Model 3=Model 2+Patient's severity indicators. In these analyses, the goodness of fit for the GEE model was assessed through using the quasi-likelihood under the independence criteria (QIC). The lower value for QIC indicated a better model fit.[86]

In addition, during the study period, other health policies about reducing the copayment of cancer patients were also introduced (1st phase in Jan 2004, 2nd phase in Sep 2005, and 3rd phase in Dec 2009). Based on the results of previous studies, the 2nd and 3rd phases of policies were found to affect patient behaviors. Therefore, we needed to compare our findings with the policy on reducing copayment of cancer patients when evaluating the impact of public reporting surgical volume for changes in patient's choice. To this effect, we performed a sensitivity analysis for the interrupted time series analysis adjusting for additional health policies about reducing copayment in Sep 2005 and Dec 2009, to identify whether the changes in patients' choice of hospital were affected by other health policies for cancer patients. We also performed a sub-group analysis for the interrupted time series analysis, to examine the differences in association with public reporting according to income level, types of insurance coverage, region, types of treatment, and types of surgery. It was conducted for both models that either considered the copayment policy or not.

2) Differences in the volume-outcome relationship by public reporting

In the analysis of the volume-outcome relationship on LOS, inpatient cost, and 1-year mortality, to identify the changes in hospital behavior caused public reporting, we examined the average of LOS and inpatient cost over the study period, and compared the trend before and after the introduction of public reporting. We performed an analysis of variance (ANOVA) and a chi-square to compare the averages and standard deviation of LOS, inpatient cost, and 1-year mortality for each variable. Then, survival curves were generated by the Kaplan-Meier product limit method, and log-rank tests were used to compare 1-year gastrectomy survival rates between surgical volume groups. In addition, we performed a two-way ANOVA and Cochran Mantel Haenszel test for comparing the LOS, inpatient cost, and 1-year mortality by both the hospital volume and the introduction of public reporting.

Next, on identifying the volume-outcome relationships using either the linear regression analysis with the GEE model or the survival analysis using the Cox proportional hazard model, we performed a trend adjusted difference in difference (DID) analysis using generalized linear regression through the GEE model with a gamma distribution and log link function, to identify the effect modification between the introduction of public reporting and surgical volume for LOS and inpatient cost.[87,88] Further, survival analysis was conducted using the DID Cox proportional hazards model adjusted to examine the association between surgical volume and 1-year mortality by the introduction of public reporting.[89] We then estimated the results of each analysis by adjusting the interaction terms between surgical volume and the introduction of public reporting.

3) Optimal volume for achieving a better volume-outcome relationship

We calculated the optimal predicted survival rates cut-off of surgical volumes for achieving a better volume-outcome relationship using the Youden index (sensitivity+specificity-1) using the following formula: it is the maximum vertical distance between the ROC and diagonal line, and the idea is to maximize the difference between a true positive and false positive.[90] The optimal cut-off is at where the Youden Index is the highest.

$$\textit{Cut-off volume}=\left\{log\left(\frac{p}{1-p}\right)-\ \beta_0\right\}\div\beta_1$$

P=probability at maximizing the Youden index; β_0=intercept; β_1=coefficient of surgical volume

Based on this new cut-off, we categorized surgical volume into two groups as “high” and “low.” We then compared the outcomes between the original analysis and re-analyses for LOS, inpatient cost, and 1-year mortality using surgical volume categories based on the new optimal cut-off volume. In these analyses, the goodness of fit was assessed by either QIC or -2 log likelihood statistics, and lower values had a better model fit. We used the SAS 9.4 (SAS Institute, Cary, NC) for all the statistical analyses in this study. The statistical tests in this study were two-tailed and the results rejected the null hypotheses of absence of statistically significant differences if P-values were less than .05, or equivalently, if the 95% confidence intervals did not include 1.

4. Ethics Statement

This study was approved by an Institutional Review Board, Yonsei University Graduate School of Public Health (2-1040939-AB-N-01-2016-411-01).

IV. Results

1. The introduction of public reporting and patients' choice of hospital

1) General characteristics by the patients' preference for visiting hospitals with high volume

Table 4 shows the frequencies and percentages of patients who were newly diagnosed with gastric cancer and underwent gastrectomy by visiting a hospital with surgical volume more than that reported in the first quartile of the previous year, and the results of the chi-square test for identifying the distribution of the study population by their choice of a hospital with high volume during 2004–2012. There were 2,214 patients with gastrectomy from 2004 to 2012, 79.27% of which visited a hospital with high surgical volume as compared to that in the first quartile of the previous year (n=1,755 patients). Overall, patients who visited a hospital with a high volume of gastrectomies reduced after the introduction of public reporting, but this difference was not statistically significant (before: 80.66%, after: 78.36%, P-value=0.1909). There were no differences in visiting a hospital with high volume based on the sex of the patients. Further, those with a higher income level tended to visit a hospital with high volume (less than 30 percentile: 72.47%, 31–60 percentile: 75.76%, 61–80 percentile: 80.00%, 81–100 percentile: 85.44%; P-value<.0001). The patients covered by NHI, and those who were employed tended to visit a hospital with high volume than others did (Medical Aid: 67.12%; NHI, self-employed: 74.97%; NHI, employed: 82.47%; P-value<.0001). Patients with total gastrectomy or surgery with chemotherapy or radio therapy tended to visit a hospital with high volume more frequently, but these results were not statistically significant. In addition, patients with low CCI tended to visit a hospital with high volume than did patients with a higher score, even though there were no statistically significant associations.

Table 4. Patients' preference for visiting a hospital with high volume

Variables	Total		Visiting a hospital with high volume				P-value
			Visit		Non-visit		
	N	%	N	%	N	%	
Introduction of public reporting							
Before	874	39.48	705	80.66	169	19.34	0.1909
After	1,340	60.52	1,050	78.36	290	21.64	
Year of surgery							
2004	222	10.03	202	90.99	20	9.01	0.0003
2005	245	11.07	185	75.51	60	24.49	
2006	225	10.16	176	78.22	49	21.78	
2007	197	8.90	151	76.65	46	23.35	
2008	257	11.61	198	77.04	59	22.96	
2009	238	10.75	179	75.21	59	24.79	
2010	261	11.79	218	83.52	43	16.48	
2011	283	12.78	228	80.57	55	19.43	
2012	286	12.92	218	76.22	68	23.78	
Sex							
Male	1,510	68.20	1,185	78.48	325	21.52	0.1785
Female	704	31.80	570	80.97	134	19.03	
Age							
~39	100	4.52	87	87.00	13	13.00	0.0986

(continued)

Variables	Total		Visiting a hospital with high volume				P-value
			Visit		Non-visit		
	N	%	N	%	N	%	
40-49	342	15.45	281	82.16	61	17.84	
50-59	584	26.38	451	77.23	133	22.77	
60-69	656	29.63	523	79.73	133	20.27	
70+	532	24.03	413	77.63	119	22.37	
Income level							
~30 percentile	454	20.51	329	72.47	125	27.53	<.0001
31-60 percentile	528	23.85	400	75.76	128	24.24	
61-80 percentile	490	22.13	392	80.00	98	20.00	
81-100 percentile	742	33.51	634	85.44	108	14.56	
Types of insurance coverage							
Medical Aid	73	3.30	49	67.12	24	32.88	<.0001
NHI, self-employed	795	35.91	596	74.97	199	25.03	
NHI, employed	1,346	60.79	1,110	82.47	236	17.53	
Region							
Capital area	858	38.75	668	77.86	190	22.14	0.3971
Metropolitan	599	27.06	483	80.63	116	19.37	
Others	757	34.19	604	79.79	153	20.21	
Types of surgery							
Total gastrectomy	511	23.08	412	80.63	99	19.37	0.3879
Subtotal gastrectomy	1,703	76.92	1,343	78.86	360	21.14	
Types of treatment							
Surgery with chemotherapy or radiotherapy	507	22.90	402	79.29	105	20.71	0.9891
Only surgery	1,707	77.10	1,353	79.26	354	20.74	
CCI							
0-1	500	22.58	401	80.20	99	19.80	0.3905
2	897	40.51	719	80.16	178	19.84	
3+	817	36.90	635	77.72	182	22.28	
Total	**2,214**	**100.00**	**1,755**	**79.27**	**459**	**20.73**	

2) The monthly proportion of patients who visited a hospital with high volume

The proportion of patients who visited a hospital with high volume as compared to that observed in the first quartile of the previous year among patients who were diagnosed with gastric cancer and received the gastrectomy increased gradually after the introduction of public reporting. In particular, the step changes in the preference for a hospital with high volume increased after the introduction of public reporting, and slightly increased trends were observed in the proportion of patients visiting a hospital with high volume after public reporting was introduced (Figure 6).

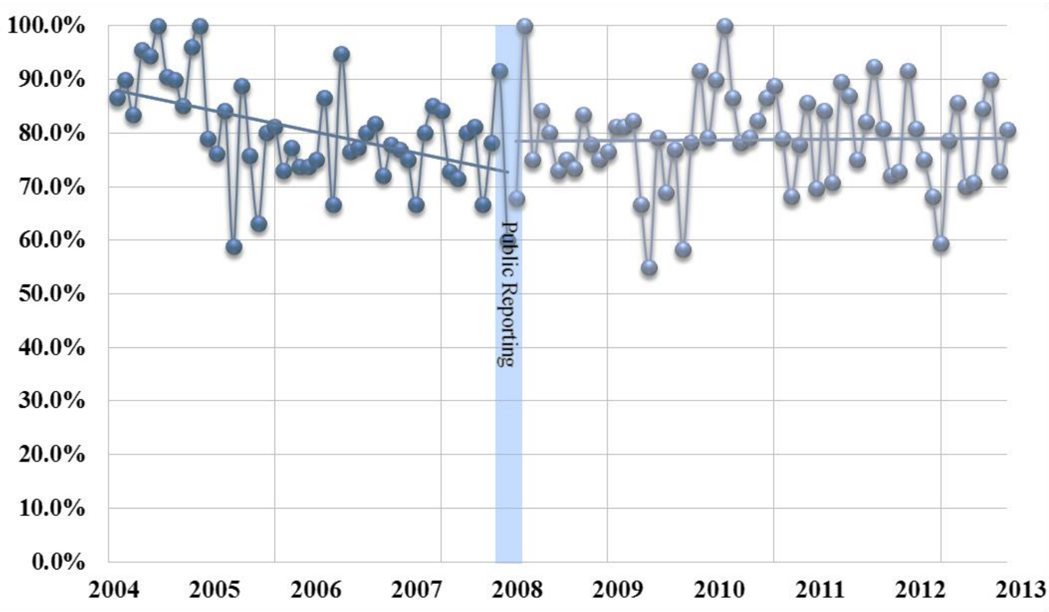


Figure 6. Monthly proportion of patients who visit a high volume hospital

3) Results of the interrupted time series analysis on public reporting

3.1) Model 1

In Model 1, the baseline trend was inversely associated with the visiting high volume hospitals, and the introduction of public reporting had no statistically significant association with it. After public reporting was introduced, there were slight positive trend for visiting a high volume hospital (RR [Relative risk]: 1.004, 95% CI: 1.002–1.007, P-value: 0.0028; Table 5).

Table 5. Results of the interrupted time series analysis (Model 1)

Variables	**Visiting a hospital with high volume**			
	RR	**95% CI**		**P-value**
Introduction of public reporting				
Before	1.000	-	-	-
After	0.961	0.875	1.055	0.4034
After public reporting	1.004	1.002	1.007	0.0028
Baseline trends	0.996	0.994	0.999	0.0017
QIC	20821.9625			

3.2) Model 2

Results on Model 2 revealed that the time trend after the introduction of public reporting was positively associated with visiting a high volume hospital, similar to Model 1 (RR: 1.004, 95% CI: 1.001–1.007, P-value=0.0039). However, the step change by introduction of public reporting had no statistically significant association with visiting a hospital with high volume, and the baseline trends had a significant inverse association. Younger patients visited a hospital with high volume more often, while having a lower income was inversely associated with visiting a high volume hospital (less than 30 percentile=RR: 0.860, 95% CI: 0.804–0.920; P-value<.0001, 31–60 percentile=RR: 0.888, 95% CI: 0.838–0.940; P-value<.0001, 61–80 percentile=RR: 0.932, 95% CI: 0.884–0.940; P-value=0.0100, ref=81–100 percentile). Such differences were also analyzed by types of insurance coverage (Medical Aid=RR: 0.871, 95% CI: 0.733–1.035, P-value=0.1158; NHI, self-employed=RR: 0.913, 95% CI: 0.872–0.957, P-value=0.0001, ref=NHI, employed; Table 6).

Table 6. Results of the interrupted time series analysis (Model 2)

Variables	Visiting a hospital with high volume			
	RR	95% CI		P-value
Introduction of public reporting				
Before	1.000	-	-	-
After	0.964	0.878	1.058	0.4362
After public reporting	1.004	1.001	1.007	0.0039
Baseline trends	0.997	0.994	0.999	0.0039
Sex				
Male	0.973	0.931	1.018	0.2396
Female	1.000	-	-	-
Age				
~39	1.142	1.045	1.247	0.0032
40-49	1.078	1.008	1.153	0.0292
50-59	1.020	0.957	1.087	0.5388
60-69	1.043	0.982	1.107	0.1674

(continued)

Variables	Visiting a hospital with high volume			
	RR	95% CI		P-value
70+	1.000	-	-	-
Income level				
~30 percentile	0.860	0.804	0.920	<.0001
31-60 percentile	0.888	0.838	0.940	<.0001
61-80 percentile	0.932	0.884	0.983	0.0100
81-100 percentile	1.000	-	-	-
Types of insurance coverage				
Medical Aid	0.871	0.733	1.035	0.1158
NHI, self-employed	0.913	0.872	0.957	0.0001
NHI, employed	1.000	-	-	-
Region				
Capital area	0.955	0.908	1.005	0.0787
Metropolitan	0.996	0.944	1.051	0.8825
Others	1.000	-	-	-
QIC	20670.50			

3.3) Model 3

The introduction of public reporting had no statistically significant association with visiting a high volume hospital, and the baseline trends had a significant inverse association. On the other hand, the time trend after introduction of public reporting was positively associated with risk in visiting a high volume hospital (per 1 month, RR: 1.004, 95% CI: 1.000–1.008, P-value=0.0329). By the patient's socio-economic status, the results were similar to those derived from Model 2. Younger patients visited a hospital with high volume more often, and being in the lower income group or being a self-employed beneficiary of NHI was inversely associated with risk of visiting a high volume hospital. The patient's region had no association with risk of visiting a hospital with high surgical volume. In addition, in terms of clinical severity in gastric cancer patients, there were no statistically significant results by types of surgery, types of treatment, or CCI score. With reference to the goodness of fit of the QIC, Model 3 had lower QIC values and it had better goodness of fit than the other models did (Table 7).

Table 7. Results of the interrupted time series analysis (Model 3)

Variables	Visiting a hospital with high volume			
	RR	95% CI		P-value
Introduction of public reporting				
Before	1.000	-	-	-
After	0.943	0.855	1.041	0.2463
After public reporting	1.004	1.000	1.008	0.0329
Baseline trends	0.996	0.994	0.998	0.0009
Sex				
Male	0.980	0.936	1.025	0.3764
Female	1.000	-	-	-
Age				
~39	1.137	1.039	1.244	0.0051
40-49	1.074	1.004	1.149	0.0388
50-59	1.019	0.955	1.086	0.5738
60-69	1.038	0.977	1.102	0.2244
70+	1.000	-	-	-
Income level				
~30 percentile	0.851	0.796	0.910	<.0001
31-60 percentile	0.885	0.836	0.937	<.0001

(continued)

Variables	Visiting a hospital with high volume			
	RR	95% CI		P-value
61-80 percentile	0.921	0.873	0.972	0.0028
81-100 percentile	1.000	-	-	-
Types of insurance coverage				
Medical Aid	0.881	0.743	1.045	0.1467
NHI, self-employed	0.908	0.866	0.952	<.0001
NHI, employed	1.000	-	-	-
Region				
Capita area	0.943	0.896	0.992	0.0232
Metropolitan	0.997	0.945	1.051	0.9038
Others	1.000	-	-	-
Types of surgery				
Total gastrectomy	1.000	-	-	-
Subtotal gastrectomy	0.978	0.931	1.028	0.3901
Types of treatment				
Surgery with chemotherapy or radiotherapy	0.973	0.924	1.024	0.2915
Only surgery	1.000	-	-	-
CCI				
0-1	1.068	0.966	1.182	0.2005
2	1.031	0.981	1.084	0.2249
3+	1.000	-	-	-
QIC	20638.66			

4) Interrupted time series analysis with reference to reduction in copayment

There was a positive association with visiting a high volume hospital after the introduction of the 2nd and 3rd copayment policy or after the time trends of such policies. However, the introduction of public reporting about surgical volume was not significantly associated with visiting a high volume hospital (Table 8).

Table 8. Results of the interrupted time series analysis with reference to reduction in copayment

Variables	Visiting a hospital with high volume			
	RR	95% CI		P-value
Introduction of 2nd copayment policy (Sep 2005)				
Before	1.000	-	-	-
After	1.013	0.880	1.167	0.8534
After 2nd copayment policy	1.019	1.009	1.030	0.0002
Introduction of public reporting (Dec 2007)				
Before	1.000	-	-	-
After	0.933	0.808	1.077	0.3443
After public reporting	0.998	0.988	1.007	0.6203
Introduction of 3rd copayment policy (Dec 2009)				
Before	1.000	-	-	-
After	1.142	1.012	1.289	0.0311
After 3rd copayment policy	0.993	0.984	1.002	0.1233
Baseline trends	0.984	0.976	0.992	<.0001
QIC	20653.43			

5) Sub-group analysis for the interrupted time series analysis

5.1) Results of the sub-group analysis by income level

A significant positive association was revealed between increase in visiting a hospital with high volume and the time trends after the introduction of public reporting, but the baseline trends were inversely associated with risk of visiting a hospital with high surgical volume (per 1 month, RR: 0.993, 95% CI: 0.988–0.999, P-value=0.0142). In addition, the step changes were not statistically significant in any of the sub-groups. In the analysis considering copayment policies, there was no association between public reporting and visiting a hospital with high surgical volume (Table 9).

Table 9. Results of the sub-group analysis by income level

Sub-group	Variables	Visiting a hospital with high volume							
		Model 3				Model 3 + copayment policies			
		RR	95% CI		P-value	RR	95% CI		P-value
~30 percentile	Introduction of public reporting	1.183	0.920	1.522	0.1898	0.918	0.633	1.330	0.6515
	After public reporting	0.996	0.987	1.005	0.3966	1.005	0.980	1.030	0.7082
	Baseline trends	0.999	0.992	1.006	0.7521	0.982	0.958	1.008	0.1683
31-60 percentile	Introduction of public reporting	0.946	0.764	1.172	0.6144	0.966	0.705	1.323	0.8280
	After public reporting	1.002	0.994	1.011	0.5923	0.991	0.968	1.014	0.4266
	Baseline trends	0.999	0.993	1.004	0.6148	0.981	0.962	1.000	0.0536
61-80% percentile	Introduction of public reporting	1.061	0.853	1.320	0.5944	1.061	0.773	1.457	0.7120
	After public reporting	1.011	1.003	1.019	0.0084	0.996	0.973	1.020	0.7664
	Baseline trends	0.993	0.988	0.999	0.0142	0.983	0.966	1.000	0.0552
81-100 percentile	Introduction of public reporting	1.056	0.912	1.223	0.4643	0.863	0.701	1.063	0.1650
	After public reporting	1.005	1.000	1.010	0.0668	0.999	0.985	1.013	0.8870
	Baseline trends	0.996	0.993	0.999	0.0032	0.989	0.980	0.998	0.0183

5.2) Results of the sub-group analysis by types of insurance coverage

The sub-group analysis according to types of insurance coverage revealed that the time after introduction of public reporting about surgical volume had a positive association with risk of visiting a high volume hospital in only self-employed patients with NHI (per 1 month, RR: 1.013, 95% CI: 1.007–1.020, P-value<.0001), but there were decreased baseline trends (per 1 month, RR: 0.993, 95% CI: 0.989–0.998, P-value=0.0026). Considering copayment policies, visiting a high volume hospital was not associated with public reporting (Table 10).

Table 10. Results of the sub-group analysis by types of insurance coverage

Sub-group	Variables	Visiting a hospital with high volume							
		Model 3				Model 3 + copayment policies			
		RR	95% CI		P-value	RR	95% CI		P-value
Medical Aid	Introduction of public reporting	1.001	0.478	2.096	0.9973	0.939	0.279	3.158	0.9190
	After public reporting	1.002	0.979	1.025	0.8788	1.024	0.953	1.100	0.5150
	Baseline trends	1.000	0.982	1.017	0.9579	1.019	0.968	1.073	0.4736
NHI, self-employed	Introduction of public reporting	1.025	0.842	1.246	0.8080	0.929	0.699	1.234	0.6105
	After public reporting	1.013	1.007	1.020	<.0001	0.997	0.978	1.016	0.7459
	Baseline trends	0.993	0.989	0.998	0.0026	0.985	0.970	1.001	0.0624
NHI, employed	Introduction of public reporting	1.078	0.965	1.203	0.1849	0.930	0.790	1.094	0.3794
	After public reporting	0.998	0.994	1.003	0.4461	0.996	0.985	1.008	0.5232
	Baseline trends	0.998	0.995	1.000	0.0838	0.981	0.972	0.990	<.0001

5.3) Results of the sub-group analysis by region

Results of the sub-group analysis by region, such as capital area, metropolitan, and others, revealed a statistically significant increase in visiting a hospital with high surgical volume by time trends after introduction of public reporting only patients who lived in others area (per 1 month, RR: 1.008, 95% CI: 1.002–1.015, P-value=0.0072), but it was not significant in patients who lived in either capital or metropolitan areas. However, the step changes after introduction of public reporting were not statistically significant in any of the groups. In addition, the results for public reporting considering copayment policies were not statistically significant (Table 11).

Table 11. Results of the sub-group analysis by region

Sub-group	Variables	Visiting a hospital with high volume							
		Model 3				Model 3 + copayment policies			
		RR	95% CI		P-value	RR	95% CI		P-value
Capital area	Introduction of public reporting	1.161	0.988	1.364	0.0693	1.031	0.831	1.278	0.7828
	After public reporting	1.000	0.994	1.006	0.9778	0.997	0.981	1.013	0.6973
	Baseline trends	1.049	0.816	1.348	0.7087	0.988	0.974	1.003	0.1089
Metropolitan	Introduction of public reporting	0.914	0.757	1.105	0.3539	0.760	0.569	1.017	0.0649
	After public reporting	1.004	0.997	1.011	0.2218	1.000	0.981	1.020	0.9972
	Baseline trends	0.993	0.879	1.122	0.9136	0.987	0.974	1.000	0.0456
Others	Introduction of public reporting	1.027	0.864	1.221	0.7649	0.942	0.727	1.221	0.6531
	After public reporting	1.008	1.002	1.015	0.0072	1.000	0.982	1.017	0.9665
	Baseline trends	1.034	0.819	1.307	0.7770	0.981	0.968	0.994	0.0043

5.4) Results of the sub-group analysis by clinical indicators

Results of the sub-group analysis for types of treatment revealed that the positive step changes by public reporting on visiting a hospital with high volume were significant in patients who underwent surgery with other treatments (RR: 1.274, 95% CI: 1.043–1.556, P-value=0.0176, ref=before), but did it was nonsignificant in those who only underwent surgery. In both groups, there was no statistically significant association by time trends after public reporting was introduced. In addition, the results of the sub-group analysis by types of surgery showed that the positive impact in the time trends after public reporting was introduced on increases in visiting a high volume hospital was statistically significant in only subtotal gastrectomy (subtotal gastrectomy=RR: 1.006, 95% CI: 1.002–1.010, P-value=0.0075). However, considering copayment policies, public reporting had no statistically significant association with visiting a hospital with high surgical volume (Table 12).

Table 12. Results of the sub-group analysis by types of treatment or surgery

Sub-group	Variables	Visiting a hospital with high volume							
		Model 3				Model 3 + copayment policies			
		RR	95% CI		P-value	RR	95% CI		P-value
Surgery with chemotherapy or radiotherapy	Introduction of public reporting	1.274	1.043	1.556	0.0176	0.969	0.730	1.286	0.8294
	After public reporting	1.002	0.994	1.010	0.7077	1.003	0.984	1.023	0.7363
	Baseline trends	0.994	0.989	0.998	0.0067	0.982	0.969	0.995	0.0072
Only surgery	Introduction of public reporting	0.992	0.887	1.110	0.8907	0.914	0.775	1.079	0.2889
	After public reporting	1.004	1.000	1.008	0.0560	0.996	0.985	1.008	0.5264
	Baseline trends	0.997	0.995	1.000	0.0462	0.986	0.976	0.997	0.0096
Total gastrectomy	Introduction of public reporting	1.080	0.897	1.300	0.4148	1.047	0.810	1.353	0.7269
	After public reporting	0.997	0.990	1.005	0.4651	0.993	0.975	1.011	0.4631
	Baseline trends	0.999	0.994	1.003	0.5874	0.984	0.968	1.000	0.0566
Subtotal gastrectomy	Introduction of public reporting	1.065	0.949	1.196	0.2849	0.909	0.766	1.078	0.2717
	After public reporting	1.006	1.002	1.010	0.0075	0.999	0.987	1.010	0.8157
	Baseline trends	0.995	0.993	0.998	0.0005	0.984	0.975	0.993	0.0006

2. Differences in the volume-outcome relationship by public reporting

1) LOS, inpatient cost, and 1-year mortality

1.1) Distribution of patients by hospital-level surgical volume

Compared with that before public reporting, patients who were diagnosed with gastric cancer and underwent gastrectomy generally visited a hospital with high surgical volume hospital more often after the introduction of public reporting (Before, Q3: 24.3%, Q4: 27.46%; After, Q3: 28.58%, Q4: 28.58%; Table 13).

Table 13. Distribution of patients by the introduction of public reporting

Surgical volume	Before		After	
	N	%	N	%
Q1 (low)	169	19.34	290	21.64
Q2	253	28.95	284	21.19
Q3	212	24.26	383	28.58
Q4 (high)	240	27.46	383	28.58
Total	**874**	**100.00**	**1,340**	**100.000**

1.2) Distribution of LOS, inpatient cost, and 1-year mortality by public reporting

The quarterly averages of LOS decreased after the introduction of public reporting, and it showed continuously decreasing trends over the time after public reporting was introduced (first quarter in 2004: 18.19 days, fourth quarter in 2007: 14.80 days, and fourth quarter in 2012: 13.06 days; Figure 7).

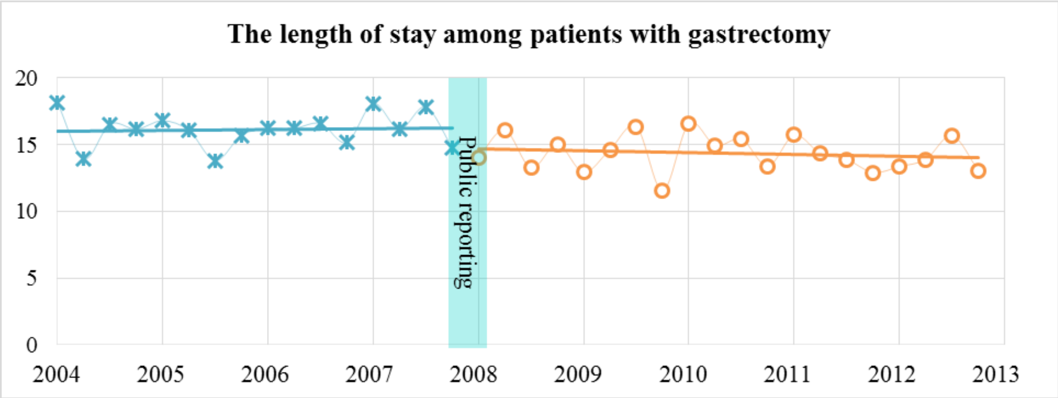


Figure 7. Quarterly averages of length of stay

On the other hand, the quarterly averages of inpatient cost decreased after the introduction of public reporting, and it showed slightly positive trends over the time after the introduction of public reporting as compared to that before the introduction (first quarter in 2004: 4,216, fourth quarter in 2007: 5,459, and fourth quarter in 2012: 6,041 [1,000 KRW]; Figure 8).

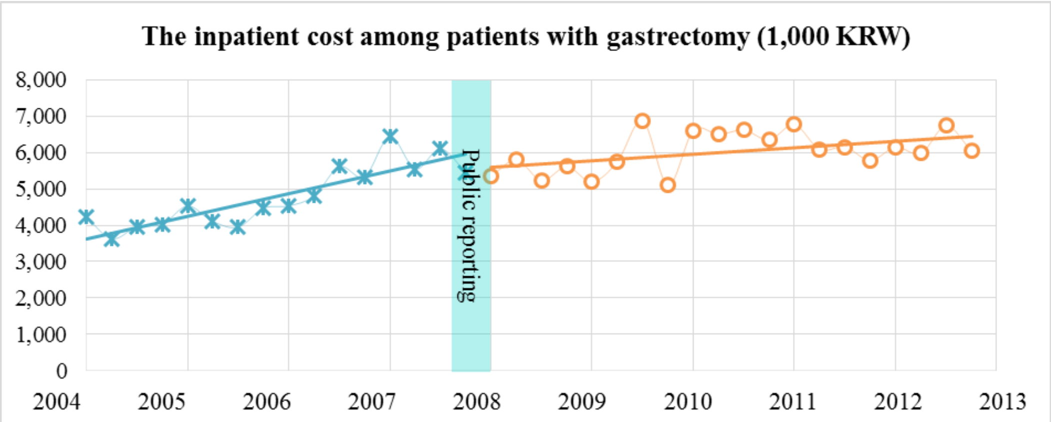


Figure 8. Quarterly averages of inpatient cost

For 1-year mortality, hospitals with Q4 surgical volume had higher survival time than other groups did (mean: 360.50 days, Standard Error [SE]: 1.14, P-value for log-rank test=0.0164). By the introduction of public reporting, this association was not statistically significant, but there were significant differences between surgical volume groups after the introduction of public reporting (before, P-value for log-rank test=0.2518; after, P-value for log-rank test=0.0335; Figure 9).

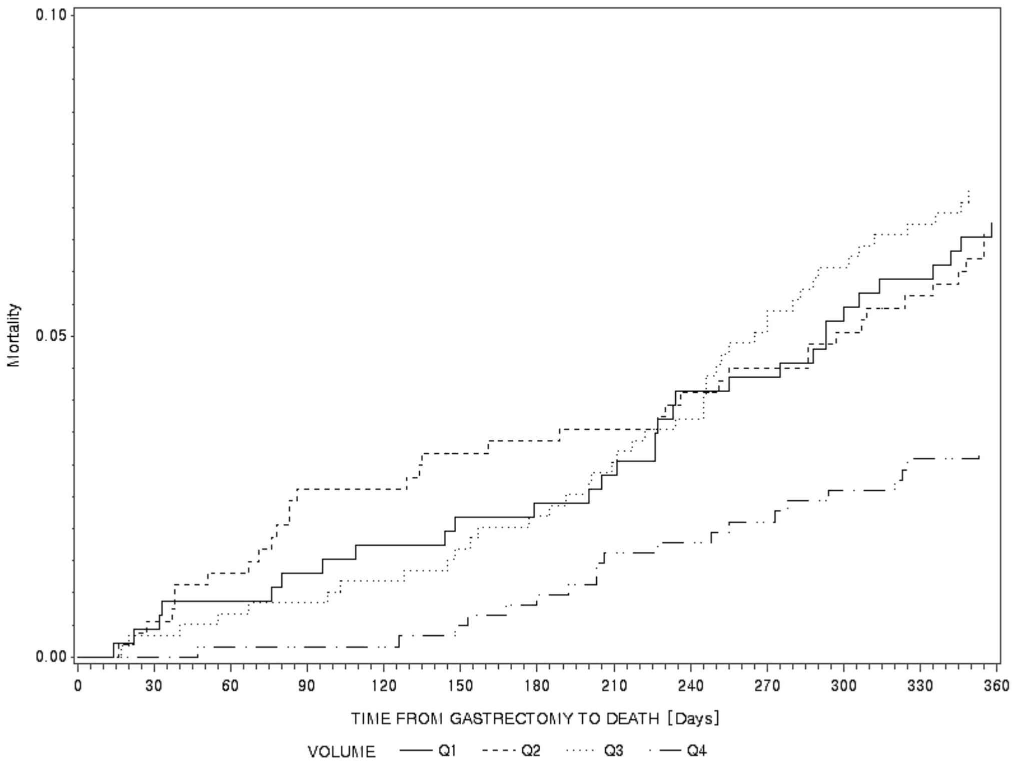


Figure 9. Mortality curves by the surgical volume at a hospital

Hospitals with high volume in the previous year generally had a lower value of LOS, inpatient cost, and 1-year mortality, and these results were statistically significant except for the 1-year mortality before the introduction of public reporting.

Additionally, LOS and 1-year mortality decreased significantly after public reporting was introduced (Table 14). The overall distribution of LOS, inpatient cost, and 1-year mortality by each variable has been presented in Appendix B1–B3.

Table 14. Length of stay, inpatient cost, and 1-year mortality by volume and public reporting

Hospital volume	LOS (Mean)		Inpatient cost (Mean, 1,000 KRW)		1-year Mortality (%)	
	Before	After	Before	After	Before	After
Q1 (low)	20.05	16.21	5,433.81	6,471.49	6.51	7.24
Q2	16.77	14.95	5,007.78	6,381.89	5.14	7.75
Q3	15.80	14.55	4,657.97	6,122.96	6.60	7.57
Q4 (high)	13.07	12.14	4,093.23	5,294.31	3.33	3.13
Total	**16.15**	**14.31**	**4,754.17**	**6,016.42**	**5.26**	**6.27**
P-value	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**0.3779**	**0.0288**
	0.0142		**0.6702**		**0.0127**	

2) The volume-outcome relationship

2.1) Volume-outcome relationship for LOS

Hospital-level surgical volume was inversely associated with LOS (Q2=ratio of LOS [RL]: 0.901, 95% CI: 0.846–0.959, P-value=0.0011, Q3=RL: 0.886, 95% CI: 0.834–0.941, P-value<.0001, Q4=RL: 0.785, 95% CI: 0.714–0.862, P-value<.0001, ref=Q1). Further, the introduction of public reporting had an inverse association with LOS (after=RL: 0.866, 95% CI: 0.794–0.944, P-value=0.0011, ref=before), but the overall trends were not associated with LOS (Table 15). The overall results of analysis for LOS have been presented in Appendix B.

Table 15. Results of the linear regression analysis for length of stay

Variables	LOS per case with gastrectomy			
	Model 3			
	RL	95% CI		P-value
Hospital volume in the previous year				
Q1 (low)	1.000	-	-	-
Q2	0.901	0.846	0.959	0.0011
Q3	0.886	0.834	0.941	<.0001
Q4 (high)	0.785	0.714	0.862	<.0001
Introduction of public reporting				
Before	1.000	-	-	-
After	0.866	0.794	0.944	0.0011
Overall trends	1.001	0.999	1.003	0.2740

2.2) Volume-outcome relationship for inpatient cost

Hospital-level surgical volume for gastrectomy was inversely associated with the inpatient cost (Q2=ratio of cost [RC]: 0.963, 95% CI: 0.906–1.022, P-value=0.2143, Q3=RC: 0.927, 95% CI: 0.878–0.979, P-value=0.0063, Q4=RC: 0.817, 95% CI: 0.740–0.901, P-value<.0001, ref=Q1). In addition, the introduction of public reporting about surgical volume had positive association with lower inpatient cost, per case, with gastrectomy (after=RC: 0.875, 95% CI: 0.808–0.948, P-value=0.0011). However, the overall time trend during the study period was associated with an increase in inpatient cost (per 1 month, RC: 1.009, 95% CI: 1.007–1.010, P-value<.0001; Table 16). The overall results of the analysis for inpatient cost have been presented in Appendix B.

Table 16. Results of the linear regression analysis for inpatient cost

Variables	Inpatient cost per day in case with gastrectomy			
	Model 3			
	RC	95% CI		P-value
Hospital volume in the previous year				
Q1 (low)	1.000	-	-	-
Q2	0.963	0.906	1.022	0.2143
Q3	0.927	0.878	0.979	0.0063
Q4 (high)	0.817	0.740	0.901	<.0001
Introduction of public reporting				
Before	1.000	-	-	-
After	0.875	0.808	0.948	0.0011
Overall trends	0.963	0.906	1.022	0.2143

2.3) Volume-outcome relationship for 1-year mortality

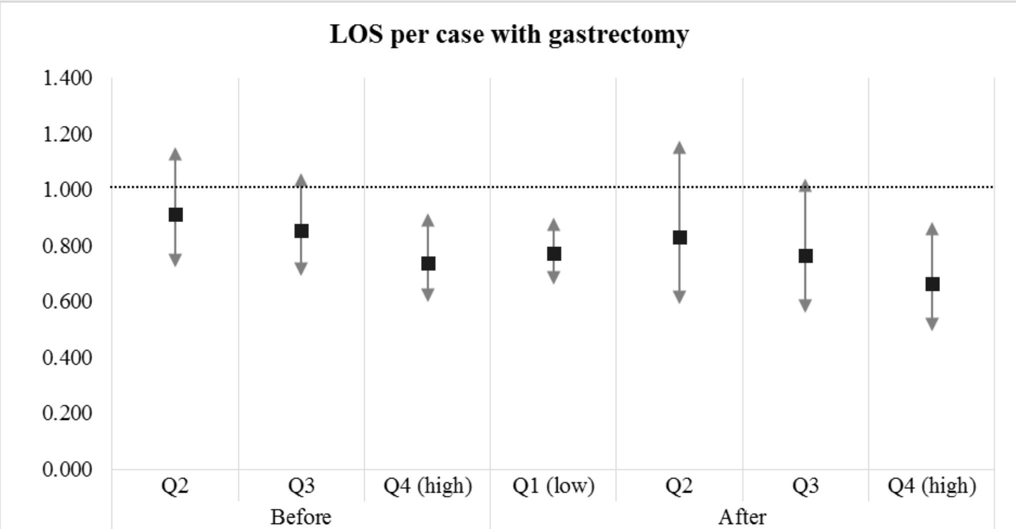
Table 17 shows the results of the survival analysis using the cox proportional hazard model. Based on these results, patients who underwent gastrectomy at a hospital with high surgical volume (Q4) had a lower risk of 1-year mortality after gastrectomy than did those who underwent gastrectomy at a hospital with low volume (Q2=HR [Hazard ratio]: 0.876, 95% CI: 0.534–1.439, P-value=0.6013, Q3=HR: 0.937, 95% CI: 0.568–1.545, P-value=0.7975, Q4=HR: 0.334, 95% CI: 0.124–0.903, P-value=0.0307, ref=Q1). The overall results of the analysis for 1-year mortality have been presented in Appendix B.

Table 17. Results of the survival analysis for 1-year mortality

Variables	1 year mortality after gastrectomy			
	Model 3			
	HR	95% CI		P-value
Hospital volume in the previous year				
Q1 (low)	1.000	-	-	-
Q2	0.876	0.534	1.439	0.6013
Q3	0.937	0.568	1.545	0.7975
Q4 (high)	0.334	0.124	0.903	0.0307
Introduction of public reporting				
Before	1.000	-	-	-
After	1.477	0.957	2.279	0.0784

3) Volume-outcome relationship by public reporting

Considering the main effect and interaction terms with reference to LOS, patients who underwent gastrectomy at a hospital with high volume had an inverse association with LOS both before and after the introduction of public reporting. In addition, in same groups of volume, the introduction of public reporting also had an inverse association with LOS (Q1 after=RL: 0.902, 95% CI: 0.660–0.772, P-value=0.0012, ref=Q1 before). The volume-outcome relationship between surgical volume and LOS were greater after the introduction of public reporting as compared to that before (Q4 before=RL: 0.739, 95% CI: 0.597–0.914, P-value=0.0053, ref=Q1 before; Q4 after=RL: 0.661, 95% CI: 0.494–0.886, P-value=0.0056, ref=Q1 after; Figure 10).



	Q2 (Before)	Q3 (Before)	Q4 (high) (Before)	Q1 (low) (After)	Q2 (After)	Q3 (After)	Q4 (high) (After)
UCL	1.153	1.058	0.914	0.902	1.174	1.039	0.886
LCL	0.723	0.689	0.597	0.660	0.588	0.560	0.494
■RL	0.913	0.854	0.739	0.772	0.831	0.763	0.661

Ref=Q1 at before	Ref=Q1 at after

Figure 10. Estimated results on length of stay considering interaction terms

In the results for inpatient cost were similar to those for LOS. There were also volume-outcome relationship between surgical volume and inpatient cost in both before and after the introduction of public reporting; undergoing gastrectomy at a hospital with high surgical volume was associated with low inpatient cost, and the volume-outcome relationship between surgical volume and inpatient cost was greater after the introduction of public reporting as compared to that before (Q3 before=RC: 0.724, 95% CI: 0.604–0.868, P-value=0.0071, Q4 before=RC: 0.724, 95% CI: 0.604–0.868, P-value=0.0005, ref=Q1 before; Q3 after=RC: 0.661, 95% CI: 0.506–0.863, P-value=0.0023, Q4 after=RC: 0.651, 95% CI: 0.501–0.846, P-value=0.0013, ref=Q1 after). The introduction of public reporting also had a positive impact on reducing inpatient cost (Q1 after=RC: 0.851, 95% CI: 0.746–0.970, P-value=0.0160, ref=Q1 before; Figure 11).

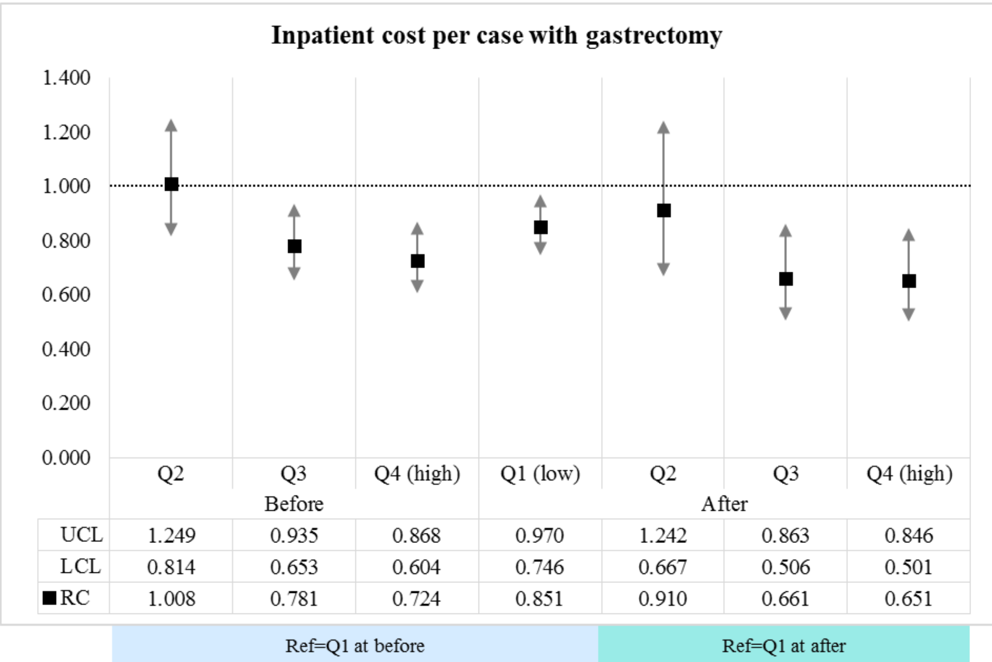
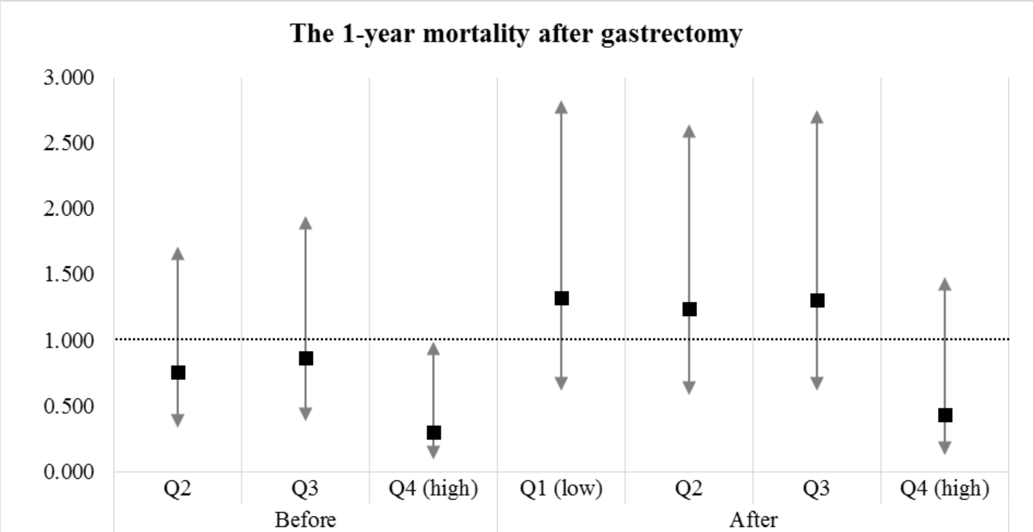


Figure 11. Estimated results of inpatient cost considering interaction terms

For the 1-year mortality, we performed a survival analysis using the Cox proportional hazard model adopting DID methods to investigate the changes in the volume-outcome relationship between surgical volume and 1-year mortality among patients with gastrectomy. Patients who underwent gastrectomy at a high surgical volume hospital had low risk of 1-year mortality than did patients who did the same at a low volume hospital before the introduction of public reporting (Q4 before=HR: 0.301, 95% CI: 0.091–0.988, P-value=0.0477, ref=Q1 before). However, there was no volume-outcome relationship after the introduction of public reporting, and the introduction of public reporting did not reduce the 1-year mortality as compared to that before public reporting (Figure 12).



	Before			After			
	Q2	Q3	Q4 (high)	Q1 (low)	Q2	Q3	Q4 (high)
UCL	1.713	1.945	0.990	2.829	2.643	2.755	1.477
LCL	0.336	0.381	0.091	0.619	0.581	0.618	0.127
■HR	0.759	0.861	0.300	1.323	1.239	1.305	0.434

Ref=Q1 at before | Ref=Q1 at after

Figure 12. Estimated results of 1-year mortality considering interaction terms

3. Optimal volume for achieving better volume-outcome relationship

1) Cut-off of surgical volume using the Youden's J index

Using the Yoden's J Index, we identified the cut-off volume in gastrectomy based on the previous year's surgical volume in each hospital. The surgical volume with a maximizing Youden's J index was 11.01 per year in this study (J=0.1648). Based on the surgical volume, which was categorized into "high" and "low", we compared patient utilization and outcomes by surgical volume (Appendix C1).

2) LOS, inpatient cost, and 1-year mortality by the new volume criterion

The LOS, inpatient cost, and 1-year mortality were relatively lower in high volume hospitals, and statistically significant differences were observed between surgical volume groups based on Youden's J index. However, the differences by the introduction of public reporting were not statistically significant (Table 18).

Table 18. LOS, inpatient cost, and 1-year mortality by cut-off volume and public reporting

Hospital volume	LOS (Mean)		Inpatient cost (Mean, 1,000 KRW)		1-year mortality (%)	
	Before	After	Before	After	Before	After
Low	17.74	15.18	5189.37	6277.16	6.23	7.72
High	13.30	11.87	3970.25	5292.96	3.53	2.25
Total	**16.15**	**14.31**	**47.54.17**	**6016.42**	**5.26**	**6.27**
P-value	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**0.0865**	**0.0003**
	0.1120		**0.3871**		**0.1749**	

3) Volume-outcome relationship based on cut-off value

With reference to LOS, the introduction of public reporting or high surgical volume were inversely associated with LOS (hospital volume, high=RL: 0.820, 95% CI: 0.776–0.866, P-value<.0001; after introduction of public reporting=RL: 0.837, 95% CI: 0.769–0.912, P-value<.0001; Table 19). The overall results for the LOS have been shown in Appendix C.

Table 19. Results for length of stay based the new criterion for surgical volume

Variables	LOS			
	RL	95% CI		P-value
Hospital volume in the previous year				
Low	1.000	-	-	-
High	0.820	0.776	0.866	<.0001
Introduction of public reporting				
Before	1.000	-	-	-
After	0.837	0.769	0.912	<.0001
Overall trends	1.001	1.000	1.003	0.1309

With reference to inpatient cost, the hospital volume and the introduction of public reporting had inverse associations with inpatient cost (hospital with high surgical volume=RC: 0.810, 95% CI: 0.765–0.857, P-value<.0001; after introduction of public reporting=RC: 0.846, 95% CI: 0.783–0.914, P-value<.0001). However, the overall trends were positively correlated with inpatient cost during the study period (per 1 month=RC: 1.009, 95% CI: 1.007–1.010, P-value<.0001; Table 20). The overall results for inpatient cost have been shown in Appendix C.

Table 20. Results for inpatient cost based on the new criterion for surgical volume

Variables	Inpatient cost			
	RC	95% CI		P-value
Hospital volume in the previous year				
Low	1.000	-	-	-
High	0.810	0.765	0.857	<.0001
Introduction of public reporting				
Before	1.000	-	-	-
After	0.846	0.783	0.914	<.0001
Overall trends	1.009	1.007	1.010	<.0001

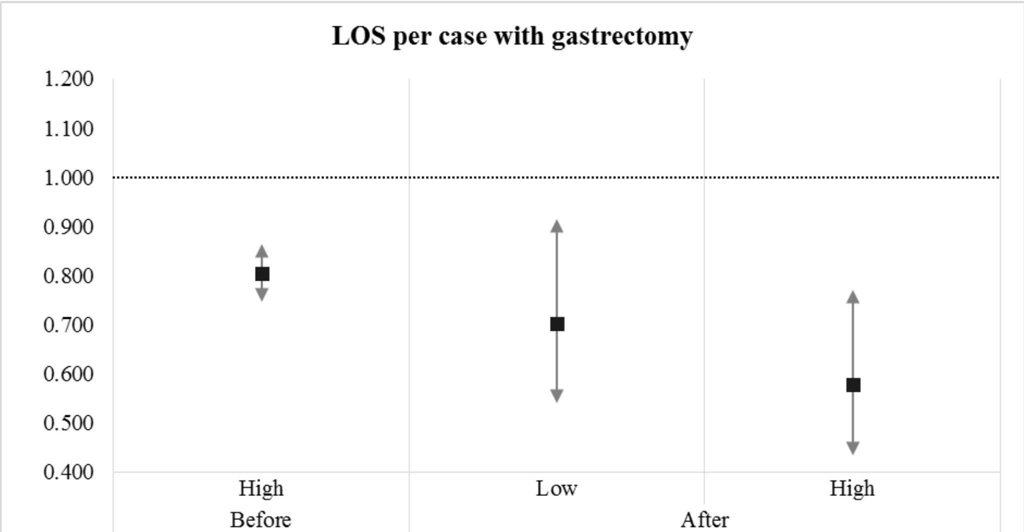
The survival analysis using the Cox proportional hazard model for 1-year mortality showed that the patients who received the gastrectomy at a hospital with high surgical volume had a lower 1-year mortality risk than patients at a hospital with low surgical volume (hospital with high surgical volume=HR: 0.378, 95% CI: 0.186–0.771, P-value=0.0074, ref=hospital with low surgical volume). However, the introduction of public reporting about surgical volume did not have a statistically significant impact on 1-year mortality (Table 21). The overall results for mortality have been shown in Appendix C.

Table 21. Results for 1-year mortality based the new criterion for surgical volume

Variables	1-year mortality after gastrectomy			
	HR	95% CI		P-value
Hospital volume in the previous year				
Low	1.000	-	-	-
High	0.378	0.186	0.771	0.0074
Introduction of public reporting				
Before	1.000	-	-	-
After	1.384	0.893	2.146	0.1459

4) Volume-outcome relationship using the DID method based on the cut-off value

A linear regression analysis on LOS revealed a volume-outcome relationship between surgical volume and LOS regardless of the introduction of public reporting, and it was greater after the introduction of public reporting compared to that before (high before=RL: 0.804, 95% CI: 0.748–0.865, P-value<.0001, ref=low before; high after=RL: 0.578, 95% CI: 0.434–0.770, P-value=0.0002, ref=low after). In addition, the introduction of public reporting had an inverse association with LOS (low after=RL: 0.703, 95% CI: 0.541–0.914, P-value=0.0086, ref=low before; Figure 13).



	High (Before)	Low (After)	High (After)
UCL	0.865	0.914	0.770
LCL	0.748	0.541	0.434
■RL	0.804	0.703	0.578

Figure 13. Estimated results of length of stay considering interaction terms

Similar results were observed for inpatient cost. Patients visiting a hospital with high surgical volume had low inpatient cost than did those who visited a hospital with low surgical volume, both before and after the introduction of the policy. In addition, the volume-outcome relationship between surgical volume and inpatient cost per case with gastrectomy was greater after the introduction of public reporting as compared to that in the past (high before=RC: 0.711, 95% CI: 0.632–0.801, P-value<.0001, ref=low before; high after=RC: 0.597, 95% CI: 0.483–0.738, P-value<.0001; ref=high before). Similarly, there was an inverse association with inpatient cost by the introduction of public reporting (low after=RC: 0.851, 95% CI: 0.781–0.928, P-value=0.0003, ref=low before; Figure 14).

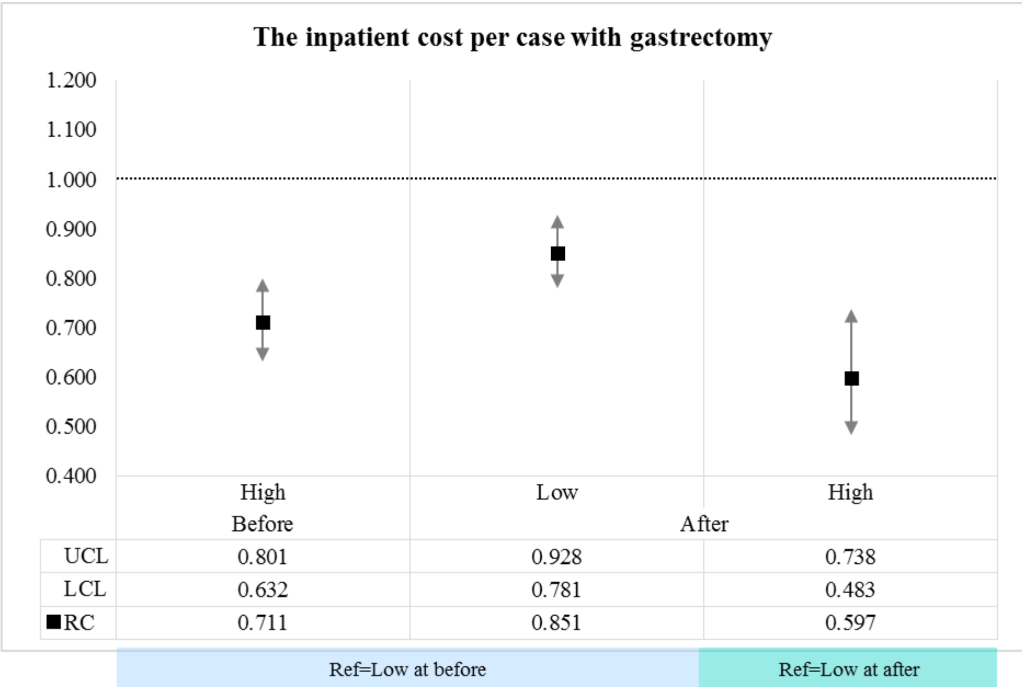


Figure 14. Estimated results of inpatient cost considering interaction terms

The survival analysis revealed a volume-outcome relationship between surgical volume and 1-year mortality after gastrectomy among patients with gastric cancer before the introduction of public reporting about surgical volume (high before=HR: 0.471, 95% CI: 0.236–0.942, P-value=0.0333, ref=low before). However, such reduction in 1-year mortality was not observed by the introduction of public reporting (HR: 1.458, 95% CI: 0.942–2.256, P-value=0.0905, ref=low before). In addition, the differences by surgical volumes disappeared after the introduction of public reporting (HR: 0.466, 95% CI: 0.207–1.046, P-value=0.0640, ref=low at after; Figure 15).

Figure 15. Estimated results of 1-year mortality considering interaction terms

V. Discussion

1. Discussion of Study Methods

To investigate the changes in patient and hospital behavior after the introduction of public reporting, we analyzed the relationship between the introduction of public reporting about surgical volume and patients' choice to visit a hospital with high surgical volume in the previous year among patients who were diagnosed with gastric cancer and underwent gastrectomy. We also examined the volume-outcome relationship for LOS, inpatient cost, and 1-year mortality after the introduction of public reporting.

In this study, we used the NHI national sampling cohort data from 2004–2012. As already mentioned in methods section, this data was originally produced using systematic sampling methods based on the total population in 2002, and it consisted of follow up data on 1,025,340 individuals during 2002–2013. These data had strengths with reference to the generalizability for the results of this study. By the crude annual incidence rates, the average of annual incidence rates during 2004–2012 in our dataset was 62.2 per 100,000 people, which was similar with those reported in the Cancer Registration Statistics in South Korea (57.3 per 100,000 people during 2004–2012; Appendix A5).[3] There were slight differences between both datasets, and we only included the patients who underwent gastrectomy to treat their gastric cancer. Nevertheless, it could reflect the general distribution of gastric cancer among South Korean. Thus, the findings of this study would be helpful in establishing evidence-based health policies and effective alternatives for reforming the current policies and programs to improve the health outcomes and quality of life of patients with gastric cancer.

In the statistical analysis, we performed the interrupted time series analysis using GEE models through adopting a segmented Poisson regression analysis. This method was useful in measuring the impact of the policy or intervention. It could control for prior trends in the outcome variable and analyze the dynamics of change by public reporting without a control group. Thus, the interrupted time series analysis could measure the baseline trends, step change, and trend change caused by the introduction of public reporting. In addition, to investigate the volume-outcome relationship for LOS and inpatient cost by the introduction of public reporting, we used the linear regression analysis using the GEE model with a gamma distribution and log link function. The GEE model does not require multivariate distribution, and it could apply various observation values and clusters. For 1-year mortality, we performed the survival analysis using the Cox proportional hazard model. This method has a strength in that it can reflect the relationship of survival time, through the hazard function. Finally, to compare the volume-outcome relationship for LOS, inpatient cost, and 1-year mortality by the introduction of public reporting about surgical volume among patient with gastrectomy, we adopted the DID methods in this study. The DID method was used to compare the differences between case group and control group by intervention using interaction terms. It could take into account the general change over time that are common to both groups, and does not need the assumption that all differences between groups have been measured.

2. Discussion of Study Results

With emerging problems related to cancer, many health policies about cancer care have been introduced since 2000. In 2007, the public reporting about surgical volume in each hospital was introduced in part of the Healthcare Quality Assessment in South Korea. This public reporting aimed to increase the options available to patients and to improve the overall quality performance in hospitals though informing surgical volume as proxy indicators related to quality of care for the public. Such flows of policies were already observed in the US, before public reporting was introduced in South Korea. In the US, the Agency for Healthcare Research and Quality (AHRQ) and Leapfrog Group initiated the public reporting on hospital minimum volume for some services, to assist patient's choice of hospitals based on the volume-outcome relationship, before it was introduced in South Korean in Dec 2007.[91,92] Thus, patients could knowledgeably navigate the medical delivery system owing to the greater availability of information by the introduction of public reporting. However, there were some controversies about the actual effectiveness of such programs and the negative impact of health information on patient choice.[93] Nevertheless, the introduction of public reporting would improve the quality of care in hospitals, especially in hospitals with relative low performance.[65]

Considering the positive role of public reporting in the US, the introduction of public reporting about surgical volume for some surgeries in South Korea might have had a positive impact for both patients and hospitals. In particular, this introduction was the first attempt to evaluate the quality of care in cancer patients even though surgical volume was just a proxy indicator of quality performance. However, based on another theory of "selective referral pattern" in the volume-outcome relationship, introduction of public reporting for quality indicators could cause concentration of patients in some hospitals, and would continue to reduce efficiency in hospitals due to the excessive patient volume. In addition, there are some controversies on the criterion of optimal volume, because it is calculated based on quartiles, and is graded highly if hospitals have a surgical volume matching at least the 25th percentile. Further, public reporting is changing into informing about surgical mortality rather than about surgical volumes, but such information about mortality could be sensitive data for patients, and could cause distorted choice of hospitals. Thus, it was necessary to evaluate the impact of public reporting for surgical volume related to cancer on patient and hospital behaviors in South Korea, and to suggest more effective alternatives to the present nature of public reporting. However, there were no studies related to public reporting for surgical volume on cancer care in South Korea despite the positive impacts of public reporting on outcomes in cancer care. Therefore, we examined the relationship between patients' choice of hospital and the introduction of public reporting about surgical volume among patients who were diagnosed with gastric cancer and underwent gastrectomy. In addition, to identify the impact of public reporting on hospital behavior, we investigated that changes in the volume-outcome relationship after the introduction of public reporting.

Based on the results of this study, patients' choice of a hospital with a high surgical volume had slightly increased after the introduction of public reporting. Based on the conceptual framework of Bloom et al., increased information would lead to more informed patient choices and more intense provider competition, which will continue to improve the quality of care and prevent excessive medical expenditures. Finally, it would lead to better health outcomes in patients. In addition, in previous studies, patients were reported to visit a hospital based on subjective criteria such as distance, hospital staff, hospital size, image, and reputation, rather than on objective criteria, before the introduction of public reporting. However, Bloom et al. reported that this changed after the introduction of public reporting because patients made hospital choice decisions based on public information such as quality indicators. Our findings were in line with those of Bloom et al.

However, until now, the cancer policies in South Korea focused on the aspects of accessibility and reducing cost burden, and, according to the findings of previous studies, such policies had substantial impacts on cancer patients. Previous studies reported that the reduction in the copayment in cancer care and the extension of benefit coverage in cancer could reduce the inequality between income levels, which could reduce the catastrophic expenditures involved in cancer care.[94] In addition, the policy on copayment in cancer patients could strengthen the treatment options for cancer patients.[95,96] Further, cancer patients could receive optimal treatment in the early stages by the introduction of such policies.[97] On the other hand, the public reporting about surgical volume was relatively out of the spotlight because the expected effect was smaller than that of other policies. Thus, we also performed a sensitivity analysis to examine the impact of public reporting considering the impact of the policy on reducing copayment in cancer care. The results of this analysis showed that public reporting was not associated with patient choice for hospitals with high volume, unlike that reported in the conceptual framework of Bloom et al.

Similar findings were analyzed in the sub-group analysis. There were some statistically significant differences in the impact of public reporting according to sub-group variables. However, these associations also disappeared after adjusting for the impact of policies on reducing copayment in cancer care, which was similar to the results of the sensitivity analysis. These results might be caused by the relatively weaker impact of public reporting on patients than that of other policies which supported their economic aspects. Thus, in cancer care, the policy related to economic support is more likely to affect patients rather than other policies, including public reporting of hospital-level surgical volume, and the positive association of public reporting on patient choice and the differences according to sub-groups might be actually be caused by the impact of the economic support provided through other policies. It means that the public reporting, which aims to support the availability of health information, was not effective in improving cancer care. Thus, there is a need to review the strategies for activating the utility of public reporting for patients.

In the analysis on the volume-outcome relationship to examine the changes in hospital behavior after the introduction of public reporting, our findings suggested that the increased information caused higher quality, lower cost, and better health outcomes, as suggested in the framework of Bloom et al. The LOS and inpatient cost were smaller in hospitals with high surgical volume, and these differences were greater after the introduction of public reporting. In healthcare research, LOS is often used as one of the indirect indicators that reflect the efficiency of the healthcare system.[98] Reduction in the LOS and cost without worsening health outcomes would be helpful in improving efficiency. Therefore, these results suggested that, after the introduction of public reporting, there has been an improvement in the efficiency of cancer care, in particular, at hospitals with high surgical volume. Further, the results for 1-year mortality might be caused by the overall improvement in the quality of cancer care. There has been a remarkable improvement in the mortality due to gastric cancer in South Korea, with a reduction of about 50%.[99] Thus, the disappearance of the differences between hospitals in the 1-year mortality after gastrectomy after the introduction of public reporting was might be caused by the overall improvement in the quality of care. Therefore, the public reporting of surgical volume had a positive impact on the overall quality of healthcare related to cancer patients in South Korea.

These changes have substantial implications on prospective health policies. Before the introduction of public reporting, the health policies and strategies of each hospital were mainly focused on the development of infrastructure and the quantitative growth for controlling the incidence of cancer. Therefore, there was a remarkable growth in healthcare resources such as hospital staffing and structural resources until early 2000's, and patients' accessibility to cancer care also improved compared to that in the past. However, such quantitative growth was accompanied with other problems. Patients with severe diseases tend to carefully choose a hospital because the quality of treatment for cancer is a matter of life and death. The rapid increase in the resources for cancer care might naturally continue to increase the dilemma of patients regarding the choice of hospital. Most patients unavoidably select the hospital based on subjective criteria. With such situations, public reporting would help in the benchmarking for motivating increased quality of care in each hospital as a part of their competitive strategies. Accordingly, the introduction of public reporting might have had some positive effects on patient outcomes based on our findings, even though the impact of public reporting on patient behavior was rare.

In addition, these results indirectly reflect the healthcare markets related to cancer care in South Korea. After many changes in the quantitative growth of the healthcare system, major hospitals turned their focus toward improving the quality of care as survival strategies to meet both the overflow of the healthcare market and the changes in health policies. With the establishment of a specialized cancer hospital in one of the Big 5 hospitals in 2006, many hospitals have initiated such services for cancer patients. This has led to what seems like a “Korean new medical arms race”.[101] Such hospital strategies could lead to patient concentration in the capital area. Although such qualitative improvement in each hospital may have led to better health outcomes in cancer patients, an excessive increase in specialized care could increase the burden of cancer by providing profitable services. It also raises questions about the efficiency of cancer care from the national perspective, and such strategies may lead to excessive cost-burden from the long-term point of view. Therefore, health policy makers and decision makers have to consider the optimal evaluation of quality of care to discriminate gems from pebbles in cancer care. The regionalization of efficient distribution of cancer has to be considered through such a process.

Further, there are some controversies related to the public reporting of surgical volume. First, in the present public reporting framework, the criterion for surgical volume was mainly defined based on percentiles rather than considering scientific methods. Therefore, a hospital was designated as a better hospital for gastric cancer if it had more than 41 cases of gastrectomy per year, which would mean that 3–4 cases of gastrectomy per month would be superior. Such a criterion might obstruct the use of public reporting, which was also suggest in our results that public reporting was not associated with patients' hospital choice. In addition, we think that it is not the best method for achieving an optimal volume-outcome relationship. Thus, to suggest the optimal cut-off for the criterion related to surgical volume, we performed a re-analysis for the volume-outcome relationship using the new criterion based on Youden's J index. We found more significant results with the new cut-off, than those observed in our previous analyses. This finding suggests the need for more detailed and high standards for designating superior hospitals. Therefore, policy makers have to review the criteria for evaluation in the Healthcare Quality Assessment, and to develop more optimal evaluation tools. Second, public reporting is moving towards informing about surgical outcomes instead of informing about surgical volumes. However, surgical outcomes may be sensitive information for patients, which may adversely affect hospital choice even if the information was accurate. Based on the conceptual framework depicting the potential predictors of cancer information overload, excessive health information could cause negative effects or side effects and may lead to confusion in patients. We think that the complementary information between surgical volume and outcomes would best for improving the quality of care for cancer patients. Therefore, health policy makers have to consider the strategies for cancer care using complementary information rather than completely changing the reporting to that of surgical outcomes.

The summary of the present results has been presented in Table 22, by study design and outcome variable. In conclusion, this study found that the introduction of public reporting was not effective in changing patient behavior, and patients were more affected by policies pertaining to economic support, such as reducing copayment. However, public reporting had significant effects on changes in hospital behavior. The volume-outcome relationship for LOS and inpatient cost was greater after the introduction of public reporting. For 1-year mortality, such an association disappeared the after introduction of public reporting. In addition, in the case of applying new criteria of surgical volume, which was based on more scientific methods for reducing the controversies related to the criteria for public reporting, there were more significant results compared to those derived from preexisting models.

Table 22. Summary of the results of this study

Criteria	Variables	Choice	Utilization	Outcome
Current criteria	After public reporting	Indifferent	↓	Indifferent
	Time trends after public reporting	Indifferent		
	V-O relationship		↓	↓
	V-O relationship before public reporting		↓	↓
	V-O relationship after public reporting		↓↓	Indifferent
New criteria	V-O relationship		↓↓	↓↓
	V-O relationship before public reporting		↓↓	↓↓
	V-O relationship after public reporting		↓↓↓	Indifferent

3. Limitations of the study

This study has some limitations related to the nature of claim data and statistical analysis. First, previous studies identified several factors such as socio-economic status and educational levels to be associated with informed patient choice in the process of treatment after the introduction of public reporting.[72-75] However, by the nature of the present dataset, we could not consider variables which could reflect such variations on informed patient choice, except for types of insurance coverage and income levels. Second, patients with healthy behavior or more attention to health information would generally make more informed decisions regarding the selection of hospitals.[100] These factors were also not included in this study due to the limitation of the data. Although the NHI national sampling cohort included information about health examination, the participation rates for that aspect of the survey were relatively low, and the criteria for screening was not applied to all individuals in the sampling cohort. Thus, we did not consider this data owing to the concerns related to the generalizability of the findings if health examination information was included in this study. Third, cancer staging is major factor that reflects the severity of cancer patients, it affected the decision for treatment and patient outcomes among cancer patients. However, the data used in this study did not include the information about cancer staging such as TNM staging or SEER summary staging even though the cancer registration program had already been implemented. In this study, to solve the limitations due to the absence of data on cancer staging, we considered types of surgery and types of treatment as independent variables in the analyses.[13] Fourth, in the methods, we defined the outcome variable based on the first quartile value of surgical volume in the previous year, because the criteria for better hospitals in the public reporting about surgical volume was defined based the quartile of surgical volume. However, by the nature of sampling data, the first quartile of surgical volume could be underestimated. Thus, the events of visiting a hospital with higher surgical volume than that observed in the first quartile in the previous year could be overestimated, and the study results on patient choice could differ from the actual situation. Therefore, we recommend that readers exercise caution while interpreting the results. Fifth, in the analysis for the healthcare utilization and outcomes in this study, we analyzed the impact of public reporting on the LOS and inpatient cost as indicators of patient utilization. The inpatient cost was measured as the total inpatient cost per case with gastrectomy among patients who were diagnosed with gastric cancer. However, by the nature of the claim data, we could not consider medical cost for non-insurance covered services, which is one of most expensive parts in healthcare. Therefore, inpatient cost might be underestimated in this study. Sixth, we used the 1-year mortality as one of outcome variables in this study. In many previous studies on cancer, the measure of health outcomes among cancer patients was the 5-year mortality. However, we could not consider 5-year mortality due to the size and duration of data used in this study. In addition, 1-year mortality was measured by all-causes mortality in patients after gastrectomy, within 1-year. It was also caused by limitations due to the sample size. Nevertheless, in several previous studies, all-causes mortality after surgical treatment within 1 year was evaluated as an appropriate measure of outcomes that were caused by the negative impact of surgery in a short term period. Thus, we thought that the results of this study could reflect the negative outcomes after gastrectomy. Finally, there were many hospital factors which were associated with LOS, inpatient cost, and 1-year mortality, such as specialist related to cancer, availability of multidisciplinary care, nurse staffing, and various types of inpatient beds. However, the data used in this study was only included the hospital factors such as number of doctor, inpatient bed, and types of medical institution. Although such factors could be not included in this study, the results on the association between other hospital factors and health utilization were similar with those of previous studies.

Regarding statistical analysis, first, the interrupted times series analysis was performed to investigate the association between patient choice and public reporting. However, this method could not reflect the linear trend in each segment, and was not appropriate for short intervals of less than 50 time points. We performed the linear regression analysis for LOS and inpatient cost using the GEE model with a gamma distribution and log link function, but this analysis required the data with large numbers of clusters, more than 20 cluster for GEE. Related to survival analysis, it could reflect the covariates at baseline without considering the time-varied change of covariates. In adopting the DID methods, it could not consider difference in the potential for trend change by intervention.

As mentioned above, there were some limitations related to data and statistical analyses used in this study. Therefore, caution is needed when interpreting the results of this study. Nevertheless, this study was the first attempt to evaluate the impact of public reporting about surgical volume for gastric cancer as a part of Healthcare Quality Assessment in South Korea. Although the further studies using more detailed data without above limitations were needed in near future, this findings would be helpful for health policy makers and healthcare professionals in establishing evidence-based health policy.

VI. Conclusion

We analyzed the patient choice, utilization, and outcome by the introduction of public reporting about surgical volume among patient with gastric cancer and received the gastrectomy using the NHI national sampling cohort data during 2004–2012 to investigate the influence of public reporting on patient and hospital behavior. This study showed that the public reporting was not associated with patient choice regarding the impact of public reporting disappeared in case of considering the policy on reducing copayment in cancer care. On the other hand, the volume-outcome relationships for patient's utilization and outcome were changed by public reporting; public reporting affected to greater volume-outcome relationship for both LOS and inpatient cost, and also the association for 1-year mortality disappeared after public reporting. In addition, this study suggested alternatives related to criteria for surgical volume for achieving an effective volume-outcome relationship. In conclusion, the public reporting about surgical volume in gastric cancer had no positive role of extending the patient's option on healthcare utilization, but it attributed to the activating efficiency of cancer care through informing quality indicators and leading benchmarking between hospitals. Based on our findings, health policy makers and decision makers have to review the impact of public reporting for quality indicators in cancer care, and develop the strategies that improve the quality of care with optimal evaluation considering both equality and efficiency of healthcare. Through such evidence-based policies, we expected to reduce the burden of South Korean related to cancer.

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Appendix

Appendix A. The introduction of public reporting and patients' choice of hospital

- Appendix A1. The distribution of surgical volume in the previous year
- Appendix A2. General characteristics of gastric cancer patients by hospital-level surgical volume
- Appendix A3. The number of hospitals by surgical volume and year of surgery
- Appendix A4. Results of the interrupted time series analysis with reference to reduction in copayment
- Appendix A5. The annual crude incidence rates of gastric cancer

Appendix A1. The distribution of surgical volume in the previous year

Study Year	N	Surgical volume in the previous year		
		25 percentile	50 percentile	75 percentile
2004	222	2	7	16
2005	245	3	9	18
2006	225	2	5	17
2007	197	3	6	10
2008	257	4	6	10
2009	238	1	3	8
2010	261	2	5	16
2011	283	2	4	11
2012	286	3	7	20

Appendix A2. General characteristics of gastric cancer patients by hospital-level surgical volume

Variables	Total		Surgical volume in the previous year								P-value
			First quartile		Second quartile		Third quartile		Fourth quartile		
	N/ Mean	%/ SD	N/ Mean	%/ SD	N/ Mean	%/ SD	N/ Mean	%/ SD	N/ Mean	%/ SD	
Introduction of public reporting											
Before	874	39.48	169	19.34	253	28.95	212	24.26	240	27.46	0.0004
After	1,340	60.52	290	21.64	284	21.19	383	28.58	383	28.58	
Year of surgery											
2004	222	10.03	20	9.01	89	40.09	56	25.23	57	25.68	<.0001
2005	245	11.07	60	24.49	61	24.90	55	22.45	69	28.16	
2006	225	10.16	49	21.78	56	24.89	58	25.78	62	27.56	
2007	197	8.90	46	23.35	49	24.87	45	22.84	57	28.93	
2008	257	11.61	59	22.96	30	11.67	93	36.19	75	29.18	
2009	238	10.75	59	24.79	56	23.53	64	26.89	59	24.79	
2010	261	11.79	43	16.48	64	24.52	81	31.03	73	27.97	
2011	283	12.78	55	19.43	59	20.85	81	28.62	88	31.10	
2012	286	12.92	68	23.78	73	25.52	62	21.68	83	29.02	
Sex											
Male	1,510	68.20	325	21.52	356	23.58	403	26.69	426	28.21	0.4925
Female	704	31.80	134	19.03	181	25.71	192	27.27	197	27.98	
Age											
~39	100	4.52	13	13.00	16	16.00	38	38.00	33	33.00	0.0004
40-49	342	15.45	61	17.84	88	25.73	92	26.90	101	29.53	
50-59	584	26.38	133	22.77	123	21.06	141	24.14	187	32.02	
60-69	656	29.63	133	20.27	159	24.24	175	26.68	189	28.81	
70+	532	24.03	119	22.37	151	28.38	149	28.01	113	21.24	
Income level											
~30 percentile	454	20.51	125	27.53	102	22.47	145	31.94	82	18.06	<.0001
31-60 percentile	528	23.85	128	24.24	123	23.30	141	26.70	136	25.76	
61-80 percentile	490	22.13	98	20.00	124	25.31	128	26.12	140	28.57	
81-100 percentile	742	33.51	108	14.56	188	25.34	181	24.39	265	35.71	

(continued)

Variables	Total		Surgical volume in the previous year								P-value
			First quartile		Second quartile		Third quartile		Fourth quartile		
	N/ Mean	%/ SD	N/ Mean	%/ SD	N/ Mean	%/ SD	N/ Mean	%/ SD	N/ Mean	%/ SD	
Types of insurance coverage											
Medical Aid	73	3.30	24	32.88	15	20.55	26	35.62	8	10.96	<.0001
NHI, self-employed	795	35.91	199	25.03	189	23.77	200	25.16	207	26.04	
NHI, employed	1,346	60.79	236	17.53	333	24.74	369	27.41	408	30.31	
Region											
Metropolitan	1,457	65.81	306	21.00	338	23.20	400	27.45	413	28.35	0.4389
Others	757	34.19	153	20.21	199	26.29	195	25.76	210	27.74	
Types of surgery											
Total gastrectomy	511	23.08	99	19.37	120	23.48	142	27.79	150	29.35	0.7270
Subtotal gastrectomy	1,703	76.92	360	21.14	417	24.49	453	26.60	473	27.77	
Types of treatment											
Surgery with chemotherapy or radiotherapy	507	22.90	105	20.71	120	23.67	135	26.63	147	28.99	0.9639
Only surgery	1,707	77.10	354	20.74	417	24.43	460	26.95	476	27.89	
CCI											
0-1	500	22.58	99	19.80	112	22.40	124	24.80	165	33.00	0.0043
2	897	40.51	178	19.84	210	23.41	277	30.88	232	25.86	
3+	817	36.90	182	22.28	215	26.32	194	23.75	226	27.66	
Total	2,214	100.00	459	20.73	537	24.25	595	26.87	623	28.14	

Appendix A3. The number of hospitals by surgical volume and year of surgery

Year of surgery	Hospital	
	High surgical volume	Low surgical volume
2004	47	13
2005	26	31
2006	28	21
2007	28	26
2008	24	34
2009	25	32
2010	38	23
2011	40	19
2012	37	28

Appendix A4. Results of the interrupted time series analysis with reference to reduction in copayment

Variables	Visiting hospital with high volume			
	RR	95% CI		P-value
Introduction of 2nd copayment policy (Sep 2005)				
Before	1.000	-	-	-
After	1.013	0.880	1.167	0.8534
After 2nd copayment policy	1.019	1.009	1.030	0.0002
Introduction of public reporting about surgical volume (Dec 2007)				
Before	1.000	-	-	-
After	0.933	0.808	1.077	0.3443
After public reporting about surgical volume	0.998	0.988	1.007	0.6203
Introduction of 3rd copayment policy (Dec 2009)				
Before	1.000	-	-	-
After	1.142	1.012	1.289	0.0311
After 3rd copayment policy	0.993	0.984	1.002	0.1233
Baseline trends	0.984	0.976	0.992	<.0001
Sex				
Male	0.979	0.936	1.025	0.3651
Female	1.000	-	-	-
Age				
~39	1.133	1.035	1.239	0.0065
40-49	1.077	1.006	1.153	0.0333
50-59	1.021	0.958	1.088	0.5308
60-69	1.035	0.976	1.099	0.2529
70+	1.000	-	-	-
Income level				
~30 percentile	0.848	0.794	0.907	<.0001
31-60 percentile	0.886	0.838	0.938	<.0001
61-80 percentile	0.923	0.875	0.974	0.0035
81-100 percentile	1.000	-	-	-
Types of insurance coverage				
Medical Aid	0.878	0.739	1.043	0.1397
NHI, self-employed	0.901	0.860	0.944	<.0001
NHI, employed	1.000	-	-	-
Region				
Capital area	0.941	0.894	0.990	0.0195
Metropolitan	0.995	0.944	1.049	0.8635
Others	1.000	-	-	-
Types of surgery				
Total gastrectomy	1.000	-	-	-
Subtotal gastrectomy	0.980	0.933	1.030	0.4307
Types of treatment				
Surgery with chemotherapy or radiotherapy	0.973	0.925	1.024	0.3002
Only surgery	1.000	-	-	-
CCI				
0-1	1.140	1.017	1.276	0.0240
2	1.034	0.984	1.086	0.1907
3+	1.000	-	-	-
QIC	20653.43			

Appendix A5. The annual crude incidence rates of gastric cancer (per 100,000 people)

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012
Cancer Registration Statistics	48.7	54.1	54.1	54.6	57.5	60.4	61.4	63.6	61.6
NHI national sampling cohort	64.3	61.0	55.3	55.3	63.1	65.4	57.9	73.4	63.8

Appendix B. Differences in the volume-outcome relationship by public reporting

- Appendix B1. The averages and standard deviation of LOS in case with gastrectomy
- Appendix B2. The averages and standard deviation of inpatient cost in cases with gastrectomy
- Appendix B3. The distribution of study population by 1-year mortality
- Appendix B4. Results of the linear regression analysis for length of stay
- Appendix B5. Results of the linear regression analysis for inpatient cost
- Appendix B6. Results of the survival analysis for 1-year mortality

Appendix B1. The averages and standard deviation of LOS in case with gastrectomy

Variables	Case with gastrectomy			
	N	LOS		
		Mean	SD	P-value
Hospital volume in the previous year				
Q1 (low)	459	17.63	9.40	<.0001
Q2	537	15.81	8.23	
Q3	595	14.99	7.35	
Q4 (high)	623	12.50	5.42	
Introduction of public reporting				
Before	889	16.15	8.46	0.0096
After	1,325	14.31	7.24	
Year of surgery				
2004	222	16.08	8.33	0.0136
2005	245	15.58	9.09	
2006	225	16.10	7.14	
2007	197	16.70	9.10	
2008	257	14.63	6.75	
2009	238	13.80	7.35	
2010	261	15.17	8.09	
2011	283	14.18	7.04	
2012	286	13.88	6.98	
Region of hospital				
Capital area	1,370	14.49	7.47	0.4906
Metropolitan	602	15.79	8.14	
Others	242	16.21	8.48	
Types of medical institution				
Tertiary hospital	1,639	14.54	7.30	0.4007
General hospital	575	16.46	8.92	
Sex				
Male	1,510	15.30	8.17	0.0806
Female	704	14.47	6.91	
Age				
~39	100	12.67	4.58	<.0001
40-49	342	14.05	6.34	
50-59	584	14.41	7.34	
60-69	656	15.26	8.11	
70+	532	16.51	8.88	
Income level				
~30 percentile	454	15.49	7.33	0.8834
31-60 percentile	528	15.11	7.52	
61-80 percentile	490	15.15	8.94	
81-100 percentile	742	14.63	7.45	
Types of insurance coverage				
Medical Aid	73	15.60	7.58	0.9917
NHI, self-employed	795	15.22	7.73	
NHI, employed	1,346	14.89	7.85	
Region				
Capital area	858	15.10	8.25	0.1312
Metropolitan	599	14.90	7.61	
Others	757	15.06	7.41	
Types of surgery				
Total gastrectomy	511	16.73	7.93	<.0001
Subtotal gastrectomy	1,703	14.53	7.68	
Types of treatment				
Surgery with chemotherapy or radiotherapy	507	16.57	8.46	<.0001
Only surgery	1,707	14.58	7.53	
CCI				
0-1	500	13.44	6.31	<.0001
2	897	14.54	7.83	
3+	817	16.56	8.31	
Total	**2,214**	**15.03**	**7.80**	

Appendix B2. The averages and standard deviation of inpatient cost in cases with gastrectomy

Variables	Case with gastrectomy			
	N	Inpatient cost		
		Mean	SD	P-value
Hospital volume in the previous year				
Q1 (low)	459	6,089.43	2,788.13	<.0001
Q2	537	5,734.50	3,406.44	
Q3	595	5,600.98	3,426.00	
Q4 (high)	623	4,831.61	2,065.57	
Introduction of public reporting				
Before	889	4,754.17	2,810.72	0.084
After	1,325	6,016.42	3,010.92	
Year of surgery				
2004	222	3,939.75	2,079.36	<.0001
2005	245	4,253.62	3,290.02	
2006	225	5,105.67	2,420.13	
2007	197	5,881.52	2,791.51	
2008	257	5,502.12	2,138.78	
2009	238	5,689.17	3,156.92	
2010	261	6,522.45	3,947.43	
2011	283	6,189.84	2,864.33	
2012	286	6,191.62	2,654.16	
Region of hospital				
Capital area	1,370	5,475.00	3,200.47	0.0911
Metropolitan	602	5,410.19	2,479.43	
Others	242	6,030.87	2,943.38	
Types of medical institution				
Tertiary hospital	1,639	5,521.32	3,156.48	0.0003
General hospital	575	5,509.05	2,489.84	
Sex				
Male	1,510	5,675.69	3,300.57	0.0057
Female	704	5,180.19	2,173.79	
Age				
~39	100	4,689.21	1,448.34	<.0001
40-49	342	4,875.15	1,904.71	
50-59	584	5,243.33	2,083.37	
60-69	656	5,507.48	2,961.72	
70+	532	6,402.09	4,227.02	
Income level				
~30 percentile	454	5,725.90	3,161.75	0.8545
31-60 percentile	528	5,450.61	2,628.12	
61-80 percentile	490	5,506.41	3,319.42	
81-100 percentile	742	5,446.81	2,914.92	
Types of insurance coverage				
Medical Aid	73	5,885.89	2,771.26	0.7715
NHI, self-employed	795	5,526.95	2,942.80	
NHI, employed	1,346	5,492.98	3,041.07	
Region				
Capital area	858	5,761.97	3,507.41	0.0484
Metropolitan	599	5,233.86	2,298.65	
Others	757	5,466.71	2,834.65	
Types of surgery				
Total gastrectomy	511	6,545.02	3,213.13	<.0001
Subtotal gastrectomy	1,703	5,210.01	2,859.07	
Types of treatment				
Surgery with chemotherapy or radiotherapy	507	5,601.85	2,485.83	0.2469
Only surgery	1,707	5,493.27	3,133.15	
CCI				
0-1	500	5,932.20	2,319.85	<.0001
2	897	5,094.73	2,541.29	
3+	817	5,729.59	3,692.11	
Total	**2,214**	**5,518.13**	**2,997.10**	

Appendix B3. The distribution of study population by 1-year mortality

Variables	Total		1 year mortality after gastrectomy				P-value
			Died		Survived		
	N/ Mean	%/ SD	N/ Mean	%/ SD	N/ Mean	%/ SD	
Hospital volume in the previous year							
Q1 (low)	459	20.73	32	6.97	427	93.03	0.0099
Q2	537	24.25	35	6.52	502	93.48	
Q3	595	26.87	43	7.23	552	92.77	
Q4 (high)	623	28.14	20	3.21	603	96.79	
Introduction of public reporting							
Before	889	40.15	46	5.17	843	94.83	0.2529
After	1,325	59.85	84	6.34	1,241	93.66	
Year of surgery							
2004	222	10.03	9	4.05	213	95.95	0.6504
2005	245	11.07	12	4.90	233	95.10	
2006	225	10.16	13	5.78	212	94.22	
2007	197	8.90	12	6.09	185	93.91	
2008	257	11.61	15	5.84	242	94.16	
2009	238	10.75	12	5.04	226	94.96	
2010	261	11.79	22	8.43	239	91.57	
2011	283	12.78	15	5.30	268	94.70	
2012	286	12.92	20	6.99	266	93.01	
Region of hospital							
Capital area	858	38.75	41	4.78	817	95.22	0.1024
Metropolitan	599	27.06	34	5.68	565	94.32	
Others	757	34.19	55	7.27	702	92.73	
Types of medical institution							
Tertiary hospital	1,639	74.03	92	5.61	1,547	94.39	0.3823
General hospital	575	25.97	38	6.61	537	93.39	
The number of doctors	568.53	406.16	489.92	355.96	573.44	408.66	0.0229
The number of inpatient beds	1,449.99	767.89	1,301.95	683.62	1,459.22	772.05	0.0234
Sex							
Male	1,510	68.20	96	6.36	1,414	93.64	0.1544

(continued)

Variables	Total		1 year mortality after gastrectomy				P-value
			Died		Survived		
	N/ Mean	%/ SD	N/ Mean	%/ SD	N/ Mean	%/ SD	
Female	704	31.80	34	4.83	670	95.17	
Age							
~39	100	4.52	7	7.00	93	93.00	<.0001
40-49	342	15.45	10	2.92	332	97.08	
50-59	584	26.38	19	3.25	565	96.75	
60-69	656	29.63	38	5.79	618	94.21	
70+	532	24.03	56	10.53	476	89.47	
Income level							
~30 percentile	454	20.51	29	6.39	425	93.61	0.9572
31-60 percentile	528	23.85	30	5.68	498	94.32	
61-80 percentile	490	22.13	29	5.92	461	94.08	
81-100 percentile	742	33.51	42	5.66	700	94.34	
Types of insurance coverage							
Medical Aid	73	3.30	5	6.85	68	93.15	0.3463
NHI, self-employed	795	35.91	39	4.91	756	95.09	
NHI, employed	1,346	60.79	86	6.39	1,260	93.61	
Region							
Capital area	1,370	61.88	69	5.04	1,301	94.96	0.0921
Metropolitan	602	27.19	45	7.48	557	92.52	
Others	242	10.93	16	6.61	226	93.39	
Types of surgery							
Total gastrectomy	511	23.08	67	13.11	444	86.89	<.0001
Subtotal gastrectomy	1,703	76.92	63	3.70	1,640	96.30	
Types of treatment							
Surgery with chemotherapy or radiotherapy	507	22.90	60	11.83	447	88.17	<.0001
Only surgery	1,707	77.10	70	4.10	1,637	95.90	
CCI							
0-1	500	22.58	29	5.80	471	94.20	0.0001
2	897	40.51	32	3.57	865	96.43	
3+	817	36.90	69	8.45	748	91.55	
Total	2,214	100.00	130	5.87	2,084	94.13	

Appendix B4. Results of the linear regression analysis for length of stay

Variables	LOS per case with gastrectomy											
	Model 1				Model 2				Model 3			
	RL	95% CI		P-value	RL	95% CI		P-value	RL	95% CI		P-value
Hospital volume in the previous year												
Q1 (low)	1.000	-	-	-	1.000	-	-	-	1.000	-	-	-
Q2	0.897	0.840	0.958	0.0012	0.899	0.844	0.958	0.0010	0.901	0.846	0.959	0.0011
Q3	0.854	0.802	0.909	<.0001	0.881	0.830	0.935	<.0001	0.886	0.834	0.941	<.0001
Q4 (high)	0.709	0.668	0.753	<.0001	0.764	0.693	0.843	<.0001	0.785	0.714	0.862	<.0001
Introduction of public reporting												
Before					1.000	-	-	-	1.000	-	-	-
After					0.893	0.822	0.971	0.0077	0.866	0.794	0.944	0.0011
Overall trends					0.999	0.998	1.001	0.2609	1.001	0.999	1.003	0.2740
Region of hospital												
Capital area					0.964	0.892	1.042	0.3545	0.9756	0.9057	1.0510	0.5155
Metropolitan					1.008	0.930	1.092	0.8546	1.034	0.957	1.117	0.4027
Others					1.000	-	-	-	1.000	-	-	-
Types of medical institution												
Tertiary hospital					0.970	0.913	1.030	0.3155	0.984	0.928	1.044	0.5872
General hospital					1.000	-	-	-	1.000	-	-	-
The number of doctors					1.026	1.010	1.041	0.0011	1.024	1.009	1.039	0.0018
The number of inpatient beds					0.985	0.979	0.991	<.0001	0.984	0.978	0.990	<.0001
Sex												
Male					1.045	1.003	1.088	0.0345	1.042	1.002	1.084	0.0390
Female					1.000	-	-	-	1.000	-	-	-
Age												
~39					0.798	0.733	0.868	<.0001	0.793	0.732	0.860	<.0001
40-49					0.856	0.804	0.911	<.0001	0.846	0.797	0.898	<.0001
50-59					0.880	0.830	0.932	<.0001	0.875	0.826	0.927	<.0001
60-69					0.919	0.867	0.974	0.0045	0.917	0.867	0.971	0.0028
70+					1.000	-	-	-	1.000	-	-	-
Income level												

(continued)

Variables	LOS per case with gastrectomy												
	Model 1				Model 2				Model 3				
	RL	95% CI		P-value	RL	95% CI		P-value	RL	95% CI		P-value	
~30 percentile					1.024	0.967	1.085	0.4121	1.026	0.971	1.084	0.3606	
31-60 percentile					1.013	0.961	1.069	0.6323	1.009	0.959	1.061	0.7279	
61-80 percentile					1.013	0.958	1.071	0.6524	1.015	0.959	1.073	0.6110	
81-100 percentile					1.000	-	-	-	1.000	-	-	-	
Types of insurance coverage													
Medical Aid					1.010	0.902	1.131	0.8633	1.003	0.895	1.123	0.9617	
NHI, self-employed					1.010	0.969	1.054	0.6254	1.003	0.962	1.044	0.9013	
NHI, employed					1.000	-	-	-	1.000	-	-	-	
Region													
Capital area					1.048	0.998	1.101	0.0597	1.0437	0.9949	1.0949	0.0800	
Metropolitan					0.993	0.942	1.047	0.7926	0.985	0.935	1.037	0.5627	
Others					1.000	-	-	-	1.000	-	-	-	
Types of surgery													
Total gastrectomy									1.000	-	-	-	
Subtotal gastrectomy									0.873	0.835	0.913	<.0001	
Types of treatment													
Surgery with chemotherapy or radiotherapy									1.118	1.065	1.173	<.0001	
Only surgery									1.000	-	-	-	
CCI													
0-1									0.850	0.784	0.921	<.0001	
2									0.901	0.858	0.946	<.0001	
3+									1.000	-	-	-	
QIC	67977.72				72712.31				76619.82				

Appendix B5. Results of the linear regression analysis for inpatient cost

Variables	Inpatient cost per case with gastrectomy											
	Model 1				Model 2				Model 3			
	RC	95% CI		P-value	RC	95% CI		P-value	RC	95% CI		P-value
Hospital volume in the previous year												
Q1 (low)	1.000	-	-	-	1.000	-	-	-	1.000	-	-	-
Q2	0.942	0.882	1.005	0.0717	0.963	0.906	1.024	0.2302	0.963	0.906	1.022	0.2143
Q3	0.920	0.862	0.981	0.0111	0.925	0.874	0.980	0.0078	0.927	0.878	0.979	0.0063
Q4 (high)	0.793	0.752	0.837	<.0001	0.785	0.706	0.874	<.0001	0.817	0.740	0.901	<.0001
Introduction of public reporting												
Before					1.000	-	-	-	1.000	-	-	-
After					0.948	0.876	1.025	0.1828	0.875	0.808	0.948	0.0011
Overall trends					1.005	1.004	1.006	<.0001	1.009	1.007	1.010	<.0001
Region of hospital												
Capital area					1.000	0.928	1.078	0.9997	1.0157	0.9495	1.0865	0.6502
Metropolitan					0.936	0.874	1.003	0.0619	0.963	0.905	1.025	0.2350
Others					1.000	-	-	-	1.000	-	-	-
Types of medical institution												
Tertiary hospital					1.088	1.025	1.156	0.0058	1.117	1.056	1.182	0.0001
General hospital					1.000	-	-	-	1.000	-	-	-
The number of doctors					1.015	0.997	1.034	0.1095	1.010	0.993	1.027	0.2553
The number of inpatient beds					0.990	0.983	0.997	0.0065	0.990	0.983	0.997	0.0041
Sex												
Male					1.060	1.019	1.103	0.0038	1.058	1.021	1.097	0.0020
Female					1.000	-	-	-	1.000	-	-	-
Age												
~39					0.786	0.729	0.848	<.0001	0.793	0.741	0.849	<.0001
40-49					0.802	0.753	0.854	<.0001	0.807	0.764	0.853	<.0001
50-59					0.845	0.795	0.897	<.0001	0.857	0.810	0.907	<.0001
60-69					0.899	0.842	0.959	0.0012	0.908	0.855	0.964	0.0017
70+					1.000	-	-	-	1.000	-	-	-
Income level												

(continued)

Variables	Inpatient cost per case with gastrectomy											
	Model 1				Model 2				Model 3			
	RC	95% CI		P-value	RC	95% CI		P-value	RC	95% CI		P-value
~30 percentile					1.021	0.962	1.082	0.5005	1.029	0.975	1.086	0.2955
31-60 percentile					1.013	0.963	1.065	0.6191	1.013	0.969	1.059	0.5750
61-80 percentile					1.040	0.981	1.102	0.1903	1.040	0.982	1.100	0.1823
81-100 percentile					1.000	-	-	-	1.000	-	-	-
Types of insurance coverage												
Medical Aid					1.053	0.946	1.171	0.3475	1.055	0.952	1.169	0.3052
NHI, self-employed					1.009	0.968	1.051	0.6819	0.998	0.960	1.038	0.9260
NHI, employed					1.000	-	-	-	1.000	-	-	-
Region												
Capital area					1.066	1.010	1.125	0.0201	1.0633	1.0115	1.1178	0.0161
Metropolitan					0.989	0.943	1.037	0.6454	0.9875	0.9443	1.0325	0.5794
Others					1.000	-	-	-	1.000	-	-	-
Types of surgery												
Total gastrectomy									1.000	-	-	-
Subtotal gastrectomy									0.788	0.753	0.824	<.0001
Types of treatment												
Surgery with chemotherapy or radiotherapy									1.034	0.992	1.078	0.1175
Only surgery									1.000	-	-	-
CCI												
0-1									0.732	0.681	0.787	<.0001
2									0.875	0.835	0.918	<.0001
3+									1.000	-	-	-
QIC	151460.29				190489.02				216789.04			

Appendix B6. Results of the survival analysis for 1-year mortality

Variables	1 year mortality after gastrectomy											
	Model 1				Model 2				Model 3			
	HR	95% CI		P-value	HR	95% CI		P-value	HR	95% CI		P-value
Hospital volume in the previous year												
Q1 (low)	1.000	-	-	-	1.000	-	-	-	1.000	-	-	-
Q2	0.945	0.585	1.527	0.8179	0.887	0.541	1.452	0.6324	0.876	0.534	1.439	0.6013
Q3	1.040	0.658	1.643	0.8665	0.910	0.556	1.491	0.7091	0.937	0.568	1.545	0.7975
Q4 (high)	0.455	0.260	0.796	0.0058	0.332	0.126	0.873	0.0253	0.334	0.124	0.903	0.0307
Introduction of public reporting												
Before					1.000	-	-	-	1.000	-	-	-
After					1.165	0.794	1.710	0.4344	1.477	0.957	2.279	0.0784
Region of hospital												
Capital area					1.257	0.653	2.420	0.4933	1.392	0.710	2.730	0.3357
Metropolitan					1.431	0.769	2.662	0.2575	1.875	0.998	3.523	0.0509
Others					1.000	-	-	-	1.000	-	-	-
Types of medical institution												
Tertiary hospital					1.094	0.668	1.790	0.7210	0.982	0.599	1.609	0.941
General hospital					1.000	-	-	-	1.000	-	-	-
The number of doctors					1.007	0.884	1.148	0.9161	0.999	0.877	1.138	0.9894
The number of inpatient beds					1.023	0.956	1.095	0.5121	1.022	0.953	1.096	0.5460
Sex												
Male					1.311	0.881	1.952	0.1820	1.236	0.825	1.852	0.3043
Female					1.000	-	-	-	1.000	-	-	-
Age												
~39					0.763	0.339	1.716	0.5128	0.697	0.303	1.603	0.3957
40-49					0.301	0.152	0.596	0.0006	0.230	0.115	0.462	<.0001
50-59					0.314	0.185	0.534	<.0001	0.244	0.142	0.420	<.0001
60-69					0.556	0.364	0.847	0.0063	0.502	0.327	0.770	0.0016
70+					1.000	-	-	-	1.000	-	-	-
Income level												
~30 percentile					1.111	0.664	1.860	0.6882	1.193	0.713	1.998	0.5014

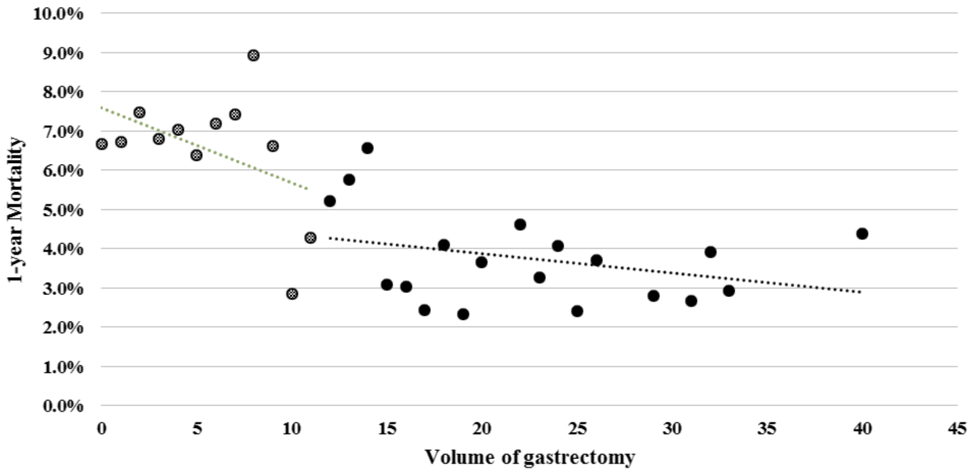
(continued)

Variables	1 year mortality after gastrectomy											
	Model 1				Model 2				Model 3			
	HR	95% CI		P-value	HR	95% CI		P-value	HR	95% CI		P-value
31-60 percentile					1.124	0.691	1.828	0.6377	1.048	0.642	1.711	0.8508
61-80 percentile					1.139	0.706	1.839	0.5935	1.121	0.691	1.817	0.6446
81-100 percentile					1.000	-	-	-	1.000	-	-	-
Types of insurance coverage												
Medical Aid					1.120	0.418	2.998	0.8215	0.989	0.367	2.660	0.9820
NHI, self-employed					0.768	0.521	1.130	0.1803	0.737	0.499	1.088	0.1251
NHI, employed					1.000	-	-	-	1.000	-	-	-
Region												
Capital area					0.683	0.423	1.102	0.1186	0.638	0.390	1.044	0.0739
Metropolitan					0.725	0.451	1.164	0.1835	0.640	0.394	1.039	0.0709
Others					1.000	-	-	-	1.000	-	-	-
Types of surgery												
Total gastrectomy									1.000	-	-	-
Subtotal gastrectomy									0.302	0.210	0.433	<.0001
Types of treatment												
Surgery with chemotherapy or radiotherapy									3.090	2.133	4.476	<.0001
Only surgery									1.000	-	-	-
CCI												
0-1									0.667	0.408	1.091	0.1071
2									0.420	0.273	0.645	<.0001
3+									1.000	-	-	-
-2 Log Likelihood Statistics	1980.49				1940.77				1829.65			

Appendix C. Optimal volume for achieving better volume-outcome relationship

- Appendix C1. Cut-off of surgical volume using the Youden's J index
- Appendix C2. Results for length of stay based the new criterion for surgical volume
- Appendix C3. Results for inpatient cost based on the new criterion for surgical volume
- Appendix C4. Results for 1-year mortality based the new criterion for surgical volume

Appendix C1. Cut-off of surgical volume using the Youden's J index



Appendix C2. Results for length of stay based the new criterion for surgical volume

Variables	LOS			
	RL	95% CI		P-value
Hospital volume in the previous year				
Low	1.000	-	-	-
High	0.820	0.776	0.866	<.0001
Introduction of public reporting				
Before	1.000	-	-	-
After	0.837	0.769	0.912	<.0001
Overall trends	1.001	1.000	1.003	0.1309
Region of hospital				
Capital area	0.974	0.905	1.047	0.4696
Metropolitan	1.008	0.933	1.089	0.8385
Others	1.000	-	-	-
Types of medical institution				
Tertiary hospital	0.958	0.903	1.018	0.1648
General hospital	1.000	-	-	-
The number of doctors	1.023	1.010	1.036	0.0006
The number of inpatient beds	0.985	0.980	0.991	<.0001
Sex				
Male	1.045	1.005	1.087	0.0272
Female	1.000	-	-	-
Age				
~39	0.787	0.725	0.853	<.0001
40-49	0.845	0.797	0.897	<.0001
50-59	0.875	0.826	0.928	<.0001
60-69	0.917	0.867	0.970	0.0026
70+	1.000	-	-	-
Income level				
~30%	1.032	0.978	1.089	0.2541
31-60%	1.022	0.971	1.075	0.4035
61-80%	1.022	0.967	1.081	0.4363
81-100%	1.000	-	-	-
Types of insurance coverage				
Medical Aid	1.014	0.906	1.136	0.8051
NHI, self-employed	1.008	0.968	1.049	0.7062
NHI, employed	1.000	-	-	-
Region				
Capital area	1.045	0.995	1.096	0.0765
Metropolitan	0.985	0.935	1.037	0.5542
Others	1.000	-	-	-
Types of surgery				
Total gastrectomy	1.000	-	-	-
Subtotal gastrectomy	0.872	0.834	0.911	<.0001
Types of treatment				
Surgery with chemotherapy or radiotherapy	1.120	1.067	1.175	<.0001
Only surgery	1.000	-	-	-
CCI				
0-1	0.842	0.778	0.911	<.0001
2	0.906	0.864	0.950	<.0001
3+	1.000	-	-	-
QIC	77,315.03			

Appendix C3. Results for inpatient cost based on the new criterion for surgical volume

Variables	Inpatient cost per case			
	RC	95% CI		P-value
Hospital volume in the previous year				
Low	1.000	-	-	-
High	0.829	0.785	0.876	<.0001
Introduction of public reporting				
Before	1.000	-	-	-
After	0.844	0.780	0.913	<.0001
Overall trends	1.009	1.007	1.010	<.0001
Region of hospital				
Metropolitan	0.981	0.926	1.039	0.5042
Others	1.000	-	-	-
Types of medical institution				
Tertiary hospital	1.072	1.015	1.132	0.0129
General hospital	1.000	-	-	-
The number of doctors	1.015	1.000	1.031	0.0508
The number of inpatient beds	0.990	0.983	0.997	0.0067
Sex				
Male	1.060	1.023	1.099	0.0015
Female	1.000	-	-	-
Age				
~39	0.782	0.730	0.837	<.0001
40-49	0.804	0.761	0.851	<.0001
50-59	0.849	0.801	0.900	<.0001
60-69	0.903	0.849	0.960	0.0011
70+	1.000	-	-	-
Income level				
~30 percentile	1.030	0.977	1.086	0.2720
31-60 percentile	1.016	0.972	1.062	0.4913
61-80 percentile	1.042	0.985	1.104	0.1538
81-100 percentile	1.000	-	-	-
Types of insurance coverage				
Medical Aid	1.052	0.951	1.163	0.3265
NHI, self-employed	0.998	0.960	1.037	0.9055
NHI, employed	1.000	-	-	-
Region				
Metropolitan	1.036	0.994	1.080	0.0972
Others	1.000	-	-	-
Types of surgery				
Total gastrectomy	1.000	-	-	-
Subtotal gastrectomy	0.786	0.752	0.822	<.0001
Types of treatment				
Surgery with chemotherapy or radiotherapy	1.037	0.996	1.081	0.0790
Only surgery	1.000	-	-	-
CCI				
0-1	0.721	0.671	0.775	<.0001
2	0.882	0.841	0.924	<.0001
3+	1.000	-	-	-
QIC	215,494.18			

Appendix C4. Results for 1-year mortality based the new criterion for surgical volume

Variables	1-year mortality after gastrectomy			
	HR	95% CI		P-value
Hospital volume in the previous year				
Low	1.000	-	-	-
High	0.357	0.178	0.715	0.0036
Introduction of Public reporting				
Before	1.000	-	-	-
After	1.374	0.886	2.130	0.1558
Region of hospital				
Metropolitan	1.570	0.874	2.823	0.1315
Others	1.000	-	-	-
Types of medical institution				
Tertiary hospital	0.974	0.610	1.555	0.9119
General hospital	1.000	-	-	-
The number of doctors	0.985	0.870	1.115	0.8055
The number of inpatient beds	1.014	0.952	1.080	0.6697
Sex				
Male	1.249	0.834	1.871	0.2809
Female	1.000	-	-	-
Age				
~39	0.721	0.315	1.651	0.4395
40-49	0.248	0.124	0.496	<.0001
50-59	0.257	0.150	0.440	<.0001
60-69	0.529	0.345	0.812	0.0035
70+	1.000	-	-	-
Income level				
~30 percentile	1.209	0.724	2.020	0.4678
31-60 percentile	1.095	0.672	1.786	0.7147
61-80 percentile	1.125	0.694	1.825	0.6323
81-100 percentile	1.000	-	-	-
Types of insurance coverage				
Medical Aid	1.024	0.381	2.749	0.9627
NHI, self-employed	0.737	0.500	1.085	0.1219
NHI, employed	1.000	-	-	-
Region				
Metropolitan	0.628	0.430	0.918	0.0163
Others	1.000	-	-	-
Types of surgery				
Total gastrectomy	1.000	-	-	-
Subtotal gastrectomy	0.312	0.217	0.448	<.0001
Types of treatment				
Surgery with chemotherapy or radiotherapy	2.907	2.010	4.204	<.0001
Only surgery	1.000	-	-	-
CCI				
0-1	0.623	0.381	1.016	0.0579
2	0.431	0.281	0.661	0.0001
3+	1.000	-	-	-
-2 Log Likelihood Statistics	1829.32			

Korean Abstract

수술 진료량 평가결과 공개가 환자 및 병원 행태에 미치는 영향

한규태

서 론: 2007 년 요양급여 적정성 평가의 일환으로 위암수술을 포함한 주요 7 개 질환에 대해 적정 수술 진료량을 평가 및 공개를 시행하였다. 이는 암환자의 치료 접근성 향상 및 비용부담완화에 초점을 두었던 이전의 보건 의료정책과 달리, 암환자의 관리에서 간접적으로나마 질적 지표를 최초로 공개하였다는 점에서 의미가 있다. 하지만, 다른 정책에 비해 적은 기대효과 등에 따라, 암환자진료의 질적 지표공개의 효과 및 개선방안 등과 관련된 연구는 부족한 실정이다. 따라서, 이 연구의 목적은 수술 진료량 공개가 위암환자에서의 환자 및 병원 행태에 미치는 영향을 파악하는 것이다.

자료 및 방법: 이 연구는 국민건강보험공단 표본 코호트 자료를 활용하여, 2004-2012 년 동안 새롭게 위암으로 진단받고, 위암수술을 받은 환자 2,214 명을 대상으로 분석하였다. 분석방법은 환자행태에서의 변화를 관찰하고자, 위암환자에서 해당 정책의 공개에 따라 이전 년도 기준으로 수술 진료량이 많은 병원에 방문하였는지, 포아송 분포 및 일반화 추정방정식(Generalized Estimated Equation)을 이용하여 중도절단 시계열 분석(Interrupted time series analysis)을 수행하였다. 다음으로, 병원 행태의 변화로 방문한 병원에서의 의료이용 및 진료결과를 정책 시행 전, 후에 따라 비교하고자 재원일수 및 입원진료비용에 대한 감마분포 및 일반화 추정방정식을 이용한 선형회귀분석과 수술 후 1 년 내 사망률에 대해 콕스비례위험모형(Cox proportional hazard model)을 이용한 생존분석(Survival analysis)에 대해 이중차분법(Difference In Difference)을 적용하여 비교하였다. 또한, 수술 진료량에 대한 기준을 새롭게 제시하고자 유덴지수를 활용하여 추정한 수술 진료량 기준을 바탕으로 분석을 반복하였다.

결 과: 연구기간 동안 이전 년도 수술 진료량의 1 분위수를 기준으로 높은 수술 진료량을 가진 병원에 방문한 환자는 전체의 79.27%였다. 이는 수술 진료량 공개 이후 감소하였지만, 통계적으로 유의하지 않았다(80.66~78.36%, P=0.1909). 위암수술을 받은 환자의 평균 재원일수는 15.03 일, 입원진료비

용은 5.51 백만원이었으며, 정보공개 이후, 재원일수는 통계적으로 유의하게 감소하였고, 입원진료비용은 증가하는 추세를 보였다(16.15~14.31 일, P<0.05; 4.75~6.02 백만원, P=0.084). 또한, 연구기간 동안 위암수술 1 년 내에 5.87%의 환자가 사망하였으며, 이는 정보공개 이후 증가하는 추세를 보였다(5.17%~6.34%, P=0.2529). 중도절단 시계열분석 결과에 따르면, 수술 진료량 공개가 환자의 행태에 영향을 미치는 것처럼 보였으나, 본인부담 감소정책의 효과를 고려할 때, 해당 효과가 사라지는 것으로 분석되었다. 진료량-결과관계의 유무를 확인하기 위해 시행한 회귀분석 및 생존분석에 따르면, 수술 진료량이 많은 병원에서 낮은 재원일수, 입원진료비용, 1 년 내 사망률과의 관계가 있음을 확인하였다. 수술량과 진료결과의 관계가 정보공개 시행 전, 후에 따라 차이가 있는지 알아보기 위해 시행한, 이중차분법을 적용한 회귀분석 및 생존분석에 따르면, 재원일수 및 입원진료비용은 제도 시행에 따라 더 큰 관계를 보이는 것으로 분석되었다. 반면, 1 년 내 사망률과의 관계는 제도 시행 후, 통계적으로 유의한 차이가 사라졌다. 해당 정책과 관련해 새로운 적정진료량 기준을 제시하고자, 유덴지수를 활용한 재분석한 결과에서는 상기 결과가 더 큰 차이를 보임을 확인하였다.

고찰 및 결론: 이 연구의 결과에 따르면, 위암수술에 대한 적정 수술 진료량 공개는 암환자의 의료기관 선택과 관계가 없었다. 환자 행태에 있어 경제적 지원과 같은 정책이 정보공개에 비해 많은 영향을 미쳤으며, 환자 행태 변화는 정보공개에 따른 변화라기보다는 큰 병원 선호효과에 따라 유발될 가능성이 존재한다. 따라서, 이 연구의 결과에 따르면 수술 진료량 공개는 환자의 선택권 강화 및 의사결정에 있어 효과적인 도움을 주지 못했음을 확인하였다. 반면, 병원 행태에 있어, 수술 진료량 공개는 병원 간 벤치마킹을 유도함으로써, 위암환자의 수술적 치료 효율성 개선에 영향을 미친 것으로 확인되었다. 비록 적정 수술 진료량 선정기준 및 관련 보건의료정책의 흐름과 관련된 몇 가지 논란이 존재하지만, 이 연구의 결과에 따르면, 병원 행태 측면에서 수술 진료량 공개의 긍정적 영향을 확인하였다. 따라서, 이 연구의 결과를 바탕으로 해당 정책에 대한 효과적 평가 및 보완을 시행할 필요가 있다. 특히, 환자에 대한 정보공개 정책에 대한 인식을 강화시키고, 장기적 관점에서 해당 정책의 활성화를 위한 노력을 기울일 필요가 있으며, 이를 통해 우리나라에서 암환자 진료의 전반적 수준의 향상을 기대할 수 있을 것으로 기대한다.

핵심어: 위암, 수술진료량, 정보공개, 의료의 질