The Effect of Geographic Units of Analysis on Measuring Geographic Variation in Medical Services Utilization

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Objectives: We aimed to evaluate the effect of geographic units of analysis on measuring geographic variation in medical services utilization. For this purpose, we compared geographic variations in the rates of eight major procedures in administrative units (districts) and new areal units organized based on the actual health care use of the population in Korea.

Methods: To compare geographic variation in geographic units of analysis, we calculated the age–sex standardized rates of eight major procedures (coronary artery bypass graft surgery, percutaneous transluminal coronary angioplasty, surgery after hip fracture, knee-replacement surgery, caesarean section, hysterectomy, computed tomography scan, and magnetic resonance imaging scan) from the National Health Insurance database in Korea for the 2013 period. Using the coefficient of variation, the extremal quotient, and the systematic component of variation, we measured geographic variation for these eight procedures in districts and new areal units.

Results: Compared with districts, new areal units showed a reduction in geographic variation. Extremal quotients and inter-decile ratios for the eight procedures were lower in new areal units. While the coefficient of variation was lower for most procedures in new areal units, the pattern of change of the systematic component of variation between districts and new areal units differed among procedures.

Conclusions: Geographic variation in medical service utilization could vary according to the geographic unit of analysis. To determine how geographic characteristics such as population size and number of geographic units affect geographic variation, further studies are needed.

Key words: Small-area analysis, Delivery of health care, Utilization

INTRODUCTION

Geographic variation in medical services utilization refers to a phenomenon in which the health care use of a population varies according to the geographically defined unit. Since it was not explained only by patient characteristics, but rather by supplier characteristics, this phenomenon was termed 'unwarranted variation' [1] and has remained a major topic in the field of health services research for decades [2]. With rising health care costs and increased awareness of uncertainty in medicine, many research initiatives to investigate geographical variation are being implemented at national and multinational levels [3]. As geographic variation studies evolve from measurements of variation in one nation into international comparison, organizing new areal units which are more homogenous and which accurately reflect health care use has

emerged as an important issue.

Geographic variation studies have been conducted with two kinds of geographic units of analysis: units organized for the purpose of variation analysis and administrative units. While newly organized units such as hospital service areas can reflect the actual health care use of the region, they, being ad hoc units, may be of limited use for policy. Administrative units, having merit in terms of policy making, health care planning, and provision [4], have been frequently used for geographic variation studies.

Administrative units, however, may be incomplete as a unit of analysis for the following two reasons. First, heterogeneity in population size and number of units can produce extra-variation [4]. Second, administrative units are not necessarily consistent with actual health care use. As one of the main purposes of variation studies is to estimate the influence of the area's health care supply on its use, each unit should be, ideally, self-sufficient in health care use for a variation study [5]. In this respect, variation analysis based on administrative units could lead to an erroneous attribution of health care use to health care suppliers. This is especially relevant in Korea because, as revealed in previous studies [6], the proportion of residents of an area using health care within their own unit of residence is known to be low compared with other countries.

In Korea, variation studies have been mainly performed on the basis of administrative units [7-14]. While there have been attempts to organize new areal units, they have mostly maintained the form of existing administrative units [15-20]. And, to the best of our knowledge, a comparison of variation and population structure between administrative units and new areal units has not been performed in Korea. This study aimed to evaluate the effect of geographic units on measuring geographical variation in health care use by comparing administrative units and new areal units organized to reflect geographic health care use accurately and to examine the relevance of each areal unit for measuring geographic variation.

METHODS

Data

The study data were extracted from the National Health Insurance (NHI) database in Korea for the 2013 period (January 1 to December 31). The NHI database comprises patients who are registered for the NHI—about 97% of the country's population—and medical aid beneficiaries who comprise 3% of the total population [21]; thus it can be considered to be comprehensive for the whole Korean population, except in the case of some procedures which are not covered by the NHI. The database includes information on patient demographics, procedure codes (Electronic Database Interchange codes), and diagnosis codes (Korean Standard Classification of Diseases codes). Data for the population distribution of areal units were acquired from Statistics Korea.

We studied geographic variation in utilization rates for the following eight procedures: coronary artery bypass graft surgery (CABG), percutaneous transluminal coronary angioplasty (PTCA), surgery after hip fracture, knee-replacement surgery, hysterectomy, caesarean section, computed tomography scan (CT), and magnetic resonance imaging scan (MRI). These procedures were selected by the criteria of high cost, large volume, and policy relevance [22]. Procedure utilization rates were calculated based on the patient's place of residence. The rates were age-adjusted and sex-adjusted to the Korean Resident Population 2013. The rate of caesarean section was standardized to the measurement of Korean Live Births 2013, according to the age of mother. The rates were calculated per 100 000 population aged 15 and over. For CABG and PTCA the rate was per 100 000 population aged 20 and over. In the case of caesarean section, the rate was per 1000 live births.

Unit of Analysis

The administrative units in Korea are divided into two categories: Provincial level (special metropolitan city, metropolitan city, special self-governing city, do, and special self-governing province) and municipal level (si, gun, and gu). While both of these two levels have been frequently used in previous studies, municipal level units have been applied mainly in two different ways; (i) si/gun [14,15,19]; (ii) si/gun/gu [12,13]. As si is a homogenous unit in terms of supply and accessibility of health care service [20], and has concentrated residence [19], we used si/gun (subsequently referred to as districts) as administrative units instead of si/gun/gu, where a si can be divided into the subunit gu.

New areal units were organized for the following three purposes: (i) To establish areal units that cover actual health care use. (ii) To understand the pattern of health care utilization based on health care supply. (iii) To prepare the ground for monitoring and ensuring health care supply.

New areal units were organized by merging and selecting. Merging was done on the 163 districts (si/gun). Merging was

performed on the basis of the multiplication of a relevance index and a commitment index. The relevance index (RI) refers to the proportion of the hospitalizations that occurred within an area over the total number of hospitalizations done in that area. The commitment index (CI) refers to the proportion of the hospitalizations that occurred within an area over the total number of hospitalizations of the area's residents. To reflect both the dependence of residents' health care use on certain areas and the dependence of an area on the residents of certain areas, we utilized the multiplication of RI and CI. Data for hospitalization was from the NHI database (October 2012 to September 2013).

To select the combination of the merged areal units, we applied three criteria: (i) Minimum value of the RI of an areal unit: 40%. (ii) Minimum population size of an areal unit: 150 000. (iii) Maximum travel time: 60 minutes [23]. The minimum value of the RI and population size are based on the results from a previous study on organizing areal units for health care use [20], where the average value of the RI of the 163 districts (si/gun) was about 40%. To ensure that the minimum RI of new areal units attained the average RI of the existing units, we set the minimum value of the RI as 40%. On the basis of the analysis of the RI and the population size of the districts, we concluded that the population size should be at least over 150 000 to attain the minimum RI. Travel time refers to the time required for a car to move from one area to another area. Based on previous studies where 60 minutes was defined as a critical period for reducing mortality in emergency medical conditions [20, 23], we set the maximum travel time as 60 minutes. Travel time was calculated between center points of the populations of areal units.

Quantification of Variation

Statistics of variation based on age–sex standardized rates were calculated to assess the effect of the geographic units on geographic variation. The analysis was performed as follows. First, by comparing non-parametric kernel density estimates according to geographic units, we attempted to visually assess the effect of geographic units on the distribution of procedure rates. Kernel density estimation, a non-parametric way to estimate the probability density function, is widely used in data mining and econometrics for inference procedures [24]. Kernel density estimation was also used for comparing the rate distribution of geographic units [3]. This study used the Gaussian kernel function. Second, we calculated the 'extremal quotient'

$$ \text{SCV} = \frac{1}{N} \left\{ \sum_{k=1}^{i} \frac{(O_i - E_i)^2}{E_i^2} - \sum_{k=1}^{i} \frac{1}{E_i} \right\}_{, \text{multiplied by 100}} $$

Figure 1. Formula for the systematic component of variation (SCV) [28]. N, number of areas; O_i, observed number of procedures; E_i, expected number of procedures.

(EQ), the 'inter-decile ratio' (IDR), and the 'coefficient of variation' (CV) to assess the effect of geographic units on geographic variation in procedure rates. The EQ is the ratio of the highest geographic unit rate to the lowest geographic unit rate of a procedure. The EQ, intuitive and easy to understand [22], is appealing to researchers and policy makers [25] and therefore has often been used in geographic variation studies. However, as the EQ is very sensitive to extreme values, we calculated the IDR, the ratio of the rate in the area in the 90th to the 10th percentile of the distribution, to reduce the influence of outliers [22]. The CV is the ratio of the standard deviation to the mean of procedure rates in given geographic units. Since the CV is insensitive to the scale, it has been frequently used to study heterogeneity of different units [26]. And finally, we estimated the systematic component of variation (SCV). The SCV is the estimate of the true part of variation (variation across areas) separated from the random part of variation (within-region variation) [27]. We used the formula (Figure 1) proposed by McPherson et al. [28].
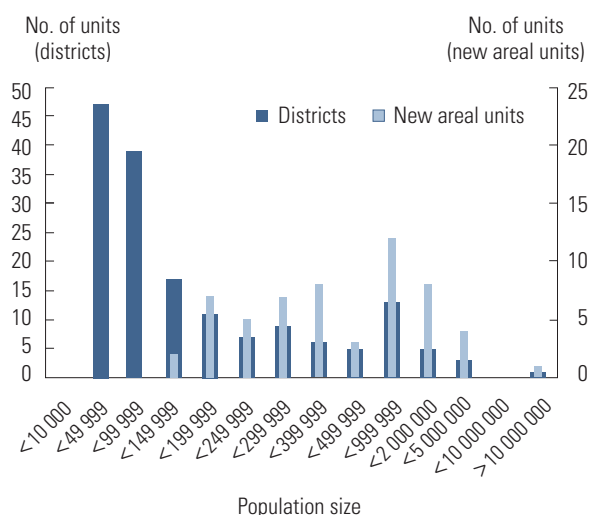
International Comparison

To grasp the heterogeneity in the population sizes of geographic units in Korea, we compared the distribution of population size and variation statistics of new areal units and administrative units (districts) in Korea with those of the 13 Organization for Economic Cooperation and Development (OECD) member countries. For comparison of the distribution of population size, we collected data on the populations of the 18 corresponding areal units from the 13 countries and calculated the average and the CV of the population sizes.

To compare the variation statistics of Korea with the 13 OECD countries [22], we calculated variation statistics based on procedure rates computed in an identical way as in the OECD report. Rates were age-adjusted and sex-adjusted to the OECD 2010 standard population and the 2011 Italian population structure according to the mother's age for the caesarean section rate.

The study was carried out with SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

RESULTS

The population distributions of the geographic units are as follows. The average population size was 313 751 in districts and 897 219 in new areal units. The CV of the population size was 2.87 in districts and 1.67 in new areal units. While 86 out of 163 districts had fewer than 99 999 inhabitants, no new areal unit had fewer than 99 999 inhabitants (Figure 2). The total number of procedures and the nationwide rate of procedures are presented in Supplemental Table 1. With regard to the ef-

fect on the distribution of procedure rates, kernel curves showed distinct differences in CABG and surgery after hip fracture, which showed less dispersion in new regional areas (Figure 3).

Regarding the variation in procedure rates between districts and new areal units (Table 1), the EQ and the IDR were lower in new areal units for all procedures. The CV was also lower in new areal units, except for MRI. The SCV was lower in new areal units in surgery after hip fracture, knee-replacement surgery, and caesarean section. For CABG, PTCA, hysterectomy, and MRI, the SCV was higher in new areal units.

When we compared variations among procedures, CABG, PTCA, knee-replacement surgery, and hysterectomy showed high variation both in districts and new areal units. CABG showed the highest values, followed by PTCA.

We compared the distribution of population sizes and variation statistics of Korea (districts and new areal units) with those of the 13 OECD member countries (Table 2). The average population size of the geographic units of the 13 countries ranged from 130 000 to 1 600 000 while that in Korea was about 300 000 (districts) and 900 000 (new areal units). The CV of population sizes in the 13 countries ranged from 0.26 to 1.44 with the average of the CV being 0.9. In Korea, the CV was 2.87 (districts) and 1.67 (new areal units) exceeding the maximum value among the administrative units of 13 countries (Table 2).

In the case of the CV of the procedure rates, both districts and new areal units showed a higher CV than the average CV of the 13 OECD member countries in CABG. In the other procedures, the CVs in districts and new areal units did not show

Figure 2. The distributions of the populations in the administrative units (districts) and new areal units.

Table 1. The statistics of variation in the administrative units (districts) and the new areal units

	EQ		IDR		CV		SCV	
	Districts	New areal units	Districts	New areal units	Districts	New areal units	Districts	New areal units
CABG	21.75	5.53	3.12	1.97	0.52	0.30	4.2	4.7
PTCA	3.63	2.50	1.69	1.55	0.22	0.20	3.8	4.0
HIP	3.45	1.92	1.58	1.43	0.20	0.14	2.6	1.6
KNEE	3.92	2.56	2.04	1.73	0.27	0.22	11.9	5.5
HYS	3.54	2.53	1.63	1.48	0.20	0.17	2.1	2.8
CSEC	2.97	1.70	1.49	1.39	0.16	0.13	2.5	1.9
CT	2.06	1.48	1.31	1.25	0.12	0.09	1.9	1.1
MRI	2.81	2.31	1.37	1.34	0.16	0.16	2.3	2.5

EQ, extremal quotient; IDR, inter-decile ratio; CV, coefficient of variation; SCV, systematic component of variation; CABG, coronary artery bypass graft surgery; PTCA, percutaneous transluminal coronary angioplasty; HIP, surgery after hip fracture; KNEE, knee-replacement surgery; HYS, hysterectomy; CSEC, caesarean section; CT, computed tomography scan; MRI, magnetic resonance image scan.
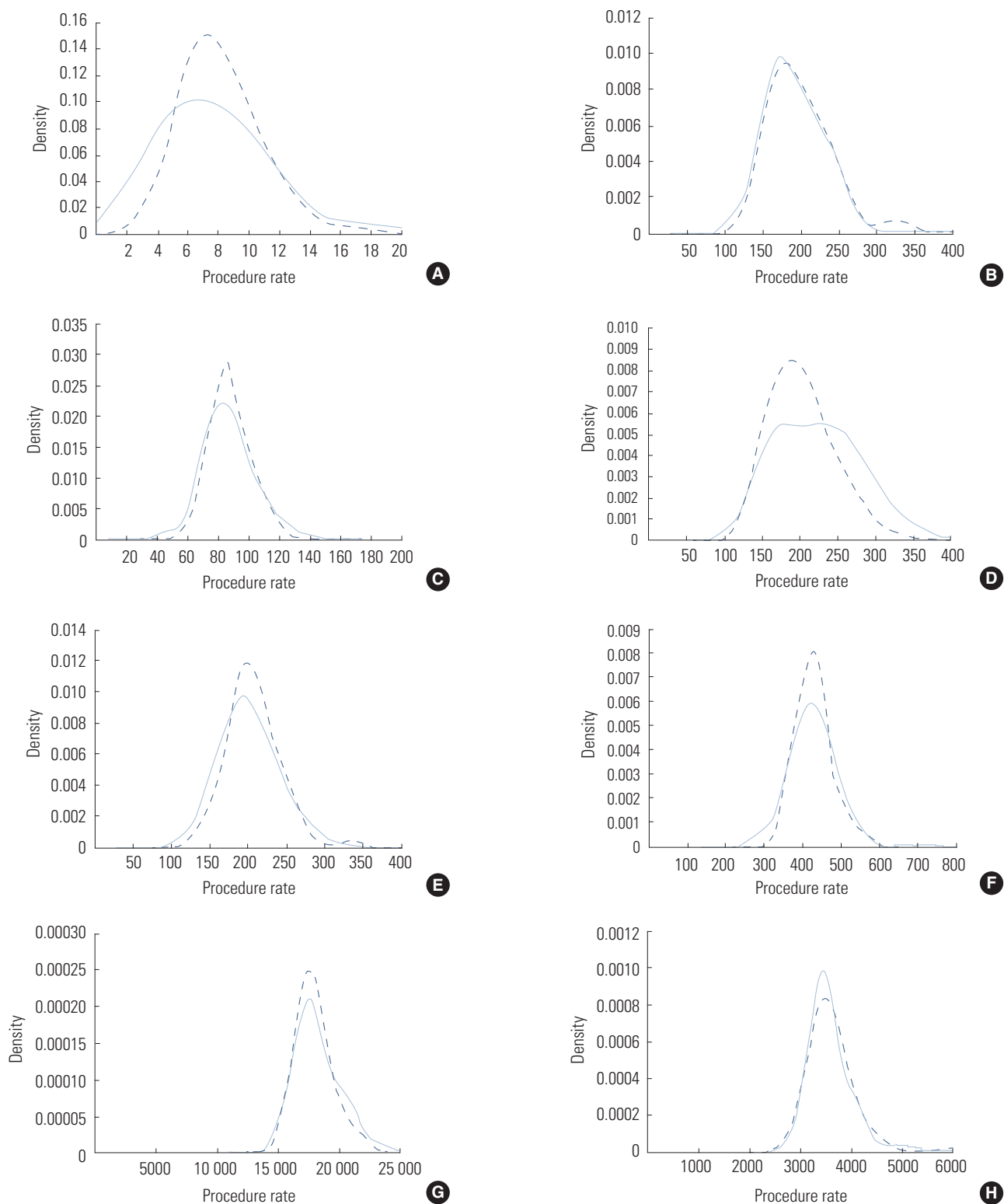
Figure 3. The kernel density function for age–sex standardized rates of the eight (A: coronary artery bypass graft surgery, B: percutaneous transluminal coronary angioplasty, C: surgery after hip fracture, D: knee-replacement surgery, E: hysterectomy, F: caesarean section, G: computed tomography scan, and H: magnetic resonance image scan) procedures in the administrative units (districts) and the new areal units. Solid lines represent the rate distribution in the administrative units (districts) and dotted lines represent the rate distribution in the new areal units.

a marked difference from the average of the other countries.

DISCUSSION

In this study, we compared population distribution and variation in procedure rates between administrative units and new areal units to evaluate the effect of the geographic unit of analysis on measuring geographic variation. The results showed that the variation both in the population size and the rate of some procedures decreased with the use of new areal units.

Although variation in population sizes decreased in new areal units, the CV of population sizes in new areal units was the highest in comparison to the 18 administrative units of the 13 OECD member countries and close to twice the average CV of the 18 geographic units. Given that the disparity in population sizes of the administrative units in those countries is considered large enough to cause extra-variation [3] and that the variation in population distribution in new areal units in this study is still larger compared with the administrative units in those countries, the population distribution of actual health care use in Korea seems highly uneven.

When comparing variation statistics between districts and new areal units, the EQ, the IDR, and the CV decreased for most of the procedures in new areal units. A decrease in variation was prominent in the rate of CABG. This result is consistent with a previous study, where the impact of geographic units on variation appeared significant in infrequent conditions (less than 100 per 100 000 inhabitants) [3]. Compared with other procedures, CABG is performed less frequently (Supplemental Table 1) and mainly performed in large-scale hospitals. In this study, procedure rates were calculated on the basis of the patient's place of residence. A sharp decrease in variation in CABG between districts and new areal units indicates the likelihood that the rate of CABG is strongly influenced by the presence of an available hospital.

The change of the SCV between new areal units and districts is not consistent among procedures as in CV, which showed a decrease in the new areal units. As SCV is designed to extract the part of the variation caused by the deviation of the population structure of the units from that of the whole population, we can suppose that the new areal units concern mainly population distribution and the variation of procedure rates among the units, but less the population structure within the unit. In a previous study that compared the variation between administrative units and new areal units [3], change to the SCV was ambiguous while the EQ and the IQR showed decreases in new areal units. However, the present study is different from the previous study in that there was an explicit decrease or increase in SCV depending on the procedure. While the decrease in the SCV in new areal units can be explained as the decrease in variation, as in the case of the CV, an increase in the SCV in new areal units in some procedures such as CABG, PTCA, hysterectomy, and MRI suggests that true variation based on actual healthcare use increased despite the decrease in the apparent variation (CV). The CVs of procedure rates were high in CABG and knee-replacement surgery in both geographic units. This result is similar to results in previous studies [29,30]. In the case of CABG, the cardiologist performing the index catheterization and the treating hospital are known to be major factors in determining treatment options [31]. And patient preference also plays an important role [29]. With regard to knee-replacement surgery, the absence of clear guidelines or indication may contribute to geographic variation [30]. In addition, the patient's preference is deemed important in making a decision on knee-replacement surgery [32].

Regarding the SCV, it has been suggested that an SCV greater than 3.0 could indicate that the variation is due to differences in practice style or medical discretion and variation with an SCV greater than 5.4 can be considered high, with an SCV greater than 10 considered very high [27]. In this study, the SCV was the highest in knee-replacement surgery, at 11.9 in the districts and 5.5 in new areal units. And in CABG and PTCA, the SCV was greater than three in both geographic units. This result is consistent with the previous study [27].

We compared the CV in districts and new areal units in Korea with that in the administrative units of the 13 OECD member countries. Although districts in Korea showed a higher CV than the average of the 13 countries for CABG, considering that the average population size in the districts and the new areal units is smaller than the average population size of the 13 OECD member countries and that CABG is a less frequently performed procedure, a higher CV for CABG in Korea is likely to be an overestimation. In the case of new areal units, the degree of variation was at a similar level with that in the other countries. As we discussed in the previous section, variation in population sizes in Korean administrative units is markedly higher than that in the other countries under analysis. Although the CVs in the OECD report were calculated on the basis of administrative units, prominently high variation in population size among the districts in Korea might have influenced

Table 2. The distributions of populations and the coefficient of variation of the utilization rates of the eight procedures in 14 countries

Country	Distribution of populations			CV of utilization rates of the eight procedures[1]							
	Geographic unit (total no. of units)	Average of the population sizes of the units	CV of population size	CABG	PTCA	HIP	KNEE	HYS	CSEC	CT	MRI
Australia[2]	Medicare locals (61)	365 966	0.56	0.21	0.24	0.23	0.19	0.20	0.10	N/A	N/A
Belgium[3]	Provinces (11)	1 447 994	1.07	0.17	0.18	0.16	0.14	0.13	0.09	0.18	0.18
Canada[4]	Provinces/territories (13)	2 641 738	1.44	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Health regions (80)	418 413	1.06	0.25	0.22	N/A	0.32	0.27	0.16	0.36	0.32
Czech Republic[5]	Regions (14)	754 444	0.43	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Districts (77)	137 172	1.04	N/A	N/A	N/A	0.16	0.39	0.11	N/A	N/A
Finland[6]	Hospital districts (20)	268 646	1.18	0.34	0.30	0.13	0.18	0.20	0.18	0.24	0.24
France[7]	Departments (96)	660 166	0.76	0.29	0.23	0.09	0.19	0.18	0.12	N/A	N/A
Germany[8,9]	Lands (16)	5 074 846	0.92	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Spatial planning regions (96)	838 789	0.74	0.24	0.22	0.11	0.17	0.14	0.13	N/A	N/A
Israel[10]	Districts (6)	1 251 900	0.26	0.27	0.12	0.14	0.28	0.23	0.16	N/A	N/A
Italy[11]	Regions (20)	3 031 322	0.81	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Provinces (110)	551 150	1.09	0.30	0.23	0.14	0.20	0.17	0.29	N/A	N/A
Portugal[12]	Groups of municipalities (28)	360 077	1.12	0.41	0.27	0.15	0.39	0.27	0.13	N/A	N/A
Spain[13]	Autonomous communities (17)	2 741 286	0.89	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Provinces (50)	884 746	1.20	0.50	0.30	0.20	0.31	0.21	0.26	N/A	N/A
Switzerland[14]	Cantons (26)	315 235	1.05	0.26	0.17	0.20	0.17	N/A	0.15	N/A	N/A
UK/England[15]	Primary care trusts (151)	333 983	0.59	0.30	0.22	0.16	0.19	N/A	0.11	N/A	N/A
OECD average[16]		1 226 549	0.90	0.30	0.23	0.16	0.22	0.22	0.15	0.26	0.25
Korea	Districts (163)	313 751	2.87	0.50	0.22	0.15	0.26	0.16	0.20	0.12	0.15
	New areal units (57)	897 219	1.67	0.32	0.21	0.16	0.21	0.12	0.17	0.09	0.16

CABG, coronary artery bypass graft surgery; PTCA, percutaneous transluminal coronary angioplasty; HIP, surgery after hip fracture; KNEE, knee-replacement surgery; HYS, hysterectomy; CSEC, caesarean section; CT, computed tomography scan; MRI, magnetic resonance image scan; CV, coefficient of variation; N/A, not available; OECD, Organization for Economic Cooperation and Development.
[1]CVs of the OECD countries except Korea were extracted from Geographic variation in health care, OECD (2014).
Sources from [2]Medicare local population estimates update 2012, Australian Government Department of Human Services; [3]Total regional population of Belgium 2012, Statistics Belgium; [4]Health indicators 2012, Canadian Institute for Health Information; [5]Czech Republic general information, Czech Statistical Office; [6]Geographic variation in health care, OECD (2014); [7]Population from 1968 to 2014, National Institute of Statistics and Economic Studies (France); [8]Spatial planning region by area and population, Federal Statistical Office (Germany); [9]Population on the basis of census, Federal Statistical Office (Germany); [10]Population, by District, Sub-District and Religion, Central Bureau of Statistics (Israel); [11]Demographic balance for the year 2011 and resident population on the 8th October, National Institute of Statistics (Italy); [12]Population provisional estimates of resident, National Institute of Statistics (Portugal); [13]Population and housing census 2011, National Statistics Institute (Spain); [14]Permanent resident population per canton, Swiss Federal Statistical Office; [15]NHS (England) summarised accounts 2010-2011, UK for the Stationery Office; [16]Calculated based on the information presented in this table.

the variation. And among the administrative units in the 13 OECD countries with which we compared the areal units in Korea, there are differences in the average and variation of the population sizes. Therefore, comparing variation in procedure rates based on those areal units may be statistically inappropriate. In interpreting the comparison, those limitations should be considered. To make a fair comparison of variation among countries, these issues should be addressed in future studies.

There are several limitations to this study. First, describing mainly the difference in variation among geographic units, we did not investigate which characteristics of geographic units influence geographic variation. Although we suspected that the population size of the unit and the total number of geographic units could influence variation, we did not identify other sources of variation. Second, regarding a decrease in the geographic variation in new areal units, we did not measure how much the number of geographic units and the variation in population distribution contributed to geographic variation. Third, although this study used an age–sex standardized rate to adjust population characteristics in measuring variation,

population characteristics such as disease prevalence might not have been adjusted. Fourth, in the case of MRI, whose NHI coverage does not apply to all cases, the variation statistics produced in this study may not fully reflect the actual variation of the rate of all the MRI procedures performed in Korea.

Through this study we confirmed that geographic variation in medical services utilization could vary according to the geographic unit of analysis. And we also found that current administrative units in Korea might be vulnerable to extra-variation because of high variation in population size. In that respect, a statistically more comparable unit of analysis is needed. Future studies should be performed to elucidate how regional characteristics like population distribution affect geographic variation and to identify other factors that can influence geographic variation.

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CONFLICT OF INTEREST

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Supplemental Table 1. Use of the eight selected procedures and annual rate (2013 period, Korea)

	No. of procedures	Annual rate per 100 000 population (CSEC: per 1000 live births)
CABG	3112	7.7
PTCA	68 731	170.6
HIP	30 433	69.5
KNEE	67 244	153.8
HYS	47 482	216.1
CSEC	161 780	370.9
CT	7 100 895	15 735.1
MRI	1 304 966	2913.9

CABG, coronary artery bypass graft surgery; PTCA, percutaneous transluminal coronary angioplasty; HIP, surgery after hip fracture; KNEE, knee-replacement surgery; HYS, hysterectomy; CSEC, caesarean section; CT, computed tomography scan; MRI, magnetic resonance image scan.