Association between years since manufacture and utilization of computed tomography scanner in South Korea

A cross-sectional study (a STROBE-compliant article)

Jae-Seok Hong, PhD*

Abstract

Health care institutions that acquire an expensive, brand-new computed tomography (CT) scanner are likely to perform excessive scanning in an attempt to recover their investment as early as possible. We examined the association between the age of CT scanners and the number of CT scans at small-sized hospitals and clinics in Korea and assessed the notable increase in scanning quantity at health care institutions with a recently manufactured CT scanner.

A cross-sectional study designed to analyze whether the age of CT scanners was associated with the number of scans at small-sized hospitals and clinics that were operating a CT scanner for the full year 2008 (n = 703). Data were obtained by linking the National Health Insurance Claims Database and Health Care Institution Statistics.

A multiple regression analysis found that the older a CT scanner was, the fewer CT scans were performed in terms of annual total ($b = -34.8; P < .001$) and patient average ($b = -0.0018; P < .001$).

Health care institutions with newer CT scanners administered more CT scans in terms of annual total and scans per patient. Because this may indicate the practice of excessive scanning with newly acquired equipment, it is necessary to have a system of regularly monitoring the quantity and retake rate of CT scanning in these health care institutions so as to prevent unnecessary use of CT.

Abbreviations: CCI = Charlson Comorbidity Index, CT = computed tomography, FFS = fee-for-service, HIRA = Health Insurance Review and Assessment, MRI = magnetic resonance imaging.

Keywords: age of computed tomography scanner, computed tomography scanner, utilization

1. Introduction

Rising demand for medical services using cutting-edge instruments has accelerated the installation and operation of high-cost medical diagnostic equipment such as computed tomography (CT) and magnetic resonance imaging (MRI) scanners in health care institutions. Expensive medical equipment is cited as a major cause for the recent rise in medical service costs.[1–3]

The number of CT scans in the United States was 50.1 million in 2003, which is a 10% increase from 45.4 million in the previous year.[10] The number also grew in Korea, by 20% every year from 2003 to 2007; the number was 2.26 million in 2003, 2.71 million in 2006, and 3.29 million in 2007.[4]

In Korea, regulations on the installation of expensive medical equipment, including CT and MRI scanners, at health care institutions have been relaxed since an import permit system for such equipment was changed to an import reporting system in 1988. CT examinations started to be covered by national health insurance in January 1996, and from then on, many health care institutions, mostly small-sized hospitals and clinics, have jumped into a competition to attract more ambulatory patients with the introduction of high-cost medical diagnostic equipment.

The number of CT scanners per million in Korea is currently about twice the OECD average. Based on such statistics, the introduction of an inordinate amount of expensive medical equipment has been the subject of growing concern in recent years.[11,12] Criticism over unreasonable and reckless introduction of expensive medical equipment into small-sized hospitals or clinics has also continued unabated.[6–8]

Korean health care providers under the national health insurance system have been reimbursed on a fee-for-service (FFS) basis. This FFS model provides an incentive for physicians to render more health care services to bring in more payments.[9]

Berenson et al.[10] found that profitable diagnostic imaging procedures rapidly migrated from hospitals to physician-owned ambulatory centers after 2000. In the Medicare FFS system, as
another report pointed out, specialist physicians who operate an ambulatory center with a high-priced medical device installed could perform more procedures to earn more income.\(^{11}\)

Generally, the improvement in medical equipment technology not only brings about functional enhancement but also increases price. Therefore, under an FFS reimbursement system, a health care institution that acquires a high-cost advanced CT scanner is likely to engage in excessive scanning to recover the large investment as quickly as possible.

This study examined the association between the age of CT scanners installed and operated at small-sized hospitals and clinics in Korea and the annual number of CT scans performed. The study also assessed the notable increase in scanning quantity at health care institutions with recently manufactured CT scanners, and thus providing relevant information needed to establish a policy regarding the reasonable use of CT.

2. Methods

2.1. Data source

Insurance claims for CT use submitted in 2008, which were obtained from the National Health Insurance Claims Database, were linked with Health Care Institution Statistics. CT uses for nonbenefit items were excluded from analysis. In the Korean National Health Insurance system, a physician is required to submit a claim showing medical services and prescriptions of medication rendered to patients. Forty-nine million Koreans, 98% of the total population, are currently national health insurance subscribers, and thus construction of national database with a huge amount of health insurance claims has been enabled.\(^{14}\)

Health Care Institution Statistics contain information on the human resources, facilities, and medical devices of Korean health care institutions. According to the Enforcement Rule of the National Health Insurance Act of Korea, a health care institution must report its human resources, facilities, medical devices, and any changes of the information to the Health Insurance Review and Assessment Service (HIRA). The reported information is regularly verified, and any omitted information is additionally collected by the HIRA.

2.2. Study design and subjects

This was a cross-sectional study designed to examine the association between the age of CT scanners and the number of CT scans at health care institutions in 2008. The unit of analysis was a small-sized hospital or clinic. To analyze institutions with a CT scanner in use over the same period, hospitals or clinics that acquired or disposed of a CT scanner during the year 2008 were excluded from analysis.

A total of 761 hospitals or clinics were operating a CT scanner for the full year of 2008. Of these, institutions that had 2 or more CT scanners with a different year of manufacture (\(n=8\)) were excluded from analysis because we could not identify which scanner was used from the data. Institutions at which CT was performed on fewer than 30 patients (\(n=50\)) were additionally excluded (Fig. 1). The final recruited study subjects were 703 institutions consisting of 361 hospitals and 342 clinics in South Korea.

This study was approved by the Institutional Review Boards of the HIRA.

2.3. Study variables

The number of CT scans was the dependent variable of this study. It was computed from all health insurance claims for CT scan services rendered by hospitals and clinics during the year 2008.

The age of a CT scanner installed and operated at a health care institution was the primary independent variable of this study. The age referred to a time period, expressed in years, from the manufacture of the CT scanner through its current use in 2008.

Covariates consisted of the characteristics of health care institutions and the characteristics of patients who underwent CT scans in a health care institution. The characteristics of health care institutions included type of institution (hospital or clinic), residency of radiologist (resident or nonresident), and location of institution (Seoul, metropolitan city, city, or county). In this study, Korea’s geographical location was classified into 4 regions: Seoul, as a special city, metropolitan areas, cities, and counties. The administrative divisions of Korea include 1 special city (Seoul), 6 metropolitan cities, and 9 provinces. Each province is subdivided into cities and counties. Each city has a population of at least 150,000. Each county has a population of <150,000.\(^{12,13}\)

The characteristics of patients who underwent CT scans in a health care institution included the proportion of male patients, mean age of patients, proportion of patients who underwent a surgical operation after the scan, proportion of inpatients, proportion of Medical Aid recipients, and mean of the Charlson Comorbidity Index (CCI). CCI was calculated based on diagnostic information of patients for 1 year before their CT scan in 2008.

2.4. Statistical analysis

The \(t\) test and analysis of variance were performed to assess differences in the annual total number of CT scans and the number of CT scans per patient by the age of the CT scanner and the characteristics of the health care institution, and a multiple regression analysis was performed to examine whether the age of the CT scanner was associated with the annual total number of CT scans or the number of CT scans per patient. The SAS System (Version 8.1 for Microsoft Windows) was used as statistical software.

3. Results

3.1. Comparison of the annual total number of CT scans by CT scanner age

The annual total number of CT scans by CT scanner age is shown in Figure 2. Institutions that had a CT scanner <7 years old...
administered, on average, more than 1000 CT scans in 2008. However, the annual total number of CT scans rapidly decreased in institutions that had a CT scanner aged 7 years or above.

The annual total number of CT scans in institutions that had a 0- to 4-year-old CT scanner averaged 1205.9, which was 1.8 times more than that in institutions that had a CT scanner aged 10 years or above (mean, 576.0). The number of CT scans per patient was also higher when the CT scanner was younger (Table 1).

In a comparison of the characteristics of health care institutions (Table 1), the annual total number of CT scans was higher in hospitals than in clinics and was also higher in institutions with a radiologist. The number of CT scans per patient showed a similar trend.

In terms of institution location, the annual total number of CT scans was highest in institutions located in a metropolitan city (mean, 1115.5), whereas the number of CT scans per patients was highest in institutions located in Seoul (mean, 1.078).

### 3.2. Association between CT scanner age and number of CT scans

The association between CT scanner age and number of CT scans was examined using a multiple regression analysis (Table 2). After adjusting for the characteristics of health care institutions, the annual total number of CT scans decreased as the CT scanner age increased (Model 1: $\beta = -35.7; P < .001$). After additionally adjusting for the characteristics of patients who underwent CT scans, increasing age of the CT scanner lowered the annual total number of CT scans (model 2: $\beta = -34.8; P < .001$) and was also associated with a decrease in the number of CT scans per patient (model 1: $\beta = -0.0022, P < .001$; model 2: $\beta = -0.0018, P = <.001$).

![Figure 2. Number of CT scans by CT scanner age in 2008. CT = computed tomography.](image)

| Number of computed tomography scans by characteristics of health care institutions. |
|---------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| No. institutions | Annual total no. CT scans | No. CT scans per patient |
|------------------|-----------------------------|---------------------------|
| N | % | Mean | SD | P | Mean | SD | P |
|------------------|-----------------------------|---------------------------|
| Total | 703 | 877.1 | 926.6 | 1.062 | 0.070 |
| Age of CT scanner | | | | | | |
| 0–4 y | 220 | 31.3 | 1205.9 | 1078.2 | <.001 | 1.079 | 0.080 | <.001 |
| 5–9 y | 225 | 32.0 | 900.7 | 968.1 | 1.068 | 0.079 |
| 10+ y | 258 | 36.7 | 576.0 | 594.8 | 1.043 | 0.045 |
| Type of health care institution | | | | | | |
| Hospital | 361 | 51.4 | 998.2 | 1001.3 | <.001 | 1.091 | 0.079 | <.001 |
| Clinic | 342 | 48.6 | 749.2 | 822.9 | 1.032 | 0.042 |
| Resident | 390 | 55.5 | 1066.6 | 1066.6 | <.001 | 1.067 | 0.068 | .055 |
| Nonresident | 313 | 44.5 | 468.5 | 468.5 | 1.057 | 0.073 |
| Location | | | | | | |
| Seoul | 82 | 11.7 | 802.0 | 977.4 | <.001 | 1.078 | 0.117 | <.001 |
| Metropolitan city | 195 | 27.7 | 1115.5 | 1204.1 | 1.051 | 0.054 |
| City | 338 | 48.1 | 768.2 | 758.0 | 1.054 | 0.053 |
| County | 88 | 12.5 | 836.6 | 632.2 | 1.102 | 0.085 |

ANOVA = analysis of variance, CT = computed tomography.

* A time period, expressed in years, from the manufacture of CT scanner through its current use in 2008.

† t test.
Patient characteristics

| Age of CT scanner | Parameter estimate | Standard error | P   |
|-------------------|--------------------|----------------|-----|
| 1989-1993         | -35.7              | 6.6            | <.001|
| 1994-1996         | -34.8              | 6.4            | <.001|

Diagnostic imaging services using high-cost medical equipment such as CT and MRI scanners are the most rapidly expanding sector of health care services.\textsuperscript{2,3,14-16} According to a Congressional testimony by the United States Medicare Payment Advisory Commission, over the time period of 1999 to 2004, diagnostic imaging services reimbursed under the physician fee schedule increased more rapidly than did the other 3 broad categories of physician services (procedures, evaluation and management, and laboratory services).\textsuperscript{19}

Such a trend is observed in Korea as well. The number of CT scanners installed at Korean health care institutions increased 5.9 times from 262 in 1990 to 1537 in 2005.\textsuperscript{19} Claims for CT scan services increased 2.2 times from 1.5 million in 2002 to 3.29 million in 2007, and 2.8 times from 262.3 billion Won [KRW] in 2002 to 701.9 billion Won [KRW] in 2007.\textsuperscript{4,20} In particular, it is reported that the number of CT scans increases as the number of beds and specialists increases and higher in institutions located on big cities. It seems to be related to the diversity of medical specialty and disease.\textsuperscript{14,16} In this study, the annual total number of CT scans was higher in hospitals than in clinics and was also higher in institutions with a radiologist and located on Seoul and metropolitan city.

Major factors contributing to the recent increase in diagnostic imaging services include advancement in technology and its resultant wider availability, increased demand by patients and physicians, and favorable reimbursement of services.\textsuperscript{2} With the advent of better technology, a more compact scanner makes it easier for physicians to provide imaging in their offices, providing the increased convenience of in-office imaging. Added revenue from diagnostic imaging services, such as radiologist interpretation fees, and physicians practicing defensive medicine also are understood to have contributed to the growth in diagnostic imaging services.\textsuperscript{1,2} In the early 1980s, the import of high-cost medical equipment to Korea, the only source of supply for the equipment at that time, was regulated with a permit system to ensure efficient utilization of medical equipment and to prevent wasted medical costs. The permit system was eased to a reporting system in 1988. The government’s administrative controls regarding the introduction of high-cost medical equipment into health care institutions were removed in 1994. Small-sized hospitals and even clinics then started to introduce expensive medical equipment. Currently, 70% of all CT scanners in operation in Korea are installed at

4. Discussion

The adjusted $R^2$ of the multiple regression model (Model 2) was approximately 21–33%, and the significance of explanatory variables is shown with a 95% confidence interval. Multicollinearity was not observed because the variation inflation factor was <10, and no autocorrelation in the residuals was observed given that the Durbin-Watson statistic was approximately 2. As a result of the residual analysis, the assumptions of the model were also satisfied. The Cook distance values for examining the outliers was <1.0.

The adjusted $R^2$ of the multiple regression model (Model 2) was approximately 21–33%, and the significance of explanatory variables is shown with a 95% confidence interval. Multicollinearity was not observed because the variation inflation factor was <10, and no autocorrelation in the residuals was observed given that the Durbin-Watson statistic was approximately 2. As a result of the residual analysis, the assumptions of the model were also satisfied. The Cook distance values for examining the outliers was <1.0.
small-sized hospitals and clinics.\textsuperscript{[6]} Although an appropriate number of CT scanners for small-sized hospitals and clinics to operate is not known, the fact that two thirds of CT scanners are installed at small-sized hospitals and clinics is clearly not ideal from the perspective of the efficient use of CT scanners and the disease severity of patients visiting those hospitals and clinics. Accordingly, there are growing concerns that such questionable and haphazard installation of equipment may cause unnecessary diagnostic imaging services to be performed and ultimately worsen the national health insurance financial situation.

This study shows that a small-sized hospital or clinic with a CT scanner <5 years old performed, on average, >1200 scans in 2008, whereas the same kind of institution having a CT scanner >9 year old performed about 600 scans. After adjusting for institution characteristics (specialty, location, and residency of radiologist) and patient characteristics (proportion of male patients, mean age of patients, proportion of patients who underwent a surgical operation after the scan, proportion of inpatients, proportion of Medical Aid recipients, and mean CCI of patients), the annual total number of CT scans tended to be higher in institutions with a newer CT scanner. The number of CT scans per patient was particularly higher in institutions having a more recently manufactured CT scanner, suggesting overuse of the CT scan at those institutions.

The intensifying competition between health care providers in Korea is attributed to the separation of prescribing from dispensing in July 2000, the growing number of physicians, a low birth rate, and an aging population. In this environment, the introduction of advanced medical equipment has been perceived as one of the means for a health care provider to be more competitive. However, a health care provider who acquires expensive equipment beyond his or her financial capabilities is necessarily likely to perform excessive tests for added revenue. The overuse of CT scans is also more likely to occur in an institution that acquired a brand-new CT scanner because it is important to recover the investment as early as possible. Therefore, an appropriate evaluation or measurement scheme regarding this issue needs to be provided.

This study has some limitations. First, cause and effect cannot be distinctively established. Even with statistically significant correlation between age of the CT scanner and the number of scans performed, it still only describes a correlation and not causal relationship. It is not clear whether hospitals and clinics acquired high-cost medical diagnostic equipment to be more competitive and thus overused the device for an early recovery of investment, or whether increasing demands by patients for scan services caused by lowered patient burden for the use of high-cost medical diagnostic equipment drove health care providers to acquire the high-cost medical diagnostic equipment. Similarly, it is difficult to define excessive use of the new equipment without looking at the billing codes and diagnostic use of each case. Relman reported that the introduction of new technology in the hands of specialists, expended insurance coverage, and unregulated FFS payments all combined to rapidly increase the flow of money into the health care system and thus sowed the seeds of a new, pro-finance situation.

Second, this study could not analyze CT scans for patients not covered by national health insurance, such as patients with injuries from automobile accidents. Although these injuries may entail fractures, and these patients are likely to undergo diagnostic imaging such as CT scans, relevant care records were not found in claims data. We imagined that institutions located in cities in which more traffic accidents occur might omit records for CT scans, and thus we attempted to minimize the effects of uninsured benefits by taking location into account.

Third, this study used the data of the year 2008 and it could be a problem to apply to the current situation. However, this result is to suggest the possibility that an institution acquiring a brand-new CT scanner is likely to perform excessive tests to recover the investment as early as possible. It could be meaningful to apply this result to set the rule for monitoring overuse of CT scans in current practices. In this regard, further study will be needed to examine the relationship using recent data.

This study examined the association between scanner age and number of scans using information on CT scans performed by all small-sized hospitals and clinics across Korea in 2008. Despite some limitations, this study has significance in that the association was empirically verified, as the number of CT scans increased in health care institutions that acquired more recently manufactured CT scanners.

To rein in the excessive use of profitable high-cost equipment, we need to develop appropriate payment methods. Above all, the effects of incentive payments for more services in the FFS system must be controlled.\textsuperscript{[13]} The Centers for Medicare and Medicaid Services provides relevant information to physicians who claim higher costs for diagnostic and imaging procedures than their peers and educates them to prevent inefficient payment in relevant areas and control the increase in scans for a certain period.\textsuperscript{[24]} This monitoring system regularly reviews the number of scans per device and the retake rate in health care institutions, providing control of unnecessary use as well as excessive use of the device. Therefore, prior to directly establishing a policy, a system to trace the scan information of a device is essential.

As concerns over the increase in medical service costs caused by the use of high-cost medical diagnostic equipment are growing, this study implies that governments or insurers should take into account complex effects of various factors influencing a health care provider’s economic motivation.

5. Conclusions

The annual total number of CT scans and the number of CT scans per patient were higher in health care institutions with more recently manufactured CT scanners, raising a concern over excessive use of newly acquired equipment. In an effort to prevent this, we need to establish a system that regularly monitors the number of scans or the retake rate in health care institutions.

This study presents the correlation between brand-new, high-cost medical devices and their excessive use and suggests that various factors need to be considered to block health care providers’ economic motivation when a relevant policy is prepared.

Author contributions

Jae-Seok Hong contributed to conception and design, or analysis and interpretation of data; and to drafting the article or revising it critically for important intellectual content; and on final approval of the version to be published.
References

[1] Amis ES Jr, Butler PF. ACR white paper on radiation dose in medicine: three years later. J Am Coll Radiol 2010;7:865-70.

[2] Smith-Bindman R, Miglioretti DL, Larson EB. Rising use of diagnostic medical imaging in a large integrated health system. Health Aff (Millwood) 2008;27:1491-502.

[3] Mitchell JM. Utilization trends for advanced imaging procedures: evidence from individuals with private insurance coverage in California. Med Care 2008;46:460-6.

[4] National Health Insurance Statistical Yearbook [Korean]. National Health Insurance Corporation, Health Insurance Review and Assessment Service: Seoul; 2008.

[5] Organization for Economic Cooperation and Development (OECD). Health Data, 2009. Available at: https://stats.oecd.org/index.aspx?DataSetCode=HEALTH_STAT. Accessed October 13, 2018.

[6] Oh YH, Kim JH. The demand and supply of major medical equipment and policy recommendations [Korean]. Health Soc Welfare Rev 2007;27:96-121.

[7] Lee SY, Oh YH, Song HJ, et al. The Present Condition of Supply and Demand for Healthcare Resources and Management Policy Implications [Korean]. Seoul: Korea Institute for Health and Social Affairs, 2003.

[8] Chung W, Yoon KI, Park YT, et al. Study on the Utilization of High Price Medical Equipments [Korean]. Korea Institute for Health and Social Affairs, Seoul,2000.

[9] Bodenheimer TS, Grumich K. Improving Primary Care: Strategies and Tools for a Better Practice. McGraw-Hill, New York:2007.

[10] Berenson RA, Ginsburg PB, May JH. Hospital-physician relations: cooperation, competition, or separation? Health Aff (Millwood) 2007;26:w31-43.

[11] Bodenheimer TS, Grumich K. Understanding Health Policy: A Clinical Approach. 5th ed. New York:McGraw-Hill; 2008.

[12] Ministry of the Interior and Safety. Cities and Provinces in Korea. Available at: <http://www.mois.go.kr/eng/subs/a04/citiesProvinces/screen.do>. 2018. Accessed April 30, 2018.

[13] Hong JS, Kang HC. Regional differences in treatment frequency and case-fatality rates in Korean patients with acute myocardial infarction using the Korea National Health Insurance claims database: findings of a large retrospective cohort study. Medicine (Baltimore) 2014;93:e287.

[14] Bhargavan M, Sunshine JH. Utilization of radiology services in the United States: levels and trends in modalities, regions, and populations. Radiology 2005;234:824-32.

[15] Oh EH, Imakaka Y, Evans E. Determinants of the diffusion of computed tomography and magnetic resonance imaging. Int J Technol Assess Health Care 2005;21:73-80.

[16] Medicare Payment Advisory Commission. A Data Book: Healthcare Spending and the Medicare Program. 2010. Available at: http://www.macgroupandassociates.com/pdf/Jun12DataBookEntireReport.pdf. Accessed October 13, 2018.

[17] Glijins AC, Halm EA. The Changing Economics of Medical Technology. National Academy Press, Washington, DC:1991.

[18] Hendee WR. The dilemma of health care quality, access, and cost and its effect on MR imaging. J Magn Reson Imaging 1991;1:615-7.

[19] Hackbarth GM. MedPAC Recommendations on Imaging Services. Medicare Payment Advisory Commission; 2006:7. Available at: http://67.59.137.244/documents/071806_Testimony_imaging.pdf. Accessed October 13, 2018.

[20] National Health Insurance Statistical Yearbook [Korean]. National Health Insurance Corporation, Health Insurance Review and Assessment Service, Seoul:Available at: https://www.hira.or.kr/sViewer/index.do?ebookSn=342. Accessed October 13, 2018.

[21] Bae ER. The Study on the Main Factor Influencing CT [Dissertation]. Seoul: Korean University; 2008. [Korean]

[22] Miller ME. MedPAC Recommendations on Imaging Services. Medicare Payment Advisory Commission; 2005:3. Available at: https://www.aaos.org/govt/pubs/public/Imaging/MedPAC_Imaging.pdf. Accessed October 13, 2018.

[23] Relman AS. A Second Opinion: Rescuing America’s Health Care. Public Affairs, New York, NY,2007.

[24] U.S. Government Accountability Office. Medicare Part B Imaging Services: Rapid Spending Growth and Shift to Physician Offices Indicate Need for CMS to Consider Additional Management Practices; 2008:6. Available at: https://www.gao.gov/new.items/d08452.pdf. Accessed October 13, 2018.