Association of the Implementation of PACS with Hospital Revenue

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The purpose of this study is to assess the association of implementation of PACS with the inpatient and outpatient revenue of a general hospital. The authors analyzed the in- and outpatient revenue data of all general hospitals (212) in South Korea obtained from the Korean National Health Insurance Corporation (KNHIC) during the period from 1996 through 1999 using the mixed model for repeated measure data. The following variables were used in the analysis: status of picture archiving and communication systems (PACS) implementation, population size, state of competition, inhabitant's income, hospital location, hospital size, whether a tertiary hospital, whether public or private, the effect of year. The revenues from both in- and outpatient departments were significantly higher one year after the introduction of PACS while controlling for the confounding variables. Although the causality needs to be clarified, the implementation of PACS was correlated significantly to the increased amount of inpatient and outpatient revenue.

KEY WORDS: Picture archiving and communication systems, revenue, performance, insurance

P ICTURE ARCHIVING and Communication Systems (PACS) first were introduced to Korea in 1994, and 8.0% of the general hospitals were using the system in 1999.[1] PACS is expected to make the departments more efficient, reduce operating costs, and improve the communication between radiologist and referring physician.[2] Many prior articles have reported the improvement of productivity with implementation of PACS that could affect financial performance of medical institutions.[3-5] However, the effects of PACS on the financial performance of medical institutions have not been studied widely because of the difficulty in obtaining satisfactory performance data.

The purpose of this study is to assess the association of the implementation of PACS with the inpatient and outpatient revenue of a general hospital using the actual revenue of all general hospitals in Korea.

MATERIALS AND METHODS

Subjects

We analyzed every general hospital in Korea that submitted insurance claim data to the Korean National Health Insurance Corporation (KNHIC) from 1996 through 1999 after excluding hospitals that opened or closed during the study period. Therefore, 4 years of panel data (848) were available from 212 hospitals.

The status of PACS implementation was obtained from a survey conducted by the Korean Society of Medical Informatics (KOSMI) in 1998.[1] The hospital's revenue and characteristics were obtained from the KNHIC. The regional socioeconomic characteristics were obtained from the yearbook published by the Korean Statistical Bureau and local governments.

Statistical analysis

Variables were analyzed by either *t* test (for dummy independent variables) or by analysis of variance (ANOVA) (for continuously independent variables) after grouping

them into four categories using interquartile. We also conducted multivariate analysis to control for the effects of confounding variables. However, multiple regression analysis with ordinary least square (OLS) could not be used because the study data were repeated measures data that did not meet the independence assumption for OLS.[6] Moreover, the randomized block design for repeated measures data could not be used here because all observations within the blocks were not correlated equally. Accordingly, we used the mixed model with a special parametric structure of covariance matrices.[6] Autoregressive order 1 covariance was chosen for the covariance structure of our model using AIC (Akaike' Information Criterion) and SBC (Schwarz' Bayesian Criterion). This analysis was performed according to the PROC MIXED procedure in SAS version 8.1.

Variables

The dependent variable was annual revenue from 1996 through 1999. These revenue data were adjusted to the current value of the year 1996 using an annual increase rate in the fee schedule (ie, 8.15% in 1997, 7.68% in 1998, and 3.90% in 1999).[7]

The independent variables were status of PACS implementation, population size, state of competition, inhabitant's income, location of the hospital, hospital size, whether a tertiary hospital, and whether public or private, which were selected by the prior socioeconomic studies about the revenue of hospitals. Although controlling natural trend by mixed model, we also controlled for the effect of the year (ie, 1997 Asian crisis) using dummy variables. All independent variables except the status of PACS implementation were considered as confounding variables influencing the revenue, so these were controlled to examine the more valid association of PACS with the revenue of general hospital.

The status of PACS implementation was determined by the published data of KOSMI. KOSMI surveyed the year when the hospital introduced PACS to information system directors of all of Korean general hospitals by questionnaire and telephone survey.[1] Therefore, we had to use "whether introduced PACS" as independent variable regardless of the scope, network, or interfaces of implemented PACS.

The administrative units for population, competition, and income were city, county, and district. Competition was defined as the number of hospitals within the unit. Income was defined as the inhabitant tax per capita adjusted by the inflation rate. Location of the hospital was defined as either urban or rural. Hospital size was expressed in terms of the number of physicians and beds. We allowed a one-year time lag for revenue data after PACS introduction to reflect the delayed effects of PACS on revenue.

RESULTS

The characteristics of general hospitals are listed in Table 1. Eleven hospitals (5.2%) had introduced PACS in 1996, and 17 hospitals (8.0%) had introduced it in 1999. The percent-

ages of tertiary care and public hospitals in the hospitals that introduced PACS were higher then those in the hospitals that did not. The mean number of beds and physicians of the hospital that introduced PACS were greater than those of the hospital that did not.

The results of the univariate analyses are listed in Table 2. The outpatient and inpatient revenues from 1996 through 1999 for hospitals that introduced PACS were greater than those of the hospitals that did not, based on univariate analysis. However, it was not significant, except for the outpatient revenue in 1999. The relationships between revenues and the tertiary status of a hospital, and the urban status of a hospital, the number of physicians, the population of the district, and the inhabitant tax per capita were statistically significant from 1996 through 1999. However, the number of competing hospitals was found to be positively related to the outpatient and inpatient revenues, and the revenue differences of public and private hospitals were not significant except the outpatient revenue in 1996.

The results of the multivariate analyses are listed in Table 3. Our analysis of the 4 years' panel data of 212 hospitals from 1996 through 1999 showed that the revenues from both in- and outpatient departments were significantly higher one year after the introduction of PACS, while controlling for the confounding variables ($P < .01$). The relationships between revenue and the number of beds and physicians, and the tertiary status of a hospital were statistically significant. In addition, the relationships between outpatient revenue and the urban status of a hospital also were statistically significant. However, the relationships between revenue and population size, and the number of competing hospitals, and the inhabitant tax per capita were not statistically significant.

DISCUSSION

It is known that the use of information technology (IT) can increase the competitiveness and the productivity of the enterprises by improving customer service, reducing production cost, and inhibiting market penetration by competing enterprises.[8,9] However, the effects of IT introduction on organizational perfor-

Table 1. General Characteristics of General Hospitals from 1996 to 1999

Variables (Unit)		1996	1997	1998	1999
Tertiary-care hospital					
PACS*	Yes	3 (27.3)	3 (25.0)	6 (40.0)	7 (41.2)
	No	8 (72.7)	9 (75.0)	9 (60.0)	10 (58.8)
Non-PACS	Yes	34 (16.9)	34 (17.0)	32 (16.2)	32 (16.4)
	No	167 (83.1)	166 (83.0)	165 (83.8)	163 (83.6)
Public/private hospital					
PACS*	Public	6 (54.5)	6 (50.0)	6 (40.0)	8 (47.0)
	Private	5 (45.5)	6 (50.0)	9 (60.0)	9 (53.0)
Non-PACS	Public	38 (18.9)	38 (19.0)	38 (19.3)	36 (18.5)
	Private	175 (81.1)	162 (81.0)	159 (80.7)	159 (81.5)
Region					
PACS*	Rural	7 (63.6)	7 (58.3)	7 (46.7)	7 (41.2)
	Urban	4 (36.4)	5 (41.7)	8 (53.3)	10 (58.8)
Non-PACS	Rural	77 (38.3)	77 (38.5)	77 (39.1)	77 (39.5)
	Urban	124 (61.7)	123 (61.5)	120 (60.9)	118 (60.5)
No. of beds (bed)					
PACS*		434.3 ± 365.7	433.9 ± 348.7	646.4 ± 598.2	640.3 ± 559.6
Non-PACS		387.5 ± 266.3	391.7 ± 272.6	384.8 ± 238.9	386.6 ± 239.9
No. of physicians (person)					
PACS*		127.4 ± 178.6	124.8 ± 168.5	245.7 ± 330.4	204.2 ± 257.8
Non-PACS		102.0 ± 143.6	102.7 ± 143.4	94.8 ± 110.2	92.3 ± 108.3
Population of the district (1,000 person)					
PACS*		402.3 ± 278.8	406.2 ± 270.7	425.2 ± 255.5	412.1 ± 250.7
Non-PACS		340.2 ± 209.8	342.3 ± 213.7	343.8 ± 216	347.0 ± 220.5
No. of competing hospitals (hospital)					
PACS*		1.3 ± 1.5	1.3 ± 1.6	1.3 ± 1.5	1.4 ± 1.5
Non-PACS		1.2 ± 1.3	1.2 ± 1.3	1.2 ± 1.3	1.3 ± 1.3
Inhabitant tax per capita[†] (1,000 won/person)					
PACS*		57.4 ± 72.2	67.7 ± 84.5	69.5 ± 75.6	64.0 ± 75.6
Non-PACS		70.8 ± 125.5	180.2 ± 163.3	92.5 ± 243.1	84.7 ± 195.5
Revenue of outpatient[‡] (million won)					
PACS*		5,799.4 ± 7,423.3	7,711.0 ± 9,478.8	16,922.7 ± 21,028.3	18,427.7 ± 23,272.0
Non-PACS		5,675.9 ± 6,453.0	6,151.8 ± 7,481.6	5,873.7 ± 6,023.0	6,436.9 ± 6,769.6
Revenue of inpatient[‡] (million won)					
PACS*		12,218.2 ± 16,505.1	12,738.8 ± 17,261.2	24,301.0 ± 30,602.5	27,121.8 ± 35,562.1
Non-PACS		9,518.0 ± 11,510.8	9,641.3 ± 12,049.9	8,981.6 ± 9,162.0	9,704.4 ± 10,062.3
Total revenue[‡] (million won)					
PACS*		18,017.6 ± 23,806.6	20,449.8 ± 26,634.8	41,223.7 ± 51,488.4	45,549.6 ± 58,591.7
Non-PACS		15,193.9 ± 17,798.5	15,793.0 ± 19,392.5	14,855.2 ± 15,003.5	16,141.3 ± 16,698.5

NOTE. Values are expressed as frequency and percents in parentheses or means ± SD.

*Introduced in the previous year.

[†]Deflated by consumer price index.

[‡]Deflated by increase rate of fee schedule for health insurance.

mance have not been studied systematically, and the majority of studies have been limited to the effects of IT introduction on user satisfaction and efficiency, or on performance within a division using IT.[10] Similarly, the effect of PACS, which is an essential component of a hospital information system (HIS), has not been well studied.

In previous studies, after transition from the file-based to filmless operation, technologists reported reduction in perceived levels of stress and fatigue,[5,11] and Chan et al[12] reported that their experience with PACS has been successful, with a high degree acceptance and satisfaction of referring physicians. The virtual radiologist feature was very powerful and greatly appreciated by the referring physicians and radiologists. These factors could improve the staff's satisfaction. Arenson[2] described that patient care could improve with faster access to images, and faster access also leads to earlier actions on patients in acute situations such as in the in-

Table 2. The Result of Univariate Analysis for the Hospital Revenue[†] from 1996 to 1999

Variables (Unit)	Outpatient				Inpatient			
	1996	1997	1998	1999	1996	1997	1998	1999
PACS[‡]								
Yes	5,799.4	7,711.0	16,922.7	18,427.7	12,218.1	12,738.8	24,301.0	27,121.8
No	5,675.9	6,151.8	5,873.7	6,769.9	9,518.0	9,641.3	8,981.6	9,704.4
	t = 0.06	t = 0.69	t = 2.03	t = 2.12*	t = 0.74	t = 0.84	t = 1.93	t = 2.01
Public/private hospital								
Public	4,177.7	4,873.5	5,047.1	5,618.3	7,311.7	7,932.9	8,008.7	8,578.0
Private	6,076.4	6,597.9	7,076.7	7,864.7	10,272.6	10,310.0	10,604.2	11,761.9
	t = −2.48*	t = −1.56	t = −1.9	t = −1.79	t = −1.95	t = −1.33	t = −1.56	t = −1.66
Tertiary-care hospital								
Yes	15,532.6	18,020.2	19,133.1	21,567.4	29,088.9	30,258.8	30.155.2	33,385.9
No	3,599.7	3,749.4	3,930.4	4,204.3	5,549.9	5,494.5	5,699.9	6,077.4
	t = 8.12***	t = 8.15***	t = 7.6***	7.64***	t = 9.2***	t = 9.02***	t = 8.9***	t = 8.19***
Region								
Urban	7,252.0	8,103.7	8,692.8	9,710.6	12,222.1	12,507.3	12,761.9	14,187.5
Rural	3,290.5	3,400.1	3,550.9	3,875.1	5,751.1	5,716.6	5,956.6	6,398.0
	t = 5.29***	t = 5.42***	t = 5.36***	t = 5.27***	t = 4.65***	t = 4.68***	t = 4.64***	t = 4.58***
Number of beds (bed)								
<200	1,442.5	1,441.6	1,318.5	1,399.4	1,868.8	1,880.9	1,863.7	1,978.4
<350	2,264.9	2,371.4	2,420.6	2,589.3	3,685.8	3,678.4	3,791.0	4,027.6
<500	5,548.3	5,633.1	5,787.9	6,134.7	8,616.9	8,342.8	8,313.3	8,898.1
Above 500	13,176.4	14,895.5	15,671.2	17,570.9	23,635.8	24,150.0	23,927.3	26,472.8
	F = 81.30***	F = 77.06***	F = 67.70***	F = 64.7***	F = 86.78***	F = 80.57***	F = 77.76***	F = 65.76***
Number of physicians (person)								
<25	1,571.2	1,541.6	1,637.2	1,708.0	2,286.4	2,258.5	2,523.1	2,640.8
<35	3,110.4	3,233.5	3,190.1	3,850.6	5,087.4	4,923.0	4,810.6	5,643.8
<50	6,565.3	7,044.7	7,571.0	7,557.3	10,078.9	10,099.3	10,587.2	10,977.0
≥ 50	13,416.4	15,125.7	16,589.0	18,848.1	23,887.9	24,516.6	25,434.6	28,477.1
	F = 97.26***	F = 87.88***	F = 78.83***	F = 75.68***	F = 98.41***	F = 90.35***	F = 92.31***	F = 78.09***
Population of the district (1,000 person)								
<150	3,404.8	4,060.4	4,099.6	4,462.9	5,494.4	5,998.9	6,132.5	6,486.2
<300	4,862.1	5,202.6	5,563.0	6,086.7	8,530.0	8,685.0	8,786.7	9,551.3
<450	7,897.8	8,020.6	8,750.3	9,744.4	12,858.6	12,315.5	12,882.1	14,091.1
≥ 450	6,375.9	7,266.3	7,721.0	8,794.2	11,247.0	11,495.2	11,661.6	13,377.8
	F = 4.43**	F = 2.95*	F = 3.09*	F = 3.15*	F = 3.67**	F = 2.67*	F = 2.88*	F = 2.92*
Number of competing hospitals (hospital)								
0	4,380.1	4,916.7	5,497.0	6,304.6	7,603.4	7,911.6	8,454.5	9,809.8
1	5,380.2	5,745.9	5,935.4	6,657.5	9,090.5	8,928.7	9,115.7	10,015.7
2	7,292.2	8,973.7	10,061.2	10,508.8	11,948.7	13,505.2	14,261.8	14,345.9
≥ 3	7,336.9	7,248.1	6,973.9	7,539.5	12,629.1	11,808.1	10,935.5	11,997.5
	F = 2.83*	F = 2.86*	F = 2.69*	F = 1.80	F = 2.21	F = 2.23	F = 2.02	F = 1.01
Inhabitant tax per capita (1,000 won)[§]								
<20	3,173.0	3,561.9	2,888.9	3,944.9	6,043.0	6,183.7	4,672.9	6,489.5
<35	4,039.8	4,376.1	4,806.8	5,663.1	6,469.0	6,640.1	7,513.7	8,659.0
<50	7,129.8	7,388.2	7,750.6	9,574.7	12,219.4	11,732.0	11,981.6	14,272.4
≥ 50	7,670.2	8,913.5	9,200.0	9,608.8	13,238.3	14,066.7	13,319.3	13,989.5
	F = 5.9***	F = 5.63***	F = 5.03***	F = 3.92**	F = 5.61***	F = 5.40**	F = 4.33**	F = 3.25*

NOTE. Unit: million won.

*$P < 0.05$.

**$P < 0.01$.

***$P < 0.001$.

[†]Deflated by the of health insurance fee schedule increase rate.

[‡]Introduced in the previous year.

[§]Deflated by Consumer Price Index.

Table 3. The Result of Multivariate Analysis for the Hospital Revenue[†] Using the Mixed Model

Variables	Outpatient			Inpatient		
	Parameter Estimate	S.E.	t value	Parameter Estimate	S.E.	t value
Intercept	−3,410.0	653.0	−5.22***	−4,586.8	793.2	−5.78***
PACS[‡]	3810.3	608.7	6.26**	3323.3	786.1	4.23**
Number of beds	15.6	1.1	14.38***	24.5	1.4	18.01***
Number of physicians	6.8	2.0	3.48***	15.9	2.6	6.15***
Private Hospital[§]	888.2	588.3	1.51	1,004.1	708.7	1.42
Tertiary-care hospital[¶]	3,299.8	757.9	4.35***	6,946.0	957.0	7.26***
Urban[††]	1,565.7	539.0	2.90**	967.5	650.0	1.49
Population of the district[‡‡]	0.4	1.2	0.34	1.7	1.5	1.15
Number of competing hospitals	−105.0	143.8	−0.73	−153.4	182.3	−0.84
Inhabitant tax per capita[§§]	0.2	1.0	0.17	−1.5	1.2	−0.84
The fiscal year 1997[¶¶]	462.7	127.2	3.64***	30.8	171.5	0.18
The fiscal year 1998[¶¶]	660.2	175.2	3.77***	−31.3	234.4	−0.13
The fiscal year 1999[¶¶]	1,328.9	207.6	6.40***	907.3	276.0	3.29**
	AIC = 15,274.6			AIC = 15,726.3		
	SBC = 15.281.3			SBC = 15,733.0		

NOTE. Unit: million won.

*$P < 0.05$.

**$P < 0.01$.

***$P < 0.001$.

[†]Deflated by Increase Rate of Fee Schedule for health insurance.

[‡]Introduced in the previous year, Yes = 1, No = 0.

[§]Private = 1, Public = 0. Yes = 1, No = 0.

[††]Urban = 1, Rural = 0.

[‡‡]Unit = 1,000 person.

[§§]Deflated by Consumer Price Index, Unit = 1,000 won/person.

[¶¶]Standard fiscal year = 1996.

tensive care units. The combination of computed radiology and softcopy interpretation often has resulted in a major decrease in the need to retake images, thereby improving the quality of service to the patient.[13] Moreover, Reiner et al[14] reported the association of the transition to filmless operation with increases in inpatient and outpatient utilization of radiologic services that could more directly affect the revenue of hospitals. Therefore, improving staff's satisfaction and quality of service with increasing staff's productivity as described in the introduction could lead to increased number of patients and increased revenue for the hospital. The result of multivariate analysis for the number of patients by the same model and variables also showed that both the number of patients also were statistically significantly higher one year after introduction PACS (Table 4).

The results of our study show that both outpatient and inpatient revenue were higher one year after the introduction of PACS.

However, the revenue of a hospital is related to the social security system, which differs from country to country. The National Health Insurance System of Korea is the social insurance, covering the whole population and including whole medical institutions. Beneficiaries should pay 20% of total inpatient care expenses, and 60% to 65% of total outpatient care expenses in general hospitals depending on whether it is a tertiary hospital. The current payment plan is based mainly on a fee-for-service scheme paid on a per-visit and a per-procedure basis. However, the government is planning to introduce a case payment system, which is known as *diagnosis-related groups* (DRG). Therefore, the pilot project of DRG is being applied to eight categories for some volunteer hospitals: cesarean section, tonsillectomy, appendectomy, cataract operation, normal delivery, hysterectomy, abdominal hernia.[15]

Specifically, the relationships between revenue and the number of beds and physicians, and

Table 4. The Result of Multivariate Analysis for the Number of Patients Using the Mixed Model AR(1)

	Outpatient			Inpatient		
Variables	Parameter Estimate	S.E	t Value	Parameter Estimate	S.E.	t Value
Intercept	−19,777	8131	−2.43*	−1,553	774	−2.01*
PACS[†]	50,704	8,005	6.33**	2,132	672	3.17*
Number of beds	174	14	12.56***	19	1	16.38***
Number of physicians	1158	26	6.04***	8	2	3.62***
Private hospital[‡]	12,483	7,272	1.72	1,776	703	2.53*
Tertiary-care hospital[§]	18,111	9,770	1.85	4,371	857	5.10***
Urban[¶]	19,743	6,637	2.96**	492	643	0.77
Population of the district[††]	12	15	0.77	2	1	1.62
Number of competing hospitals	−802	1,860	−0.43	−15	162	−0.10
Inhabitant tax per capita[‡‡]	12	12	0.95	−0	1	−0.42
The fiscal year 1997[§§]	6,993	1,738	4.02***	267	135	1.98*
The fiscal year 1998[§§]	5,108	2,377	2.15*	−108	187	−0.58
The fiscal year 1999[§§]	15,836	2,801	5.65***	896	223	4.02**
	AIC = 19,598.6			AIC = 15,423.2		
	SBC = 19,605.3			SBC = 15,429.9		

NOTE. Unit: Person.

*$P < 0.05$.

**$P < 0.01$.

***$P < 0.001$.

[†]Introduced in the previous year, Yes = 1, No = 0.

[‡]Private = 1, Public = 0.

[§]Yes = 1, No = 0.

[¶]Urban = 1, Rural = 0.

[††]Unit = 1,000 person.

[‡‡]Deflated by Consumer Price Index, Unit = 1,000 won/person.

[§§]Standard fiscal year = 1996.

the tertiary status of a hospital were not only consistent with the findings of other studies but were statistically significant. In addition, the relationship between outpatient revenue and urban status of hospital also was consistent with the findings of other studies and statistically significant.

The relationship between the number of competing hospitals and hospital revenue was not consistent with other studies by the univariate analysis but was consistent with other studies by multivariate analysis. This may have been the result of the effects of confounding variables, such as the number of beds, the number of physicians, the tertiary status of the hospital, and urban status of the hospital. Correlation analysis showed that competition was correlated positively with these variables. Therefore, it seems that both outpatient and inpatient revenues decreased as competition increased.

The primary strength of our study is the accuracy of each hospital's actual revenue and the comprehensive scope, in that all general hospitals in Korea were included. One organization, KNHIC, under the control of the Korean government pays all medical insurance claims submitted by all hospitals. Therefore, the data obtained from KNHIC for our study was the actual and accurate payments to general hospitals from 1996 through 1999. Second, we allowed a one-year time lag between the implementation of PACS and the revenue data for reflecting on the temporal relationship between the two. Third, we separately analyzed the effects of PACS on outpatient and inpatient revenue, because content, process, case mix and copayment rate of inpatient care differ from those of outpatient care. Fourth, we controlled various economic confounding variables to investigate the more valid association of implementation of PACS with the revenues.

There are some limitations in our study. First, we had to use only the implementation PACS as the independent variable, because

KOSMI surveyed only the year in which the hospital introduced PACS. However, the scope of PACS service, the amount of filmless operation, and the number and kinds of modalities connected to PACS, possibly are more related to hospital financial performance. Second, comprehensive economic feasibility could not be determined because the cost of implementing PACS was not considered in our study. Third, it is possible that various biases exist in our study. Because size of radiology department, number of imaging examinations per year, level of imaging technology, and other information technology such as Physician Order Entry system were not controlled, and the revenues of the radiology department were not used as dependent variables in this study. For example, despite a controlled natural increase and various control variables by mixed model, there is the possibility that PACS was introduced in hospitals that anticipated an increase in revenue.

CONCLUSION

Although the causality needs to be clarified, the implementation of PACS was correlated significantly to the increased amount of inpatient and outpatient revenue, while controlling for various confounding variables. In the future, the effects of different types and characteristics of PACS on the performance of hospitals should be examined. In addition, the costs of PACS should be included by using case studies where detailed data collection and multiinstitutional collaboration are possible.

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