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Association between Electronic Medical Record System Adoption and Healthcare Information Technology Infrastructure

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Objectives: The objective of this study was to investigate the relationship between the level of Electronic Medical Record (EMR) system adoption and healthcare information technology (IT) infrastructure. **Methods:** Both survey and various healthcare administrative datasets in Korea were used. The survey was conducted during the period from June 13 to September 25, 2017. The chief information officers of hospitals were respondents. Among them, 257 general hospitals and 273 small hospitals were analyzed. A logistic regression analysis was conducted using the SAS program. **Results:** The odds of having full EMR systems in general hospitals statistically significantly increased as the number of IT department staff members increased (odds ratio [OR] = 1.058, confidence interval [CI], 1.003–1.115; $p = 0.038$). The odds of having full EMR systems was significantly higher for small hospitals that had an IT department than those of small hospitals with no IT department (OR = 1.325; CI, 1.150–1.525; $p < 0.001$). Full EMR system adoption had a positive relationship with IT infrastructure in both general hospitals and small hospitals, which was statistically significant in small hospitals. The odds of having full EMR systems for small hospitals increased as IT infrastructure increased after controlling the covariates (OR = 1.527; CI, 1.317–4.135; $p = 0.004$). **Conclusions:** This study verified that full EMR adoption was closely associated with IT infrastructure, such as organizational structure, human resources, and various IT subsystems. This finding suggests that political support related to these areas is indeed necessary for the fast dispersion of EMR systems into the healthcare industry.

Keywords: Electronic Medical Records, Electronic Health Records, EMR Adoption, EHR Adoption

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I. Introduction

Many healthcare organizations (HCOs) have been adopting Electronic Medical Record (EMR) systems worldwide. It is known that more than 85% of hospitals have adopted EMR systems in both the United States and European Union countries [1-4]. EMR systems are very promising for the provision of high quality of care and managerial efficiency. However, not everyone can benefit from these advantages. Only those who are equipped with sophisticated EMR systems may reap those benefits.

One previous study empirically described levels of EMR adoption as ‘no EMR system’, ‘minimal’, ‘basic’, and ‘fully functional EMR system' based on frequently used functionalities. This study found that the breast examination rates of providers increase as the EMR adoption levels increase from no or minimal EMR systems to full EMR systems [5]. The level of EMR systems generally measured in terms of functional and technical integration of information have been significantly associated with 'mortality', 'postoperative hemorrhage', and 'postoperative hip fracture' rates [6]. Several other studies clearly showed that EMR systems bring quality of care improvements [7,8]. However, the results of some studies suggest that EMR systems have no relationship with quality of care, while others have found mixed results in relation to quality of care [9,10]; therefore, the level of EMR system adoption may be a critical factor that requires further investigation.

Many studies have considered the factors affecting EMR system adoption. For example, in one study, internal features, such as IT infrastructure, location of hospitals, organic organizational culture, and environmental factors influencing competition were associated with EMR adoption [11]. In other studies, practice size, location, maintenance costs of IT systems, and specialty type were also related to EMR/Electronic Health Record (EHR) adoption [12-14]. EMR systems were related to affiliation status of practice with a medical center or university health system and practice network status in another study [15]. However, a few studies have investigated the relationship between the level of EMR system adoption and healthcare IT infrastructure focusing on organizational features.

For the rest of hospital covariates, this study suggests that full EMR adoption is closely associated with healthcare IT infrastructure. IT infrastructure generally refers to IT components, such as computer hardware, software, etc.; human and technical IT capabilities, such as knowledge, skills, etc.; and shared IT services, such as networks, data management, communication technology, etc. [16-18]. Thus, three features of IT infrastructure were selected for this study, namely, the number of IT staff members, the existence of an IT department, and the adoption of various IT subsystems. This study predicted and proposed two hypotheses. First, the number of IT staff members and the existence of an IT department are related to level of EMR system adoption (H1). Second, IT subsystems are positively associated with the level of EMR system adoption measured by full (rather than partial) EMR system adoption (H2).

Theoretically, structural contingency theory may fit well in this situation: H1 & H2. There are many perspectives on contingency theory. However, the main explanation of the theory is that organizations are affected by internal and external factors, but there is no best way to achieve better performance or organizational effectiveness or to organize a corporation [19]. Structural contingency theory focuses more on internal structural features. It states that organizational structure changes due to internal and external impetus to adopt the most efficient practices [20,21].

Regarding H1, we argue that EMR systems, generally speaking, bring many advantages of better performance in HCOs, such as quality of care, managerial efficiency, and electronic healthcare information exchange. Employees working in IT areas of HCOs see and experience various improvements related to EMR systems in the healthcare industry. EMR system adoption is widespread in HCOs. Thus, they would be likely to express their opinions to top-level managers or decision-makers of hospitals suggesting the advantages of introducing full EMR systems. Those voices would increase as the number of those staff members increases. In contrast, when there are few IT employees, there would be a low probability of full EMR adoption because reports or feedback to top-level managers would be weaker. Similarly, if there are IT departments in HCOs, then their influence would be greater in comparison to HCO that do not have IT departments. Thus, these kinds of internal pressure would affect the level of full EMR adoption.

According to a previous study, hospitals with partial EMR adoption had greater difficulties in recruiting ICT staff members than hospitals with full EMR adoption [15]. Although the study result was subjective, the finding suggests that full EMR system adoption could be connected with IT staffs or IT departments. Practically, the installation of EMR systems requires a team approach and staff members who have various IT skills and knowledge [22]. IT infrastructure, including technical support, is an important factor for the implementation of EMR systems [23]. Thus, hospitals with those employees are more likely to have full EMR systems. Even though these previous studies were not empirical, they could support our arguments in that they dealt with similar study subjects.

Regarding H2, EMR systems generally have a dominant role that links various internal and external IT systems. Thus, hospitals with high levels of IT subsystems are more likely to install full EMR systems because those hospitals could easily make their various systems connect with EMR systems. They would also have lower marginal costs and high marginal utility by investing financial resources in EMR systems. However, hospitals with lower levels of subsystems do not have these motivations because of low marginal util-

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ity or efficiency. Thus, the level of EMR system adoption would increase when the level of IT infrastructure increases.

Several empirical studies support this argument. One previous study showed that there was a direct association between IT infrastructure and EMR adoption [11]. According to an empirical study on small physician practices, current computer infrastructure that was interoperable with existing systems was one of three important factors in the process of EMR system selection [24].

Thus, the purpose of this study was to investigate the relationship between full EMR system adoption and healthcare IT infrastructure, which was measured by considering the number of IT staff members (general hospitals), the establishment of an IT department (hospitals), and various IT systems in both HCOs. Findings from this study would contribute to areas related to EMR system adoption, such as policy making, EMR dispersion support, monitoring of EMR system sophistication, and academic EMR adoption studies.

II. Methods

1. Study Design

This study had a cross-sectional design, and the unit of analysis was HCOs, or hospitals. In Korea, the medical law categorizes hospitals into five types, namely, general hospitals, small hospitals, dental hospitals, oriental-medicine hospitals, and long-term care hospitals. According to the law, a 'general hospital' is a medical accommodation facility with 100 or more beds and at least 7 medical specialty departments, whereas a 'small hospital' is a medical facility accommodating 30 or more beds. This study only considered these two types of hospitals as the main study subject for the generalization of study findings. According to previous studies, the size of hospitals, teaching status, location, multi-hospital systems, and affiliation were related to EMR system adoption [13-15]. Thus, this study used the number of beds as a proxy variable for the size of a hospital and location in the model to control those effects. However, data on teaching status and affiliation status could not be obtained, so those variables were not included in the model.

Finally, regarding the ethical issue of human study subjects, approval of the Institutional Review Board was not obtained because the study did not directly consider human study subjects, rather it focused on HCOs.

2. Data Source

This study used a nationwide healthcare IT survey and various healthcare administrative data obtained from the Korea Health Industry Development Institute (KHIDI). The survey was conducted by the KHIDI and the Health Insurance Review and Assessment Service (HIRA) to assess the current IT status and to support healthcare IT of the healthcare industry. The survey was conducted from June 13 to September 25, 2017. Based on the population of the study hospitals, the KHIDI and HIRA randomly selected a group of hospitals based on their prescheduled methodological guidelines. The survey tool was a structured questionnaire. A total of 275 general hospitals (response rate [RR] = 83.1%) and 298 small hospitals (RR = 32.7%) participated in the survey. The data obtained by this survey were merged with KHIDI's health-related administrative data. During this process, this study excluded 18 and 25 study subjects of general hospitals and small hospitals, respectively, due to missing values regarding the number of beds, number of doctors, IT staff members, and the Herfindahl-Hirschman Index (HHI). Thus, the final results obtained from 257 general hospitals and 273 small hospitals were analyzed.

3. A Major Outcome and Independent Variables

This study had one outcome variable, namely, level of EMR system adoption: full versus partial EMR system adoption. This study descriptively defined it as the degree of digitalization of patients' demographic and clinical information. HCOs were simply considered as having full EMR systems when they were storing and pulling patients clinical information electronically without using paper-based charts and as having partial EMR systems when they were using both electronic medical charts and paper-based charts. This scale of measurement is almost the same as those used in previous studies [25-27].

Regarding major independent variables, this study descriptively defined IT infrastructure as computer hardware, software, human resources, and shared knowledge related with healthcare IT resources following the general definition used in previous studies [16-18]. IT infrastructure was measured in terms of three factors: IT staff members (general hospitals), IT department (small hospitals), and various IT subsystems (both general and small hospitals). The number of staff members in IT departments included full-time equivalent employees and staff members directly contracted and working for the HCOs from outsourced IT companies. Most of the general hospitals considered in this study had IT departments; thus, this study considered the number of IT department staff members as one of the organizational structure measures for general hospitals. However, almost half of the small hospitals did not have IT departments due to their relatively small size; thus, this study included the existence of an IT department in the model for small hospitals. We considered whether an HCO had an IT department or not. IT subsystems were considered by counting the following IT systems: (1) computerized physician order entry system, (2) picture archiving communication system, (3) laboratory information system, (4) pharmacy management system, (5) patient referral system, (6) telemedicine system, (7) medical examination system, (8) billing and health insurance claim processing system, (9) enterprise resource planning system, (10) electronic sanction system, and (11) data warehouse system. Thus, IT infrastructure has number values ranging from a maximum of 11 to a minimum of zero.

The location of HCOs was measured as Seoul and mega metro cities or others. If the population of the local administrative district area was greater than one million including Seoul, then they were considered Seoul and mega metro cities; otherwise, they were considered as belonging to the other group. Regarding the type of foundation, if HCOs were for-profit organizations, such as private foundations, corporate foundations, medical foundations, or privately owned hospitals, then they were considered private; otherwise, they were considered public. The number of beds was measured according to the number of operating beds, and the number of physicians was the number of full-time equivalent physicians. The HHI was calculated based on the sum of the squares of the total running beds of the hospitals within each local area; thus, it was the sum of the squares of the bed portion of the specific hospitals in a local area.

4. Statistical Analysis

This study first looked at the descriptive statistics targeting the main independent variables and an outcome variable showing full EMR system adoption. For the main statistical analysis, which is the association of the main dependent variable, level of EMR system adoption, with two independent variables, a logistic regression analysis was conducted using the logistic procedure of the SAS program version 9.4 (SAS Institute Inc., Cary, NC, USA).

III. Results

Table 1 shows the general characteristics of the study subjects. Regarding the main independent variables of general hospitals, the average numbers of IT staff members and IT subsystems were 8.7 persons and 7.7 systems, respectively. Seventy percent of general hospitals had adopted full EMR systems, and the remaining 30% has adopted partial EMR systems. For small hospitals, almost 43% had IT departments, and these hospitals had an average of 5 subsystems. Approximately 60% of these small hospitals had adopted full EMR systems, and the remaining 40% had adopted partial EMR systems.

Table 2 shows the current status of IT infrastructure measured in terms of 11 IT subsystems. As presented in Table 2, the percentage having 11 IT subsystems was higher in general hospitals than small hospitals.

Table 3 presents the logistic regression results showing the relationship between EMR system adoption level and the main independent variables, namely, the number of IT staff

Table 1. General characteristics of study subjects

Characteristic	Value
General hospitals[a] (n = 257)	
Located in Seoul or mega metro cities (%)	44.4
Private foundation (%)	52.9
Number of beds	437.3 ± 272.9 (1,400.0–100.0)
Number of physicians	115.2 ± 142.4 (808.0–10.0)
Herfindahl–Hirschman Index	0.145 ± 0.108 (0.664–0.031)
Number of staff members in IT department	8.7 ± 11.9 (102.0–1.0)
Number of healthcare IT subsystems	7.7 ± 1.7 (11.0–2.0)
% of full EMR system adoption	70.0
Small hospitals (n = 273)	
Located in Seoul or mega cities (%)	46.5
Private foundation (%)	93.4
Number of beds	116.5 ± 84.4 (660.0–30.0)
Number of physicians	7.2 ± 5.3 (31.0–1.0)
Herfindahl–Hirschman Index	0.130 ± 0.115 (0.987–0.031)
% of having IT departments	42.5
Number of healthcare IT subsystems	5.0 ± 2.1 (11.00–1.0)
% of full EMR system adoption	59.7

Values are presented as mean ± standard deviation (max–min).
EMR: Electronic Medical Record, IT: information technology.
[a]includes tertiary hospitals.

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Table 2. Installation status of various IT subsystems in Korea

Type of IT subsystems	Response rate (%)		χ^2 or *p*-value
	General hospitals (n = 257)	Small hospitals (n = 273)	
Computerized physician order entry system	100	100	-
Picture archiving communication system	99.6	87.6	-
Laboratory information system	88.3	54.5	<0.0001
Pharmacy management system	80.9	44.3	<0.0001
Patient referral system	48.6	19.4	<0.0001
Telemedicine system	15.2	7.7	0.0066
Medical examination system	93.0	40.3	<0.0001
Billing and health insurance claim processing system	98.4	93.8	-
Enterprise resource planning system	68.5	28.6	<0.0001
Electronic sanction system	49.4	15.0	<0.0001
Data warehouse system	29.2	11.4	<0.0001

Table 3. Association of full EMR system adoption with IT infrastructure (IT staff members and IT department)

Variable	OR	95% CI	*p*-value
General hospitals			
Seoul or mega metro cities (ref = the others)	0.361	0.022–0.763	0.0239
Private foundation (ref = public)	0.966	0.499–1.742	0.8257
Number of beds	1.000	0.997–1.002	0.8750
Number of physicians	1.000	0.994–1.005	0.8841
Herfindahl–Hirschman Index	0.028	0.002–0.511	0.0158
Number of staff members in IT department	1.058	1.003–1.115	0.0378
Small hospitals			
Seoul or mega metro cities (ref = the others)	0.863	0.214–2.584	0.6418
Private foundation (ref = public)	1.196	0.497–4.115	0.5078
Number of beds	1.003	1.000–1.006	0.0877
Number of physicians	0.934	0.888–0.982	0.0075
Herfindahl–Hirschman Index	2.796	0.119–65.677	0.5232
Having IT department (ref = no IT department)	1.325	1.150–1.525	<.0001

EMR: Electronic Medical Record, IT: information technology, OR: odds ratio, CI: confidence interval.

members (general hospitals) and IT department (small hospitals). Level of EMR system adoption was statistically significantly related with IT infrastructure measured in terms of IT staff members and IT department. The odds of full EMR system adoption increases 5.8% for a one-unit increase in the number of IT staff members after controlling the general hospital's covariates (odds ratio [OR] = 1.058; confidence interval [CI], 1.003–1.115; $p = 0.038$). The odds of full EMR system adoption for a small hospital with an IT department was 1.325 times higher than those of a small hospitals without an IT department, which was statistically significant (OR = 1.325; CI, 1.150–1.525; $p < 0.001$).

Table 4 shows the logistic regression results for the relationship between level of EMR system adoption and IT subsystems after controlling HCO's covariates. Full EMR adoption was significantly associated with IT subsystems in small hospitals. When the number of IT subsystems increases by one unit, the odds of full EMR system adoption shows a 1.527 times increase after controlling small hospital's covariates (OR = 1.527; CI, 1.317–4.135; $p = 0.004$). In the case of environmental competition, HHI was significantly associated with full EMR system adoption in general hospitals ($p = 0.014$), but not small hospitals.

IV. Discussion

There has been little study investigating factors related with level of EMR system adoption. This study investigated the relationship between level of EMR system adoption and the internal features of general hospitals and smaller hospitals based on the prediction of the structural contingency theory. Level of EMR system adoption was measured in terms of full EMR system or partial EMR system adoption. In the former case, patients' clinical data is electronically stored and pulled out when it is needed. In the latter case, patients' clinical data are electronically stored or kept in paper-based medical charts.

This study proposed two hypotheses. First, the number

Table 4. Association of full EMR system adoption with IT infrastructure (IT subsystems)

Variable	OR	95% CI	*p*-value
General hospitals			
Seoul or mega metro cities (ref = the others)	0.374	0.025–0.795	0.0265
Private foundation (ref = public)	0.963	0.495–1.734	0.8113
Number of beds	1.000	0.998–1.002	0.9601
Number of physicians	1.002	0.997–1.007	0.4429
Herfindahl–Hirschman Index	0.029	0.002–0.490	0.0142
Healthcare IT subsystem	1.038	0.875–1.232	0.6693
Small hospitals			
Seoul or mega metro cities (ref = the others)	0.913	0.248–2.802	0.7679
Private foundation (ref = public)	1.208	0.522–4.087	0.4713
Number of beds	1.003	1.000–1.006	0.0802
Number of physicians	0.931	0.884–0.981	0.0075
Herfindahl–Hirschman Index	2.944	0.126–68.999	0.5023
Healthcare IT subsystem	1.527	1.317–4.135	0.0037

EMR: Electronic Medical Record, IT: information technology, OR: odds ratio, CI: confidence interval.

of IT staff members and the existence of an IT department is related to the level of EMR systems adoption. Second, healthcare IT subsystems are positively associated with level of EMR system adoption. The two hypotheses were statistically significantly supported except the relationship between full EMR system adoption and IT subsystems in general hospitals. Although this relationship in general hospitals was not statistically supported, the study results show the same relationship direction as the proposed hypotheses, which was positive association.

More specifically, the number of IT department staff members and the existence of IT departments were significantly associated with full EMR system adoption regarding H1. The study results show that the number of IT staff members and the existence of IT departments are equally associated with full EMR system adoption, although there are different regulating guidelines, such as the number of beds and the number of medical specialty departments according to Korean medical law. The results of this study show agreement with the results of previous international studies [15,23]. For example, according to a study on EHR adoption, lack of availability of IT staff members was an important barrier to the adoption of EMR systems for hospitals that lacked these systems. Hospitals adopting EMR systems considered technical support for implementation of EMR system as an important facilitator [15]. Although this study was based on survey results, the results indirectly imply that IT departments and IT staff members may be important factors for full EMR system adoption.

Another study result regarding H2, in contrast, was somewhat surprising. Contrary to our expectation, the full EMR adoption of larger hospitals, such as general hospitals, was not related with IT subsystems, but the level of EMR system adoption was statistically significantly associated with IT subsystems in small hospitals. This means that IT infrastructure has a critical role in full EMR system adoption in small hospitals. This finding also agrees with the results of a previous study [24]. Thus, H2 has several meaningful implications in that we may need to focus more on various aspects of the IT infrastructure of small hospitals.

Regarding the other hospital covariates other than the two main independent variables, this study found that full adoption rates of EMR system in general hospitals and small hospitals were 70.0% (180/257) and 59.7% (163/273), respectively. The location of small hospitals was not associated with full EMR adoption contrary to our expectations and the results of previous studies [13-15]. The size of hospitals measured in terms of the number of physicians was related to full EMR adoption in small hospitals. Interestingly, HHI was also significantly associated with full EMR system adoption in general hospitals, but not in small hospitals.

Although this study produced several meaningful findings, there were some limitations. First, a simple measure of EMR system adoption, such as full or partial EMR system adoption, would be weak from a methodological point of view because the current measure, by itself, might not fully detect the variation coming from more sophisticated EMR functionalities. Future studies are necessary to incorporate various healthcare IT standards, functionalities, and usability into full EMR system adoption measures [5,28,29]. Second, the fact that full EMR adoption was measured according to the respondents' memories was another limitation. There is the possibility of memory errors or incorrect recording. However, using a larger sample would reduce some bias effects caused by this subjective data measure. Third, another limitation is related to the study design. This study had a cross sectional dataset. The results only provide some associations or relationships rather than causal relationships. Thus,

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further research should be conducted with longitudinal data.

In conclusion, full EMR system adoption has crucial relationships with IT staff members, IT departments, and IT subsystems of general hospitals and smaller hospitals. Prediction based on organizational theory well explained the relationship and supported our two hypotheses. Widespread dispersion of sophisticated EMR systems is important because there is a high probability that sophisticated EMR systems are related to the provision of high quality of care. These days, most HCOs are adopting EMR systems. We expect that our study results will provide some research insights to those who are interested in levels of EMR system adoption.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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