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Does Hospital Information Technology Infrastructure Promote the Implementation of Clinical Practice Guidelines? A Multicenter Observational Study of Japanese Hospitals

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Keywords:	Clinical practice guidelines, evidence-based practice, quality indicators, healthcare quality, hospital IT infrastructure, evidence-practice gaps

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Does Hospital Information Technology Infrastructure Promote the Implementation of Clinical Practice Guidelines? A Multicenter Observational Study of Japanese Hospitals

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Abstract

Objectives: It remains unclear whether insufficient information technology (IT) infrastructure of hospitals hinder implementation of clinical practice guidelines (CPGs) and affects health care quality. The objectives of this study were to describe the present state of IT infrastructure provided in acute care hospitals across Japan and to investigate possible determinants of healthcare quality.

Methods: A questionnaire survey of hospital administrators was conducted in 2015 to gather information on hospital-level policies and elements of IT infrastructure. We calculated each respondent's number of positive responses to the survey topics. Next, a composite quality indicator score of hospital adherence to CPGs for perioperative antibiotic prophylaxis was calculated using secondary administrative data. Based on this quality indicator score, we performed a chi-squared automatic interaction detection (CHAID) analysis to identify determinants of hospital healthcare quality. The independent variables included hospital size and teaching status in addition to hospital policies and elements of IT infrastructure.

Results: Wide variations were observed in the availability of various IT infrastructure elements across hospitals, especially in local area network availability and access to paid evidence databases. The CHAID analysis showed that hospitals with a high level of access to paid databases and Internet were strongly associated with increased care quality in larger or teaching hospitals.

Conclusions: Hospitals with superior IT infrastructure may provide high-quality care. This allows clinicians to easily access the latest information on evidence-based medicine and facilitate the dissemination of CPGs. The systematic improvement of hospital IT infrastructure may promote CPG use and narrow the evidence-practice gaps.

Key words: Clinical practice guidelines; evidence-based practice; quality indicators; healthcare quality; hospital IT infrastructure; evidence-practice gaps.

Strengths and limitations of this study

- In this multicenter study, we observed wide variations in the provision of IT infrastructure across acute care hospitals in Japan.
- Hospitals with superior IT infrastructure tended to have higher adherence to CPGs for perioperative antibiotic prophylaxis.
- We found that high level of access to paid medical evidence databases and accessibility to the Internet were the key factors of care quality in acute care hospitals using the CHAID analysis.
- We shed light on new knowledge that establishment of hospital IT infrastructure for medical information retrieval may support greater awareness and adherence to CPGs in clinicians and narrow the evidence-practice gaps.
- The QI of the adherence to the CPGs for perioperative antibiotic use may describe only one aspect of healthcare quality and the results from the survey conducted in Japan may limit the generalizability.

1. Introduction

Due to the flood of renewed medical information and frequent updates to clinical practice guidelines (CPGs) in the Internet era, clinicians can find it difficult to keep abreast of the latest evidence. The availability and usability of the hospital information technology (IT) infrastructure such as wireless local area networks (LAN) and medical evidence databases may affect the ability of clinicians to update their knowledge and practice, which can influence the quality of provided care. These infrastructure elements may facilitate accessibility to various updated CPGs, which would be essential for CPG implementation in daily practice [1].

CPGs for various diseases have been developed worldwide not only to help clinicians but also to promote shared decision making with patients [2-4]. However, CPGs continue to be underused even in developed countries despite intense efforts toward their development and dissemination over the past several decades. These gaps between medical evidence and clinical practice (i.e., "evidence-practice gaps") can lead to the provision of substandard or potentially harmful treatments to patients [5-11]. System-level barriers as well as individual-level barriers to evidence-based practice have been revealed in previous studies [12-14,17]. For example, institutional equipment, technological capital, accessibility to guideline-related resources are noted to be important in addition to individual awareness, familiarity and agreement to the contents [15-17]. Clinical quality indicators (QIs) can monitor clinicians' adherence to the guidelines, but they are not necessarily utilized to assess guideline implementation [18]. Furthermore, there are no clear evidence whether hospital IT infrastructure may affect quality of provided care using these QIs.

On the other hand, health IT implementation studies are growing and they report positive effects on quality, safety and efficiency [19-24]. However, most of these studies have focused on clinical decision support systems, order entry, telecommunication systems, e-Prescriptions [19,20] and strategic management systems [21]. It therefore remains unclear as to whether the lack of an adequate IT infrastructure for medical information retrieval is a crucial system-level barrier for CPG implementation. In Japan, over 180 evidence-based CPGs have been assessed and disseminated by the Medical Information Network Distribution Service (Minds) Guideline Center [22] over the last decade, but the actual use of these CPGs in daily clinical practice also remains unknown.

This multicenter study aimed to describe the present state of IT infrastructure provided in Japanese acute care hospitals and to investigate the possible determinants of healthcare quality, including hospital size, hospital policies toward promoting evidence-based practice, and hospital IT infrastructure.

2. Methods

2.1. Data sources

This study employed both primary data (based on a questionnaire survey of hospital administrators) and secondary data (administrative claims data) in the analysis. Data were obtained from hospitals enrolled in the Quality Indicator/Improvement Project (QIP), which is an ongoing project launched in 1995 to monitor and improve clinical performance in acute care hospitals across Japan through the analysis of administrative claims data [23,24]. Currently, over 500 QIP member hospitals voluntarily submit data for analysis, and the project generates periodic reports of clinical and economic performance. The participating hospitals vary widely in type (e.g., teaching status and hospital ownership), region of location, patient and physician volume, bed numbers, and composition of specialties.

The Minds-QIP project was initiated in 2014 with the objective of effectively implementing and disseminating CPGs across Japan. A survey was conducted as part of this project by mailing questionnaires to the hospital administrators (including general managers) of QIP member hospitals between January and March 2015. The questionnaire included items on hospital policies toward evidence-based practice and hospital IT infrastructure, actual provision of IT infrastructure (including LAN deployment and usability of medical evidence databases), QI monitoring, and the use of clinical pathways. This study focused on hospital policies and IT infrastructure. The questionnaire was developed based on a literature review, discussions with experts, and semi-structured face-to-face interviews with several hospital administrators and IT managers from 5 major teaching hospitals. Survey respondents were asked to answer questions from a concise list about their institution and policies as representatives of their hospital.

2.2. Hospital policy and IT infrastructure

In order to identify each hospital's policies toward promoting evidence-based practice, the questionnaire included items on whether the hospital has an explicit policy to enhance IT infrastructure to improve accessibility to medical information, explicitly recommends the utilization of evidence-based medicine, and explicitly recommends to use CPGs.

The questionnaire was also designed to focus on the following 3 elements of hospital IT infrastructure: (i) accessibility to the Internet and other information sources, including wired/wireless LAN availability; (ii) access to paid medical evidence databases in English and Japanese; and (iii) medical library and intranet usability, such as the availability of a well-organized intranet interface, number of full-time medical librarians, and activities for improving the medical library.

2.3. Hospital quality of care

As a measure of hospital quality of care, a QI of adherence to CPGs for perioperative antibiotic prophylaxis was calculated using diagnosis procedure combination (DPC) administrative claims data from the QIP. The DPC is a Japanese case-mix classification system for hospital reimbursements, and more than 1600 hospitals nationwide had adopted this system by 2016. The DPC database includes information on hospital codes, patient demographics, admission and discharge dates, admission routes, outcomes, primary and secondary diagnoses based on International Classification of Diseases (10th revision) codes, comorbidities, complications, surgeries performed, and high cost procedures [23,24]. DPC data from April 2013 to March 2014 were used as these were the most recent data available for analysis.

The QI of interest for this study was a composite score (range: 0 to 100) that indicated a hospital's proportion of adherence to CPGs for perioperative antibiotic prophylaxis [25], and was aggregated from the results of the following 11 surgical types: evacuation of intracranial hematoma, gastrectomy, cholecystectomy, total hip replacement, mastectomy for breast cancer, thyroid surgery, prostate cancer surgery, uterine myoma surgery, uterine cancer surgery, benign ovarian tumor surgery, and ovarian cancer surgery.

2.4. Statistical analysis

We first calculated descriptive statistics for the hospitals' and respondents' baseline characteristics, which included hospital bed numbers, teaching status, number of full-time physicians, number of resident physicians (representing younger physicians who may be more likely to incorporate IT into their practice), as well as respondent sex, age, and appointment. The responses to the questions on the topics of hospital policies and IT infrastructure were also summarized. The main items of interest in the questionnaire consisted of yes/no questions, and we calculated each hospital's number of positive responses within each topic. The hospitals were categorized into subgroups based on these response numbers, and the mean QI score was calculated for each subgroup.

Finally, we performed a chi-squared automatic interaction detection (CHAID) tree analysis to identify factors that determine hospital quality of care. The independent variables included hospital size and teaching status, hospital policies toward promoting evidence-based practice, and IT infrastructure (accessibility to the Internet and other information sources, access to paid medical evidence databases, and medical library and intranet usability within hospitals). The dependent variable was the mean QI score for perioperative antibiotic prophylaxis. The CHAID tree analysis repeatedly uses chi-square statistics to split independent variables into child nodes [26-28] to identify the relative interactions between the independent variables and the outcome variables. This method is a classification tree algorithm that is often utilized as a data mining method in fields with complex data sets, such as marketing, health care [27], and nursing [28].

Statistical computations were conducted using SPSS software, version 20.0J and Decision

Tree (SPSS Inc, Chicago, IL).

2.5. Patient and public involvement

Patients or public were not involved in the design and analysis of this study.

3. Results

3.1. Baseline characteristics, hospital policy, and IT infrastructure

Among the 239 hospitals that responded the questionnaire (response rate: 57.2%), we were able to calculate and integrate the target QI data for 153 hospitals. Hospitals that had data on at least one target QI were included. The hospital selection flow diagram is presented in Figure 1. The baseline characteristics of the participant hospitals and respondents are shown in Table 1. The median number of hospital beds were 303 (range:63–1161). Approximately 75% of all the hospitals were teaching hospitals, and there was a mean of approximately 21 junior and senior residents in each hospital.

Table 2 shows the results of the survey on hospital policies and IT infrastructure. Almost all respondents reported that their hospitals had an explicit policy to enhance IT infrastructure (94.1%). However, the provision of wireless LAN (71.9%) and access to paid medical evidence databases in English (54.9%) was limited. Further, an intranet homepage was provided only in a minority of hospitals (27.5%).

Figure 2 shows the information sources freely available or specifically provided by the participating hospitals. There were large variations in the provision of paid medical evidence databases, and hospitals tended to subscribe to the Japanese-language database (77.1%) rather than the English-language databases (9.8–46.4%). In general, the print editions of various CPGs and medical information were provided more frequently than the electronic editions, and there were relatively few hospitals that provided CPGs in either edition (41.2% in the print edition and 15.0% in the electronic edition).

3.2. Determinants of hospital quality of care

Table 3 shows the mean QI scores for the use of perioperative antibiotics according to the various independent variables. Hospitals with a lower number of positive responses to topics about hospital policies and IT infrastructure tended to have a lower QI score. Using the CHAID analysis, we identified 3 major determinants of the QI score (Fig. 3). Hospital size and teaching status was the strongest determinant of the QI score. The subgroup of "≤500-bed non-teaching hospitals" had the lowest QI score (73.1 points, Node 2), and the other subgroup (comprising larger or teaching hospitals) was further separated into 2 groups based on the provision of access to paid medical evidence databases. The derived subgroup of "Japanese and/or English databases" was again separated into 2 groups according to (i) accessibility to the Internet, (ii) wireless LAN availability, and (iii) wired LAN availability at outpatient clinics/wards; hospitals in the subgroup that provided the highest positive responses to these 3 topics had the highest QI score (87.2 points, Node 6) among all nodes. In contrast, the subgroup that provided positive responses to 2 or fewer of these topics had a lower QI score (83.1 points, Node 5). The subgroup of hospitals with no IT infrastructure elements had the lowest QI score (75.1 points, Node 4) among the larger or teaching hospitals. These results indicated that the provision of access to paid medical evidence databases and accessibility to the Internet (including LAN availability) were strongly associated with hospital quality of care.

4. Discussion

In this multicenter study, we observed wide variations in the provision of IT infrastructure across hospitals in Japan. Our results indicated that hospitals with superior IT infrastructure tended to have higher adherence to CPGs for perioperative antibiotic prophylaxis. Using a CHAID tree analysis, we found that the provision of access to paid medical evidence databases and accessibility to the Internet (including LAN availability) were strong indicators of quality of care in larger or teaching hospitals

Despite the wide availability of new medical evidence, clinicians are not always able to acquire and apply the most recent and relevant information at the right moment in their daily practice. The lack of adequate IT infrastructure may affect the ability of clinicians to access this information, thereby contributing to evidence-practice gaps. There are more than

8,000 hospitals in Japan, of which 80% (and almost all clinics) are privately owned [29]. Different leadership approaches among these hospitals may have resulted in considerable variations in IT infrastructure. Our analysis found that there was an overall inadequate provision of LAN, and accessibility to the Internet and electronic health records was limited among the hospitals. In addition, the print editions of various CPGs and medical information were provided more frequently than electronic editions. Previous studies on the activities to improve accessibility to medical information within specific hospital networks [30,31] have indicated the importance of hospital leadership in the development of IT infrastructure.

Our CHAID analysis found that the 3 most important determinants of hospital quality of care were hospital size and teaching status, access to paid medical evidence databases, and high accessibility to the Internet. Notably, hospital policies and library/intranet usability were not identified as major determinants of healthcare quality. The identification of these 3 factors may be explained by the following reasons. Firstly, from an economic perspective, teaching hospitals are tended to be large and more likely to have the economic capability to provide resources such as IT infrastructure and full-time librarians engaged to work on intranet development. The results in Table 2 indicate that more than half of the participating hospitals do not hire full-time medical librarians. Interviews with the administrators of several leading teaching hospitals prior to the survey revealed that some administrators were actively working to enhance their hospital's intranet environment. This included the hiring of full-time librarians to create user-friendly intranet homepages designed to guide clinicians to the most recent and relevant clinical information. Our results are consistent with those of previous reports that improvements in medical library functionality can improve patient health outcomes while reducing the time needed for clinicians to search for required information [32,33].

Secondly, we found that hospital administrators tended to provide access to free medical databases first, followed by the paid Japanese database, and finally the paid databases in English (Fig. 2). Besides the high cost of subscribing to English-language databases, the administrators may have prioritized the Japanese database due to the possible language barrier for Japanese clinicians; this phenomenon has also been observed in Taiwan [34]. However, the failure to provide medical databases in English raises concerns that the clinicians may be unable to retrieve the newest relevant information in a timely manner, which can directly impact daily clinical practice. In addition, the availability of information in English may be crucial to the efficient dissemination and effective implementation of CPGs.

Thirdly, the importance of Internet accessibility (including LAN availability) to healthcare quality has been similarly observed in previous studies [1,21,30]. Our study sample comprised a fairly high proportion of hospitals without wireless LAN (28.1%) or with limited wired LAN availability at outpatient clinics and wards (64.1%). In order to encourage the implementation of IT infrastructure that facilitates easy retrieval of evidence in all types of hospitals, it may be necessary to develop a standardized assessment tool for hospital IT infrastructure and to include such assessments as a component of hospital accreditation.

In daily clinical practice, clinicians have limited time to search for and retrieve medical information. Thus, an ideal search platform would allow the use of clinical questions with several keywords and provide the requested information promptly and accurately. In addition to improving the accessibility and usability of online information, it may be useful to actively provide paid medical evidence databases (especially English-language databases) at the hospital level to supply multiple layers of information ranging from abstracts to full-text articles, as well as recommendations for CPGs and their evidence sources. In order to maximize the use of this system, individual physicians should work to improve not only their English language skills, but also their information searching skills and ability to implement new knowledge into practice.

Our findings suggest that larger or teaching hospitals would have the most potential for improvements in IT infrastructure that can lead to better quality of care (see Nodes 4, 5, and 6 in Fig. 3). As Doebbeling et al. noted, IT implementation is dependent on the support of hospital management and “should be tailored to the needs of the organization, and not as a ‘one size fits all’ solution” [35]. It is also necessary to conduct balanced assessments of the costs and effectiveness of these IT infrastructures in order to efficiently support the implementation of evidence into practice under limited budgets.

There are several limitations in this study. First, respondents were hospital administrators, and the results may not indicate the usability of various IT infrastructure elements from the physicians' perspective. Because individual physicians are the primary target users and are likely to be the link between IT infrastructure and quality of care, further studies are required to clarify the quality improvement mechanism in greater detail. Second, this survey was performed in Japan, which may limit the generalizability of our results to other countries. Third, the QI that we used was limited to adherence to the CPGs for perioperative antibiotic use, and therefore describes only one aspect of healthcare quality. Finally, we were not able to identify the amount of investment or affordability of each hospital's IT infrastructure, and further studies are needed to examine the total effect of these issues on the quality of hospital care.

5. Conclusions

Hospitals with superior IT infrastructure may provide high-quality care. The provision of access to paid medical evidence databases and accessibility to the Internet were strongly associated with hospital quality of care, and may be key factors for improving healthcare quality in larger or teaching hospitals. These infrastructure elements may allow healthcare professionals to retrieve the latest information on evidence-based medicine with greater ease and facilitate the dissemination of CPGs in the Internet era. Hospitals should focus on establishing adequate IT infrastructure to support the effective implementation of CPGs. The systematic improvement of IT infrastructure in hospitals may support greater adherence to CPGs and narrow the evidence-practice gaps.

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Contributors

NS and YI had full access to all the data in the study and take responsibility for the analysis and interpretation. Conception and design:NS,YI; Acquisition of data and analysis:NS, YI; Interpretation of data:NS, NY,AO,MY, HS,YI; Drafting of the manuscript and statistical analysis:NS,YI; Obtaining funding:NY,YI. All the authors (NS, NY,AO, MY, HS, and YI) were involved in critical revisions and approved the final manuscript for publication.

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Competing interests

The authors declare that they have no competing interests.

Ethics approval

This study was approved by both the Ethics Committee of Kyoto University Graduate School and Faculty of Medicine, Japan (R0979, R0135) and that of Japan Council for Quality Health Care (Rin26-4).

Provenance and peer review

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Data sharing statement

No additional data are available.

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Figure legends

Figure 1. Flow diagram of the subject hospital selection process.

Figure 2. Information sources freely available or specifically provided by the participating hospitals (153 hospitals).

Figure 3. Chi-squared automatic interaction detection tree diagram showing the determinants of the QI score.

* These values indicate the numbers of positive responses to topics regarding (i) Electronic health records and Internet availability, (ii) wireless LAN availability, and (iii) wired LAN availability at outpatient clinics/wards. DB, database; LAN, local area network; QI, quality indicator; SD, standard deviation.

1

Table 1. Characteristics of the hospitals and respondents [a] (153 hospitals)

Hospital characteristics		
Beds, mean±SD (range); median	339 ± 182 (63-1161); 303	
Teaching hospitals, n (%)	115 (75.2)	
Full-time physicians, mean±SD (range)	61.9±43.3 (8-268)	
Resident physicians, mean±SD (range)	21.2±29.2 (0-197)	
Respondent characteristics	n	(%)
Sex		
Male	125	(81.7)
Female	19	(12.4)
No response	9	(5.9)
Age		
20–29 years	5	(3.3)
30–39 years	21	(13.7)
40–49 years	28	(18.3)
50–59 years	50	(32.7)
60–69 years	39	(25.5)
No response	10	(6.5)
Appointment		
Hospital administrator (physician)	69	(45.1)
Chief general manager (non-physician)	38	(24.8)
Others	34	(22.2)
No response	12	(7.8)

[a] Respondents answered the questions as representatives of their hospital.
SD, standard deviation.

2

3

Table 2. Hospital policies and IT infrastructure (153 hospitals)

Questionnaire topics	n	(%)
Hospital policies		
Explicit policy to enhance IT infrastructure to improve accessibility to medical information (YES)	144	(94.1)
Explicit recommendation for the utilization of evidence-based medicine (YES)	88	(57.5)
Explicit recommendation for adherence to clinical practice guidelines (YES)	84	(54.9)
Accessibility to the Internet and other information sources		
Electronic health records and Internet access		
Access to both electronic health records and the Internet	110	(71.9)
Others	43	(28.1)
Wireless LAN		
Available with no limitations/with limited access points	110	(71.9)
Not available	43	(28.1)
Major locations with wired LAN access *(Multiple answers allowed)*		
Outpatient clinics/wards	98	(64.1)
Other locations (including medical offices and library)	144	(94.1)
Access to paid medical evidence databases *(Multiple answers allowed)*		
Igaku Chuo Zasshi (ICHUSHI) Database <in Japanese>	118	(77.1)
Medical databases such as UpToDate®, Clinical Key®, Ovid®, and DynaMed®	84	(54.9)
Medical library and intranet usability within the hospital		
Provision of an intranet homepage with user-friendly interface	42	(27.5)
Number of full-time medical librarians		
$\geq$1	66	(43.1)
0	87	(56.9)
Medical library activities *(Multiple answers allowed)*		
Periodic meetings held to improve the information retrieval environment	84	(54.9)
Continuously working to improve library services and usability	60	(39.2)
Participation in hospital librarian associations and communication with other hospital librarians	25	(16.3)
Others	23	(15.0)

IT, information technology, LAN, local area network.

Table 3. QI scores of hospital groups according to the number of positive responses to topics on hospital policies, IT infrastructure, and hospital size (153 hospitals)

Number of topics with positive responses	Mean QI score	n
Hospital policies [a]		
0	78.73	4
1	81.92	51
2	84.95	29
3	78.92	69
IT infrastructure		
Accessibility to the Internet and other information sources [b]		
0	78.59	5
1	82.20	32
2	78.70	62
3	83.32	54
Access to paid medical evidence databases [c]		
0	72.55	25
1	79.76	54
2	84.88	74
Medical library and intranet usability within the hospital [d]		
0	81.70	21
1	78.45	45
2	80.25	39
3	84.40	26
4–6	83.27	22
Hospital size and teaching status		
>500-bed non-teaching	87.64	4
>500-bed teaching	83.28	21
≤500-bed teaching	83.16	94
≤500-bed non-teaching	73.10	34

Questionnaire topics are as follows:

[a] Three topics: having explicit policy to enhance IT infrastructure, explicit recommendation for the utilization of evidence-based medicine, and explicit recommendation to use clinical practice guidelines.

[b] Three topics: Electronic health records and Internet availability, wireless LAN availability, wired LAN availability at outpatient clinics/wards.

[c] Two topics: provision of access to the Japanese medical database and access to English-language medical databases.

[d] Six topics: provision of access to an intranet homepage, one or more full-time medical librarians, periodic meetings for library improvement, continuously working to improve library services and usability, communication with other hospital librarians, and others.

IT, information technology; LAN, local area network; QI, quality indicator.

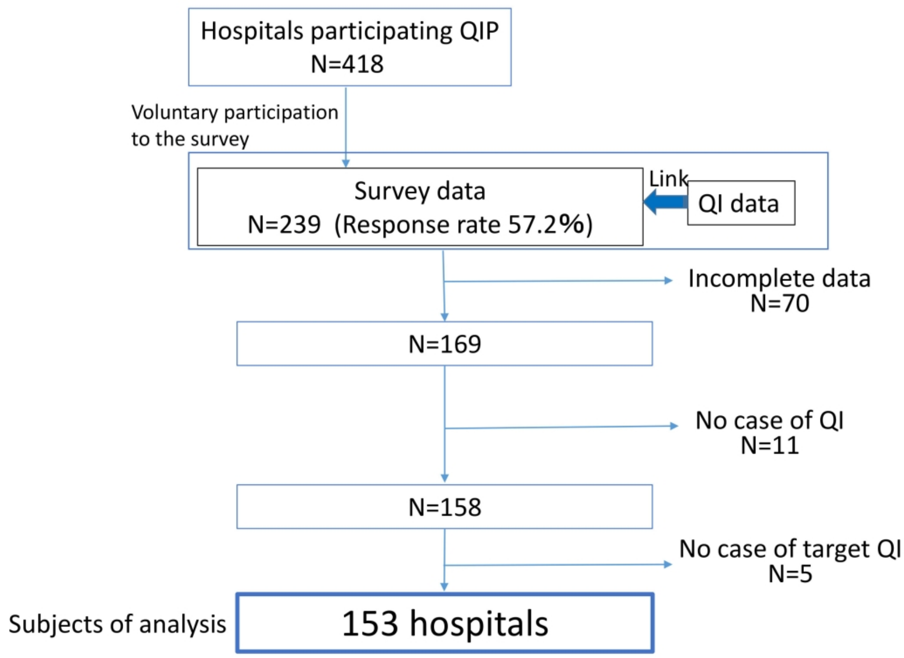

Figure 1. Flow diagram of the subject hospital selection process.

254x190mm (300 x 300 DPI)

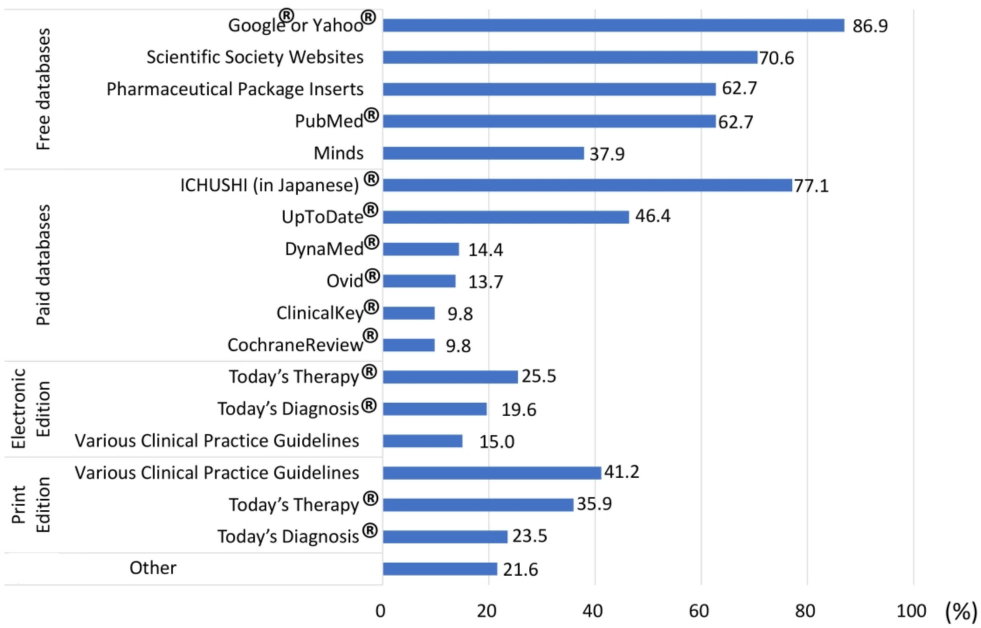

Figure 2. Information sources freely available or specifically provided by the participating hospitals (153 hospitals).

245x158mm (300 x 300 DPI)

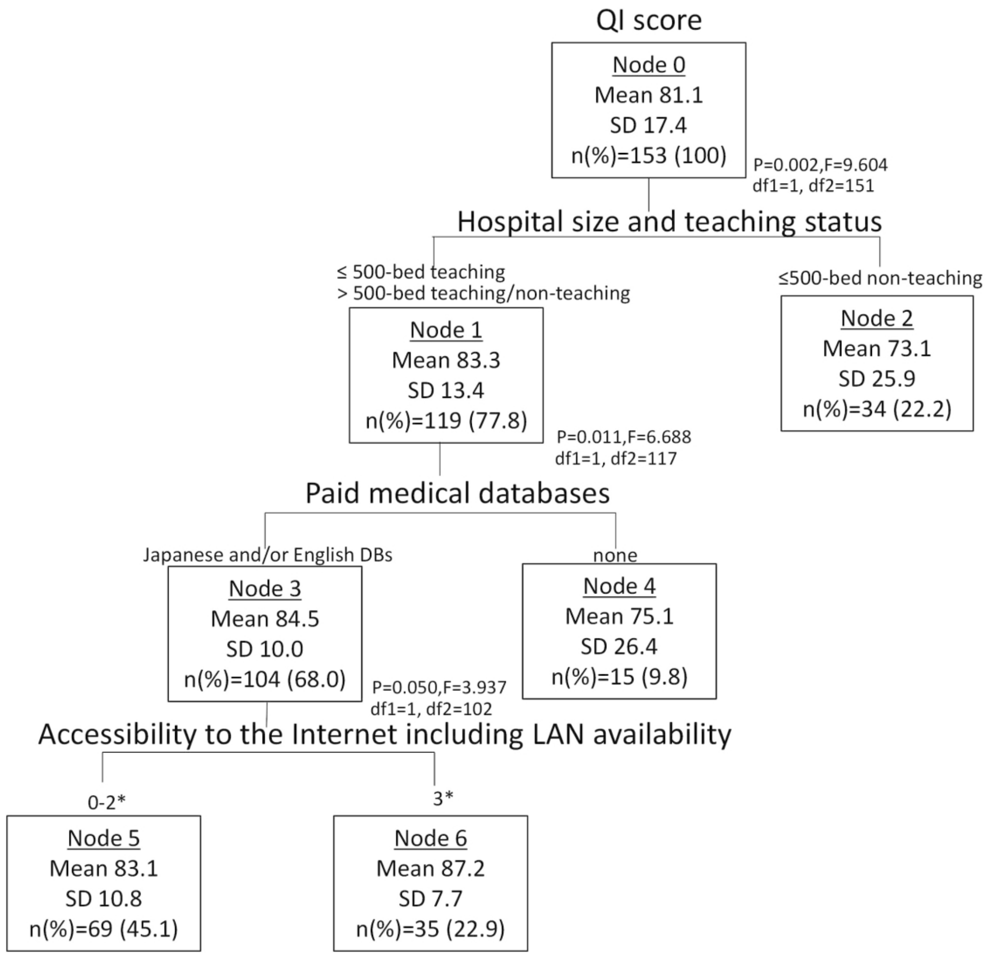

Figure 3. Chi-squared automatic interaction detection tree diagram showing the determinants of the QI score.

* These values indicate the numbers of positive responses to topics regarding (i) Electronic health records and Internet availability, (ii) wireless LAN availability, and (iii) wired LAN availability at outpatient clinics/wards. DB, database; LAN, local area network; QI, quality indicator; SD, standard deviation.

196x188mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2, 5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	2,6
Methods			
Study design	4	Present key elements of study design early in the paper	2,7-8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	2,7-10
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-10
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-10
Bias	9	Describe any efforts to address potential sources of bias	17
Study size	10	Explain how the study size was arrived at	7-11
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-10、Table3
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-11
		(*b*) Describe any methods used to examine subgroups and interactions	9-11
		(*c*) Explain how missing data were addressed	Fig1.
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	*
		(*e*) Describe any sensitivity analyses	*
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11, Fig1.
		(b) Give reasons for non-participation at each stage	*
		(c) Consider use of a flow diagram	11, Fig1.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11, Table 1.
		(b) Indicate number of participants with missing data for each variable of interest	Fig1.
Outcome data	15*	Report numbers of outcome events or summary measures	Table 3. Figure 2.
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-13, Table 2.
		(*b*) Report category boundaries when continuous variables were categorized	11-13, Table 3
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	*
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11-13, Table 3 Figure 3.
Discussion			
Key results	18	Summarise key results with reference to study objectives	2-4,13,17-18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	4, 17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	4,13-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	4,17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Does Hospital Information Technology Infrastructure Promote the Implementation of Clinical Practice Guidelines? A Multicenter Observational Study of Japanese Hospitals

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Does Hospital Information Technology Infrastructure Promote the Implementation of Clinical Practice Guidelines? A Multicenter Observational Study of Japanese Hospitals

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Abstract

Objectives: It remains unclear whether insufficient information technology (IT) infrastructure in hospitals hinders implementation of clinical practice guidelines (CPGs) and affects health care quality. The objectives of this study were to describe the present state of IT infrastructure provided in acute care hospitals across Japan and to investigate its association with healthcare quality.

Methods: A questionnaire survey of hospital administrators was conducted in 2015 to gather information on hospital-level policies and elements of IT infrastructure. The number of positive responses by each respondent to the survey items was tallied. Next, a composite quality indicator score of hospital adherence to CPGs for perioperative antibiotic prophylaxis was calculated using secondary administrative data. Based on this quality indicator score, we performed a chi-squared automatic interaction detection (CHAID) analysis to identify correlates of hospital healthcare quality. The independent variables included hospital size and teaching status in addition to hospital policies and elements of IT infrastructure.

Results: Wide variations were observed in the availability of various IT infrastructure elements across hospitals, especially in local area network availability and access to paid evidence databases. The CHAID analysis showed that hospitals with a high level of access to paid databases ($p<0.05$) and Internet ($p<0.05$) were strongly associated with increased care quality in larger or teaching hospitals.

Conclusions: Hospitals with superior IT infrastructure may provide higher-quality care. This allows clinicians to easily access the latest information on evidence-based medicine and facilitate the dissemination of CPGs. The systematic improvement of hospital IT infrastructure may promote CPG use and narrow the evidence-practice gaps.

Key words: Clinical practice guidelines; evidence-based practice; quality indicators; healthcare quality; hospital IT infrastructure; evidence-practice gaps.

Strengths and limitations of this study

- In this multicenter study, we observed wide variations in the provision of IT infrastructure across acute care hospitals in Japan.
- Hospitals with superior IT infrastructure tended to have higher adherence to CPGs for perioperative antibiotic prophylaxis.
- We found that a high level of access to paid medical evidence databases and accessibility to the Internet were the key factors of care quality in acute care hospitals using the CHAID analysis.
- We shed light on new knowledge that establishing a hospital IT infrastructure for medical information retrieval may promote greater awareness and adherence to CPGs by clinicians and narrow evidence-practice gaps.
- The QI of adherence to CPGs for perioperative antibiotic use describe only one aspect of healthcare quality; that the survey was conducted only in Japan and may limit generalizability.

1. Introduction

Due to the growth of renewed medical information and frequent updates to clinical practice guidelines (CPGs) in the Internet era, clinicians can find it difficult to keep abreast of the latest evidence. The availability and usability of hospital information technology (IT) infrastructure such as wireless local area networks (LAN) and medical evidence databases may affect the ability of clinicians to update their knowledge and practice, which can influence the quality of provided care. These infrastructure elements may facilitate accessibility to various updated CPGs, which would be essential for CPG implementation in daily practice [1].

CPGs for various diseases have been developed worldwide not only to help clinicians but also to promote shared decision making with patients [2-4]. However, CPGs continue to be underused even in countries even where CPGs are well developed over the past several decades. These gaps between medical evidence and clinical practice (i.e., "evidence-practice gaps") can lead to the provision of substandard or potentially harmful care to patients [5-11]. System-level barriers as well as individual-level barriers to evidence-based practice have been revealed in previous studies [12-17]. For example, institutional equipment, technological capital, and accessibility to guideline-related resources have been found to be important in addition to individual awareness, familiarity and agreement with the contents [15-17]. Clinical quality indicators (QIs) can monitor clinicians' adherence to the guidelines, but they are not necessarily utilized to assess guideline implementation [18]. Furthermore, there is no clear evidence regarding whether hospital IT infrastructure may affect the quality of provided care using these QIs.

On the other hand, research related to the adoption of health information technology at the organizational level is growing, and a number of studies have reported positive effects on quality, safety and efficiency [19-21]. However, most of these studies have focused on clinical decision support systems, order entry, telecommunication systems, e-Prescriptions [19,20] and strategic management systems [21]. It thus remains unclear as to whether the lack of an adequate IT infrastructure for medical information retrieval is a crucial system-level barrier for CPG implementation. In Japan, over 180 evidence-based CPGs have been assessed and disseminated by the government-funded Medical Information Network Distribution Service (Minds) Guideline Center [22] over the last decade, but the actual use of these CPGs in daily clinical practice remains unknown.

This multicenter study aimed to describe the present state of IT infrastructure provided in Japanese acute care hospitals and to investigate its association with healthcare quality, taking into account hospital size, hospital policies promoting evidence-based practice.

2. Methods

2.1. Data sources

This study employed both primary data (based on a questionnaire survey of hospital administrators) and secondary data (administrative claims data) in the analysis. Data were obtained from hospitals enrolled in the Quality Indicator/Improvement Project (QIP), which is an ongoing project launched in 1995 to monitor and improve clinical performance in acute care hospitals across Japan through the analysis of administrative claims data [23,24]. Currently, over 500 QIP member hospitals voluntarily submit data for analysis, and the project generates periodic reports of clinical and economic performance. The participating hospitals vary widely in type (e.g., teaching status and hospital ownership), region of location, patient and physician volume, bed numbers, and composition of specialties.

The Minds-QIP project, as a part of the activities of the Minds Guideline Center, was initiated in 2014, with the objective of effectively implementing and disseminating CPGs across Japan. A survey was conducted as part of this project by mailing questionnaires to the hospital administrators (including general managers) of QIP member hospitals between January and March 2015. The questionnaire included items on hospital policies regarding evidence-based practice and hospital IT infrastructure, actual provision of IT infrastructure (including LAN deployment and usability of medical evidence databases), QI monitoring, and the use of clinical pathways. This study focused on hospital policies and IT infrastructure. The questionnaire was developed based on literature reviews, discussions with experts, and semi-structured face-to-face interviews with several hospital administrators and IT managers from five major teaching hospitals. Survey respondents were asked to answer questions from a concise list about their institution and policies as representatives of their hospital (Appendix Table).

2.2. Hospital policy and IT infrastructure

In order to identify each hospital's policies promoting evidence-based practice, the questionnaire included items on whether the hospital has an explicit policy to enhance IT infrastructure in order to improve accessibility to medical information, whether it explicitly recommends the practice of evidence-based medicine, and whether it explicitly encourages the use of CPGs.

The questionnaire was also designed to focus on the following three elements of hospital IT infrastructure: (i) accessibility to the Internet and other information sources, including wired/wireless LAN availability; (ii) access to paid medical evidence databases in English and Japanese; and (iii) medical library and intranet usability, such as the availability of a well-organized intranet interface, number of full-time medical librarians, and activities for improving the medical library.

2.3. Hospital quality of care

As a measure of hospital quality of care, a QI of adherence to CPGs for perioperative antibiotic prophylaxis was calculated using diagnosis procedure combination (DPC) administrative claims data from the QIP. The DPC is a Japanese case-mix classification system for hospital reimbursements, and more than 1600 hospitals nationwide had adopted this system by 2016. The DPC database includes information on hospital codes, patient demographics, admission and discharge dates, admission routes, outcomes, primary and secondary diagnoses based on International Classification of Diseases (10th revision) codes, comorbidities, complications, surgeries performed, and high cost procedures [23,24]. DPC data from April 2013 to March 2014 were used as these were the most recent data available for analysis.

The QI of interest for this study was a composite score (range: 0 to 100) that indicated a hospital's proportion of adherence to CPGs for perioperative antibiotic prophylaxis [25], and was aggregated from the results of the following 11 surgical types (i.e., target QI in Fig.1) : evacuation of intracranial hematoma, gastrectomy, cholecystectomy, total hip replacement, mastectomy for breast cancer, thyroid surgery, prostate cancer surgery, uterine myoma surgery, uterine cancer surgery, benign ovarian tumor surgery, and ovarian cancer surgery.

2.4. Statistical analysis

We first calculated descriptive statistics for the hospitals' and respondents' baseline characteristics, which included hospital bed numbers, teaching status, number of full-time physicians, number of resident physicians (representing younger physicians who may be more likely to incorporate IT into their practice), as well as respondent sex, age, and appointment. The responses to the questionnaire items related to hospital policies and IT infrastructure were also summarized. The main items of interest consisted of yes/no questions; we calculated each hospital's number of positive responses within each item. The hospitals were categorized into subgroups based on these response numbers, and the mean QI score was calculated for each subgroup.

Finally, we performed a chi-squared automatic interaction detection (CHAID) tree analysis to identify factors that determine hospital quality of care. The independent variables included hospital size and teaching status, hospital policies regarding the promotion of evidence-based practice, and IT infrastructure (accessibility to the Internet and other information sources, access to paid medical evidence databases, and medical library and intranet usability within hospitals). The dependent variable was the mean QI score for perioperative antibiotic prophylaxis. CHAID tree analysis repeatedly uses chi-square statistics to split independent variables into child nodes [26-28] to identify the relative interactions between the independent variables and the outcome variables. This method is a classification tree algorithm that is often utilized as a data mining method in fields with complex data sets, such as marketing, health care [27], and nursing [28]. We used the exhaustive CHAID algorithm, a modified version of the basic algorithm that performs a more thorough merging and testing of independent variables [29]. Statistical calculations were performed using SPSS 20.0J software and Decision Tree (SPSS Inc, Chicago, IL).

2.5. Patient and public involvement

There was no patients or public involvement in the design and analysis of this study.

3. Results

3.1. Baseline characteristics, hospital policy, and IT infrastructure

From the 239 hospitals that responded to the questionnaire (response rate: 57.2%), we were able to calculate and integrate the target QI data for 153 hospitals. Hospitals with data on at least one target QI were included. The hospital selection flow diagram is presented in Figure 1. The baseline characteristics of the participant hospitals and respondents are shown in Table 1. The median number of hospital beds was 303 (range: 63–1161). Approximately 75% of all the hospitals were teaching hospitals; the mean number of junior and senior residents in each hospital was approximately 21.

Table 2 shows the results of the survey on hospital policies and IT infrastructure. Almost all respondents reported that their hospitals had an explicit policy to enhance IT infrastructure (94.1%). However, the provision of wireless LAN (71.9%) and access to paid medical evidence databases in English (54.9%) was limited. Further, an intranet homepage was provided only in a minority of hospitals (27.5%).

Figure 2 shows the information sources freely available or specifically provided by the participating hospitals. There were large variations in the provision of paid medical evidence databases, and hospitals tended to subscribe to the Japanese-language database (77.1%) rather than the English-language databases (9.8–46.4%). In general, the print editions of various CPGs and medical information were provided more frequently than the electronic editions, and there were relatively few hospitals that provided CPGs in either edition (41.2% in the print edition and 15.0% in the electronic edition).

3.2. Correlates of hospital quality of care

Table 3 shows the mean QI scores for the use of perioperative antibiotics according to the various independent variables. Hospitals with a lower number of positive responses to items related to hospital policies and IT infrastructure tended to have a lower QI score. Using CHAID analysis, we identified three major correlates of QI score (Fig. 3; hospital size and teaching status were the strongest correlates. The subgroup of "≤500-bed non-teaching hospitals" had the lowest QI score (73.1 points, Node 2). The other subgroup (comprising larger or teaching hospitals) was divided into two groups based on the provision of access to paid medical evidence databases. The derived subgroup of "Japanese and/or English databases" was further divided into two groups according to (i) accessibility to the Internet, (ii) wireless LAN availability, and (iii) wired LAN availability at outpatient clinics/wards; hospitals in the subgroup that had the highest number of positive responses to these three items had the highest QI score (87.2 points, Node 6) among all nodes. In contrast, the subgroup that had positive responses to two or fewer of these items had a lower QI score (83.1 points, Node 5). The subgroup of hospitals with no IT infrastructure elements had the lowest QI score (75.1 points, Node 4) among the larger or teaching hospitals. These results indicated that the provision of access to paid medical evidence databases and accessibility to the Internet (including LAN availability) were strongly associated with hospital quality of care.

4. Discussion

In this multicenter study, we observed wide variations in the provision of IT infrastructure across hospitals in Japan. Our results indicated that hospitals with superior IT infrastructure tended to have higher adherence to CPGs for perioperative antibiotic prophylaxis. Using a CHAID tree analysis, we found that the provision of access to paid medical evidence databases and accessibility to the Internet (including LAN availability) were strong indicators of quality of care in larger or teaching hospitals

Despite the wide availability of new medical evidence, clinicians are not always able to acquire and apply the most recent and relevant information at the right moment in their daily practice. The lack of adequate IT infrastructure may affect the ability of clinicians to access this information, thereby contributing to evidence-practice gaps. There are more than 8,000 hospitals in Japan, of which 80% (and almost all clinics) are privately owned [30]. Different leadership approaches among these hospitals may have resulted in considerable variations in IT infrastructure. Our analysis found that there was an overall inadequate provision of LAN, and accessibility to the Internet and electronic health records was limited among the hospitals. In addition, the print editions of various CPGs and medical information were provided more frequently than electronic editions. Previous studies on the activities to improve accessibility to medical information within specific hospital networks [31,32] have indicated the importance of hospital leadership in the development of IT infrastructure.

Our CHAID analysis found that the three most important correlates of hospital quality of care were hospital size and teaching status, access to paid medical evidence databases, and high accessibility to the Internet. Notably, hospital policies and library/intranet usability were not identified as major correlates. There are likely several reasons for the identification of hospital size and teaching status, access to paid medical evidence databases, and high accessibility to the Internet as the most important factors. Firstly, from an economic perspective, teaching hospitals tend to be large and more likely to have the economic capability to provide resources such as IT infrastructure and full-time librarians engaged to work on intranet development. The results in Table 2 indicate that more than half of the participating hospitals do not hire full-time medical librarians. Interviews with the administrators of several leading teaching hospitals prior to the survey revealed that some administrators were actively working to enhance their hospital's intranet environment. This included the hiring of full-time librarians to create user-friendly intranet homepages designed to guide clinicians to the most recent and relevant clinical information. Our results are consistent with those of previous reports that show improvements in medical library functionality can improve patient health outcomes while reducing the time needed for clinicians to search for required information [33,34].

Secondly, we found that hospital administrators tended to provide access to free medical databases first, followed by the paid Japanese database, and finally the paid databases in English (Fig. 2). Besides the high cost of subscribing to English-language databases, the administrators may have prioritized the Japanese database due to the possible language barrier for Japanese clinicians; this phenomenon has also been observed in Taiwan [35]. However, the failure to provide medical databases in English raises concerns that the clinicians may be unable to retrieve the newest relevant information in a timely manner, which can directly impact daily clinical practice. In addition, the availability of information in English may be crucial to the efficient dissemination and effective implementation of CPGs.

Thirdly, the importance of Internet accessibility (including LAN availability) to healthcare quality has been similarly observed in previous studies from the US and UK [1,21,31]. Our study sample included a fairly high proportion of hospitals without wireless LAN (28.1%) or with limited wired LAN availability at outpatient clinics and wards (64.1%). In order to encourage the implementation of IT infrastructure that facilitates easy retrieval of evidence in all types of hospitals, it may be necessary to develop a standardized assessment tool for hospital IT infrastructure and to include such assessments as a component of hospital accreditation.

In daily clinical practice, clinicians have limited time to search for and retrieve medical information. Thus, an ideal search platform would allow the use of clinical questions with several keywords and provide the requested information promptly and accurately. In addition to improving the accessibility and usability of online information, it may be useful to actively provide paid medical evidence databases (especially English-language databases) at the hospital level to supply multiple layers of information ranging from abstracts to full-text articles, as well as recommendations for CPGs and their evidence sources. In order to maximize the use of this system, individual physicians should work to improve not only their English language skills, but also their information searching skills and ability to implement new knowledge into practice.

Our findings suggest that larger or teaching hospitals would have the most potential for improvements in IT infrastructure that can lead to better quality of care (see Nodes 4, 5, and 6 in Fig. 3). As Doebbeling et al. noted, IT implementation is dependent on the support of hospital management and “should be tailored to the needs of the organization, and not as a ‘one size fits all’ solution” [36]. It is also necessary to conduct balanced assessments of the costs and effectiveness of these IT infrastructures in order to efficiently support the implementation of evidence into practice under limited budgets.

In a broader context, barriers to implementing CPG recommendations in daily practice vary greatly at the individual level of specialists and physicians (e.g.perception, education, incentives, professional autonomy), the institutional level (e.g., physician leadership, hospital policies, finance, institutional culture, teamwork, IT infrastructure), national level (e.g., policies to promote CPG use, hospital accreditation) and the societal level (e.g.a culture of shared-decision making with patients, information derived from mass media) [37,38,39]. Yet, given the growing importance of IT use in an innovative society, the impact of IT adoption on healthcare quality warrants far more consideration of the types of relationships that were revealed in this study. According to previous research, IT itself needs to be understood as having two distinct components—information technology and communication technology—and these differently affect the autonomy of workers [40]. Further examination is needed to clarify these issues in order to implement IT in practice settings.

There are several limitations to this study. First, the respondents were hospital administrators, which means the results may not indicate the usability of various IT infrastructure elements from a physician's perspective. In addition, as this was a self-reported survey, the possible presence of social desirability bias may have caused these respondents to underestimate the barriers being investigated. Because individual physicians are the primary target users and are likely to be the link between IT infrastructure and quality of care, studies focusing physicians are required in the future to clarify the quality improvement mechanism in detail. Second, the survey was conducted in Japan, which may limit the generalizability of our results to other countries. Third, the QI that we used was limited to adherence to the CPGs for perioperative antibiotic use and therefore describes only one aspect of healthcare quality. Fourth, as we used administrative claims data, we could not know the clinical information in detail including appropriate exceptions in clinical practice. However, in this study, we focused on perioperative antibiotic prophylaxis of the 11 surgeries, which we could identify accurately based on the information of surgical procedure and drug use from the database. Finally, we were not able to identify the amount of investment or the affordability of each hospital's IT infrastructure, and further studies are needed to examine the total effect of these issues on the quality of hospital care.

5. Conclusions

Hospitals with superior IT infrastructure may provide higher-quality care. The provision of access to paid medical evidence databases and accessibility to the Internet were strongly associated with hospital quality of care, and may be key factors for improving healthcare quality in larger or teaching hospitals. These infrastructure elements may allow healthcare professionals to retrieve the latest information on evidence-based medicine with greater ease and facilitate the dissemination of CPGs in the Internet era. Hospitals should focus on establishing adequate IT infrastructure to support the effective implementation of CPGs. The systematic improvement of IT infrastructure in hospitals may support greater adherence to CPGs and narrow the evidence-practice gaps.

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Contributors

NS and YI had full access to all the data in the study and take responsibility for the analysis and interpretation. Conception and design:NS,YI; Acquisition of data and analysis:NS, YI;

Interpretation of data:NS, NY,AO,MY, HS,YI; Drafting of the manuscript and statistical analysis:NS,YI; Obtaining funding:NY,YI. All the authors (NS, NY,AO, MY, HS, and YI) were involved in critical revisions and approved the final manuscript for publication.

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Competing interests

The authors declare that they have no competing interests.

Ethics approval

This study was approved by both the Ethics Committee of Kyoto University Graduate School and Faculty of Medicine, Japan (R0979, R0135) and that of Japan Council for Quality Health Care (Rin26-4). Informed consent was received from all participants prior to the survey, and they were also informed that the data was being collected for research purposes. Regarding the DPC data, we collect anonymous data based on a process designated by the ethics guideline from the Japanese government, and the consent to participate from each patients was omitted.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data sharing statement

No data are available.

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Figure legends

Figure 1. Flow diagram of the subject hospital selection process.

*Target QI indicates QI of perioperative antibiotic prophylaxis of the 11 surgical procedures mentioned in the manuscript.

Figure 2. Information sources freely available or specifically provided by the participating hospitals (153 hospitals).

Figure 3. Chi-squared automatic interaction detection tree diagram showing the correlates of the QI score.

* These values indicate the numbers of positive responses to questionnaire items related to (i) Electronic health records and Internet availability, (ii) wireless LAN availability, and (iii) wired LAN availability at outpatient clinics/wards. DB, database; LAN, local area network; QI, quality indicator; SD, standard deviation.

** p=0.0499, in detail.

1

Table 1. Characteristics of the hospitals and respondents [a] (153 hospitals)

Hospital characteristics	
Beds, mean±SD (range); median	339 ± 182 (63-1161); 303
Teaching hospitals, n (%)	115 (75.2)
Hospital size, n (%)	
>500 beds	25 (16.3)
≦500 beds	128 (83.7)
Full-time physicians, mean±SD (range)	61.9±43.3 (8-268)
Resident physicians, mean±SD (range)	21.2±29.2 (0-197)
Respondent characteristics	n (%)
Sex	
Male	125 (81.7)
Female	19 (12.4)
No response	9 (5.9)
Age	
20–29 years	5 (3.3)
30–39 years	21 (13.7)
40–49 years	28 (18.3)
50–59 years	50 (32.7)
60–69 years	39 (25.5)
No response	10 (6.5)
Appointment	
Hospital administrator (physician)	69 (45.1)
Chief general manager (non-physician)	38 (24.8)
Others	34 (22.2)
No response	12 (7.8)

[a] Respondents answered the questions as representatives of their hospital.
SD, standard deviation.

2

Table 2. Hospital policies and IT infrastructure (153 hospitals)

Questionnaire items	n	(%)
Hospital policies		
Explicit policy to enhance IT infrastructure to improve accessibility to medical information (YES)	144	(94.1)
Explicit recommendation for the utilization of evidence-based medicine (YES)	88	(57.5)
Explicit recommendation for adherence to clinical practice guidelines (YES)	84	(54.9)
Accessibility to the Internet and other information sources		
Electronic health records and Internet access		
Access to both electronic health records and the Internet	110	(71.9)
Other	43	(28.1)
Wireless LAN		
Available with no limitations/with limited access points	110	(71.9)
Not available	43	(28.1)
Major locations with wired LAN access *(Multiple answers allowed)*		
Outpatient clinics/wards	98	(64.1)
Other locations (including medical offices and library)	144	(94.1)
Access to paid medical evidence databases *(Multiple answers allowed)*		
Igaku Chuo Zasshi (ICHUSHI) Database <in Japanese>	118	(77.1)
Medical databases such as UpToDate®, Clinical Key®, Ovid®, and DynaMed®	84	(54.9)
Medical library and intranet usability within the hospital		
Provision of an intranet homepage with user-friendly interface	42	(27.5)
Number of full-time medical librarians		
≥1	66	(43.1)
0	87	(56.9)
Medical library activities *(Multiple answers allowed)*		
Periodic meetings held to improve the information retrieval environment	84	(54.9)
Continuously working to improve library services and usability	60	(39.2)
Participation in hospital librarian associations and communication with other hospital librarians	25	(16.3)
Other	23	(15.0)

IT, information technology, LAN, local area network.

Table 3. QI scores of hospital groups according to the number of positive responses to questionnaire items on hospital policies, IT infrastructure, and hospital size (153 hospitals)

Number of questionnaire items with positive responses	Mean QI score	n
Hospital policies [a]		
0	78.73	4
1	81.92	51
2	84.95	29
3	78.92	69
IT infrastructure		
Accessibility to the Internet and other information sources [b]		
0	78.59	5
1	82.20	32
2	78.70	62
3	83.32	54
Access to paid medical evidence databases [c]		
0	72.55	25
1	79.76	54
2	84.88	74
Medical library and intranet usability within the hospital [d]		
0	81.70	21
1	78.45	45
2	80.25	39
3	84.40	26
4–6	83.27	22
Hospital size and teaching status		
>500-bed non-teaching	87.64	4
>500-bed teaching	83.28	21
≤500-bed teaching	83.16	94
≤500-bed non-teaching	73.10	34

Questionnaire items are as follows:
[a] Three items: having explicit policy to enhance IT infrastructure, explicit recommendation for the utilization of evidence-based medicine, and explicit recommendation to use clinical practice guidelines.
[b] Three items: Electronic health records and Internet availability, wireless LAN availability, wired LAN availability at outpatient clinics/wards.
[c] Two items: provision of access to the Japanese medical database and access to English-language medical databases.
[d] Six items: provision of access to an intranet homepage, one or more full-time medical librarians, periodic meetings for library improvement, continuously working to improve library services and usability, communication with other hospital librarians, and others.
IT, information technology; LAN, local area network; QI, quality indicator.

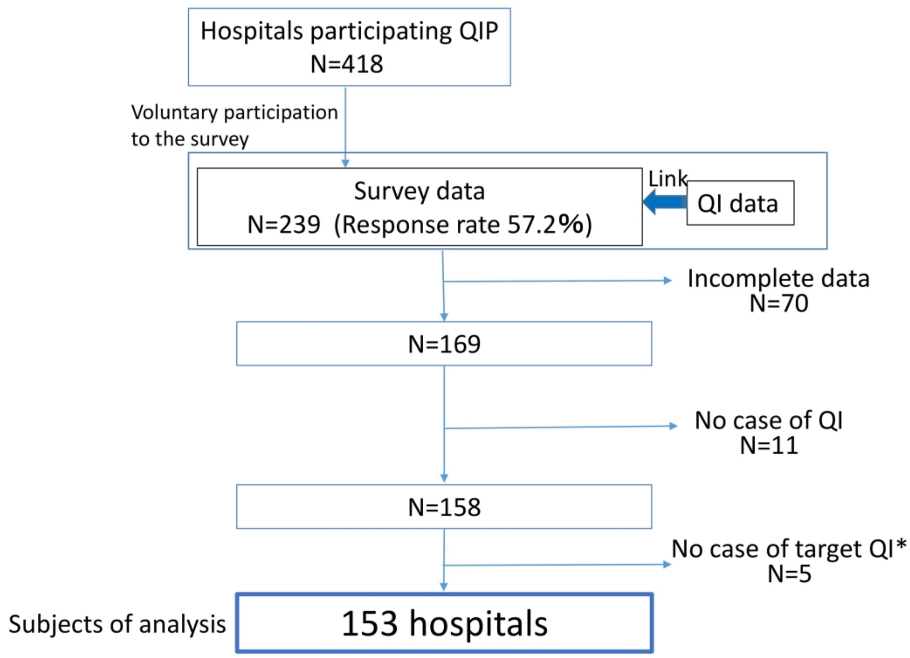

Figure 1. Flow diagram of the subject hospital selection process.
*Target QI indicates QI of perioperative antibiotic prophylaxis of the 11 surgical procedures mentioned in the manuscript.

254x190mm (300 x 300 DPI)

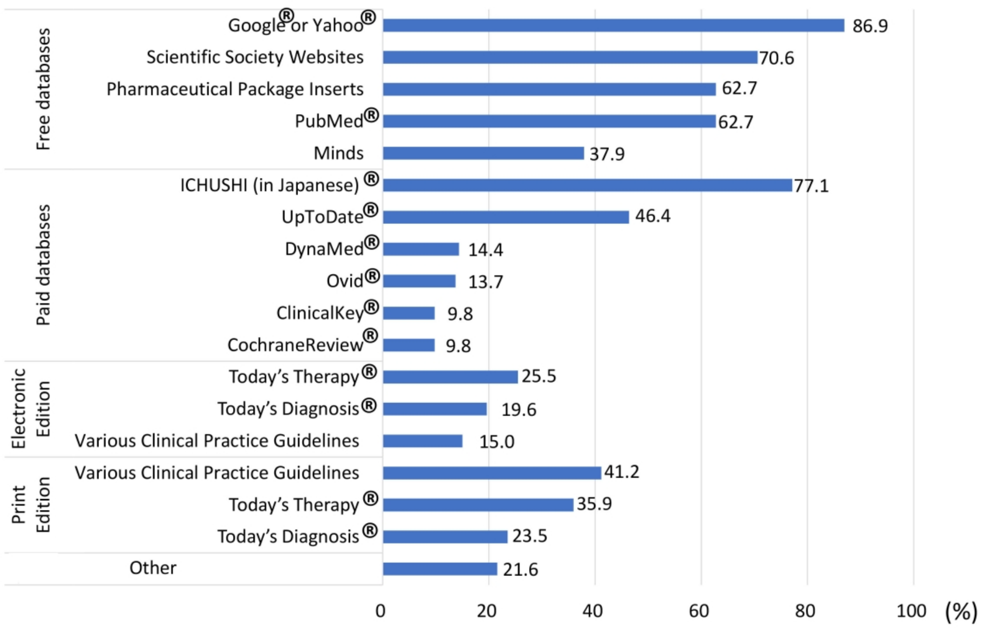

Figure 2. Information sources freely available or specifically provided by the participating hospitals (153 hospitals).

245x158mm (300 x 300 DPI)

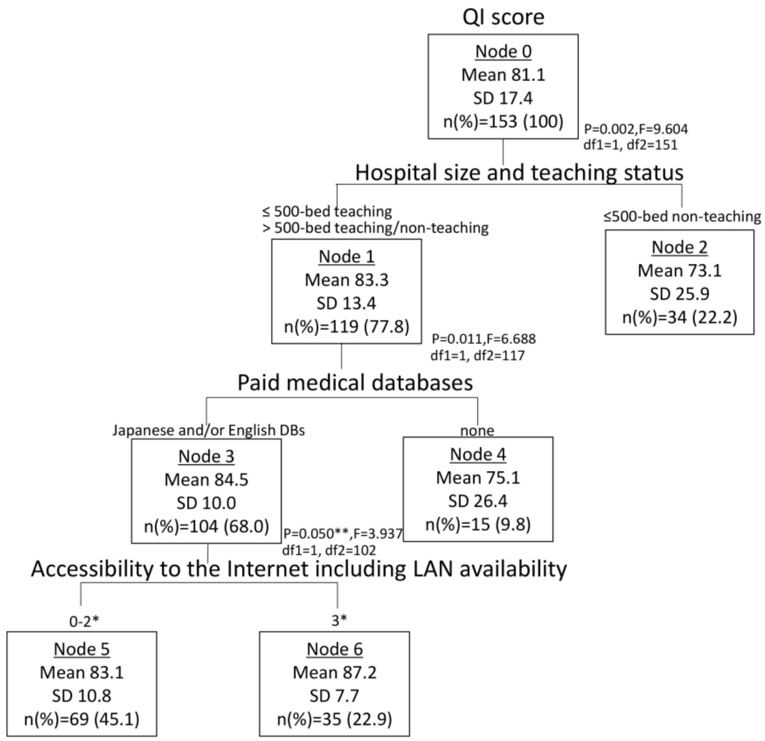

Figure 3. Chi-squared automatic interaction detection tree diagram showing the correlates of the QI score.
* These values indicate the numbers of positive responses to questionnaire items related to (i) Electronic health records and Internet availability, (ii) wireless LAN availability, and (iii) wired LAN availability at outpatient clinics/wards. DB, database; LAN, local area network; QI, quality indicator; SD, standard deviation.
** p=0.0499, in detail.

254x190mm (300 x 300 DPI)

Appendix_Table. Original Questions

Q1-1. Does your hospital have an explicit policy to enhance IT infrastructure in order to improve accessibility to medical information?
□ Yes □ No □ Other

Q1-2. What information sources are available in your hospital? (Please choose all options that would apply)
□ 1. PubMed □2. Google/Yahoo □3. Pharmaceutical Package Inserts □ 4. Pharmaceutical Interview Forms
□ 5. Scientific Society Websites □ 6. MINDS
□ 7. *Igaku Chuo Zasshi* (ICHUSHI) Medical Literature Database [**Hospital** Subscription]
□ 8. *Igaku Chuo Zasshi* (ICHUSHI) Medical Literature Database [**Medical Office** Subscription]
□ 9. UpToDate [**Hospital** Subscription] □ 10. UpToDate [**Medical Office** Subscription]
□ 11. Cochrane Review □ 12. ClinicalKey □13. Ovid □ 14. DynaMed
□ 15. *Today's Diagnosis* [**Electronic Edition**] □ 16. *Today's Therapy* [**Electronic Edition**]
□ 17. Various Clinical Practice Guidelines [**Electronic Versions**]
□ 18. *Today's Diagnosis* [**Print Edition**] □ 19. *Today's Therapy* [**Print Edition**]
□ 20. Various Clinical Practice Guidelines **[Print Versions**] □21. Other

Q2-1. What type of accessibility to the Internet and other information sources is available in your hospital?
□ Access to both electronic health records (EHRs) and the Internet is permitted from the same computer.
□ Access to both EHRs and the Internet is permitted from different computers.
□ Access to EHRs is permitted only in the hospital network. Therefore, healthcare workers have to use their own computers to access the Internet.
□ EHRs are not available.
□ Other

Q2-2. Is *wireless* LAN available in your hospital?
□Yes, available with no limitations. □Yes, with limited access points. □ No, not available.

Q2-3. Where are the major locations in your hospital for Internet use with *wired* LAN access? *(Multiple answers allowed)*
□ Outpatient clinics □ Wards □ Medical offices □ Libraries
□ Other

Q3-1. How many librarians are there in your hospital?
□ Full-time: □ Part-time:

Q3-2. Does your hospital provide an intranet homepage with user-friendly interface?
□ Yes □ No □ Other

Q3-3. Which applies to your hospital regarding medical library activities? *(Multiple answers allowed)*
□ Periodic meetings held to improve the information retrieval environment
□ Continuously working to improve library services and usability (e.g., promoting paperless movements)
□ Participation in hospital librarian associations and communication with other hospital librarians
□ Other

Q4. Do you have an explicit recommendation for the utilization of evidence-based medicine in your hospital?
□ Yes □ No □ Other

Q5. Do you have an explicit recommendation for adherence to clinical practice guidelines in your hospital?
□ Yes □ No □ Other

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2, 5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	2,6
Methods			
Study design	4	Present key elements of study design early in the paper	2,7-8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	2,7-11
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-11
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-11
Bias	9	Describe any efforts to address potential sources of bias	17
Study size	10	Explain how the study size was arrived at	7-11
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-11、Table3
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-11
		(*b*) Describe any methods used to examine subgroups and interactions	9-11
		(*c*) Explain how missing data were addressed	Fig1.
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	*
		(*e*) Describe any sensitivity analyses	*
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11, Fig1.
		(b) Give reasons for non-participation at each stage	*
		(c) Consider use of a flow diagram	11, Fig1.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11, Table 1.
		(b) Indicate number of participants with missing data for each variable of interest	Fig1.
Outcome data	15*	Report numbers of outcome events or summary measures	Table 3. Figure 2.
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-13, Table 2.
		(*b*) Report category boundaries when continuous variables were categorized	11-13, Table 3
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	*
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11-13, Table 3 Figure 3.
Discussion			
Key results	18	Summarise key results with reference to study objectives	2-4,13,17-18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	4, 17-18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	4,13-18
Generalisability	21	Discuss the generalisability (external validity) of the study results	4,18
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Does Hospital Information Technology Infrastructure Promote the Implementation of Clinical Practice Guidelines? A Multicenter Observational Study of Japanese Hospitals

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Abstract

Objectives: It remains unclear whether insufficient information technology (IT) infrastructure in hospitals hinders implementation of clinical practice guidelines (CPGs) and affects health care quality. The objectives of this study were to describe the present state of IT infrastructure provided in acute care hospitals across Japan and to investigate its association with healthcare quality.

Methods: A questionnaire survey of hospital administrators was conducted in 2015 to gather information on hospital-level policies and elements of IT infrastructure. The number of positive responses by each respondent to the survey items was tallied. Next, a composite quality indicator score of hospital adherence to CPGs for perioperative antibiotic prophylaxis was calculated using administrative claims data. Based on this quality indicator score, we performed a chi-squared automatic interaction detection (CHAID) analysis to identify correlates of hospital healthcare quality. The independent variables included hospital size and teaching status in addition to hospital policies and elements of IT infrastructure.

Results: Wide variations were observed in the availability of various IT infrastructure elements across hospitals, especially in local area network availability and access to paid evidence databases. The CHAID analysis showed that hospitals with a high level of access to paid databases ($p<0.05$) and Internet ($p<0.05$) were strongly associated with increased care quality in larger or teaching hospitals.

Conclusions: Hospitals with superior IT infrastructure may provide higher-quality care. This allows clinicians to easily access the latest information on evidence-based medicine and facilitate the dissemination of CPGs. The systematic improvement of hospital IT infrastructure may promote CPG use and narrow the evidence-practice gaps.

Key words: Clinical practice guidelines; evidence-based practice; quality indicators; healthcare quality; hospital IT infrastructure; evidence-practice gaps.

Strengths and limitations of this study

- We integrated a hospital questionnaire survey and administrative claims data at hospital level in the analysis.
- We described the present state of IT infrastructure of Japanese acute care hospitals and investigated its association with a composite quality indicator of adherence to the guidelines for perioperative antibiotic prophylaxis, using a chi-squared automatic interaction detection analysis.
- As an infrastructure to promote evidence-based practice, we focused on IT infrastructure such as accessibility to the Internet and other information sources, access to paid medical evidence databases, and medical library and intranet usability within hospitals.
- The QI that we used was limited to adherence to the guidelines for perioperative antibiotic use and therefore describes only one aspect of healthcare quality.
- As we used administrative claims data, we could not know the clinical information in detail including appropriate exceptions in clinical practice.

1. Introduction

Due to the growth of renewed medical information and frequent updates to clinical practice guidelines (CPGs) in the Internet era, clinicians can find it difficult to keep abreast of the latest evidence. The availability and usability of hospital information technology (IT) infrastructure such as wireless local area networks (LAN) and medical evidence databases may affect the ability of clinicians to update their knowledge and practice, which can influence the quality of provided care. These infrastructure elements may facilitate accessibility to various updated CPGs, which would be essential for CPG implementation in daily practice [1].

CPGs for various diseases have been developed worldwide not only to help clinicians but also to promote shared decision making with patients [2-4]. However, CPGs continue to be underused even in countries even where CPGs are well developed over the past several decades. These gaps between medical evidence and clinical practice (i.e., “evidence-practice gaps”) can lead to the provision of substandard or potentially harmful care to patients [5-11]. System-level barriers as well as individual-level barriers to evidence-based practice have been revealed in previous studies [12-17]. For example, institutional equipment, technological capital, and accessibility to guideline-related resources have been found to be important in addition to individual awareness, familiarity and agreement with the contents [15-17]. Clinical quality indicators (QIs) can monitor clinicians’ adherence to the guidelines, but they are not necessarily utilized to assess guideline implementation [18]. Furthermore, there is no clear evidence regarding whether hospital IT infrastructure may affect the quality of provided care using these QIs.

On the other hand, research related to the adoption of health information technology at the organizational level is growing, and a number of studies have reported positive effects on quality, safety and efficiency [19-21]. However, most of these studies have focused on clinical decision support systems, order entry, telecommunication systems, e-Prescriptions [19,20] and strategic management systems [21]. It thus remains unclear as to whether the lack of an adequate IT infrastructure for medical information retrieval is a crucial system-level barrier for CPG implementation. In Japan, over 180 evidence-based CPGs have been assessed and disseminated by the government-funded Medical Information Network Distribution Service (Minds) Guideline Center [22] over the last decade, but the actual use of these CPGs in daily clinical practice remains unknown.

This multicenter study aimed to describe the present state of IT infrastructure provided in Japanese acute care hospitals and to investigate its association with healthcare quality, taking into account hospital size, hospital policies promoting evidence-based practice.

2. Methods

2.1. Data sources

We integrated a hospital questionnaire survey and administrative claims data at hospital level in the analysis. Data were obtained from hospitals enrolled in the Quality Indicator/Improvement Project (QIP), which is an ongoing project launched in 1995 to monitor and improve clinical performance in acute care hospitals across Japan through the analysis of administrative claims data [23,24]. Currently, over 500 QIP member hospitals voluntarily submit data for analysis, and the project generates periodic reports of clinical and economic performance. The participating hospitals vary widely in type (e.g., teaching status and hospital ownership), region of location, patient and physician volume, bed numbers, and composition of specialties.

The Minds-QIP project, as a part of the activities of the Minds Guideline Center, was initiated in 2014, with the objective of effectively implementing and disseminating CPGs across Japan. A survey was conducted as part of this project by mailing questionnaires to the hospital administrators (including general managers) of QIP member hospitals between January and March 2015. The questionnaire included items on hospital policies regarding evidence-based practice and hospital IT infrastructure, actual provision of IT infrastructure (including LAN deployment and usability of medical evidence databases), QI monitoring, and the use of clinical pathways. This study focused on hospital policies and IT infrastructure. The questionnaire was developed based on literature reviews, discussions with experts, and semi-structured face-to-face interviews with several hospital administrators and IT managers from five major teaching hospitals. Survey respondents were asked to answer questions from a concise list about their institution and policies as representatives of their hospital (Appendix Table).

2.2. Hospital policy and IT infrastructure

In order to identify each hospital's policies promoting evidence-based practice, the questionnaire included items on whether the hospital has an explicit policy to enhance IT infrastructure intending to improve information accessibility, whether it explicitly recommends the practice of evidence-based medicine, and whether it explicitly encourages the use of CPGs.

The questionnaire was also designed to focus on the following three elements of hospital IT infrastructure: (i) accessibility to the Internet and other information sources, including wired/wireless LAN availability; (ii) access to paid medical evidence databases in English and Japanese; and (iii) medical library and intranet usability, such as the availability of a well-organized intranet interface, number of full-time medical librarians, and activities for improving the medical library.

2.3. Hospital quality of care

As a measure of hospital quality of care, a QI of adherence to CPGs for perioperative antibiotic prophylaxis was calculated using diagnosis procedure combination (DPC) administrative claims data from the QIP. The DPC is a Japanese case-mix classification system for hospital reimbursements, and more than 1600 hospitals nationwide had adopted this system by 2016. The DPC database includes information on hospital codes, patient demographics, admission and discharge dates, admission routes, outcomes, primary and secondary diagnoses based on International Classification of Diseases (10th revision) codes, comorbidities, complications, surgeries performed, and high cost procedures [23,24]. DPC data from April 2013 to March 2014 were used as these were the most recent data available for analysis.

The QI of interest for this study was a composite score (range: 0 to 100) that indicated a hospital's proportion of adherence to CPGs for perioperative antibiotic prophylaxis [25], and was aggregated from the results of the following 11 surgical types (i.e., target QI in Fig.1) : evacuation of intracranial hematoma, gastrectomy, cholecystectomy, total hip replacement, mastectomy for breast cancer, thyroid surgery, prostate cancer surgery, uterine myoma surgery, uterine cancer surgery, benign ovarian tumor surgery, and ovarian cancer surgery. The QI score was calculated based on the administrative data when and what kind of the antibiotics were used, and this medication information is very precise in the Japanese administrative data. Therefore, the QI score is accurate in any hospital.

2.4. Statistical analysis

We first calculated descriptive statistics for the hospitals' and respondents' baseline characteristics, which included hospital bed numbers, teaching status, number of full-time physicians, number of resident physicians (representing younger physicians who may be more likely to incorporate IT into their practice), as well as respondent sex, age, and appointment. The responses to the questionnaire items related to hospital policies and IT infrastructure were also summarized. The main items of interest consisted of yes/no questions; we calculated each hospital's number of positive responses within each item. The hospitals were categorized into subgroups based on these response numbers, and the mean QI score was calculated for each subgroup.

Finally, we performed a chi-squared automatic interaction detection (CHAID) tree analysis to identify factors that determine hospital quality of care. The independent variables included hospital size and teaching status, hospital policies regarding the promotion of evidence-based practice, and IT infrastructure (accessibility to the Internet and other information sources, access to paid medical evidence databases, and medical library and intranet usability within hospitals). The dependent variable was the mean QI score for perioperative antibiotic prophylaxis. CHAID tree analysis repeatedly uses chi-square statistics to split independent variables into child nodes [26-28] to identify the relative interactions between the independent variables and the outcome variables. This method is a classification tree algorithm that is often utilized as a data mining method in fields with complex data sets, such as marketing, health care [27], and nursing [28]. We used the exhaustive CHAID algorithm, a modified version of the basic algorithm that performs a more thorough merging and testing of independent variables [29]. Statistical calculations were performed using SPSS 20.0J software and Decision Tree (SPSS Inc, Chicago, IL).

2.5. Patient and public involvement

There was no patients or public involvement in the design and analysis of this study.

3. Results

3.1. Baseline characteristics, hospital policy, and IT infrastructure

From the 239 hospitals that responded to the questionnaire (response rate: 57.2%), we were able to calculate and integrate the target QI data for 153 hospitals. Hospitals with data on at least one target QI were included. The hospital selection flow diagram is presented in Figure 1. The baseline characteristics of the participant hospitals and respondents are shown in Table 1. The median number of hospital beds was 303 (range: 63–1161). Approximately 75% of all the hospitals were teaching hospitals; the mean number of junior and senior residents in each hospital was approximately 21.

Table 2 shows the results of the survey on hospital policies and IT infrastructure. Almost all respondents reported that their hospitals had an explicit policy to enhance IT infrastructure (94.1%). However, the provision of wireless LAN (71.9%) and access to paid medical evidence databases in English (54.9%) was limited. Further, an intranet homepage was provided only in a minority of hospitals (27.5%).

Figure 2 shows the information sources freely available or specifically provided by the participating hospitals. There were large variations in the provision of paid medical evidence databases, and hospitals tended to subscribe to the Japanese-language database (77.1%) rather than the English-language databases (9.8–46.4%). In general, the print editions of various CPGs and medical information were provided more frequently than the electronic editions, and there were relatively few hospitals that provided CPGs in either edition (41.2% in the print edition and 15.0% in the electronic edition).

3.2. Correlates of hospital quality of care

Table 3 shows the mean QI scores for the use of perioperative antibiotics according to the various independent variables. Hospitals with a lower number of positive responses to items related to hospital policies and IT infrastructure tended to have a lower QI score. Using CHAID analysis, we identified three major correlates of QI score (Fig. 3; hospital size and teaching status were the strongest correlates. The subgroup of "≤ 500-bed non-teaching hospitals" had the lowest QI score (73.1 points, Node 2). The other subgroup (comprising larger or teaching hospitals) was divided into two groups based on the provision of access to paid medical evidence databases. The derived subgroup of "Japanese and/or English databases" was further divided into two groups according to (i) accessibility to the Internet, (ii) wireless LAN availability, and (iii) wired LAN availability at outpatient clinics/wards; hospitals in the subgroup that had the highest number of positive responses to these three items had the highest QI score (87.2 points, Node 6) among all nodes. In contrast, the subgroup that had positive responses to two or fewer of these items had a lower QI score (83.1 points, Node 5). The subgroup of hospitals with no IT infrastructure elements had the lowest QI score (75.1 points, Node 4) among the larger or teaching hospitals. These results indicated that the provision of access to paid medical evidence databases and accessibility to the Internet (including LAN availability) were strongly associated with hospital quality of care.

4. Discussion

In this multicenter study, we observed wide variations in the provision of IT infrastructure across hospitals in Japan. Our results indicated that hospitals with superior IT infrastructure tended to have higher adherence to CPGs for perioperative antibiotic prophylaxis. Using a

CHAID tree analysis, we found that the provision of access to paid medical evidence databases and accessibility to the Internet (including LAN availability) were strong indicators of quality of care in larger or teaching hospitals

Despite the wide availability of new medical evidence, clinicians are not always able to acquire and apply the most recent and relevant information at the right moment in their daily practice. The lack of adequate IT infrastructure may affect the ability of clinicians to access this information, thereby contributing to evidence-practice gaps. There are more than 8,000 hospitals in Japan, of which 80% (and almost all clinics) are privately owned [30]. Different leadership approaches among these hospitals may have resulted in considerable variations in IT infrastructure. Our analysis found that there was an overall inadequate provision of LAN, and accessibility to the Internet and electronic health records was limited among the hospitals. In addition, the print editions of various CPGs and medical information were provided more frequently than electronic editions. Previous studies on the activities to improve accessibility to medical information within specific hospital networks [31,32] have indicated the importance of hospital leadership in the development of IT infrastructure.

Our CHAID analysis found that the three most important correlates of hospital quality of care were hospital size and teaching status, access to paid medical evidence databases, and high accessibility to the Internet. Notably, hospital policies and library/intranet usability were not identified as major correlates. There are likely several reasons for the identification of hospital size and teaching status, access to paid medical evidence databases, and high accessibility to the Internet as the most important factors. Firstly, from an economic perspective, teaching hospitals tend to be large and more likely to have the economic capability to provide resources such as IT infrastructure and full-time librarians engaged to work on intranet development. The results in Table 2 indicate that more than half of the participating hospitals do not hire full-time medical librarians. Interviews with the administrators of several leading teaching hospitals prior to the survey revealed that some administrators were actively working to enhance their hospital's intranet environment. This included the hiring of full-time librarians to create user-friendly intranet homepages designed to guide clinicians to the most recent and relevant clinical information. Our results are consistent with those of previous reports that show improvements in medical library functionality can improve patient health outcomes while reducing the time needed for clinicians to search for required information [33,34]. From a cultural perspective, "teaching" nature of the teaching hospitals makes them more committed to evidence-based thinking and promote evidence-based practice. In the Japanese context, highly motivated teaching staffs tend to gather in large-scale teaching hospitals, and these cultural elements may also explain our results in part.

Secondly, we found that hospital administrators tended to provide access to free medical databases first, followed by the paid Japanese database, and finally the paid databases in English (Fig. 2). Besides the high cost of subscribing to English-language databases, the administrators may have prioritized the Japanese database due to the possible language barrier for Japanese clinicians; this phenomenon has also been observed in Taiwan [35]. However, the failure to provide medical databases in English raises concerns that the clinicians may be unable to retrieve the newest relevant information in a timely manner, which can directly impact daily clinical practice. In addition, the availability of information in English may be crucial to the efficient dissemination and effective implementation of CPGs.

Thirdly, the importance of Internet accessibility (including LAN availability) to healthcare quality has been similarly observed in previous studies from the US and UK [1,21,31]. Our study sample included a fairly high proportion of hospitals without wireless LAN (28.1%) or with limited wired LAN availability at outpatient clinics and wards (64.1%). In order to encourage the implementation of IT infrastructure that facilitates easy retrieval of evidence in all types of hospitals, it may be necessary to develop a standardized assessment tool for hospital IT infrastructure and to include such assessments as a component of hospital accreditation.

In daily clinical practice, clinicians have limited time to search for and retrieve medical information. Thus, an ideal search platform would allow the use of clinical questions with several keywords and provide the requested information promptly and accurately. In addition to improving the accessibility and usability of online information, it may be useful to actively provide paid medical evidence databases (especially English-language databases) at the hospital level to supply multiple layers of information ranging from abstracts to full-text articles, as well as recommendations for CPGs and their evidence sources. In order to maximize the use of this system, individual physicians should work to improve not only their English language skills, but also their information searching skills and ability to implement new knowledge into practice.

Our findings suggest that larger or teaching hospitals would have the most potential for improvements in IT infrastructure that can lead to better quality of care (see Nodes 4, 5, and 6 in Fig. 3). As Doebbeling et al. noted, IT implementation is dependent on the support of hospital management and “should be tailored to the needs of the organization, and not as a ‘one size fits all’ solution” [36]. It is also necessary to conduct balanced assessments of the costs and effectiveness of these IT infrastructures in order to efficiently support the implementation of evidence into practice under limited budgets.

In a broader context, barriers to implementing CPG recommendations in daily practice vary greatly at the individual level of specialists and physicians (e.g. perception, education, incentives, professional autonomy), the institutional level (e.g., physician leadership, hospital policies, finance, institutional culture, teamwork, IT infrastructure), national level (e.g., policies to promote CPG use, hospital accreditation) and the social level (e.g. a culture of shared-decision making with patients, information derived from mass media) [37,38,39]. Yet, given the growing importance of IT use in an innovative society, the impact of IT adoption on healthcare quality warrants far more consideration of the types of relationships that were revealed in this study. According to previous research, IT itself needs to be understood as having two distinct components—information technology and communication technology—and these differently affect the autonomy of workers [40]. Further examination is needed to clarify these issues in order to implement IT in practice settings.

There are several limitations to this study. First, the respondents were hospital administrators, which means the results may not indicate the usability of various IT infrastructure elements from a physician's perspective. In addition, as this was a self-reported survey, the possible presence of social desirability bias may have caused these respondents to underestimate the barriers being investigated. Because individual physicians are the primary target users and are likely to be the link between IT infrastructure and quality of care, studies focusing physicians are required in the future to clarify the quality improvement mechanism in detail. Second, the survey was conducted in Japan, which may limit the generalizability of our results to other countries. Third, the QI that we used was limited to adherence to the CPGs for perioperative antibiotic use and therefore describes only one aspect of healthcare quality. Fourth, as we used administrative claims data, we could not know the clinical information in detail including appropriate exceptions in clinical practice. However, in this study, we focused on perioperative antibiotic prophylaxis of the 11 surgeries, which we could identify accurately based on the information of surgical procedure and drug use from the database. Finally, we were not able to identify the amount of investment or the affordability of each hospital's IT infrastructure, and further studies are needed to examine the total effect of these issues on the quality of hospital care.

5. Conclusions

Hospitals with superior IT infrastructure may provide higher-quality care. The provision of access to paid medical evidence databases and accessibility to the Internet were strongly associated with hospital quality of care, and may be key factors for improving healthcare quality in larger or teaching hospitals. These infrastructure elements may allow healthcare professionals to retrieve the latest information on evidence-based medicine with greater ease and facilitate the dissemination of CPGs in the Internet era. Hospitals should focus on establishing adequate IT infrastructure to support the effective implementation of CPGs. The systematic improvement of IT infrastructure in hospitals may support greater adherence to CPGs and narrow the evidence-practice gaps.

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Contributors

NS and YI had full access to all the data in the study and take responsibility for the analysis and interpretation. Conception and design:NS,YI; Acquisition of data and analysis:NS, YI; Interpretation of data:NS, NY,AO,MY, HS,YI; Drafting of the manuscript and statistical analysis:NS,YI; Obtaining funding:NY,YI. All the authors (NS, NY,AO, MY, HS, and YI) were involved in critical revisions and approved the final manuscript for publication.

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Competing interests

The authors declare that they have no competing interests.

Ethics approval

This study was approved by both the Ethics Committee of Kyoto University Graduate School and Faculty of Medicine, Japan (R0979, R0135) and that of Japan Council for Quality Health Care (Rin26-4). Informed consent was received from all participants prior to the survey, and they were also informed that the data was being collected for research purposes. Regarding the DPC data, we collect anonymous data based on a process designated by the ethics guideline from the Japanese government, and the consent to participate from each patients was omitted.

Provenance and peer review

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Data sharing statement

No data are available.

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Figure legends

Figure 1. Flow diagram of the subject hospital selection process.

*Target QI indicates QI of perioperative antibiotic prophylaxis of the 11 surgical procedures mentioned in the manuscript.

Figure 2. Information sources freely available or specifically provided by the participating hospitals (153 hospitals).

Figure 3. Chi-squared automatic interaction detection tree diagram showing the correlates of the QI score.

* These values indicate the numbers of positive responses to questionnaire items related to (i) Electronic health records and Internet availability, (ii) wireless LAN availability, and (iii) wired LAN availability at outpatient clinics/wards. DB, database; LAN, local area network; QI, quality indicator; SD, standard deviation.

** p=0.0499, in detail.

1

Table 1. Characteristics of the hospitals and respondents [a] (153 hospitals)

Hospital characteristics	
Beds, mean ± SD (range); median	339 ± 182 (63-1161); 303
Teaching hospitals, n (%)	115 (75.2)
Hospital size, n (%)	
> 500 beds	25 (16.3)
≤ 500 beds	128 (83.7)
Full-time physicians, mean ± SD (range)	61.9 ± 43.3 (8-268)
Resident physicians, mean ± SD (range)	21.2 ± 29.2 (0-197)
Respondent characteristics	n (%)
Sex	
Male	125 (81.7)
Female	19 (12.4)
No response	9 (5.9)
Age	
20–29 years	5 (3.3)
30–39 years	21 (13.7)
40–49 years	28 (18.3)
50–59 years	50 (32.7)
60–69 years	39 (25.5)
No response	10 (6.5)
Appointment	
Hospital administrator (physician)	69 (45.1)
Chief general manager (non-physician)	38 (24.8)
Others	34 (22.2)
No response	12 (7.8)

[a] Respondents answered the questions as representatives of their hospital.
SD, standard deviation.

2

Table 2. Hospital policies and IT infrastructure (153 hospitals)

Questionnaire items	n	(%)
Hospital policies		
Explicit policy to enhance IT infrastructure to improve accessibility to medical information (YES)	144	(94.1)
Explicit recommendation for the utilization of evidence-based medicine (YES)	88	(57.5)
Explicit recommendation for adherence to clinical practice guidelines (YES)	84	(54.9)
Accessibility to the Internet and other information sources		
Electronic health records and Internet access		
Access to both electronic health records and the Internet	110	(71.9)
Other	43	(28.1)
Wireless LAN		
Available with no limitations/with limited access points	110	(71.9)
Not available	43	(28.1)
Major locations with wired LAN access *(Multiple answers allowed)*		
Outpatient clinics/wards	98	(64.1)
Other locations (including medical offices and library)	144	(94.1)
Access to paid medical evidence databases *(Multiple answers allowed)*		
Igaku Chuo Zasshi (ICHUSHI) Database <in Japanese>	118	(77.1)
Medical databases such as UpToDate®, Clinical Key®, Ovid®, and DynaMed®	84	(54.9)
Medical library and intranet usability within the hospital		
Provision of an intranet homepage with user-friendly interface	42	(27.5)
Number of full-time medical librarians		
≥ 1	66	(43.1)
0	87	(56.9)
Medical library activities *(Multiple answers allowed)*		
Periodic meetings held to improve the information retrieval environment	84	(54.9)
Continuously working to improve library services and usability	60	(39.2)
Participation in hospital librarian associations and communication with other hospital librarians	25	(16.3)
Other	23	(15.0)

IT, information technology, LAN, local area network.

Table 3. QI scores of hospital groups according to the number of positive responses to questionnaire items on hospital policies, IT infrastructure, and hospital size (153 hospitals)

Number of questionnaire items with positive responses	Mean QI score	n
Hospital policies [a]		
0	78.73	4
1	81.92	51
2	84.95	29
3	78.92	69
IT infrastructure		
Accessibility to the Internet and other information sources [b]		
0	78.59	5
1	82.20	32
2	78.70	62
3	83.32	54
Access to paid medical evidence databases [c]		
0	72.55	25
1	79.76	54
2	84.88	74
Medical library and intranet usability within the hospital [d]		
0	81.70	21
1	78.45	45
2	80.25	39
3	84.40	26
4–6	83.27	22
Hospital size and teaching status		
> 500-bed non-teaching	87.64	4
> 500-bed teaching	83.28	21
≤ 500-bed teaching	83.16	94
≤ 500-bed non-teaching	73.10	34

Questionnaire items are as follows:

[a] Three items: having explicit policy to enhance IT infrastructure, explicit recommendation for the utilization of evidence-based medicine, and explicit recommendation to use clinical practice guidelines.

[b] Three items: Electronic health records and Internet availability, wireless LAN availability, wired LAN availability at outpatient clinics/wards.

[c] Two items: provision of access to the Japanese medical database and access to English-language medical databases.

[d] Six items: provision of access to an intranet homepage, one or more full-time medical librarians, periodic meetings for library improvement, continuously working to improve library services and usability, communication with other hospital librarians, and others.

IT, information technology; LAN, local area network; QI, quality indicator.

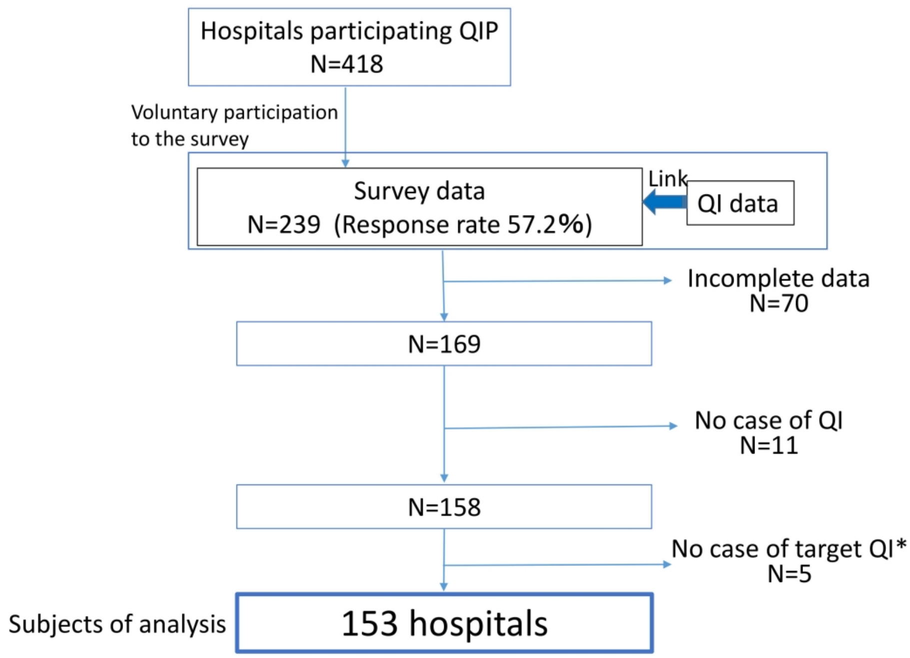

Figure 1. Flow diagram of the subject hospital selection process.
*Target QI indicates QI of perioperative antibiotic prophylaxis of the 11 surgical procedures mentioned in the manuscript.

254x190mm (300 x 300 DPI)

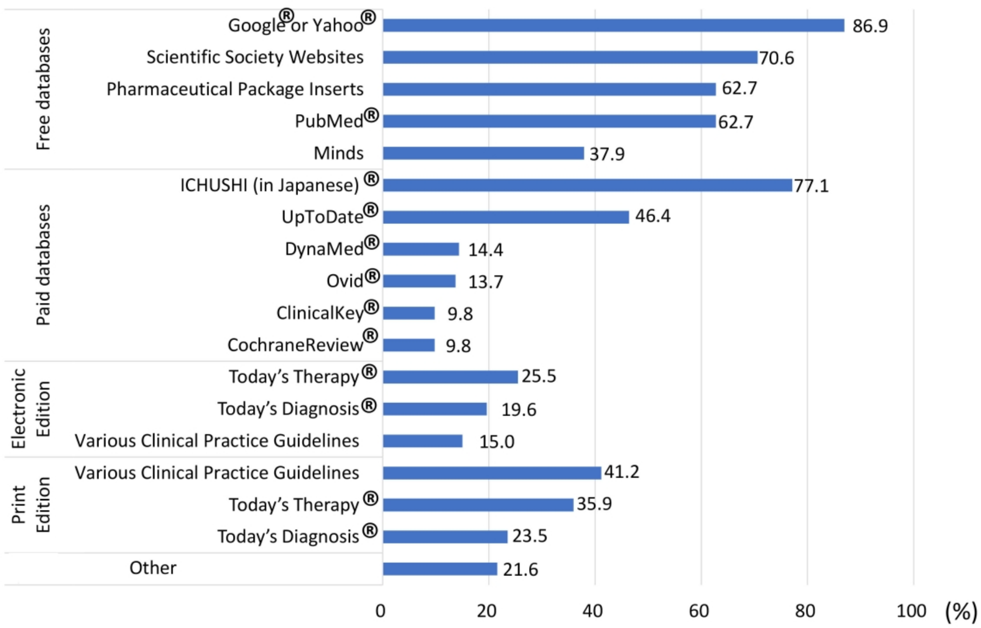

Figure 2. Information sources freely available or specifically provided by the participating hospitals (153 hospitals).

245x158mm (300 x 300 DPI)

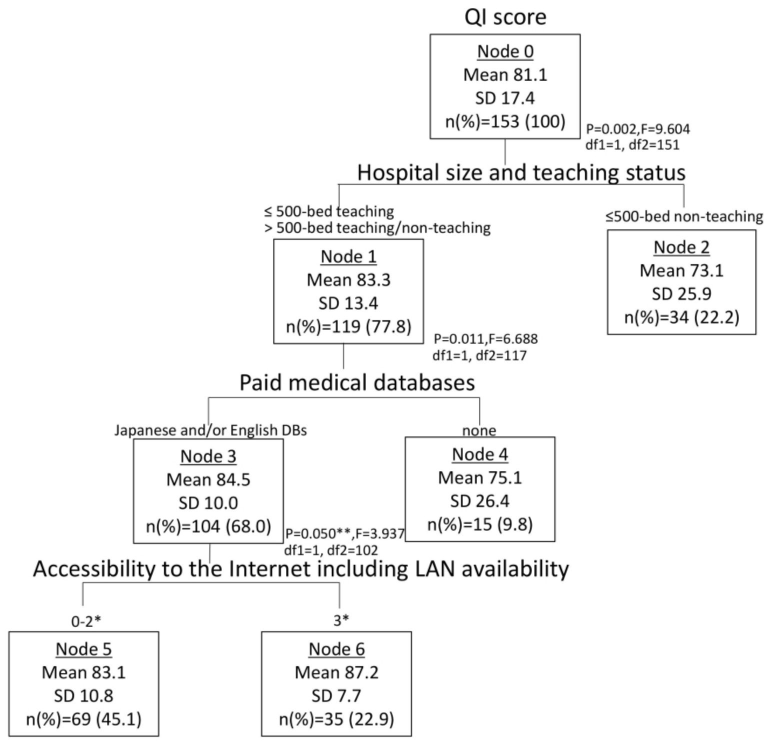

Figure 3. Chi-squared automatic interaction detection tree diagram showing the correlates of the QI score.
* These values indicate the numbers of positive responses to questionnaire items related to (i) Electronic health records and Internet availability, (ii) wireless LAN availability, and (iii) wired LAN availability at outpatient clinics/wards. DB, database; LAN, local area network; QI, quality indicator; SD, standard deviation.
** p=0.0499, in detail.

254x190mm (300 x 300 DPI)

Appendix_Table. Original Questions

Q1-1. Does your hospital have an explicit policy to enhance IT infrastructure in order to improve accessibility to medical information?
□ Yes □ No □ Other

Q1-2. What information sources are available in your hospital? (Please choose all options that would apply)
□ 1. PubMed □2. Google/Yahoo □3. Pharmaceutical Package Inserts □ 4. Pharmaceutical Interview Forms
□ 5. Scientific Society Websites □ 6. MINDS
□ 7. *Igaku Chuo Zasshi* (ICHUSHI) Medical Literature Database [**Hospital** Subscription]
□ 8. *Igaku Chuo Zasshi* (ICHUSHI) Medical Literature Database [**Medical Office** Subscription]
□ 9. UpToDate [**Hospital** Subscription] □ 10. UpToDate [**Medical Office** Subscription]
□ 11. Cochrane Review □ 12. ClinicalKey □13. Ovid □ 14. DynaMed
□ 15. *Today's Diagnosis* [**Electronic Edition**] □ 16. *Today's Therapy* [**Electronic Edition**]
□ 17. Various Clinical Practice Guidelines [**Electronic Versions**]
□ 18. *Today's Diagnosis* [**Print Edition**] □ 19. *Today's Therapy* [**Print Edition**]
□ 20. Various Clinical Practice Guidelines **[Print Versions**] □21. Other

Q2-1. What type of accessibility to the Internet and other information sources is available in your hospital?
□ Access to both electronic health records (EHRs) and the Internet is permitted from the same computer.
□ Access to both EHRs and the Internet is permitted from different computers.
□ Access to EHRs is permitted only in the hospital network. Therefore, healthcare workers have to use their own computers to access the Internet.
□ EHRs are not available.
□ Other

Q2-2. Is *wireless* LAN available in your hospital?
□Yes, available with no limitations. □Yes, with limited access points. □ No, not available.

Q2-3. Where are the major locations in your hospital for Internet use with *wired* LAN access? *(Multiple answers allowed)*
□ Outpatient clinics □ Wards □ Medical offices □ Libraries
□ Other

Q3-1. How many librarians are there in your hospital?
□ Full-time: □ Part-time:

Q3-2. Does your hospital provide an intranet homepage with user-friendly interface?
□ Yes □ No □ Other

Q3-3. Which applies to your hospital regarding medical library activities? *(Multiple answers allowed)*
□ Periodic meetings held to improve the information retrieval environment
□ Continuously working to improve library services and usability (e.g., promoting paperless movements)
□ Participation in hospital librarian associations and communication with other hospital librarians
□ Other

Q4. Do you have an explicit recommendation for the utilization of evidence-based medicine in your hospital?
□ Yes □ No □ Other

Q5. Do you have an explicit recommendation for adherence to clinical practice guidelines in your hospital?
□ Yes □ No □ Other

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2, 5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	2,6
Methods			
Study design	4	Present key elements of study design early in the paper	2,7-8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	2,7-11
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-11
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-11
Bias	9	Describe any efforts to address potential sources of bias	17
Study size	10	Explain how the study size was arrived at	7-11
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-11、Table3
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-11
		(*b*) Describe any methods used to examine subgroups and interactions	9-11
		(*c*) Explain how missing data were addressed	Fig1.
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	*
		(*e*) Describe any sensitivity analyses	*
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11, Fig1.
		(b) Give reasons for non-participation at each stage	*
		(c) Consider use of a flow diagram	11, Fig1.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11, Table 1.
		(b) Indicate number of participants with missing data for each variable of interest	Fig1.
Outcome data	15*	Report numbers of outcome events or summary measures	Table 3. Figure 2.
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-13, Table 2.
		(*b*) Report category boundaries when continuous variables were categorized	11-13, Table 3
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	*
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11-13, Table 3 Figure 3.
Discussion			
Key results	18	Summarise key results with reference to study objectives	2-4,13,17-18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	4, 17-18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	4,13-18
Generalisability	21	Discuss the generalisability (external validity) of the study results	4,18
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.