Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Improvement of the Japanese healthcare data system for the effective management of patients with COVID-19: A national survey

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ABSTRACT

Objective: The burden of data entry in public platforms used for reporting patients with novel coronavirus disease 2019 (COVID-19) is a challenge in the healthcare setting. The key to mitigating the burden of data entry is system integration and elimination of double data entry. In addition, the linkage between public platforms and electronic medical records (EMRs) involves external networks, which are an important target for security management. The purpose of this study was to elucidate the status and challenges of infrastructure for continuous data reporting from hospitals in Japan.

Materials and Methods: An online survey of Japanese care delivery institutions was conducted from January 25 to February 22, 2021, to obtain data on the admission of patients with COVID-19, use of information infrastructures, and status of network connections with external organizations. The survey request was distributed to each care delivery institution by Japanese health authorities.

Results: Of the care delivery institutions that responded to the survey, 53.9% treated patients with COVID-19. Of these institutions, 73.3% used EMRs. 57.8% of the EMRs were connected to an external network. The purpose of connecting to the external network was to contribute to regional health information-sharing with other hospitals (22.0%), report online medical insurance claims (27.5%), and conduct intrahospital system maintenance (61.5%). A frequent concern about connecting an EMR to an external network was data leakage.

Discussion: In cases where the frequency of reporting patients with COVID-19 is high, health authorities should provide information regarding anti-data-leakage measures and coordinate frameworks for efficient, sustainable data collection.

Conclusions: We obtained information on existing infrastructures for patient data sharing among care delivery institutions and public health authorities. Our findings may be referenced by the government to make informed decisions about investments.

1. Introduction

Information regarding the number of patients with coronavirus disease 2019 (COVID-19) and their hospitalization is essential for disease management. Worldwide, public health authorities have been collecting data from care delivery institutions (CDIs) using various platforms [1–3].

In Japan, Ministry of Health, Labour, and Welfare—the national public health authority—launched the Health Center Real-Time Information-Sharing System (HER-SYS) for COVID-19 in May 2020 [4]. HER-SYS is an online platform that manages information concerning COVID-19, such as basic patient data, symptoms, polymerase chain reaction test results, and vaccination status.

As information about COVID-19 accumulates, the amount of data managed on HER-SYS increases. This has been associated with the increased burden of patient data entry into HER-SYS in CDIs and

Abbreviations: CDI, Care delivery institution; EMR, Electronic medical records; HT, Hiroyuki Takao; IT, Information technology; KT, Kohei Takeshita; PACS, Picture archiving and communication system; SI, Seiya Imoto; YM, Yuichi Murayama.

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Table 1
Questionnaire items.

I. Questions about EMR introduction and external network connections
1. Has your institution introduced EMRs?
2. Can the EMRs be connected to the Internet either directly or via a database?
3. Does your institution's system have a demilitarized zone network that can be accessed from both EMRs and external networks?
4. Are there cases when you allow an all-time connection between your network and external organizations when needed?
5. If you answered "yes" to Question 4, please describe the purpose of always keeping the network connected with external organizations.
6. Please describe any possible concerns about the connection between external organizations and EMRs based on your institution's policies.
II. Questions about the admission of patients with COVID-19 and EMRs
7. Do you admit patients with COVID-19 for physical examination, tests, or hospitalization?
8. If you answered "yes" to Question 7, do you enter the data of patients with COVID-19 into EMRs when you admit them?
9. If you answered "yes" to Questions 7 and 8, does your EMR system have a template function?
10. If you answered "yes" to Questions 7 and 8, do you use the template function for entering data into the HER-SYS or reporting to government authorities?
11. If you answered "yes" to Questions 7 and 8, would you want to use a template that will allow you to enter data into the EMR system and report to government authorities simultaneously?
12. Do you record the test results of patients with COVID-19 in a laboratory test system when you admit them?
13. Is the output of test results automated?
14. Do you allocate IDs to the test results in a format that can identify individuals?
15. Are the diagnostic imaging findings of patients with COVID-19 upon admission saved electronically?
16. Please specify the system in which the data on diagnostic imaging findings are saved.
17. Do you record patient data to any system other than EMRs, laboratory tests, and diagnostic imaging systems when you admit a patient?

regional government offices [5]; similar problems have been reported outside Japan [6–8]. Therefore, reducing the COVID-19–related data entry burden for CDIs and regional government offices is essential for the effective management and alleviation of this public health challenge.

The key to solving the data entry burden is system integration and elimination of double data entry [9]. Linkage with external systems, such as public platforms, requires a connection with the institution's electronic medical record (EMR), which is an important target for security management [10–12]. In preparation for future pandemics, it is essential to build a unified information technology (IT) infrastructure that addresses the concerns of individual CDIs regarding external networks.

1.1. Objective

To elucidate the status and challenges of infrastructure for continuous data reporting from hospitals in Japan, we conducted a questionnaire survey on the status of EMRs and external network connections as well as concerns about external network connections among hospitals nationwide.

1.2. State of health IT in Japan

According to a survey by the Japanese Association of Healthcare Information Systems Industry, the rate of EMR adoption in Japan is 38.3% as of April 2018. As for the state of interoperable data exchange, the Health Information and Communication Standards Organization has been organized to build consensus on the criteria of standardization.

According to all aggregated data of insurance claims that was released as open data, it was revealed that 0.4% of patient referrals to other medical institutions involve the exchange of electronic data. As per the data, it can be inferred that data exchange is not sufficiently conducted in actual practice.

In public health IT systems, patient data is being accumulated in cancer registries, academic society registries, long-term care insurance, medical insurance claims, and the registries of pediatric chronic diseases and intractable diseases. Most of the budget for these data collection is funded by the government.

Major policy initiatives to digitize care delivery information systems have been reported by Yasunaga [13], Yoshida [14] and Raghavan [15]. The budget for the expansion of EMR was distributed from the year 2000 to 2008, but the plan to deploy hospital information systems in most of the healthcare facilities in 2010 was not accomplished. Since then, investments have been made in inter-hospital information collaboration and the use of medical data for research.

2. Materials and Methods

This survey included 8,289 Japanese CDIs that had ≥ 20 beds and used an online platform to collect information about the admission of patients with COVID-19, use of data infrastructure, and status of network connections with external organizations. Health authorities

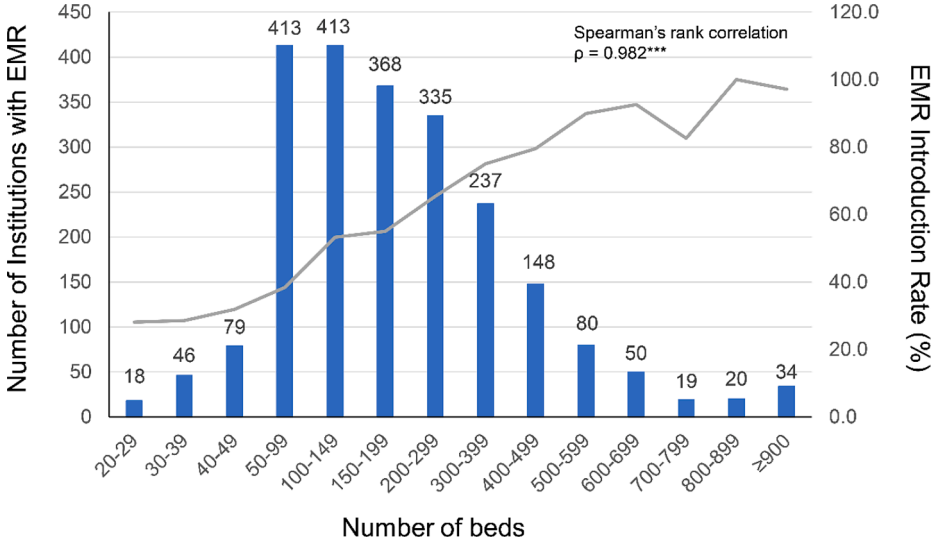

Fig. 1. EMR introduction rate in Japan based the on the number of beds. *** Correlation is significant at the 0.001 level (2-tailed). The details of the data are described in Appendix A.

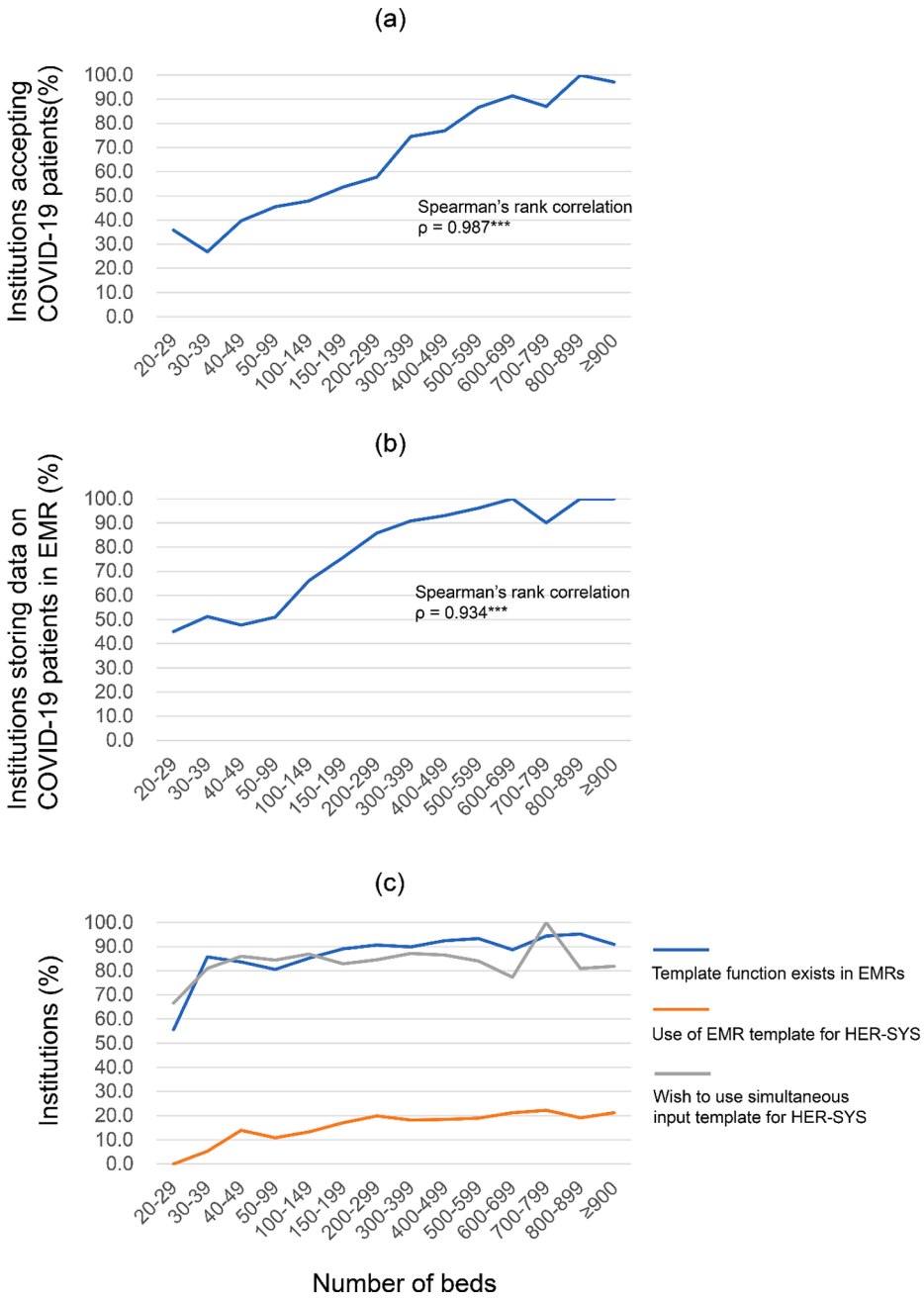

Fig. 2. Saving patient data in CDIs that accept patients with COVID-19. (a) COVID-19 patient admission. (b) COVID-19 patient data saved in EMRs. (c) Usage of the template function and expectations for the simultaneous input function. The details of the data are described in Appendix B.

conducted the survey from January to February 2021. After the names of CDIs were anonymized and the number of beds in each institution was included, the data were provided to our study team. The survey items assumed that a respondent was using EMR data to submit the data of patients with COVID-19 to HER-SYS on an external network; the survey was designed to facilitate evaluation of the CDI's infrastructure setup (Table 1). Furthermore, Japan Diabetes compREhensive database project based on an Advanced electronic Medical record System (J-DREAMS) [16] operated by Japan Diabetes Society—an existing medical data collection project—was used as a reference to inquire about the preferences of CDIs regarding a data collection framework that uses a template function for EMRs. Since a question confirmed the necessity of the template function for reducing double entry, no restriction was placed on its structure. The contents considered for the use of the template function include the HER-SYS items as described in the Introduction section.

In order to understand the impact of differences in hospital size on the responses [17,18], the questionnaires and data on the number of beds in a hospital were organized according to the number of beds in hospitals; records lacking the number of hospital beds were excluded from this analysis. Spearman's rank correlation coefficient was calculated to evaluate the correlation between answers to questionnaire and number of beds.

This study did not deal with individual patient data and dealt only with data from CDIs that agreed to the study in compliance with the Declaration of Helsinki and after written explanation from the Japanese health authorities to the CDIs who responded to the questionnaire.

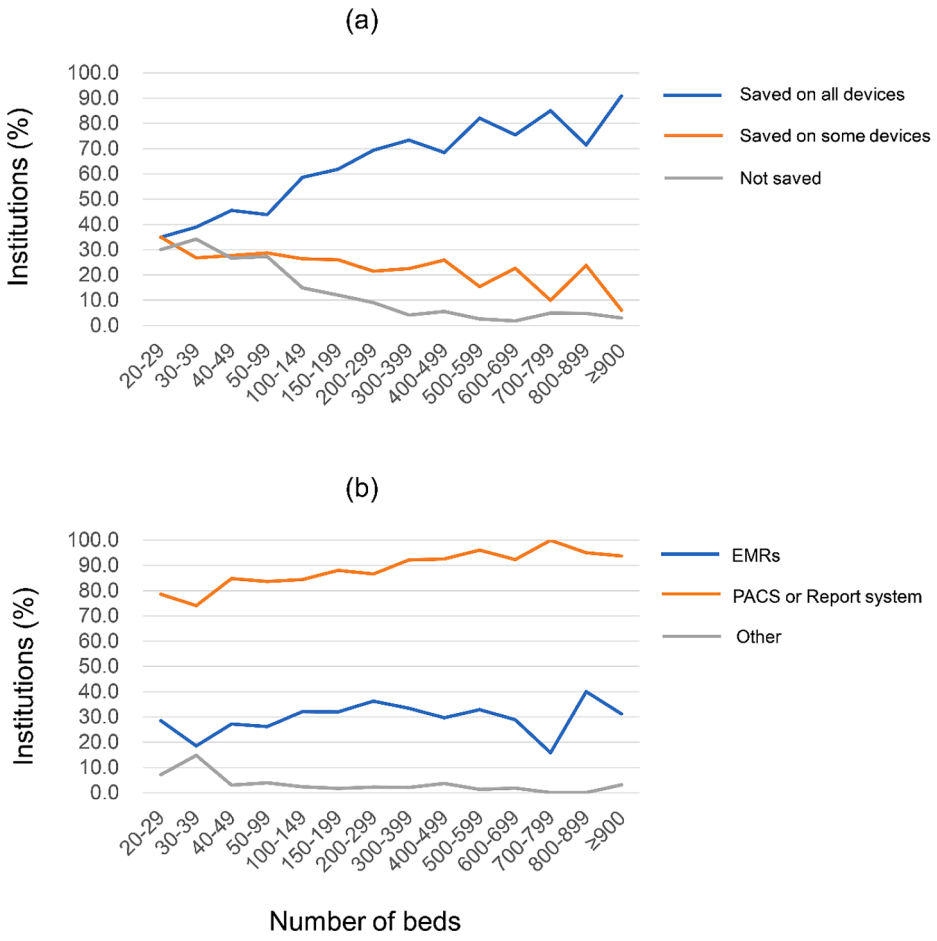

Fig. 3. Electronification of diagnostic imaging findings of patients with COVID-19 upon admission and data-saving status. (a) Status of digitalization of diagnostic images and findings. (b) Location of data saving.

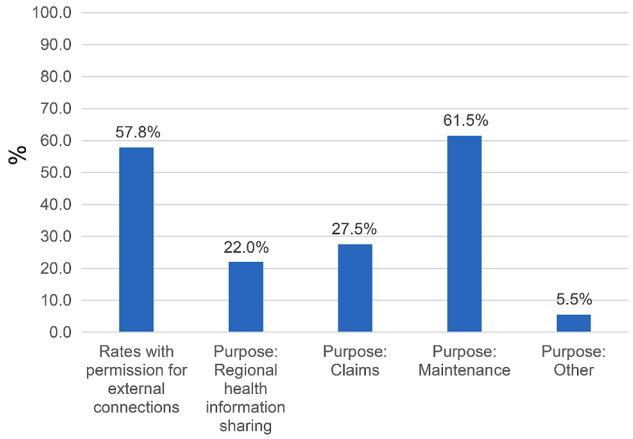

Fig. 4. Number of CDIs with electronic record systems that are always connected with external networks and purposes.

3. Results

Of the questionnaires distributed to 8,289 CDIs, 51.0% responded to questions on EMR introduction and external network connections and 48.6% responded to questions on patient admission and EMR while meeting the survey conditions. A total of 245 hospitals were excluded from the analysis because the number of beds were not listed in the anonymized data.

3.1. EMR introduction rates

Fig. 1 shows EMR introduction rates obtained from the survey. With an increase in the number of beds, the EMR introduction rate also increased: 53.4% for all institutions and 100% for institutions with 800–899 beds. A strong positive correlation was found between the number of beds and EMR introduction rate ($p < 0.001$).

3.2. Storage of COVID-19 patient data in EMR

Of the CDIs that submitted questionnaire-based surveys, 53.9% answered that they accepted patients with COVID-19 for physical examinations, testing, and hospitalization, and this rate tended to increase with an increase in the number of beds. Of the CDIs that accepted patients with COVID-19, 73.3% entered data into EMRs. The template function to record patient data was used by 16.4% respondents. To report new or suspected cases of COVID-19 in the CDI, 84.8% responded that they wish to use a template function for constructing EMRs if it becomes available. Regarding the admission of COVID-19 patients and storage of COVID-19 patient data in EMR, there was a strong positive correlation with the number of beds in the responding CDIs ($p < 0.001$). No correlation was found in the case of "wish to use templates for HER-SYS and EMR" (Fig. 2).

3.3. Storage of COVID-19 patient data in non-EMR

20.9% of the CDIs answered that they entered some patient data into a system other than EMR, with the most common alternate being Microsoft Excel. Of the 1,590 CDIs that answered that they entered data

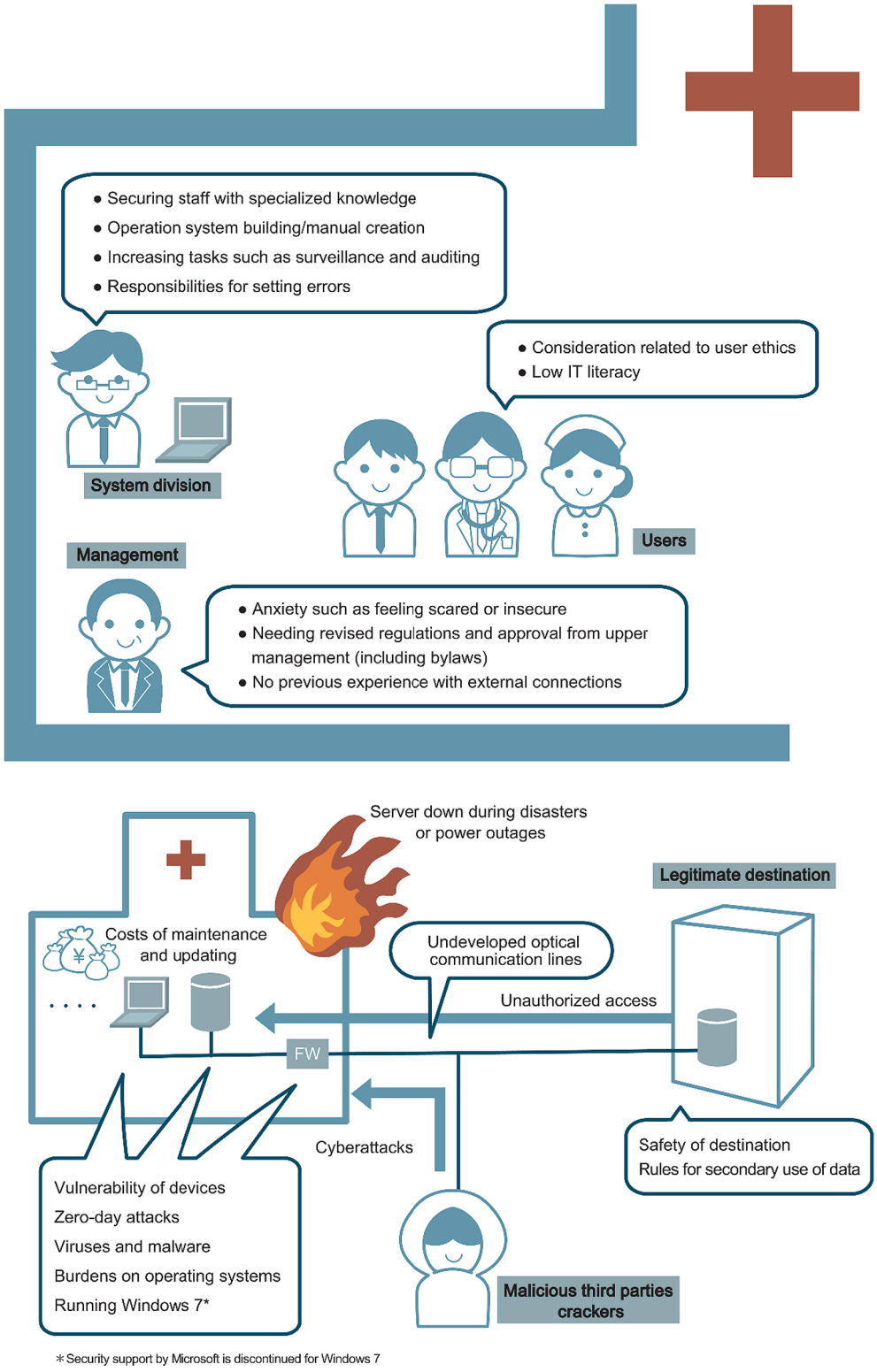

Fig. 5. Summary of concerns related to the connection between electronic records and external networks.

on the admission of patients with COVID-19 into EMRs, >10% (n = 182) responded that data that might be unsuitable for direct recording into EMRs were first entered into Excel. Furthermore, some of the surveyed institutions reported that paper-written documents which are not suitable from a data extraction perspective were scanned to save data on EMRs.

3.4. Test result data of COVID-19 patients

Of the respondents, 58.0% answered that they recorded the test results of patients with COVID-19 on admission in a laboratory test system; of these, 43.4% answered that data entry was automated, 33.6% answered that it was manual, and 23.1% answered that it was both automated and manual. Regardless of the data entry method, an ID that

allows the identification of individual patients was allocated to test result forms in ≥ 95% of the CDIs.

3.5. Diagnostic imaging and findings data of COVID-19 patients

Regarding the electronification of diagnostic imaging data of patients with COVID-19, 60.8% answered that all data were saved on all devices; 24.9% answered that data were saved on some devices; and 14.3% answered that data were not saved electronically. With an increase in the number of beds, the rate of institutions answering that data were saved on all devices tended to increase. Among institutions answering that data were saved on all or some devices, majority (87.7%) saved data on a picture archiving and communications system (PACS) or reporting system (Fig. 3).

The details of the data are described in Appendix C.

3.6. Connection between EMR and external networks

Of the CDIs that introduced EMRs, 57.8% allowed an all-time connection between the CDI's EMRs system and external networks when needed; this included 64.0% of CDIs with ≥ 200 beds and 75.9% of those with ≥ 500 beds. Respondents were asked to break down their connection status (selection of multiple options was allowed) is shown in Fig. 4. Descriptions of other purposes and modes of connections included backup and external data storage for remote areas; obtaining time stamps from a certification agency, virus definition files of security software, external interpretation of medical imaging data, or external access to medical charts, video conferences, online appointment services, online medical interview services, credit card payments, outsourcing tests, use of cloud EMRs and department systems; participation in studies such as patient data registries; and implementation of a system for checking medical insurance subscriber information.

3.7. Demilitarized zone availability

Regarding the availability of a demilitarized zone (DMZ), which is a segment of the hospital that can be accessed by both secure internal networks and potentially unsafe external networks, 22.5% of CDIs that introduced EMR were set up using a DMZ; of these CDIs, 39.4% had ≥ 500 beds. The EMRs of 19.0% of CDIs that introduced EMRs were connected with the Internet either directly or via a mediating database.

3.8. Concerns about EMR connections to external networks

When questioned about their concerns regarding connecting EMRs to external networks using an open-response form, respondents frequently mentioned "data leakage." Responses were organized on the basis of categories and were most frequently related to cyberattacks and security, regulations and external connection status, costs, and building and maintaining operating systems (in descending order). An overview of responses related to these concerns is presented in Fig. 5.

4. Discussion

The response rate to the questionnaire in this survey was about 50%, which was higher than the response rate for a similar scale. The high response rate to the study's questionnaire may reflect hospitals' strong desire to improve COVID-19 reporting The EMR introduction rate in this survey, which was conducted from January to February 2021, was 53.4%. This was similar to the approximate 52% EMR introduction rate that would be obtained by April 2021, assuming an 11.0% three-year average growth rate calculated from the number of facilities that introduced an EMR during 2015–2018, which was based on a previous study [19]. Although outpatient physician offices were not included in the aggregate for this study, the 2017 government statistics revealed that the adoption rate of EMRs in clinics (defined as 19 or fewer beds, but mostly outpatient physician offices) was 41.6%.

Of CDIs that accepted patients with COVID-19, 73.3% maintained EMRs, which was higher than the overall EMR introduction rate of 53.4%. Considering the introduction rate of EMRs, it was confirmed that admission of patients with COVID-19 was high in large-sized hospitals with a high introduction rate of EMRs.

The goal of realizing an option to create a report for government authorities (with the condition that data output to external networks is possible) on new patients with COVID-19 using the template function of EMRs was supported by 84.8% of the CDIs. This outcome indicates that respondents welcomed a system that would enable creating medical records and reports for government authorities simultaneously. At the time when this study was conducted, the clinical practice of COVID-19 treatment in Japan was in hospitals but not in clinics. Currently, primary care clinicians are providing COVID-19 treatment in Japan due to the prevalence of the Omicron strain. From the viewpoint of medical infrastructure, it is desirable to build a system that includes reports from primary care clinicians. J-DREAMS, an existing domestic system, makes it is possible to develop a system that saves data in the electronic template—not on the EMR database but in another storage system—which may enable developing a system without overdependence on EMR vendors of individual CDIs [16]. Streamlining existing systems and resource integration is essential to implement such a system nationwide. However, templates may not be useful when there are many items to enter, as the burden of input would be excessive, even if templates were available [20]. Careful consideration of item selection and maximized automated entry are important for both collectors and providers of information. The purpose of improving the efficiency of data entry into HER-SYS using EMRs should not be digitalization or information exchange; rather, government authorities should prepare and rapidly develop infrastructures with the purpose of reducing the number of tasks while improving their efficiency and productivity [21]. However, while developing an infrastructure-related investment, subsequent maintenance and possible sharing with other systems must be considered from a cost-management perspective. Regarding investments in EMRs, the United States Health Information Technology for Economic and Clinical Health Act of 2009 [22] assisted and incentivized CDIs, which promoted the adoption of EMRs. Since their adoption, data are being used in an increasingly advanced manner, exemplified by the development of frameworks to improve therapeutic outcomes while balancing incentives and disincentives [23]. Moreover, an open-ended system design is desired, considering its use in the future.

This study was the first to reveal the nationwide connectivity among EMR systems of Japanese CDIs with external networks. Of the CDIs that introduced EMRs, 57.8% were connected with external networks, and > 20% were connected with the regional health information-sharing system and online claim systems, which exchange personal information with external parties. A connection for maintenance by intrahospital system vendors was practiced by 61.5% of care delivery institutions, which exceeded the rate of response to the question about connections with external networks (57.8%), indicating that the lines for maintenance by intrahospital system vendors are not regarded as external networks by survey respondents.

The primary concern of CDIs concerning connecting EMRs with external networks is data leakage; several responses cited cyberattacks as a risk factor for data leakage and security breaches. To continuing operations that are important for medical data systems and prevent data leakage, the extent of recent EMR damage caused by ransomware and trade of medical data on the dark web have been reported [24,25]. Such reports may have contributed to the responses. To reduce the burden of data entry into HER-SYS by promoting connections between EMRs and external networks as a universal infrastructure, public health authorities should devise measures to tackle cyberattacks and security issues, update regulations and external connections, and manage costs and operations. Considering the responsibility in case of accidents and the cost of network monitoring and management, centralized management by the

government and related agencies is needed. If a centrally managed network is established, it can be used not only for infectious disease reporting but also for other purposes, thus increasing the utilization of the network and relatively lowering the cost of maintaining the network. It is important to build efficient, sustainable data collection frameworks that incentivize various stakeholders to coordinate a consensus regarding burdens [17,21]. Investment in information infrastructure and external network connectivity is also important, not only at the government level, but also at the individual hospital level. Hospital leaders must first create scenarios that improve their operational efficiency, the quality of care they provide, and the revenue they generate. Scenarios in hospitals without EMRs may lack a rationale. The implementation of EMRs should be considered in order to increase certainty. The data exchange capabilities of individual hospitals may be enhanced by the adoption of standardized data sets and the construction of DWH, which are also useful for business analysis.

Of the CDIs that introduced EMRs, 22.5% answered that they were equipped with DMZ, and of CDIs with $\geq$ 500 beds, 39.4% answered the same. It may be easier for large-sized CDIs to set up a DMZ for purchasing devices or securing specialized human resources. To exchange information, it is essential to improve the aspects that are visible to general users; for instance, data collection bodies making announcements, designing incentives, establishing databases, strategizing how to use the collected data to achieve objectives, and designing interfaces used by operators. In addition, it is critical that networks carry information safely and adequately [26]. In Japan, securing network experts and other workers with extensive knowledge of information and communication technology is a critical challenge [27]. In particular, CDIs lack the proactive employment of system and network engineers due to the demand of high salaries; thus, medical staff may not use information exchange tools due to the lack of IT staff.

4.1. Limitations

This study has several limitations. First, it was based on an online survey of nationwide CDIs with $\geq$ 20 beds. The response rate for the survey was approximately 50%, and some of the CDIs did not provide data on the number of beds.

Second, some questions in the survey could not be answered accurately without the knowledge of the network. It is important to interpret this survey with the awareness that due to human-resource limitations in CDIs, some of the questionnaires may have been completed by nonexperts.

Third, it was necessary to limit the number of questions in this survey to maintain the response rate. Further, the correlation coefficient based on the number of beds was used in the analysis. Correlation coefficients are not related to other factors that may affect EMR adoption, such as the type of EMR and IT budget. It is advisable to understand the current status of factors that have a strong impact on maintaining IT infrastructure, such as the budget of each care delivery institution, before undertaking specific subsidy measures for EMRs.

5. Conclusions

This study obtained information regarding CDIs with existing infrastructures that submit data on patients with COVID-19 to a platform operated by Japanese public health authorities. The results indicate that: (1) the EMR adoption rate of 53.4% is increasing every year; (2) 57.8% of EMRs are connected to external networks; (3) office software is used in some cases to manage COVID-19 reporting items; (4) the template function feature (which reduces double entry) is favored by more than 80% of hospitals; and (5) the biggest concern of medical institutions when connecting EMRs to external networks is information leakage. If promoted as a government policy initiative, the connection of EMRs to external networks and the introduction of template functions for administrative reporting are expected to provide a social infrastructure function that would increase efficiency and reduce costs to both hospitals and the government. The Japanese government can make informed investments by referring to the data obtained from this study.

Summary Table

What was already known on the topic	What this study added to our knowledge
• COVID-19 patient reporting systems are in operation in each country. • In Japan, the input burden of the patient reporting system called HER-SYS has become an issue.	• How to store COVID-19 patient data by hospital size has been clarified. • Approximately 73.3% of hospitals use electronic medical records. • Approximately 57.8% of hospitals have a track record of connecting electronic medical records to external networks. • Information leakage was the number one concern about external connections.

Funding

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Data References

Not applicable.

Video

Not applicable.

Data Visualization

Not applicable.

Mendeley Data

Not applicable.

Data Statement

The data access is limited by Ministry of Health, Labour and Welfare.

Authors' Contributions

Kohei Takeshita (KT) and Hiroyuki Takao conceived and designed the analysis. KT and Seiya Imoto contributed to data collection. KT contributed to the selection of data/analysis tools and performed the analysis. KT and Yuichi Murayama wrote the paper.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We express our sincere gratitude to the CDIs that participated in this survey while responding to patients with COVID-19 during this pandemic.

Appendix A

See Table A1.

Table A1
EMR introduction rate in Japan based the on the number of beds (ranges).

Number of beds	1. Has your institution introduced an EMR?		EMR introduction rate (%)
	Yes	No	
20–29	18	46	28.1
30–39	46	115	28.6
40–49	79	169	31.9
50–99	413	664	38.3
100–149	413	363	53.2
150–199	368	301	55.0
200–299	335	177	65.4
300–399	237	79	75.0
400–499	148	38	79.6
500–599	80	9	89.9
600–699	50	4	92.6
700–799	19	4	82.6
800–899	20	0	100.0
≥900	34	1	97.1
Total	2,260	1,970	53.4
Spearman's rank correlation (ρ)	–	–	0.982***

*** Correlation is significant at the 0.001 level (2-tailed).

Appendix B

See Table B1.

Table B1
Saving patient data in care delivery institutions that accept patients with COVID-19.

	7. COVID-19 patient admission	8. COVID-19 patient data saved in EMRs	9. Template function exists in EMRs	10. Use of template functions for HER-SYS or government reporting	11. Wish to use a template function that allows EMR data entry and government reporting simultaneously
N	4,026	2,169	1,590	1,555*	1,590
Number of beds	**Answered "Yes" (%)**	**Answered "Yes" (%)**	**Answered "Yes" (%)**	**Answered "Yes" (%)**	**Answered "Yes" (%)**
20–29	35.7	45.0	55.6	0.0	66.7
30–39	26.8	51.2	85.7	5.3	81.0
40–49	39.6	47.8	83.7	14.0	86.0
50–99	45.4	51.0	80.5	10.8	84.4
100–149	48.0	66.1	85.2	13.3	87.0
150–199	53.6	75.7	89.1	17.1	82.9
200–299	57.8	85.8	90.7	19.8	84.6
300–399	74.5	90.8	89.9	18.1	87.2
400–499	76.9	93.0	92.5	18.5	86.5
500–599	86.7	96.2	93.3	18.9	84.0
600–699	91.4	100.0	88.7	21.2	77.4
700–799	87.0	90.0	94.4	22.2	100.0
800–899	100.0	100.0	95.2	19.0	81.0
≥900	97.1	100.0	90.9	21.2	81.8
Total	53.9	73.3	87.9	16.4	84.8
Spearman's rank correlation (ρ)	0.987***	0.934***	0.846***	0.906***	0.088

*35 institutions did not respond to this question.
*** Correlation is significant at the 0.001 level (2-tailed).

Appendix C

See Table C1.

Table C1
Electronification of diagnostic imaging findings of patients with COVID-19 upon admission and data-saving status.

Number of beds	15.1. Saved on all devices (%)	15.2. Saved on some devices (%)	15.3. Not saved (%)	Location of data saving* if "Yes" to Question 15.1 or 15.2		
				EMRs (%)	PACS or report system (%)	Other (%)
20–29	35.0	35.0	30.0	28.6	78.6	7.1
30–39	39.0	26.8	34.1	18.5	74.1	14.8
40–49	45.6	27.8	26.7	27.3	84.8	3.0
50–99	43.9	28.7	27.4	26.1	83.6	4.0
100–149	58.6	26.4	14.9	32.1	84.5	2.4
150–199	61.9	26.1	12.0	32.0	88.0	1.7%
200–299	69.4	21.5	9.0	36.3	86.6	2.3
300–399	73.3	22.5	4.2	33.5	92.2	2.2
400–499	68.5	25.9	5.6	29.6	92.6	3.7
500–599	82.1	15.4	2.6	32.9	96.1	1.3
600–699	75.5	22.6	1.9	28.8	92.3	1.9
700–799	85.0	10.0	5.0	15.8	100.0	0.0
800–899	71.4	23.8	4.8	40.0	95.0	0.0
≥900	90.9	6.1	3.0	31.3	93.8	3.1
Total	60.8	24.9	14.3	31.1	87.7	4.1

*Multiple selections allowed.

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