Teleconsultation in an Extremely-busy Chinese Hospital: Practices and Challenges

Teleconsultation can increase the accessibility of medical resources and reduce patients' long-distance travel costs in seeking remote health care. Due to the lockdown policies during the COVID-19 pandemic, governments and hospitals in many countries establish teleconsultation platforms to facilitate remote patients, especially those with chronic diseases who need regular follow-up visits. Physicians are the providers of teleconsultation. Thus, their experiences are worth to be studied. Existing work mainly focuses on the general challenges that physicians face, *e.g.*, low network quality and cannot conducting physical examinations. Rare studies how teleconsultation is affected by conventional care, which directly affects the online work style, experience, and effectiveness, thus affecting the usage sustainability of the platform. This work bridges the gap by conducting a case study in China. We aim to study physicians' experiences and the challenges they face when providing teleconsultation services while extremely busy, thus revealing their requirements and inspiring design optimization. Through observations and interviews, we find that physicians have to work offline while treating online patients in their spare time. To this end, the platform is realized into a mobile application to allow physicians to work anytime anywhere. However, lacking boundaries, like temporal, spatial, and social ones, leads to inadequate access to information, asynchronous communication with patients, frequent interruptions, and oversimplified medical records. As a result, physicians have poor online work experience, low work efficiency, and can't make accurate treatment decisions. Based on these findings, we discuss the impact of lacking boundaries on teleconsultation. We also give some design suggestions accordingly.

CCS Concepts: • **Human-centered computing → Empirical studies in collaborative and social computing**.

Additional Key Words and Phrases: Teleconsultation; Chinese Hospital; Boundary; MHealth

ACM Reference Format:
. 2023. Teleconsultation in an Extremely-busy Chinese Hospital: Practices and Challenges. 1, 1 (January 2023), 25 pages. https://doi.org/10.1145/nnnnnnn.nnnnnnn

1 INTRODUCTION

Seeking medical care across cities or even provinces/states is quite common in both resource-rich and resource-constrained regions of the world [24, 39, 45]. Cross-regional care brings heavy money and time costs to remote patients [47, 59]. Teleconsultation can provide remote medical services, *e.g.*, diagnoses, consultations, and medication adjustments, to patients of inaccessible areas through video conferencing, voice call, and text messages via ICT (Information and Communication Technology) [10]. Therefore, teleconsultation is considered a promising method to provide remote healthcare interventions and reduce patients' long-distance travel costs [33]. During the COVID-19 pandemic, many countries adopt strict lockdown policies [6]. As a result, patients cannot see physicians across cities, which is unacceptable for patients with chronic diseases who need regular follow-ups. On this occasion, teleconsultation becomes increasingly essential. Many countries, like U.S., U.K., India, and China, take measures to establish or promote teleconsultation [9, 27]. For

Author's address:

XXXX-XXXX/2023/1-ART $15.00
https://doi.org/10.1145/nnnnnnn.nnnnnnn

example, teleconsultation platforms are booming all over China during the pandemic period: The number is 130 in January 2019 [27]; By June 2021, China has built over 1600 ones [60]. The Chinese government and hospitals invest a large amount of human, financial, and material resources to establish teleconsultation platforms. Therefore, these platforms must be used continuously as part of the healthcare infrastructure even in the post-pandemic era. This work studies how teleconsultation platforms are established and used under the specific healthcare characteristics of China to further inspire design optimization.

Previous work points out that one important factor that affects the usage sustainability of teleconsultation platforms is their combination with conventional care [5]. For patients, the combination means teleconsultation should make up for the shortcomings of existing healthcare infrastructure, *e.g.*, facilitating remote patients' access to medical resources, which has been proven by existing work [40]. For physicians, the combination of teleconsultation with conventional care includes two aspects: How physicians provide online consultations that meet their usage habits and requirements, and how physicians balance online and offline medical services. Current relevant research mainly focuses on the challenges physicians face when using teleconsultation platforms in practice. For example, Hiratsuka *et al.* point out that teleconsultation cannot be used for physical diagnoses, and using it may face technique problems, *e.g.*, low network and video quality [28]. However, these studies only reveal general challenges and do not take into account the particularities of scenarios, working environments, and physicians' specific requirements.

This work studies the way and challenges of establishing teleconsultation platforms in extremely busy hospitals suffering from a severe shortage of physicians, which is quite common in developing countries. For instance, China is short of 200 thousand pediatricians, accounting for about two-thirds of the total number in service [62]. The severe imbalance in the physician-patient ratio leads physicians to be very busy. For example, physicians need to see over 80 outpatients each day, spending 3-5 minutes on each of them [21]. Under such circumstances, it is hard to arrange for specific physicians to provide online services. Studying how to establish teleconsultation platforms on this occasion and investigating the challenges physicians face are of great significance. However, current research has paid little attention to that.

This work conducts a case study at one of the best pediatric hospitals in China. We aim to unveil physicians' requirements by understanding the usage practices and the challenges they face, to explore the design of suitable teleconsultation platforms in extremely busy workplaces. Specifically, we answer the following three questions: 1) What does the teleconsultation platform look like and how do doctors use it for online consultations? 2) What challenges do physicians face and how do they cope with the challenges? 3) How do these challenges affect physicians' professional duties? To answer these questions, the first author works in the Network Information Center as an intern to help with the teleconsultation project. She interviewed three staff in charge of the teleconsultation platform in the hospital to learn the design considerations. She also interviewed 22 physicians from 6 departments to learn their requirements. Among them, she in-depth interviewed 9 physicians responsible for online services to learn their usage experiences and challenges. To deeply understand physicians' requirements, the first author also observed how physicians provide medical services both online and face-to-face with patients in clinics.

Our study finds out that to fit into physicians' busy daily work, the physician end of the teleconsultation platform, CDoctor, is realized into a mobile app and requires pediatricians to provide online services in their spare time. However, the current CDoctor cannot allow physicians to provide medical services responsibly. Physicians lack sufficient information support to perform medical reasoning, which influences the accuracy of their decisions. Physicians mainly communicate with patients by text messages to protect their boundaries between work and life. Whereas that is inefficient and ineffective, *e.g.*, consuming much time and physicians sometimes only getting vague

answers. For online medical recording, physicians face challenges such as inconvenient input and cannot remember the content, which leads to simple content writing. Finally, we use boundary theory to explain these findings. We also discuss the design implications of improving CDoctor, the physician end of the teleconsultation platform.

This work for the first time studies how teleconsultation is used in extremely busy hospitals. By revealing the challenges physicians face and the effectiveness and efficiency of the platform, this work demonstrates that it is hard implementing a teleconsultation platform in such a scenario. This work contributes to the CSCW literature on how teleconsultation services are affected by complex environments. The findings highlight the importance of boundary management in teleconsultation and the difficulty of maintaining boundaries in hospitals with a shortage of physicians. Since the physician end of the teleconsultation platform is a mobile app, this work also expands the community's knowledge of applying mobile technology to physicians in medical care.

2 RELATED WORK

Our work builds on the literature of remote patient-provider communication and teleconsultation. In the following, we introduce the related work and point out the position of our work.

2.1 Remote patient-provider communication

In recent years, the online "Ask the Doctor"(AtD) platforms have emerged in many countries like Sweden [4], Israel [56], Iran [16], and China [36]. AtD platforms allow patients to ask physicians questions, without needing to offline visit first. With AtD platforms, patients typically communicate with healthcare providers via text asynchronous consultation mode. For example, patients post health related questions any time, and healthcare providers answer the questions when they are convenient. Existing studies on AtD platforms focus on the demographic characteristics of users, *e.g.*, their gender, age, and race. Previous work also unveils the types of questions that patients ask and why they use AtD platforms, including convenience, feeling more comfortable, seeking a second opinion, asking embarrassing or sensitive questions, seeking information on behalf of relatives, and preferring written communication [55]. Since AtD platforms are free, the number of physicians on the platforms are limited. Hence, their responses to patients' questions are often delayed.

Recently in China, some payment AtD platforms, like Fenda and WeDoctor are emerged. There are a large number of healthcare professionals with diverse backgrounds and specialists on these platforms. Compared to totally free AtD platforms, physicians on payment ones can provide more timely responses. Previous work finds out that these platforms allow patients to ask questions that are out of scope of traditional medical consultations and help them select appropriate offline medical services [36]. There is also work studying how patients use these platforms, *e.g.*, how to select channels and physicians [18] . These work points out that payment AtD platforms are used to integrate with offline/traditional medical resources to provide better healthcare services together. For instance, patients use AtD platforms as the navigation for offline care. These platforms, to some extent, complement offline health care.

Except for the above mentioned online AtD platforms, some physicians choose to use personal social network platforms, *e.g.*, WeChat and WhatsApp, to communicate with patients over distance [3]. The features of these platforms, such as sending texts and images, voice and video communication, and transferring documents, can meet physicians' requirements of communicating with patients and checking diagnostic reports. However, these platforms are not designed for remote healthcare. Hence, patients can contact physicians at any time in any way, which is inconvenience for physicians. Existing work focuses on how physicians set boundaries of communication content, time and meature [17].

Both the AtD platforms and personal social network apps transcend the time and space limitation of face-to-face traditional medical services, making it more convenient for patients to seek health advice comfortably. However, these platforms typically offer simple consultation instead of intervention, diagnosis, and medication adjustment. Therefore, they are suitable to serve as complementary to offline medical services. Whereas, these platforms support healthcare consultations beyond pre-existing patient-provider relationships. Therefore, they are not suitable for follow-up treatments of patients with chronic diseases, whose previous connection with physicians are necessary.

2.2 Teleconsultation services provided by hospitals

Teleconsultation services, funded by hospitals, has been widely established to facilitate remote health care, especially during the COVID-19 pandemic. Teleconsultation has been tried as an alternative to in-person clinic visits to provide disease management interventions, including ongoing monitoring, identifying complications, and conducting medication adjustments [50]. Much work focuses on investigating the benefits in reducing patients' costs and finds out that teleconsultation has been proven to be effective in increasing access to healthcare for underserved groups and reducing their costs on time and money due to long-distance travel [41, 47, 59]. Teleconsultation is also found to be effective in increasing patients' management for chronic conditions and providing comparable or more effective information and education for patients compared with traditional care [5]. In summary, Teleconsultation can improve the quality of medical care and allocate medical resources more efficiently. Besides, the cost benefits of teleconsultation are very attractive, especially for the developing countries [3].

Physicians face some challenges when using teleconsultation services in practice. Currently, teleconsultation services are mainly provided via PC. Previous studies find out that two-thirds of patient-provider telecommunication are real time via audio or video, less through texts, pictures, or other asynchronous communication ways [1, 31]. Physicians may face technique problems, *e.g.*, unstable network connection and low video quality [28], which directly decreases physicians' usage experiences. In addition, teleconsultation has many limitations, such as cannot be used for physical examination, increasing patients expectation to communicate with physicians in a timely manner, and decreasing physicians' ability to disconnect from their work [38]. For Pediatricians, child patients cannot clearly describe their symptoms, making accurate diagnosis and treatment difficult [26]. Besides, there is no conclusive evidence that teleconsultation can achieve comparable treatment effectiveness with conventional face-to-face care [1].

All the above factors may be reasons that teleconsultation has not been widely used as an alternative to in-person clinic visits [1, 31]. Whereas, since many countries adopt lock down strategies due to the widespread of COVID-19, it is becoming even more challenging for patients to visit remote physicians. Hence, teleconsultation is becoming indispensable. Teleconsultation platforms are booming all over China, motivated by reducing rural patients' difficulties in accessing high-quality healthcare services, improving the adherence to follow-up treatments, and eventually reducing the morbidity and mortality. By March 2017, China has built 68 teleconsultation platforms [61]. The number has reached 130 in January 2019 [27]. Launching teleconsultation has also been promoted by the spread of COVID-19 [35]. Since January 2020, Chinese government adopted strict travel control policies to curb the spread of the virus, which makes it difficult, even impossible, for patients to see doctors in other cities/provinces. Physical hospitals take teleconsultation as a promising method to solve this problem. By October 28, 2020, China has built over 900 teleconsultation platforms [13]. The number has reached up to 1600 by June 2021 [60].

Although these teleconsultation platforms were launched quickly during the pandemic period as stopgap, a large amount of human and material resources were invested in the platform construction

and promotion. These platforms should be continuously used during the pandemic period and even in the post-pandemic era, as part of the healthcare infrastructure, to reduce the imbalance of medical resources and to increase the accessibility of medical services in remote areas. However, there are insufficient studies on the evaluation of how these teleconsultation platforms are used. Existing work points out that studying two aspects can improve the sustainability of teleconsultation. One is evaluating different models, especially in combination with conventional care [5]. The other is considering organizational challenges introduced by the integration of teleconsultation [22].

This work makes up for the lack of existing research attention by studying the challenges of introducing teleconsultation services in real workplaces of Chinese hospitals. This work also investigates how the online medical services are influenced by the characteristics of face-to-face traditional ones. Through this study, the sustainability of these teleconsultation platforms is expected to be revealed and the corresponding improvement and optimization suggestions are put forward.

2.3 Boundaries in remote work

During the pandemic of COVID-19, remote work becomes prevalent and will likely continue in the future, complementing the traditional working mode [14, 58]. Therefore, remote work becomes a hot research topic in the HCI and CSCW fields recently. Boundary theory is an appropriate theoretical framework for understanding remote workers' experiences [9]. Researches about work from home (WFH) focus on the roles people play at work and at home, and how people set temporal, spatial, mental, and physical boundaries to better transition between roles [49, 54]. Ding *et al.* studies how physicians negotiate social, temporal, and professional boundaries with patients while using personal social platforms to provide remote medical services [17]. There is also work on how various communities set boundaries while communicating [51].

Previous work finds out that setting boundaries in remote work has many advantages, *e.g.*, helping to achieve work-life balance [11, 15] and improving work efficiency [9]. Setting boundaries can also improve communication efficiency in multi-party collaboration [12]. In telehealth, setting boundaries is necessary to ensure the quality of medical services [17]. Therefore, remote workers usually set various boundaries. The most common are social, temporal, and spacial ones [29, 32]. There are also psychological, sensory, technological, and professional boundaries to set [37]. These boundaries are often set in the context of both experience and physics, guided by historically entrenched social structures and patterns of time and space [34]. Remote workers deploy various strategies to manage boundaries. For example, some workers set device boundaries by using separate applications for personal and work emails or even remove work emails from smartphones before going home [7, 42]. Some workers set spacial boundaries by creating a dedicated space, set temporal boundaries by adhering to an office-like schedule, set psychological boundaries by getting dressed or applying makeup, set sensory boundaries by adding plants to the workplace, and set relational/social boundaries by establishing rules for family members [9].

While acknowledging the importance of boundaries, more work notices their uncertain characteristics. For example, some researchers emphasize the dynamic nature of boundaries and point out that boundaries are negotiated and change over time [2]. Because of the different requirements for boundary clarity, that is, whether two or more parties need clear divisions or boundaries, the concept of the integration-segmentation continuum is developed in boundary work [43]. Specifically, there are three different minds while setting boundaries, *i.e.*, *"the* rigid mind *emphasizes clear distinctions and order; the* fuzzy mind *seeks to eliminate barriers and ambiguity"* , and the flexible mind is a hybrid of the two above minds together [63]. These characteristics are determined by specific scenarios and different people's requirements. Although concerns, strategies, and characteristics for boundary management in remote work have been carefully studied, it has not been

studied how the work of healthcare professionals is influenced by boundaries when they provide online follow-up consultations in complex offline work and home environments. This work for the first time focuses on the boundary work of providing teleconsultations in hospitals suffering from a severe shortage of physicians and offers new insights into boundary work for future CSCW research.

3 BACKGROUND

Medical resources in China are quite unevenly distributed. High quality facilities and medical experts are mainly in metropolises of eastern China, *e.g.*, Shanghai and Beijing [44]. Patients usually need to seek high-quality medical services in the hospitals of eastern metropolises, across cities or even provinces. For example, 39.29% hospitalized patients in the tertiary hospitals of Shanghai are not residents of this city [23]. Long-distance travel brings heavy burden to patients and their families. Besides, people in China usually has no primary care or family physicians. Both inpatient and outpatient medical services are provided by integrated hospitals. As a result, patients with chronic diseases face great challenges in regular follow-up visits. To facilitate follow-ups, some even move to eastern big cities and their family members (*e.g.*, child patients' parents) become migrant workers in the city.

Teleconsultation is a promising solution to reduce patients' burden in cross-regional care. Hence, it is enthusiastically promoted by the Chinese government, and embraced by many medical organizations and physical hospitals. Teleconsultation in China has two types. One type is called "Ask the Doctor" (AtD) platforms [18], which are launched by internet companies. Patients use AtD to contact physicians that beyond pre-existing patient-provider relationships across the country to seek simple consultation and buy medicines. The other type is launched by physical hospitals. Such type of teleconsultation is typically built to provide follow-up consultations remotely, especially for patients with chronic diseases, as an alternative to in-person clinic visits in physical hospitals. Patients receive online diagnoses and treatments, *e.g.*, medication adjustments, via these platforms. The majority of existing teleconsultation services in China are now this type, which is what we study in this work. Physicians on both types of teleconsultation platforms typically work in both physical hospitals and online.

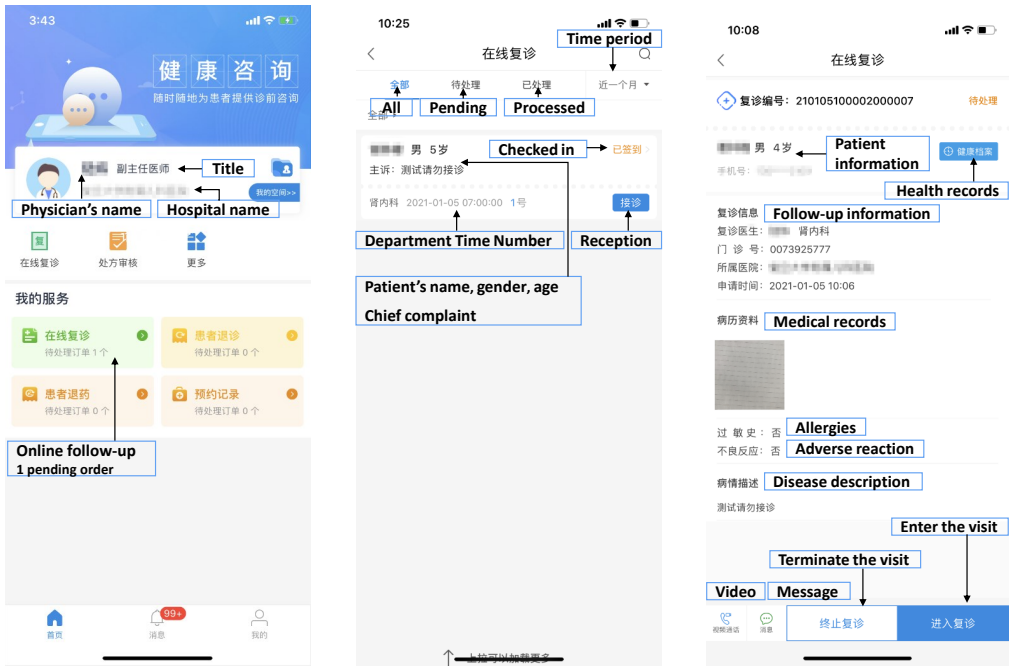
4 METHODS

4.1 Research setting and the teleconsultation platform

We conduct our study in one of the best pediatric hospitals in China[1], which provides medical services for children all over the country. The hospital has nearly two thousand employees, including 369 physicians. It has 32 clinical departments and 13 inpatient sections. Many patients of the hospital suffer from intractable diseases, who intend to obtain more accurate diagnoses and high-quality treatments from this hospital across cities/provinces. For example, nearly 70% of the inpatients of this hospital are non-local residents. Physicians in this hospital are under extreme workloads: they conduct over 42,000 inpatient surgeries, and handle over 2,200,000 outpatients and emergency visits annually.

Since the COVID-19 pandemic, patients across cities/provinces face challenges in seeing physicians due to the lockdown policy. The hospital has an eager requirement to provide online consultation services for non-local patients, especially those with chronic diseases needing regular follow-ups (*e.g.*, once a month). The target hospital was officially granted the licence of establishing teleconsultation platform on April 30. Then, its first version is released on May 13.

[1]The name is temporally removed due to double blind review requirement.



(a) Home page (b) List of patients (c) Patient information page

Fig. 1. Screen shots of Cloud Doctor. We marked all identifiable information with English. These screen shots are captured in January 2021.

The physician end of the teleconsultation platform is Cloud Doctor (CDoctor). Establishing CDoctor is challenging in the target hospital where physicians are under extreme workloads. For example, it is impossible arranging for certain physicians to sit in front of computers to see online patients via a PC website at a permanent time period. CDoctor is realized into a mobile app that can be installed on physicians' smartphones. Since smartphones have good mobility, physicians can provide online services anytime at anywhere while they are available. To ensure treatment quality, the hospital has restrictions on both the physicians who are allowed to provide online medical services and the patients who can registration: Only attending physicians and those of higher levels can see online patients; A patient who can register for online follow-up treatment must have visited the same department of the hospital within two months.

The home page of CDoctor (Figure 1(a)) demonstrates physicians' basic information and how many follow-up patients have registered. On the patient list page (Figure 1(b)), physicians can check the patients who need to be treated. On the patient information page (Figure 1(c)), physicians can look at the pictures of medical records, read the disease description, and Know a patient's allergy history and adverse reactions. Those information are provided by the patient. Physicians can choose to communicate with the patient via video conferencing or text/voice messaging. If physicians discover that the patient is not suitable for online treatment, *e.g.*, needing physical examination or in unstable condition, physicians can ask the patient to visit in-person and break off the consultation. In this case, the platform returns the patient's registration fee. After communication, physicians can prescribe medications. Currently, over three hundreds of medications can be prescribed on CDoctor. Medicines will be directly delivered to patients' home by medicine companies. Before

ending the consultation, physicians need to document critical medical data, including weights, allergies, chief complaint, history of present illness, and treatment suggestions.

4.2 Data collection

This work is studied via qualitative methods, including observations and interviews. Since the target hospital enforced strict entry control to prevent the spread of COVID-19, the first author worked as an intern at the hospital's Network Information Center, one of the departments responsible for establishing the teleconsultation platform, from September 2020 to April 2021. The first author takes notes during observations and interviews. After daily field study, the first author completes the notes to guarantee their integrity. She also writes down the comments and reflections, which can help the following data analysis and guide her to change the focus of subsequent study. The field study follows the hospital's research ethics and is approved by the director of the hospital.

4.2.1 Platform understanding. This phase focuses on exploring the design considerations and the challenges of establishing and promoting the teleconsultation platform, especially the physician end (CDoctor), in the hospital. To this end, the first author communicates with developers of the platform and reads related materials, including the operation manuals and precautions, to learn the features and usage statistics. Then, she interviews three staffs (the director, a senior engineer, and a vice director) of the Network Information Center, to understand the design considerations. Each semi-structured interview lasts for about half an hour. The first author also participates in the platform establishment meetings three times. Each meeting, involving staffs in Medical Department, Financial Department, Pharmacy Department, and Network Information Center, lasts over one hour. Through the meetings, the first author learns about the challenges of establishing and promoting the teleconsultation platform in the target hospital.

4.2.2 Usage experience exploration. At this phase, the first author conducts semi-structured interviews with physicians to learn their usage experiences and challenges. It is not an easy task interviewing the physicians who have ever used CDoctor in the hospital. Physicians are very busy. A department arranges the physicians responsible for online services and their rotation mode according to its own situation. For example, three physicians rotate once a month in the Department of Nephrology and one physician is responsible for all online services in the Department of Cardiology. The first author visits the departments using CDoctor several times and communicates with 22 physicians. The average duration is about 20 minutes. She learns physicians' requirements of CDoctor and identifies the ones who are responsible for online services in each department.

Based on the findings, the first author then conducts in-depth semi-structured interviews with 9 physicians in charge of CDoctor as shown in Table 1. Five physicians are from the departments of Nephrology and Hematology respectively, which are the two of three pilot departments using the telecommunication platform. Hence, they use CDoctor for the longest time. Four physicians from the departments of Neurology, Cardiology, Pediatric Orthopedics, and Urinary Surgery respectively. Urinary Surgery represents the surgery departments with the most online patients. Whereas, Department of Pediatric Orthopedics represents the surgery departments with a few online patients. Department of Cardiology represents the internal medicine departments seeing very few online patients, while Department of Neurology has the third highest number of online patients except for the departments of Urinary Surgery and Hematology. Each interview duration ranges from half an hour to one and a half hours. The first author customizes her interview questions for physicians of different departments. Sample questions are as follows: *How many patients do you see a day online? When do you usually see online patients? How do you communicate with online patients and why? How do you feel about CDoctor? Can you give some examples to explain the problems you encounter*

Table 1. Demographics of the interviewed physicians.

No.	Physicians	Gender	Departments
1	Dr. Jing	F	Department of Nephrology
2	Dr. Yan	F	Department of Nephrology
3	Dr. Hui	F	Department of Nephrology
4	Dr. Ye	F	Department of Hematology
5	Dr. Jun	M	Department of Hematology
6	Dr. Ping	F	Department of Neurology
7	Dr. Cui	F	Department of Cardiology
8	Dr. Chuang	M	Department of Pediatric Orthopedics
9	Dr. Zhu	M	Urinary Surgery

when using CDoctor? Do you have any suggestions on improving CDoctor? What other features do you expect in it?

The first author also observes how physicians in the Nephrology Department use CDoctor. In this department, three physicians shift each month to provide online services via CDoctor. Some patients register on the teleconsultation platform in the morning. Physicians are usually very busy at that time, *e.g.*, ward rounds or in surgeries. Therefore, they see online patients at lunch. The first author sits by and observes how physicians operate CDoctor and communicate with online patients. During the process, physicians explain their operation and the things they need to pay special attention to. When running into problems, physicians communicate with each other. They also express their usage experiences and exchange their opinions about a patient's condition. After that, the first author takes physicians' smartphones to see the contents of the communication, the number of messages, the communication duration, etc. Through observations, the first author gets first-hand information about physicians' usage habits and experiences.

4.3 Data analysis

We analyze the records of observations and interviews with grounded theory approach [8]. During data analysis, we filter out the privacy related data to protect physicians' and patients' personal information. We analyze the collected data in the following steps. First, we carefully read each sentence of recorded notes, extract and label key words, and finish the *open coding*. Examples of first-level codes include "physicians read patients' chief complaints", "physicians rely on EMR to get information", "physicians communicate with patients via texts", "physicians face challenges in asking questions", "the time physicians provide online services", "the space physicians provide online services", "physicians record patients' medical data", "patients tend to ask more questions online". After initial coding, we examine the codes carefully and classify them into different categories. We obtain their relationships to generate *axial codes*, *e.g.*, "CDoctor usage", "the way physicians obtain information", "the way patient-provider communication", "the challenges physicians face in information obtain", "the challenge physicians face in communication", "the challenges physicians face in medical recording". Finally, we extract the themes that can answer our research questions by *selective coding*.

5 FINDINGS

In this section, we first briefly introduce how CDoctor is used in different departments. Then, we demonstrate the way and the challenges physicians face in obtaining patients' historical information,

Table 2. Usage statistics and the registration return rate of the teleconsultation platform. The table is sorted by total online visits of each department. We use English abbreviations for some departments: TCM stands for Traditional Chinese Medicine; CS stands for Cardiothoracic Surgery; GIM stands for General Internal Medicine. *Ret.* means the number of online patients that physicians terminate the visits before finishing. *Ret. rate* equals to *Ret./Total* (*Total* means the overall visits of each department).

Dep. \ Month	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Ret.	Ret. rate
Urinary Surgery	9	66	86	68	43	42	37	351	84	23.93%
Hematology	20	38	37	61	56	52	63	327	12	3.67%
Neurology	18	52	45	35	57	56	61	324	44	13.58%
GIM	24	45	24	35	49	62	54	293	49	16.72%
Respiratory Medicine	10	29	15	28	40	71	59	252	27	10.71%
Gastroenterology	18	53	45	36	28	29	30	239	40	16.74%
Child Healthcare	15	36	32	32	21	33	23	192	18	9.38%
Endocrinology	26	20	31	20	15	26	21	159	62	38.99%
Nephrology	18	43	23	16	16	23	19	158	14	8.86%
General Surgery	3	17	26	17	13	17	19	112	17	15.18%
TCM	10	29	12	14	11	25	10	111	72	64.86%
Immunology	8	17	12	14	13	13	16	93	12	12.90%
Infectious Disease	3	20	14	9	9	6	8	69	12	17.39%
Hepatology	4	17	15	8	3	4	8	59	0	0.00%
Pediatric Orthopedics	4	12	6	6	10	8	6	52	5	9.62%
Rheumatology	4	5	3	5	7	8	12	44	0	0.00%
Cardiology	5	13	6	2	2	5	7	40	14	35.00%
Neurosurgery	2	14					3	19	1	5.26%
CS	3	3	1					7	0	0.00%
Total of all Dep.	204	529	433	406	393	480	456	2901	483	16.65%

communicating with patients, and recording patients' medical data on CDoctor. At last, we describe the effectiveness and efficiency of online consultation.

5.1 An overview of the usage of CDoctor

On the teleconsultation platform, physicians are required to see online patients from 8:00 to 21:00 seven days a week. If a physician does not finish seeing a registered patient before 21:00, the platform will automatically return the registration fee to the patient. "*Since our physicians are very busy. The flexible schedule gives them enough time to see online patients.*" as mentioned by Mr. Cao, the vice director of Medical Department.

The teleconsultation platform is gradually promoted in the hospital. On May 13 when the platform is first released, it is used at three departments to provide online follow-up services, including the Department of Endocrinology and Inborn Metabolic Diseases, the Department of Hematology, and the Department of Nephrology. This period is the running-in stage of technology and process. As Dr. Yan mentioned: *"At the beginning, we formed a group with developers of the platform in WeChat. They facilitated our communication with patients in case we encountered problems. Sometimes, software engineers even sat by side and guided us to see patients. We selected the patients whom we were very familiar with to try whether the whole process was smooth."* When the teleconsultation platform can

run steadily in these three departments, it is promoted to other departments. In June, the platform has been promoted in 19 departments of this target hospital as shown in Table 2.

Table 2 shows the number of online patients treated by each department. Most of the online patients are those of internal medicine departments, *e.g.*, departments of Hematology, Neurology, and Nephrology. Surgery departments, like departments of Cardiothoracic Surgery, Neurosurgery, and Pediatric Orthopedics, see relatively few online patients. Whereas, there are also exceptions. For example, Department of Urinary Surgery, belonging to surgery, sees most online patients. Departments of Cardiology and Rheumatology are internal medicine. Whereas, they see very few online patients.

The number of online patients saw by each department every month is far less than that of offline each day. For example, departments of Nephrology and General Internal Medicine see about 200 and 1300 outpatients each day relatively. However, there are only a few online patients a day. Table 2 also shows that the return rate of online registration is very high, *i.e.*, accounting for 16.65% of total online visits. Our interview physicians point out that *"one of the main reasons for the high return rate is that some medications are not suitable to be mailed and thus cannot be prescribed online. For example, some injections and proprietary Chinese patent medicines cannot be mailed."* The other reason is that physicians cannot finish their responsibilities properly via CDoctor. In the following section, we explain the reason by investigating the challenges physicians face while using CDoctor to provide online services.

5.2 Ways and challenges for physicians to access online patients' information

The teleconsultation platform is mainly used for online follow-up treatments, to which patients' historical medical data are crucial [20]. For example, to effectively treat patients with chronic diseases, physicians need to track patients' medical data and accordingly generate narratives of patients' treatment trajectories. Dr. Hui emphasizes the importance of obtaining patients' historical data in making accurate diagnoses and treatment decisions. *"The condition of patients with chronic diseases may be unstable. By looking at a patient's condition now, one wouldn't imagine how serious her disease was. You do not know which medicines she can take and which medicines she has developed resistance to. Without these historical medical data, we cannot make treatment decisions."* In addition, Dr. Ye points out that patients' historical medical data are also essential in providing the basis for making follow-up treatment plans. *"Some patients want me to tell them more information about the treatment regimen for the following weeks. However, we cannot make a long-term plan without referring to patients' historical medical data."*

However, CDoctor provides limited information. CDoctor provides physicians with patients' medical data for the last three months, including diagnoses, prescriptions, and examination reports. Patients can also upload their medical data. What they upload are usually the test reports of the last time. These data can not meet physicians' requirements for patients' historical medical data. As Dr. Jing said: *"We need the medical data generated in both the inpatient and the outpatient sections. To understand patients' conditions while they are in hospitalization, we need patients' admission data and discharge summaries. With such data, we can know what happened to a patient, his and the family members' medical histories, and how he was treated. For outpatient records, we need not only a patient's previous outpatient record in the same department but also her treatment in other departments. These data help us to know whether it is a primary disease or a secondary one and if there are any other symptoms or problems."*

The lack of patients' historical medical data is one of the physicians' main complaints when using CDoctor. To deal with such shortcomings, some physicians get needed information by keeping asking patients. Dr. Yan explained: *"We have to communicate with patients all the time. We ask them when their diseases began, what medicines they took, what are the dosages, when they changed the*

taken dosage, and how their conditions changed all the time. It takes us so much time to obtain this information." Whereas, asking patients to get needed data is impractical and unreliable. Patients may not remember their treatment trajectories clearly, especially the values of some key indicators. Besides, asking is inefficient, which increases physicians' communication time with patients.

In addition to asking patients questions, physicians also require patients to upload more medical data materials when they find them lacking. However, physicians can only get limited information in this way. Chinese patients do not have Patient Portal. They only have the paper-based medical records printed by physicians and the test and examination reports, which are mostly paper-based and electronic copies can be obtained only recently in a few hospitals. Papers get lost and damaged easily. Patients may not keep paper-based materials for a long time. Not to mention that the medical data that patients have are limited. They may not know some special cases. As Dr. Jing said: *" Of course, I can ask a patient to upload her records. However, patients do not have all information that I need. For example, patients do not know what we should pay special attention to for a patient's next visit, which we only record in our systems and typically won't provide to patients. Patients cannot provide the conclusions of our consultations with physicians of other departments either. "*

Physicians can also obtain patients' historical medical data by themselves. As Dr. Ye mentioned: *"If it is necessary and possible, I will take some time to get patients' historical medical data from EMR or Follow-up Sheet (The information summary alternative that physicians of the target hospital use during chronic disease treatment). "* However, physicians are not necessarily to get the required information in time due to the complex working scenarios. More importantly, this only works when physicians are still in the hospital. Physicians are required to work overtime, *i.e.*, 8:00 am-9:00 pm seven days a week. If a patient registers online after 7:00 pm, physicians have already gone home and cannot get patients' medical data via computers or Follow-up Sheets.

To deal with situations where physicians see online patients outside of the hospital and cannot get access to the information support systems, some physicians limit the time of patient registration. In this way, they can use EMR while treating patients on smartphones. Dr. Zhu explained what the Urinary Surgery Department did: *"When patients visit our clinics physically, we tell them to follow up via the teleconsultation platform. Specifically, we will emphasize that they have to register between 8:30 am to 9:30 am, otherwise they may not get treated. Restricting patients' registration time allows us to see online patients while we are still at the hospital. We can search for their historical medical data on computers, which is convenient."* This method works at the expense of patients' convenience.

When patients begin to get treated online, their historical medical data not only contain those generated during offline visits, but also those of online follow-ups, *e.g.*, prescriptions, medical records, and patient-provider communication messages. On CDoctor, physicians cannot see how patients were treated online if they were treated by other physicians, which brings challenges for physicians to make accurate diagnoses. Physicians emphasize that patients' online medical records should be available to all physicians on CDoctor, which is essential for information continuity. As a result, physicians have to communicate with each other face-to-face to learn about what happened the last time the patient registered online. Physicians also share patients' online historical medical data by sending screenshots. As Dr. Jing said: *"Once, Dr. Hui came by and asked what suggestions I gave to an online patient. The patient told her that he was treated online by me last time. There were different standards for reducing medications. Dr. Hui wanted to know what I had told the patient. Even though the patient had told her, she thought it would be safe to check with me again. I gave Dr. Hui a screenshot of my conversation with the patient."*

5.3 Ways and challenges for physicians to communicate with patients online

5.3.1 Communication mode. The teleconsultation platform provides three ways for patient-provider communication, *i.e.*, video, audio, and text. Previous work finds out that video is the most widely

used communication mode in teleconsultation [1]. However, our findings demonstrate that, in the target hospital, text messaging is the most common form that physicians use to communicate with patients. The flexibility of patients' registration time and the adoption of platforms on mobile devices allow physicians to see online patients at a convenient time. However, this results in physicians having to treat online patients in very complex scenarios, *e.g.*, inpatient offices, outpatient clinics, and even at home.

Most of our interview physicians do not use video conferencing mainly because video conferencing is inconvenient and even embarrassing in some scenarios. As Dr. Jing said: *"We do a lot of work every day. Seeing patients online is just an additional job. We do not have a silent place for video conferencing. Besides, we are required to provide online services until 9:00 pm. As a result, sometimes I have to see patients at home. With video, patients can see what I am doing at home. That is silly. Maybe my child is playing around. I do not want any patients to know what my home is like. "* Besides, physicians choose not to use video conferencing because of several other well-known reasons. For example, video conferencing has high requirements for network conditions [28], and the network quality is not necessarily good. Video conferencing cannot allow physicians to conduct physical examinations and using pictures is more convenient.

Despite the above shortcomings, video conferencing has outstanding advantages, such as intuitive and real-time. The Department of Urinary Surgery comes up with measures to make it easier for physicians to see online patients via video, such as limiting patients' registration time and arranging for physicians to provide online medical services at a set time duration. However, Dr. Zhu mentioned that poor connection with patients affected their experiences: *"After patients registered online, one of our physicians will call back when he has time. Since physicians need to perform operations occasionally, the video time is not fixed. Sometimes, we send a patient a video call request. She does not answer it. We will call her again a moment later. If she does not answer the video call again, we will send the patient a message and tell her to register again tomorrow. Unlike offline consultations, when patients wait outside of our clinical offices after registration, online communication has a connectivity problem."*

Voice messaging is seldom used since physicians could not find proper usage scenarios. Typically, physicians' interaction with patients in complex scenarios lasts a long time and is often interrupted for various reasons, *e.g.*, physicians' leave due to sudden emergencies and patients' unpredictable departure. If using voice messaging, physicians often forget what they have communicated with patients, which affects subsequent medical recording. Besides, some physicians consider voicing with unfamiliar people not only unnecessary but also embarrassing. As Dr. Yan said: *"Sometimes we only want to say a few words. Using voice is silly. Besides, I am not used to sending voice messages to strangers either. Besides, I may forget what I have just said. Since I have to write medical records after communicating with patients, I have to convert voice into text. Using texts directly is more convenient. "*

Text messaging is suitable for complex environments. For example, it allows physicians to communicate with patients while having meals. Text messaging is also more suitable for communicating with strangers since it can protect physicians' privacy and help maintain the boundaries of their work and life. In addition, text messaging has better flexibility: It is an asynchronous communication way, which allows physicians to communicate with patients in their fragmented time. Text messaging also helps with medical recording. These factors make text messaging the choice of the majority of physicians.

5.3.2 Communication challenges. On the teleconsultation platform, patients are required to provide chief complaints. However, the platform does not provide any guidance about how patients should describe their conditions. Patients do not understand what information physicians rely on to make treatment decisions [19]. Hence, they usually can not provide useful information initiatively. Many

patients give vague descriptions. Some even do not write the purpose of the online visits. As a result, physicians sometimes cannot understand patients, which is the primary problem physicians encounter in communicating with patients. Dr. Jing made this point: *"When begin to see a patient, I first read her chief complaint. However, sometimes, I have no idea what she is talking about since I do not know the causes and consequences of the patient's problem. She may think that she came last month and suppose I can remember her, which is impossible unless something special happened to her since I see over 80 patients a day. The patient directly says that she did some examinations and wants me to take a look at them. I do not have a clear understanding of her condition. I do not know her purpose either. Even worse, some patients just upload their reports and do not even ask any questions. "*

On these occasions, physicians have to keep asking. However, patient treatment is a complicated process. Uncommon conditions may happen. Physicians may even do not know what to ask. Besides, patients can't understand and remember all conditions. Dr. Jing explained with examples: *"Among children with renal failure, some have cramps, some have high blood pressure, and some have thyroid cysts. These symptoms are not typical. Parents may not tell physicians even if their children have these problems for not knowing that they are relevant. For example, a parent only tells me that her child has poor hemoglobin and is a little anaemic. I may not ask how her blood pressure is, and how her serum potassium is. Her serum potassium maybe 5 or even 6 mmol/L, which is the most dangerous. "*

Physicians do not encounter such problems when communicating with patients offline. According to our observations, physicians dominate the patient-provider communication processes during face-to-face clinical consultations. This communication pattern works offline since physicians have enough information support. They have already generated narratives about a patient's treatment trajectories by reading her historical medical data. The main purposes of communication are to review, refine, and supplement what physicians have learned. On this occasion, physicians ask specific questions. For example, why did the dosage of hormone decrease? Whereas, physicians usually cannot access patients' historical medical data on CDoctor. Hence, it is hard for physicians to ask specific questions.

Without enough information, Physicians could only ask some generality but ambiguous questions. However, patients may not know how to answer. Besides, the information provided by parents is not necessarily correct. As Dr. Hui said: *"Sometimes, I do not even know how to ask. If I simply ask how he is doing, he probably tells me everything about his daily life, including eating, sleeping, and exercising. That is ineffective. In addition, asking may be not necessarily helpful. Our patients are children. Some of them do not know how to express their feelings and their parents may not understand their children's conditions."*

Patients are not familiar with medical terms, which increases the difficulty of communication. During our observation, a physician asked a parent to keep a urine diary for her child. The parent did not know what to do. She asked three times and the physician explained three times in different ways to let her understand. During offline clinical consultation, physicians usually show patients the paper template, which explains how to keep a urine diary in detail. Whereas, physicians have to describe only by text since the template is not available online. In some cases, a text description is tedious, takes much time, and may not be clear enough. For example, it is difficult using texts to describe the principle of an enuresis alarm, the way of using it, and its side effects.

On the teleconsultation platform, patients instead of physicians dominate the communication process. Patients care more about the matters, *e.g.*, diets and exercises, that they pay attention to in their daily lives. Some patients also want physicians to give more explanations or confirmations of their diseases. As Dr. Jing pointed out: *"Some patients may say: 'hormone has a big side effect, can I take for a shorter period or reduce the dosage quickly?' Or they may say: 'I have used hormone for a month, can I stop taking it?' I have to explain to them: 'You cannot reduce dosage like this. It is dangerous. You should reduce the dosage slowly.' A patient may even say: 'I asked other physicians.*

They told me I can reduce the dosage.' In these cases, I can only tell them that what I give you is my advice."

Even though patients ask these types of questions during face-to-face consultations too, they tend to ask more questions online. Dr. Jun gave an example: *"A patient registers online every two days. He asks almost everything and I can't refuse to answer him. This is not rare. Many patients ask a lot of irrelevant questions online."* During offline clinical consultations, physicians usually see over 40 patients in the morning. They can only spend four to five minutes on each patient. As Dr. Jun said: *"Communicating offline is easier. Since many other patients are waiting outside of my office, a patient will be too embarrassed to keep asking."* While the teleconsultation platform has no limitations on communication time and contents. Besides, physicians online are much easier to access. As a result, online patients consult more frequently and longer. Physicians have no choice but to answer patients' various questions. However, physicians are reluctant to answer too many online questions mainly because of the following reasons: text messaging takes too much time, physicians see patients in their spare time, and therefore physicians can't spend too much time and energy online.

Patients' communication habits, *e.g.*, do not end a conversation explicitly, also lead to a poor experience for physicians. As Dr. Jing said: *"Some parents do not say whether they have any other questions for a long time. I should not terminate the consultation if I did not get an accurate response. I can terminate the communication at any time, but I want the patient to be satisfied without leaving any questions behind. If I terminate the communication, the patient has to re-register if he still wants to ask some questions. If he did not respond, I feel awful. I will end the communication if he does not respond for over three hours."*

In addition, some patients ask questions in a fragmented way, which makes communication even less efficient. As Dr. Jun said: *"Parents do not ask many questions in a single message. I answer one question. He will ask another. He may ask what he should or shouldn't eat with over ten messages. That is annoying. For example, once a parent asked whether his son could eat DHA. I answered him. Then, he asked whether he could drink a certain brand of milk. Then, he asked whether he could eat some vegetables. If the patient can ask all questions about diet in a message, I will tell him: 'you do not need to worry about any of these things.'"*

The asynchronous nature of communicating via texts online increases communication costs and makes physicians' experience worse. As Dr. Ping said: *"A patient registered at morning. We chatted for a while and the parent went away. By noon, the parent told me that he was back. Then, he uploaded some pictures as I had requested. However, I was busy at that time. We finished communicating until 16:00. The whole procedure is annoying."*

All the above factors lead to low communication efficiency. Since physicians see patients in their spare time, spending too much time on a patient is both impractical and unacceptable. Therefore, we can conclude that when teleconsultation is applied to extremely busy work environments, one of the main challenges that physicians face is how to communicate with patients effectively.

5.4 Ways and challenges for physicians to document medical records

The last phase of physicians' work is documenting patients' medical data, which is true for both face-to-face and online clinical consultations. Medical data documentation helps ensure information continuity, which is important for physicians making accurate treatment decisions. In clinics, many items are required to be recorded, including weights, allergies, pain assessment, nutritional status, functional rehabilitation, chief complaints, history of present illnesses, preliminary diagnosis, and treatment suggestions. Medical records on the teleconsultation platform are simplified. Only five items are required, including weights, allergies, chief complaints, history of present illnesses, and treatment suggestions.

Physicians complain about the challenges of writing medical records even with simplification. The first challenge is that physicians usually forget to ask about patients' weights. Some physicians used to write medical records after terminating the communication channel. If they forgot to ask about patients' weights, they cannot ask again anymore. When Dr. Jing taught Dr. Hui to use CDoctor, she emphasized that patients' weights must be asked. Many physicians consider that weights should be provided by patients.

Physicians also complain that it is troublesome to write the history of present illnesses and treatment suggestions on smartphones. As Dr. Cui said: *"We describe patients' conditions with Chinese. However, some indicators are English abbreviations, which have both capital and small characters. Hence, writing medical records requires constant switching of input methods. Besides, some units contain special characters, for example, μ mol/L, which is hard to type on smartphones. Therefore, I only write simple conclusions instead of values of key indicators for convenience. "*

Physicians further point out that writing medical records on CDoctor is repetitive work, which makes them feel worse. As Dr. Cui pointed out: *"At the end of the conversation, I would summarize the patient's medical history, for example, when he got sick, what symptoms he had, and the values of key indicators. I will first check with the patient. Then I want to copy the conclusion from the message section to the medical record part. However, CDoctor does not allow me to copy messages. I have to write the same content again. That is annoying. Besides, we cannot copy medical records of the last time. So we have to enter each word every time."* As a result, many physicians write medical records simply. For example, Dr. Jing said she simply records that the patient has normal renal function and does not record her urinary creatinine value or some other key indicators on CDoctor.

Some physicians mention that they write medical records simply also due to they cannot refer to the online-generated records during both online and offline follow-up consultations. Physicians cannot refer to any medical data if a patient was treated by other physicians online last time. All data generated in CDoctor, including the medical records, prescriptions, communication messages, and pictures uploaded by patients, are stored in the health cloud of this city for supervision instead of servers of the target hospital. Therefore, physicians cannot know how a patient was treated online when he visits clinics physically. As a result, physicians consider writing medical records meaningless since they lose tracking patients' conditions.

To ease medical record writing, designers added templates of common diseases on CDoctor in November. These templates are provided by physicians of each department. However, both designing and using templates encounter challenges. Dr. Yan designed three templates for common diseases in the Nephrology Department. She pointed out: *"It is not easy to design disease templates for follow-up patients. I put as many things in the templates as possible. For example, I wrote all common medications since the medicines that a patient takes are the subset. When using the template, I have to delete some content. "* Dr. Yan is the only physician writing medical records with templates in the Nephrology Department. The department has three physicians providing online services. Two of them, Dr. Hui and Dr. Jing, do not use templates at all. Dr. Hui explains the reason: *"Templates are suitable for initial treatment instead of follow-up ones. Whereas, all patients online are follow-up patients. For those patients, their previous medical records are the most valuable. By referring to a patient's last record, we only need to change the values of several indicators. That is very convenient."*

5.5 Consequences: low-efficient and low-effective treatment

All the above challenges make online treatment via the teleconsultation platform a time- and energy-consuming process. Every aspect of clinical consultations becomes complicated when moved online. Lacking patients' historical medical data and the ineffectiveness of patient-provider communication make things even worse. As Dr. Jing said: *"We do not have many patients online now, for example, two patients a day. But treating them takes a lot of time. Replying to each patient requests*

over 20 messages. Once, one of my colleagues replied to a patient more than 40 times, which took her over three hours. Treating a patient face-to-face only takes several minutes. The imperfect function of Cloud Doctor leads us to heavily rely on communicating with patients. Whereas, text chatting is troublesome."

Through observations, we find that physicians spend about thirty minutes on average when communicating with each patient online. Online consultations take much time due to the following reasons: 1) Both physicians and patients tend to ask more questions. 2)Inputting texts takes a lot of time. The asynchronous nature of text messaging makes communication more time-consuming. 3) The three phases of a whole treatment process, *i.e.*, preparation, consultation, and wrap-up [52], are carried out synchronously during face-to-face clinic visits. This is one major reason that a physician could treat a patient within five minutes. Whereas, the three processes are conducted sequentially online.

Another consequence of the above challenges (those mentioned in 5.2-5.4) is that the effectiveness of online treatment cannot compare with those of offline face-to-face conventional clinical consultations. The first author observed how a patient was treated online by Dr. Hui. The child was diagnosed with enuresis at 9 years old. He took a kind of medicine for three years and his condition did not turn good. Now he is 12 years old and 87 kilograms. Dr. Hui suspected that he might not only have enuresis but have obesity and other problems, *e.g.*, mental retardation, or even a tumor. *"Are we missing a patient with tumors? "* Dr. Hui said with one of her colleagues, half joking. Even though she had confusion, Dr. Hui chose to trust the diagnoses of previous physicians. She prescribed some medicines as the parent asked, and then told the patient to come physically if his condition turned bad.

Online follow-up treatment is not suitable for patients with inaccurate diagnoses. As Dr. Ye said: *"Some patients' conditions are complicated. The first diagnosis is not necessarily clear. They have to visit clinics several times and get more examinations. According to the examination results of each time, physicians figure out their primary affection and secondary affection. For these patients, we cannot adjust their medications just based on the results of one examination. This may miss the best time for disease treatment. On CDoctor, we cannot conduct physical examinations on patients. Online consultation is not accurate. For these patients, we suggest them to come physically."* Physicians further explain that face-to-face clinical consultation is a process that increases their understanding of patients' conditions and constantly modifies the treatment plans. Online follow-up treatment breaks the process. Physicians usually provide online medical services according to patients' requests. This is dangerous for patients who are not well-diagnosed. Misdiagnosis and treatment delay may occur. Physicians could not 100% understand a patient's condition online. As Dr. Hui pointed out: *"The treatment suggestions I give online are not as accurate as those of offline. I can't give patients suggestions with 100% confidence, since I could not completely understand their conditions. I will treat them online if I have 80%-90% confidence. "*

In addition, online patients' treatment compliance decreased, especially those who are not clear about their conditions. Dr. Jing gave an example: *"There is a patient tested positive for urine protein. He visited our clinics once. We considered he may have accurate interstitial nephritis and prescribed hormone to him. He took it for a month and then the urinary protein turned negative. He registered online and said that his urine protein had turned negative and he could stop taking the medicine now. I asked him to come physically. He turned me down."* Dr. Jing explained that even though a patient had visited clinics physically once, his disease was not necessarily diagnosed accurately. The urine protein of the above patient could also be a problem with rheumatism. Dr. Jing further explained: *"Patients have no medical knowledge and do not understand what arrows in examination reports mean. Some may focus on less important arrows and neglect the important ones."*

Inefficiency and ineffectiveness of online treatment cause physicians to worry about their relationships with patients. On the one hand, physicians worry that patients will not have a good experience. Dr. Ping said: *"The teleconsultation platform requires us to work in our spare time. I do not consider that patients can have good experiences. A patient may register online at 8:00 am. He is eager to ask some questions. While physicians may be unavailable at that time. The patient may not get an answer until the afternoon. Some patients even asked me why it took me so long to reply."*

On the other hand, physicians worry about being sued. They fear that online treatment delays patients' diseases, which may lead to medical disputes. Besides, the teleconsultation platform records all online-generated content of the whole treatment process, which causes physicians to be afraid of making suggestions. As Dr. Ye said: *"Communicating with patients online should be careful since they can take screenshots or quote out of context. This indeed worries me. I cannot see a patient's historical medical data and rely on his descriptions. I have to make a decision based on this data. I did not have 100% confidence about the diagnosis. All chat records are stored. All evidence is stored. We do not want anything bad to happen."* Dr. Yan shared the same opinion: *"It worries us a lot about having more possibility to be sued for mistreatment online. For example, a patient may say: 'I have seen you three times online. You did not discover my problems. Now my illness is serious. You have to take responsibility for me.' In this case, a physician cannot argue that the patient did not provide enough data or did not tell the physician what was wrong with him. The patient may say: 'I do not know those data are important. Why didn't you ask me?' Besides, there are also situations that the conditions of some patients get worse suddenly without any signs."*

The above factors contribute to the high return rate, accounting for nearly 20% of all online registrations. Given these factors, physicians are also reluctant to recommend their patients to use the teleconsultation platform. As Dr. Jing said: *"Although I do not want to recommend my patients to use any online platforms, if they have the requirements, for example, they live far away and their conditions are stable, I would rather recommend 'Listening to the Doctor' (LtD) instead of internet hospital. LtD is a platform we provide free online consultations during the pandemic. Since LtD is free, I do not have the pressure to answer each question. I can give some basic directions. In the teleconsultation platform, I have to make sure that every patient is satisfied with my service. Otherwise, he can file a complaint against me."*

From the above description, we can conclude that CDoctor is yet to be a good solution for applying teleconsultation to extremely busy work environments. Via CDoctor, physicians cannot get enough information support and communicate with patients inefficiently and ineffectively. Besides, the online generated medical records are written too simply to be used as subsequent references. However, providing teleconsultation services is necessary for the target hospital to facilitate the treatment of patients in remote areas. In the following section, according to the lessons learned from this work, we discuss what aspects are essential and should be considered when implementing a proper teleconsultation platform in hospitals suffering from severe shortages of physicians.

6 DISCUSSIONS

Teleconsultation can improve patients' access to medical resources in remote areas and reduce their long-distance travel costs [33]. Therefore, establishing teleconsultation platforms is of great significance, especially during the COVID-19 pandemic, when many countries adopt strict lockdown policies and cross-regional treatment becomes impossible [6]. However, it is hard for extremely-busy hospitals to arrange for certain physicians to provide online services dedicatedly. Pediatric hospitals in China are a typical example. On this occasion, the primary challenge of establishing a teleconsultation platform is how to ensure its high usability in helping physicians provide online medical services while their daily offline work will not be affected.

To meet physicians' requirements of providing online consultation services in complex workplace environments, CDoctor, the physician side of the teleconsultation platform, is implemented as a mobile application. CDoctor allows physicians to see online follow-up patients anytime anywhere in their spare time. Although mHealth is prevalent at present, the mobile platform is mainly used on the patient side [46, 53]. On the physician side, a mobile platform is usually used for unofficial (without the supervision of hospitals) patient-provider communication [9, 17]. Therefore, CDoctor, an official physician end of the teleconsultation platform, works as a technology probe [30], exploring the feasibility and challenges of applying teleconsultation to extremely busy hospitals and those of applying mobile technology to the physician side, inspiring design optimization. It is worth noting that although the teleconsultation platform was built during the pandemic, it will certainly continue to be used in the post-pandemic era due to a large amount of material and human input as well as a wide range of practical needs. Therefore, it is of great importance to study its shortcomings and the optimization directions.

This work focuses on how physicians use CDoctor to provide teleconsultations and the challenges they face, and further reveals the effectiveness and efficiency of online diagnoses and treatments. The findings demonstrate that when physicians use the teleconsultation platform to provide medical services, they cannot obtain enough information, their communication with online patients is ineffective, and their medical records are simple and disconnected from patients' medical data generated at offline consultations. As a result, physicians have to make treatment decisions based on unreliable, incomplete, and fragmented information, which affects the effectiveness of teleconsultation. In addition, inefficient and discontinuous communication affects the teleconsultation efficiency and degrades physicians' and patients' experiences.

Existing work about teleconsultation focuses on scenarios where online medical services are provided by specific physicians at a certain time and place via computers [1]. Physicians face challenges such as poor network connection during video conferencing [28] and cannot perform physical examinations online [33]. Whereas, the research scene of this paper is brand new, so are the challenges that physicians face. In the target hospital, physicians need to serve both online and offline patients at the same time, which leads them to provide teleconsultations in complex and varied scenarios, such as clinics, offices, public areas, and even homes. As for the new demand for providing teleconsultations in extremely complex situations, the challenges that physicians face, beyond the limitations revealed by existing work, are those caused by lacking boundaries when trying to integrate teleconsultation with conventional care. In the following, we explain the challenges that physicians face from the perspective of boundary theory and reflect on providing teleconsultations in extremely busy hospitals. Finally, we discuss design implications inspired by the findings of this work.

6.1 Boundary work in teleconsultation

Boundary theory explains how people perceive the world by drawing lines (or boundaries) [63]. According to the findings of this work, providing teleconsultation services in complex scenarios requires setting various boundaries. The temporal boundary and the spacial one are fundamental. They are coupled together. For instance, inappropriate working time, *e.g.*, working overtime, leads physicians to provide teleconsultations in workplaces or at home. Another important boundary that physicians require during teleconsultation is the social boundary, *i.e.*, what patients can register on the platform established by the target hospital. Physicians point out that patients with unclear diagnoses and unstable conditions are not suitable for online consultations. In addition, physicians want to maintain the professional boundary while using the teleconsultation platform. The findings of this work demonstrate that physicians and patients have different perspectives on how the teleconsultation platform should be used. Patients use it in a way similar to how they

use "Ask the Doctor" platforms [18, 55], *e.g.*, tending to ask for more information, explanation, and treatment suggestions. However, physicians do not like this kind of usage pattern. They expect to provide the same services online as they do in face-to-face consultations when they dominate the communication process and end it quickly, ignoring patients' information and emotional requirements [21].

This work also finds that physicians need some boundaries that are rarely mentioned in existing work: (1) The responsibility boundary. In the target hospital, providing teleconsultation services is one of the responsibilities that physicians are asked to take. Physicians have no choice. However, the features of the current platform cannot well meet physicians' requirements for providing teleconsultations. Thus, physicians cannot be able to make diagnoses and treatment decisions as accurately as in face-to-face consultation. Physicians hope that features of the platform can facilitate instead of hinder them to fulfill their responsibilities. (2) The risk boundary. Physicians' online work is supervised and audited by the target hospital. Physicians also take the same risks as offline. For example, they could be sued if medical accidents happen. This gives physicians a lot of psychological pressure. However, physicians do not receive equivalent compensation. Teleconsultation is just an extra heavy burden for them due to its low efficiency. Some physicians even said that they would rather give the money to the hospital to get rid of the teleconsultation job. Physicians expect the risks to be equal to the benefits. These two kinds of boundaries are other main reasons that physicians are reluctant to provide teleconsultation services and that the return rate of online registration is high.

The problem caused by lacking the above-mentioned boundaries is obvious. First, the lack of boundaries determines how physicians provide medical services online. This work finds out that teleconsultation is mainly suitable for follow-up patients with chronic diseases. Physicians have two main tasks in treating these patients, information acquisition and communication [52]. In face-to-face consultation, physicians obtain information via Follow-up Sheets, the paper-based information summary alternative they maintained [20]. Physicians dominate the communication process and content and patients' requirements are ignored [21]. During teleconsultation, the lack of temporal and spatial boundaries leads physicians to rely mainly on the materials provided by patients for information acquisition. Physicians use text messages to communicate with patients. The communication process is often interrupted. Patients are the dominators. In addition, it is difficult for physicians to get the required information through communication. Second, the lack of boundaries makes the teleconsultation process inefficient. This work finds out that physicians spend over 30 minutes on average treating online patients, which is about 10 times those of offline visits. Finally, the lack of boundaries affects the effectiveness of online medical services. The inadequate access to information and communication caused by the lack of boundaries prevents physicians from making high-quality medical decisions online, which is a very serious problem for health care.

Physicians take several measures to maintain boundaries. For example, physicians limit the time that patients register online to set temporal and spatial boundaries. Physicians return online registrations to set the social boundary. However, managing such boundaries is a time-consuming process, requiring negotiation between physicians and patients. For instance, physicians in the Department of Urinary Surgery communicate with patients several times to make appointments for teleconsultation via video conferencing. Physicians also need to spend a lot of time and effort to understand patients' conditions before returning the registration. However, the types of boundaries that physicians can negotiate are limited. Physicians are passive in providing teleconsultation services. It is difficult for them to maintain the professional boundary by refusing to answer patients' questions. Nor can physicians refuse to take on the responsibilities assigned by hospitals or avoid supervision.

In conclusion, physicians' requirements for boundaries are determined by three aspects including the need for follow-up treatments, conventional working habits, and features of the teleconsultation platforms. Boundaries are also maintained under the guidance of physicians' psychological preferences. Existing work has discussed whether boundaries should be clear and proposed three types, *i.e.*, segmentation, integration, and hybrid [43]. According to this work, physicians need to focus to make accurate decisions in teleconsultation. However, the complexity of the environment affects the work quality. Therefore, boundaries should be managed in medical care.

6.2 Design implications

This work demonstrates that establishing teleconsultation platforms with high usability in extremely busy hospitals is quite challenging. Based on the findings of this work, we suggest improving the physician end of the teleconsultation platform from the following aspects.

6.2.1 Maintaining information continuity. Information continuity is important for follow-up treatments [48, 57]. However, achieving information continuity is challenging, especially for patients with chronic diseases [20]. Those Patients are typically treated by various physicians of different departments *e.g.*, inpatient and outpatient ones. Hence, their medical data are quite fragmented. When some follow-up treatments are conducted online, a patient may be examined physically in one hospital and treated and prescribed online in another. The generated medical data are even more fragmented. On this occasion, realizing information continuity becomes harder.

Previous work finds that teleconsultation has always been treated as an independent part, and has seldom been integrated into hospital information systems (HIS) [31]. Existing research has also been done in parallel. However, our findings indicate that integrating the teleconsultation platform with the existing HIS is necessary. In teleconsultation, physicians provide online diagnoses and treatments instead of just education and consultations. Every aspect of clinic visits, including obtaining patients' medical data, communicating with patients, prescribing, and writing medical records, are shifted from offline to online. As a result, online and offline treatment together make up a patient's entire treatment process. Hence, integrating the teleconsultation platform with existing healthcare infrastructure is essential for treatment continuity. In addition, it is also needed to provide a physician with a patient's all medical data generated during online treatment. We suggest CDoctor break the boundaries of physicians and organize information from the perspective of patients. Thus, a physician can see others' communications with the same patient.

6.2.2 Providing sufficient medical data. The current CDoctor provides physicians with medical data for the last three months, including diagnoses, prescriptions, and reports of examinations and tests. Physicians consider these data very useful when prescribing for patients with accurate diagnoses and stable conditions. However, these data are not sufficient for physicians to treat online patients with complicated conditions. To make more accurate treatment decisions for such patients, our interview physicians consider a patient's discharge summary and admission record should be provided. A discharge summary includes the condition when a patient is discharged. With the discharge summary, physicians can know what happened to the patient during the last hospitalization and what they should pay attention to when the patient comes for the first follow-up consultation. Admission record introduces the condition when the patient is diagnosed to have a certain disease. These two types of records are essential for physicians to understand a patient's treatment trajectory.

Unlike PC, smartphones have limited data presentation capabilities because of their small screens. First, it is difficult to display a large amount of medical data on smartphones. It may be helpful to evaluate the importance of different types of data, make reasonable trade-offs between them, and present them hierarchically according to their significance. Second, how to display these data

effectively is also challenging. It may be useful if platform designers can abstract and organize these data and show them with curves. Last but not least, it may be possible to use AI technology to process these data and generate a summary description of a patient's condition. The AI system can also predict disease progression and give medication adjustment suggestions, thus assisting physicians in making decisions and reducing the time they spend viewing and interpreting patients' historical medical data. The AI system should highlight which data to base the diagnosis on to enhance interpretability.

6.2.3 Improving the efficiency of online communication. Previous work points out that videos, phone calls, and asynchronous communication modes like messages have different advantages [25]. Phone calls can be used to deal with emergency cases. Asynchronous communication mode is suitable for uncomplicated and non-urgent situations, *e.g.*, making appointments and reviewing test results. When using CDoctor, it is hard for physicians to figure out which communication method is the most appropriate since they face various work environments, *e.g.*, clinics, offices, and homes. Therefore, we suggest adding as many communication methods as possible in CDoctor, *e.g.*, an extra feature like voice call, to let physicians figure out the suitable ones to communicate with patients according to their requirements. The voice call may be preferred by some physicians. However, to protect physicians' privacy, it had better be transferred by an agency. The agency can make an appointment with a physician and tell patients when the physician is available.

This work also finds out that one important reason for low communication efficiency is that patients cannot clearly describe their situation or provide the information that physicians require. It is inefficient relying on physicians to ask them out. We suggest that CDoctor should add a feature to guide patients to describe their conditions, symptoms, and follow-up treatment purposes more clearly and completely in the chief complaint section, *e.g.*, clearly clarifying the purposes of online visits. Maybe an AI robot is helpful. The robot can ask a patient questions step by step. For example, what is the illness? what are the symptoms? what medicines are taken? what is the purpose of this follow-up treatment? In addition, the questions should be different according to the type of disease and the patient's condition. For example, for kidney disease, knowing a patient's height and blood pressure is essential.

According to our study, patients, especially those who are not familiar with their diseases, sometimes cannot well understand what physicians are talking about. Adding some assistant tools, *e.g.*, pictures and templates, in the teleconsultation platform may be helpful for those patients. For example, if a parent needs to write a urine diary for his child, physicians can show him a picture instead of describing it with text. Texts increase communication costs. Patients may not understand in the end, which may delay treatment or even cause mistakes. In addition, it may also be helpful to add a term explanation feature to the platform. When physicians use some terms, the patient end can automatically show explanations of the terms' meanings or remind patients of what need to pay attention to.

7 CONCLUSION

In this work, we study ways and challenges to implementing teleconsultations in extremely busy hospitals suffering from a severe shortage of physicians. In this study, we find out that physicians' overwhelming workloads lead them to provide online medical services while making sure to finish their offline work properly, which means teleconsultation services have to be carried out in complex scenarios, such as workplaces and homes. In order to achieve this purpose, the teleconsultation platform is realized into a mobile application, making use of the good mobility and portability of mobile terminals to facilitate physicians to provide teleconsultations anytime and anywhere. However, this leads to a serious lack of boundaries. As a result, physicians cannot obtain enough

required information. Their text-based and frequently interrupted communication with patients is inefficient. The use of mobile devices leads physicians to face challenges in recording medical data. The high registration return rate and the poor physicians' work experience mean that the current physician end of the teleconsultation platform is not a success. The findings of this work demonstrate the necessity of maintaining boundaries in implementing teleconsultations. Based on this research, we further propose ways to improve the platform design.

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