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Completed Research Paper

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Abstract

To improve online healthcare quality and efficiency, online healthcare communities (OHCs) enabled the pre-consultation function, in which an assistant physician interacts with the patient to understand and document the patient's health conditions, medical history, and consultation objectives prior to the formal online consultation with the attending physician. Using detailed service data from a Chinese OHC, this study scrutinizes the effect of using pre-consultation on online healthcare service quality and satisfaction. The results show that pre-consultation can significantly increase the attending physician's response speed, length, and the level of informational support embedded within the response, while maintaining a consistent level of emotional support. Despite the improvement in service quality, pre-consultation leads to decreased patient satisfaction with the consultation service. Furthermore, we find that pre-consultation improves service quality by enhancing the professionalism and comprehensiveness of patient case information and reducing information seeking and clarification of the attending physician with the patient.

Keywords: Pre-consultation, service quality, service satisfaction, online healthcare community

Introduction

The rapid advance of information and communication technologies (ICT) has significantly catalyzed the development of online healthcare services. For example, the global eHealth market, which was valued at US$ 69.69 billion in 2022, is anticipated to grow at a compound annual rate of 23.45% over the next decade ultimately reaching an estimated US$ 255.60 billion by 2029.[1] Undoubtedly, online healthcare services offer advantages such as high physician availability, low transportation costs, and time savings (Goh et al. 2016; Muñoz 2010; Polinski et al. 2016). However, due to the asynchronous interactions and the limited medical expertise of patients, inaccurate and incomplete patient information has been reported by physicians as a major challenge in delivering healthcare services online at a level of quality and efficiency comparable to traditional offline services (Atanasova et al., 2018; Li et al., 2022).

Pre-consultation, collecting and documenting patient information prior to formal consultations, has been widely used to improve the efficiency of healthcare consultation offline. Offline pre-consultation typically falls into two categories: conventional pre-consultations conducted by healthcare professionals using

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questionnaires or semi-structured interviews and automated pre-consultations facilitated by information systems developed by tech companies such as Goodwill[2] and Tencent[3]. Questionnaires may lack flexibility due to fixed questions while interviews may increase the workload of assistant physicians. Automated systems struggle to comprehend patients' multi-complaint conditions and accurately document patients' medical history, which may lead physicians toward incorrect diagnoses (Petitgand et al. 2020). Despite these challenges, both conventional and automated pre-consultations have demonstrated effectiveness in improving offline healthcare outcomes (Jamal et al. 2019; Murphy et al. 2022; Rickenbach 2019; Zanini et al. 2016).

In contrast, pre-consultation practices are rarely used in online healthcare services. Online consultations are often viewed as a cost-effective means for patients to communicate with physicians directly, bypassing the usual practice gatekeepers, such as office staff and nurses (Bavafa et al. 2018). Without pre-consultation, online patients have to document their case information themselves. Only recently a novel pre-consultation function was rolled out by an online healthcare community (OHC) in China for online healthcare services. This function involves ad-hoc assigned assistant physicians engaging with patients online to understand their health conditions, medical history, and consultation objectives and document such information before formal online consultations with attending physicians. To the best of our knowledge, this OHC is the first and only platform offering such a service, and adoption among physicians within the OHC remains limited.

Neither academic research nor practitioners have a clear understanding regarding the impact of the pre-consultation function on online consultation quality. On one hand, patient case information prepared by the assistant physician with medical expertise during pre-consultation tends to be more professional and comprehensive than information reported solely by the patient (Vandergrift et al. 2018). With the improved case information, the attending physician can streamline their understanding of the patient's health conditions and minimize the need for additional information gathering, and thus concentrate on providing medical suggestions, which will potentially elevate online service quality (Li et al. 2022). On the other hand, as patients possess an unparalleled understanding of their own medical history and consultation objectives, rephrasing patient case information through a third-party could lead to the loss or distortion of crucial details. Moreover, the absence of pre-consultation might encourage attending physicians to engage in more active information-seeking or clarification during the consultation, leading to a deeper understanding of the patient case. This will discourage physicians' adoption of pre-consultation.

It is also unclear how pre-consultation could affect patient satisfaction with the online healthcare service, which in turn affects physicians' engagement with OHCs. On one hand, patient satisfaction may increase when pre-consultation effectively reduces the time and effort patients must invest in preparing their case information before an online consultation or when patients perceive a noticeable enhancement in service quality as a result of pre-consultation. On the other hand, patient satisfaction may decrease due to the additional monetary cost and delayed access to the attending physician, especially when patients do not perceive a substantial quality improvement in the quality of care provided by the attending physician. This will hinder patients' acceptance of this service function.

To bridge this gap in research and practice, we ask the following research question: *How does pre-consultation affect online healthcare service quality and patient satisfaction?* We answer this question using the detailed text consultation data collected from a leading Chinese OHC that introduced a pre-consultation function in 2021. Based on service quality frameworks in prior studies (Tan and Yan 2020; Wang et al. 2020), we model the impact of pre-consultation on service quality across four key dimensions: response speed, information abundance, informational support, and emotional support. The results show that pre-consultation can significantly increase the attending physician's response speed, length, and the level of informational support embedded within the response, while maintaining a consistent level of emotional support. Although pre-consultation increases overall service quality, it paradoxically decreases patient satisfaction with the service. Additionally, our findings unveil that pre-consultation improves online healthcare service quality by enhancing the professionalism and comprehensiveness of patient case information and reducing the necessity for attending physicians to seek additional information seeking or engage in clarifications with patients.

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[2] https://www.bjgoodwill.com/platform.aspx?id=121634
[3] https://miying.qq.com/official/product/prediagnosis

Research Background

In this section, we first summarize the studies regarding pre-consultations in offline healthcare services and highlight the differences between pre-consultations by assistant physicians online and those in prior studies. Then, we review three streams of literature on online healthcare service outcomes, including the effects of information technology (IT) on online healthcare service quality, the effects of service quality on patient satisfaction, and the correlation between patients' feedback and physicians' offline service quality. Then, based on prior theory and literature, we propose two hypotheses.

Pre-consultation in Offline Healthcare Services

In offline healthcare services, pre-consultations conducted via physical or digital questionnaires, and telephone-based semi-structured interviews are regarded to be effective in collecting useful patient information for consultation. Rickenbach (2019) documented that 50% of patients felt pre-consultation questions were beneficial and most physicians felt that formal consultations were simplified with patients' answers to pre-consultation questions. Zanini et al. (2016) also found that a pre-consultation sheet that captures patients' views on their conditions and treatments could help physicians provide more pertinent medical advice. Similarly, Murphy et al. (2022) reported that the use of a pre-consultation question form results in more issues discussed, more helpful support, more efficient use of time, and higher patient satisfaction during the consultation. Jamal et al. (2019) found that digital pre-consultation, which utilizes a web-based interface for patients to report their data and calculates a risk score based on the data reported, can significantly reduce physicians' time spent on medical consultations, allowing for more efficient use of medical resources and improved patient outcomes. Torres et al. (2021) found that a nurse-led telephone-based semi-structured interview prior to the first outpatient visit, which include questions about current complaints and the medical history, can significantly reduce the consultation duration, and is associated with high patient and physician satisfaction.

Recently, pre-consultation systems built on advanced technologies such as natural language processing, deep learning, and artificial intelligence (AI) have been used to collect patient information or/and provide preliminary diagnosis automatically (Kocaballi et al. 2020). However, the performance of these pre-consultation applications is still questionable. The pre-consultation system designed by Qian et al. (2021) was found to often record patient medical history inconsistent with that recorded by physicians, which lowers its diagnostic accuracy. When the symptomatic information recorded by the system and physicians are consistent, the system outperforms physicians (Qian et al. 2021). To improve the performance of pre-consultation applications, Zhang et al. (2022) developed a bi-directional hard-negative enforced noise contrastive estimating method that can increase the accuracy of medical symptom detection. Besides the performance issue, lack of interoperability, low usability of patient information, and physicians' skepticism are the other obstacles to the adoption of pre-consultation systems in practice (Petitgand et al. 2020).

We study pre-consultations conducted by assistant physicians online, which differ from pre-consultations in previous studies. First, prior studies, including those for digital pre-consultations, primarily concentrated on pre-consultations offered for offline patients in offline settings, while we examine pre-consultations for online patients in online healthcare services. Second, pre-consultations in prior studies were mostly in the (physical or digital) form of a fixed question sheet or conducted by a system, while in our research context pre-consultations are carried out by other physicians. Additionally, whereas previous research mostly used subjective measures collected through questionnaires or interviews for healthcare service quality, our study utilizes more objective measures mined from consultation records between patients and physicians for service quality.

Online Healthcare Service Outcomes

The present study also closely relates to the literature on online healthcare service outcomes. The first stream of literature studies how IT affects online healthcare service quality. In general, the use of IT and mobile health applications have been found to improve the quality of patient care, such as reducing medical accidents (Devaraj et al. 2013), decreasing mortality rates (Devaraj and Kohli 2003), and monitoring daily health status (Källander et al. 2013). However, the online functions introduced by OHCs, such as gift-giving, have more complicated effects on service quality. Specifically, while the gift-giving function results in better

services for patients who send gifts to the physician after online consultations, such as more detailed responses and improved bedside manner (Peng et al., 2020) as well as more informational and emotional support from physicians (Wang et al., 2020), it generates a negative spillover effect on non-givers, as evidenced by slower responses and less emotional support from physicians (Zhao et al. 2022).

The second stream of literature explores how online healthcare service characteristics/quality affects patient satisfaction. Yang et al. (2015) found that the response speed of a physician and interaction frequency between the patient and physician increase the ratio of patients providing positive ratings for the physician. Tan and Yan (2020) documented that informational support, emotional support, and response speed of physicians in online consultations lead to higher rating scores from patients. Chen et al. (2020) further found that emotional support exerts a larger effect in enhancing patient satisfaction than informational support does. Additionally, several studies focused on physician-patient voice interactions and found that the physician's speech rate and voice pitch positively affect patient satisfaction, while the intensity and average voice spectral centroid affect patient satisfaction negatively (Liu et al. 2020, 2022).

Another stream of literature examines whether patient-generated online feedback regarding offline healthcare services can accurately reflect the physician's offline care quality. Some studies have documented an insignificant or weak association between online reviews/ratings and offline clinical outcomes, such as the readmission rate, emergency room visits in the context of chronic diseases (Saifee et al. 2020), and the mortality rate in the context of cardiac surgeons (Okike et al. 2016). However, others validated that online physician ratings could be a valuable information source for patients to learn about offline service quality (Gao et al. 2015; Lu and Rui 2018). Additionally, online textual reviews have been found to better characterize patients' perceived offline service quality than numerical ratings (Xu et al. 2021).

To the best of our knowledge, our study is the first to explore the impact of pre-consultation on online healthcare service quality and satisfaction. While previous studies mainly focused on how service delivered during the consultation or feedback functions used in the post-consultation stage (e.g., gift-giving) affect healthcare outcomes, we examine a new service function, pre-consultation, used prior to the consultation. Combined with its impact on service quality, our study can also shed light on whether patient reviews of online healthcare services can truly reflect service quality.

Hypothesis Development

The Effect of Pre-consultation on Service Quality

When a patient uses pre-consultation in an online consultation, the case information including health conditions, medical history, and consultation purposes is summarized by an assistant physician instead of the patient. As medical professionals, assistant physicians have experienced formal medical education, training, and practice (Vandergrift et al. 2018). For example, to practice medicine in the United States, one typically needs to complete eight to ten years of medical training.[4] Therefore, pre-consultation can improve the quality of consultation service delivered by the attending physician because of the following two advantages.

First, pre-consultation improves the professionalism of the patient case information. Patients who have little medical language proficiency often describe their diseases and concerns in vague and inaccurate informal language (Donovan 1991), which reduces the effectiveness of the communication between them and physicians (Ceccarelli 2014). In contrast, pre-consultation enables an assistant physician with professional medical knowledge and expertise to summarize patient case information in formal medical language. Medical language, composed of technical, specific, and precise medical words, terms, and phrases, minimizes communication errors and inaccurate translations to other healthcare professionals (Hull 2016).

Second, pre-consultation improves the comprehensiveness of the patient case information. Without medical expertise, patients have a limited understanding of their medical conditions and treatment history (Williams et al. 2002). As a result, they may miss out on relevant information when describing their symptoms, medical history, disease progression, etc. Incomplete information about patients has been reported by physicians as one major challenge in online healthcare services, which inhibits physicians from

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[4] https://www.emedicinehealth.com/doctors_specialties_and_training/article_em.htm#medical_school_training

giving helpful suggestions (Atanasova et al., 2018; Li et al., 2022). By contrast, the assistant physician performing pre-consultation can ask all case-related questions more comprehensively based on their medical knowledge and experience when collecting patient case information. The assistant physician may even add a different perspective from that of the attending physician on the patient case in summarizing case information.

With more accurate and comprehensive case information generated by pre-consultation, the attending physician can easily and quickly understand the patient's health condition, save time and effort in additional information seeking and clarification with the patient, and have more uninterrupted time to address the patient's health concerns with treatment suggestions. Consequently, the attending physician can understand the patient's medical problems more effectively, respond to patient enquiries more quickly, provide more helpful suggestions, etc. Therefore, we propose the following hypothesis:

H1: The use of pre-consultation is associated with higher online healthcare service quality.

The Effect of Pre-consultation on Patient Satisfaction

As pre-consultation changes the online healthcare service experienced by the patient, it can also influence the patient's satisfaction with the service. Specifically, pre-consultation may decrease patient satisfaction. First, assistant physicians act as gatekeepers in online consultations, delaying the patient's access to the attending physician, while online consultations are usually perceived as a low-cost channel for reaching physicians directly and bypassing the usual offline gatekeepers, such as office staff and nurses (Bavafa et al. 2018). The longer waiting time and inconvenience to access the attending physician caused by gatekeepers may decrease patient satisfaction with the online consultation (Wu et al. 2016). Second, pre-consultation is not free for patients. As price and quality are positively related in people's minds (Kurz et al. 2023), the patient accepting pre-consultation may have higher expectations of the service delivered by the attending physician with the additional monetary cost. Patients' expectations of their treatment are a key determinant of their satisfaction with the treatment (Newton and Cunningham 2013). Third, healthcare services are "credence" goods, whose quality information is never completely revealed to patients, even after consumption (Saifee et al. 2020; Sloan 2001). Even if pre-consultation improves service quality as predicted by H1, patients may not be able to recognize the improvement. Considering the access delay, increased service expectation, and the difficulty in recognizing service improvement, it is also likely that the patient will perceive the service as less satisfactory after using pre-consultation. This predicts the following competing hypothesis:

H2: The use of pre-consultation is associated with lower online healthcare service satisfaction.

Research Context and Data

Research Context

Our research context is a leading Chinese OHC that was established in 2006. It is a nationwide online healthcare portal that connects patients of all medical conditions and physicians as a bridge for online consultations. The healthcare platform allows patients to ask questions about their illnesses to physicians, who can then answer them via on online channel. Only certified physicians can provide services on the OHC. As of December 2022, approximately 250,000 certified physicians had joined the OHC and provided online healthcare services via text or/and phone. All online healthcare services provided by a physician are recorded and presented on the physician's homepage where reviews of the physician from both online and offline patients are also available. On this OHC, only verified patients can write reviews. To leave a review for the physician, a patient first selects an overall rating (positive or negative), then clicks the corresponding positive or negative tags pre-defined by the OHC for evaluating the physician's response speed, expertise, and attitude, and lastly writes review comments in free text format.

Figure 1. An Example of Online Consultation Service with Pre-consultation

To improve online service efficiency and healthcare collaboration, the OHC introduced a pre-consultation function for online healthcare services in 2021, in which assistant physicians interact with patients to learn about their health conditions, medical history, and consultation objectives and document such information for attending physicians prior to formal consultations. During the interaction, patients can see the case information documented by assistant physicians in real-time and communicate with assistant physicians timely in case of missing or inaccurate information. All physicians registered on the OHC can apply to be assistant physicians to conduct pre-consultations. Service orders of pre-consultation are primarily distributed to assistant physicians whose specialties match patients' diseases, and assistant physicians accept orders mainly according to their availability. Attending physicians decide whether and when to adopt the pre-consultation function. The OHC does not charge attending physicians for adopting this function. Once adopted, pre-consultation will be added to all their online consultations by default. Nevertheless, their patients can still opt out of pre-consultation and proceed to the consultation directly.[5] The OHC will charge the patients who do not opt out a small amount, approximately 6 Chinese Yuan (about \$1), additionally for pre-consultation. Figure 1 shows an example of an online consultation service with pre-consultation. For such services, we collected data on basic information about the patient, the attending physician, and the assistant physician, case information documented by the assistant physician as a result of pre-consultation, and consultation interaction between the attending physician and the patient. For an online consultation service without pre-consultation, the service record looks the same as that shown in Figure 1, except that patient case information is summarized by the patient instead of the assistant physician.

Data and Variables

We collected data on services, reviews, and demographic characteristics for all physicians who provided at least one online healthcare service and received at least one online review on the OHC between February 2022 and May 2022. This corresponds to a total of 15,675 physicians, of which 2,424 (15.46%) adopted the pre-consultation function during our observation period. The sample physicians delivered a total of 358,203 text consultations of which 35,783 (9.99%) used pre-consultation, and 122,069 phone

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[5] To decline pre-consultation, patients need to inform assistant physicians, who will then help them proceed to the consultation directly. Among the physicians who adopted pre-consultation, only around 4% of their patients did not use pre-consultation services.

consultations of which 7,763 (6.36%) used pre-consultation. As text consultations made up most services on the OHC and the interaction data of phone consultations are unavailable, our analysis is based on text consultations.

Even though there are a considerable number of theoretical frameworks for characterizing online healthcare service quality, the majority of these frameworks encapsulate the shared principle that response speed, response length, informational support, and emotional support are important dimensions when evaluating a physician's online service quality (Tan and Yan 2020; Wang et al. 2020). First, response speed reflects the immediacy of physicians' feedback. In asynchronous text consultations, fast feedback allows for effective physician-patient coordination and communication and reduces the time required to complete the consultation (Tan & Yan, 2020; Yang et al., 2015). We measure response speed ($Sameday_{i,j,c}$) as whether patient i received a response from physician j within the day when the consultation c was initiated. Second, information abundance, the amount of information in the physician's response to the patient's questions, signals the physician's expertise and caring for the patient (Zhang et al., 2019). Higher information abundance provides the patient with more specific suggestions and clear instructions. We use $Len_{i,j,c}$, the number of words in textual responses received by patient i from physician j in consultation c, to measure response abundance.

Furthermore, within the responses provided by the physician, informational support and emotional support are key information transmitted with different purposes. Informational support is rationality-dominant, skill-based, and problem-solving oriented (Ong et al. 1995), while emotional support aims to share the patient's happiness or sadness and to express caring and concern (Yan and Tan 2014). Both are considered to be key indicators of online medical service quality (Chen et al., 2020; Tan & Yan, 2020; Wu et al., 2018). Following prior literature (Peng et al., 2020; Salge et al., 2022), we leverage the 2015 version of Linguistic Inquiry and Word Count (LIWC) (Pennebaker et al. 2015), to calculate the percentage of cognitive words ($Cog_{i,j,c}$) and affective words ($Affect_{i,j,c}$) in the physician's response, and use them to measure informational and emotional support, respectively. While the use of cognitive words suggests reasoning and information processing, the use of affective words indicates feelings of emotion.

For online healthcare service satisfaction, we construct three measures. The first measure is $OnReview_{i,j,c}$, which equals 1 if patient i posted an online review for attending physician j after consultation c and 0 otherwise. The second measure is $OnRating_{i,j,c}$, which equals 1 if the review for consultation c is positive and -1 if the review for consultation c is negative. The third measure, $OnTags_{i,j,c}$, the product of $OnRating_{i,j,c}$ and the number of tags chosen by the patient, can be considered as a more fine-grained rating ranging from -6 to 7.

Our key independent variable, the use of pre-consultation, $Preconsult_{i,j,c}$, is a dummy variable which equals 1 if patient i used pre-consultation in consultation c provided by attending physician j and 0 otherwise.

To identify the effect of pre-consultation, we control for the influence of other factors related to the patient, the physician, and the patient-physician relationship. First, we control for patient demographics including age ($PatAge_i$) and gender ($PatMale_i$). Because the physician's online healthcare service outcomes are influenced by the patient's questions (Shepherd et al. 2011), we control for the number ($QuesNum_{i,j,c}$) and length ($QuesLen_{i,j,c}$) of questions that patient i asked in consultation c.

Second, online healthcare service outcomes can also be affected by physician characteristics, including physician experience (Janakiraman et al. 2023) and patient reviews (Saifee et al. 2020). We capture attending physician j's experience with the pre-consultation function ($Preconsult\_Exp_{j,c}$) by the number of online healthcare services involving pre-consultation provided by attending physician j over the observation period before consultation c. We use the number of online consultations ($Online_{j,c}$) and offline appointments ($Appoints_{j,c}$) of attending physician j prior to consultation c, to measure attending physician j's online and offline service experience, respectively. We control for patient reviews of the attending physician j using three variables: the number of reviews for online services ($OnReviews_{j,c}$), the number of reviews for offline services ($OffReviews_{j,c}$), and the average review rating for offline services ($OffRating_{j,c}$) before consultation c.

Third, the prior patient-physician relationship could also affect healthcare service outcomes (Guo et al. 2018; Olaisen et al. 2020). Therefore, we include two patient-physician control variables: $OnRelation_{i,j,c}$ and $OffRelation_{i,j,c}$, the number of times that patient i had online consulted and offline visited attending physician j during the observation period before consultation c, respectively.

Lastly, a physician's online service quality may be affected by temporal factors. For example, a physician may perform better during the working hours than off-working hours. Therefore, we control for the influence of temporal factors by including three sets of time dummy variables for consultation c: time of the day ($Offworking_c$), day of the week ($Weekend_c$), and month of the year ($Month_c$) as defined in Table 1. Table 1 presents the variable definitions and summary statistics.

Variables	Description	Mean	S.D.	Min	Max
Dependent Variables ($Y_{i,j,c}$ —— Outcome Y of consultation c between patient i and physician j)					
$Sameday_{i,j,c}$	= 1 if the first response was given on the same day when consultation c was initiated; 0 otherwise	0.989	0.103	0	1
$Len_{i,j,c}$	Number of words in physician responses	229.645	286.860	1	11,885
$Cog_{i,j,c}$	Percentage of cognitive words in physician responses	18.124	6.627	0	100
$Affect_{i,j,c}$	Percentage of affective words in physician responses	8.475	4.899	0	100
$OnReview_{i,j,c}$	= 1 if patient i provided a review for consultation c ; 0 otherwise.	0.172	0.378	0	1
$OnRating_{i,j,c}$	= 1 if the review for consultation c is positive; -1 if negative	0.977	0.213	-1	1
$OnTags_{i,j,c}$	The product of $OnRating_{i,j,c}$ and number of tags in the review for consultation c	3.988	2.684	-6	7
Independent Variables					
$Preconsult_{i,j,c}$	= 1 if the pre-consultation was used; 0 otherwise.	0.100	0.300	0	1
Control Variables ($X_{i,j,c}$)					
$PatAge_i$	Patient i's age.	32.827	21.013	1	130
$PatMale_i$	= 1 if patient i is male; 0 otherwise.	0.416	0.493	0	1
$QuesNum_{i,j,c}$	Number of questions posted by patient i in consultation c.	11.729	13.104	0	996
$QuesLen_{i,j,c}$	Length of questions posted by patient i in consultation c.	266.430	331.211	0	26,619
$Preconsult\_Exp_{j,c}$	Number of physician j's prior online consultations that used pre-consultation	6.175	31.936	0	688
$Online_{j,c}$	Number of physician j's prior online consultations	165.566	252.896	0	2,888
$Appoints_{j,c}$	Number of physician j's prior offline appointments	9.598	24.914	0	577
$OnReviews_{j,c}$	Number of reviews for physician j's online services	27.589	71.510	0	1,660
$OffReviews_{j,c}$	Number of reviews for physician j's offline services	9.426	19.084	0	332
$OffRating_{j,c}$	Average rating of physician j's offline services	3.941	0.159	1	4
$OnRelation_{i,j,c}$	Number of times patient i had online consultations with physician j before consultation c	0.210	0.615	0	20
$OffRelation_{i,j,c}$	Number of times patient i had offline appointments with physician j before consultation c	0.004	0.067	0	1
Time effects ($Time_c$)					
$Offworking_c$	= 1 if consultation c was initiated between 6 p.m. and 8 a.m.; 0 otherwise	0.429	0.495	0	1
$Weekend_c$	= 1 if consultation c was initiated during the weekend; 0 otherwise	0.268	0.443	0	1
$Month_c$	The month in which consultation c was initiated	3.417	1.075	2	5

Note. The number of observations for $OnRating_{i,j,c}$ and $OnTags_{i,j,c}$ is 61,679, and the number of observations for other variables is 358,203. S.D. stands for standard deviation.

Table 1. Definition of Variables and Summary Statistics

Methods and Results

Propensity Score Matching

Physicians' adoption of the pre-consultation function can be endogenous, as suggested by the significant differences between physicians who adopted the pre-consultation function and those who did not in Table 2. Therefore, we employ propensity score matching (PSM) and estimate models on the matched sample to alleviate the self-selection concern. PSM is used to identify non-adopted physicians in the control group who were very similar to the adopted physicians in the treatment group in terms of their observable characteristics. Specifically, we calculate the propensity score, the probability of a physician adopting pre-

consultation, based on the average physician-level characteristics (i.e., online consultations and offline appointments) and physician demographic information (i.e., registration time, title, and hospital) at the first week of our observation period. We conduct PSM with the number of the nearest neighbor specified as three and a caliper of 0.1 standard deviations of the propensity score. The matching procedure results in 2,993 non-adopted physicians in the control group and 1,518 adopted physicians in the treatment group. As shown in Table 2, the significant differences in observable characteristics between the treatment and control groups became statistically insignificant after matching, with all standardized differences smaller than 0.10 (Austin 2009).

Variable	Unmatched Matched	Mean Treated	Control	Std. Diff.	T-test
Online	U	0.87	0.78	0.029	1.08
	M	0.87	0.72	0.049	1.34
Appoints	U	0.10	0.05	0.083	3.38***
	M	0.10	0.09	0.008	0.20
Tenure	U	400.37	370.66	0.157	5.62***
	M	400.37	399.67	0.004	0.10
Title	U	1.61	1.79	-0.245	-8.59***
	M	1.61	1.61	-0.006	-0.17
Hospital	U	0.95	0.92	0.140	4.68***
	M	0.95	0.95	-0.008	-0.26
Note. The unmatched sample includes 15,675 physicians, and the matched sample includes 4,511 physicians. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.					

Table 2. Balance Test on the Treatment and Control Groups

Estimation of the Effect on Service Quality

We estimate the effect of pre-consultation on online healthcare service quality with the following model:

$$Y_{i,j,c} = \beta_0 + \beta_1 Preconsult_{i,j,c} + \gamma X_{i,j,c} + Physician_j + Time_c + \epsilon_{i,j,c}, \qquad (1)$$

$Y_{i,j,c}$ corresponds to four outcome variables for online healthcare service quality (i.e., $Sameday_{i,j,c}$, $Len_{i,j,c}$, $Cog_{i,j,c}$, and $Affec_{i,j,c}$). The coefficient of interest, β_1, captures the effect of pre-consultation on these quality variables. $X_{i,j,c}$ is a set of control variables for patient-related factors (i.e., patient age and gender, question number and length in consultation c), physician time-varying characteristics (i.e., pre-consultation experience, the number of online consultations, offline appointments, online reviews, offline reviews, and rating for offline services of attending physician j before consultation c), and physician-patient relationships (i.e., the number of online consultations and offline appointments between patient i and physician j before consultation c). We also include physician fixed effects ($Physician_j$) to account for physician heterogeneity as well as time-specific effects ($Time_c$) including time of the day, day of the week, and month of the year.

	$Sameday_{i,j,c}$		$Len_{i,j,c}$		$Cog_{i,j,c}$		$Affect_{i,j,c}$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Full	Matched	Full	Matched	Full	Matched	Full	Matched
$Preconsult_{i,j,c}$	0.003***	0.003**	36.766***	42.129***	0.203**	0.352**	-0.060	-0.090
	(0.001)	(0.001)	(3.085)	(4.520)	(0.098)	(0.142)	(0.061)	(0.088)
Patient characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physician characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physician-patient relationship	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physician fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	356,099	95,372	356,099	95,372	356,099	95,372	356,099	95,372
R²	0.189	0.286	0.668	0.666	0.229	0.219	0.208	0.194
Note. Clustered standard errors at the physician level are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.								

Table 3. Effect of Pre-consultation on Service Quality

Table 3 reports the estimates for online healthcare service quality based on the full sample and the matched sample. Columns (1) and (2) show that pre-consultation has a significant positive effect on the attending physician's response speed. Specifically, the probability of the attending physician giving responses on the same day increases by 0.003 if pre-consultation is used. Columns (3) and (4) present a consistent and significant positive effect on the attending physician's response length. In terms of magnitude, Column (3) suggests that response length increases by 42.129 words on average after pre-consultation. Columns (5) and (6) consistently show that pre-consultation increases the percentage of informational support in the attending physician's response. The matched sample results in Column (6) suggest that patients using pre-consultation receive 0.352% more informational support than those without pre-consultation. Moreover, according to columns (7) and (8), pre-consultation does not affect the percentage of emotional support significantly. Overall, the use of pre-consultation leads to faster and longer responses which consist of a higher percentage of informational support and a similar percentage of emotional support. Therefore, H1 is supported.

Estimation of the Effect on Patient Satisfaction

As there are no observations on online service ratings and tags unless the patient left an online service review, we estimate a Heckman selection model following previous studies (Goes et al. 2014), using the two-step procedure. In the first step, we model whether patient i chose to review consultation c provided by attending physician j using a Logit regression model as follows:

$$OnReview_{i,j,c} = \alpha_{10} + \alpha_{11} Preconsult_{i,j,c} + \theta_1 X_{i,j,c} + Physician_j^1 + Time_c^1 + \epsilon_{i,j,c}^1, \quad (2)$$

Based on the selection model, inverse mills ratio $\lambda(\cdot)$ is calculated and included in the second step, as shown in equation (3) and (4).

$$OnRating_{i,j,c}|(OnReview_{i,j,c} = 1) = \alpha_{20} + \alpha_{21} Preconsult_{i,j,c} + \theta_2 X_{i,j,c}$$
$$+ Physician_j^2 + Time_c^2 + \lambda_2(\cdot) + \epsilon_{i,j,c}^2, \quad (3)$$

$$OnTags_{i,j,c}|(OnReview_{i,j,c} = 1) = \alpha_{30} + \alpha_{31} Preconsult_{i,j,c} + \theta_3 X_{i,j,c}$$
$$+ Physician_j^3 + Time_c^3 + \lambda_3(\cdot) + \epsilon_{i,j,c}^3, \quad (4)$$

Table 4 reports the estimates for the effect of pre-consultation on online healthcare service satisfaction based on the full sample and the matched sample. The significant and negative coefficients of the selection model in Columns (1) and (2) suggest that the attending physician is less likely to receive a review from the patient if pre-consultation is used. The coefficients of $Preconsult_{i,j,c}$ in columns (3), (4), (5) and (6) are consistently negative and statistically significant, suggesting that the use of pre-consultation not only decreases the patient's intention to review the service, but also the review sentiment for the patient who indeed reviews the service. Therefore, H2 is supported.

	$OnReview_{i,j,c}$		$OnRating_{i,j,c}$		$OnTags_{i,j,c}$	
	(1)	(2)	(3)	(4)	(5)	(6)
	Full	Matched	Full	Matched	Full	Matched
$Preconsult_{i,j,c}$	-0.091***	-0.129**	-0.026***	-0.031***	-0.225***	-0.274***
	(0.029)	(0.039)	(0.005)	(0.008)	(0.068)	(0.094)
Patient characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Physician characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Physician-patient relationship	Yes	Yes	Yes	Yes	Yes	Yes
Physician fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	333,594	88,358	59,094	15,724	59,094	15,724
R²	0.146	0.146	0.300	0.287	0.223	0.234
Note. Clustered standard errors at the physician level are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.						

Table 4. Effect of Pre-consultation on Service Satisfaction

Robustness Checks

We conduct a series of robustness checks. First, we validate our results with another balancing method for treatment endogeneity: coarsened exact matching (CEM). Second, we use the copula approach, a semi-parametric approach that nonparametrically estimates the marginal distribution of the endogenous variables and uses a copula function to build the joint distribution of the endogenous variables and the structural error term, to account for sample selection based on unobservable confounding factors. The results are consistent with those in Table 3 and Table 4. Third, we estimate a discrete-time hazard model to examine whether physicians' adoption decisions are driven by online healthcare service outcomes. The results show that online healthcare service outcomes do not affect whether and when physicians begin to adopt the pre-consultation function. Finally, to account for potential within-hospital correlation in the effects, we include clustered standard errors at the hospital level instead of the physician level. All the results are qualitatively the same as those in Table 3 and Table 4.

Mechanism Test

Improved Case Information Quality

As we hypothesized, pre-consultation conducted by the assistant physician improves the information quality (i.e., professionalism and comprehensiveness) of the patient case, which facilitates the diagnosis and treatment of the attending physician and thus improves the service quality. If so, we would expect that the case information quality significantly mediates the relationship between pre-consultation and online healthcare service quality. To validate this possible mechanism, we leverage detailed patient case information. According to the linguistic categories provided by LIWC, we construct two variables to measure case professionalism. The first variable, $Case\_Fac_{i,j,c}$, refers to the percentage of "perceptual processes" words indicating what patients see, hear, and feel and "biological processes" words relating to body, health, sexual, and ingestion, which captures the assistant physician's medical vocabulary richness in describing factual symptomatic information (Jiang et al. 2022). The second variable, $Case\_Flu_{i,j,c}$, is the complement of the percentage of informal words including "filters" (e.g., umm) and "non-fluencies" (e.g., you know). Because the use of such informal words is not appropriate for the professional setting, $Case\_Flu_{i,j,c}$ can be used to measure language fluency and impact (Ransbotham et al. 2019). To measure case comprehensiveness, we construct two variables, the total number of words ($Case\_Len_{i,j,c}$) and the percentage of cognitive words in the patient case ($Case\_Cog_{i,j,c}$).

We first perform a simple t-test for the difference in patient cases for consultations with pre-consultation and those without. The results in Table 5 show that both professionalism and comprehensiveness of the patient cases summarized by assistant physicians are significantly higher than those organized by patients.

	Consultations without pre-consultation		Consultations with pre-consultation		T-test
	N	Mean	N	Mean	Mean Diff
Professionalism					
$Case\_Fac_{i,j,c}$	76,893	12.752	19,040	16.715	-3.963***
$Case\_Flu_{i,j,c}$	76,893	99.415	19,040	99.636	-0.221***
Comprehensiveness					
$Case\_Len_{i,j,c}$	76,893	106.348	19,040	153.010	-46.662***
$Case\_Cog_{i,j,c}$	76,893	12.063	19,040	12.650	-0.586***

Table 5. Case Information Quality Differences

With the improvement of case information quality, pre-consultation can reduce the attending physician's need for further information-seeking and clarification with the patient during the consultation. The attending physician can thus focus on the patient's medical problems and improve the service quality. Therefore, responses from the attending physician are expected to contain fewer questions and less uncertain content, but more diagnoses and suggestions. To validate this, verbal certainty of the attending physician's responses, $Doc\_Certainty_{i,j,c}$, is constructed by subtracting the percentage of interrogatives (e.g., how, when, what) and tentative terms (e.g., maybe, perhaps) from the percentage of certainty terms (e.g., always, absolute) (Markowitz 2023). Then, we estimate how it is affected by pre-consultation. As

shown in Table 6, the significantly positive coefficients of *Doc_Certainty*$_{i,j,c}$ suggest that pre-consultation increases reduces further case information seeking and clarification and increases the response certainty of the attending physician. This result further validates that pre-consultation improves patient case information.

Variable	*Doc_Certainty*$_{i,j,c}$	
	(1)	(2)
	Full	Macthed
Preconsult$_{i,j,c}$	0.190***	0.234***
	(0.051)	(0.065)
Patient characteristics	Yes	Yes
Physician characteristics	Yes	Yes
Physician-patient relationship	Yes	Yes
Physician fixed effects	Yes	Yes
Time fixed effects	Yes	Yes
Observations	352,909	95,372
R²	0.163	0.157
Note. Clustered standard errors at the physician level are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.		

Table 6. Effect of Pre-consultation on The Attending Physician's Response Certainty

Mediation Effect of Case Information Quality

We then conduct a formal mediation analysis (Bai et al. 2020; Balawi et al. 2022) for the relationship between pre-consultation and online healthcare service quality via case information quality (i.e., *Case_Fac*$_{i,j,c}$, *Case_Flu*$_{i,j,c}$, *Case_Len*$_{i,j,c}$, and *Case_Cog*$_{i,j,c}$,) as intermediate variables. Table 7 summarizes bootstrap results for the mediation effects. The bootstrap analysis in column (1) shows that pre-consultation increases the attending physician's response speed mainly through enhancing the fluency of the patient case. As shown in Column (2), the mediation effect of *Case_Fac*$_{i,j,c}$, *Case_Flu*$_{i,j}$, and *Case_Len*$_{i,j,c}$ are all positive and significant, suggesting that both case professionalism and comprehensiveness positively mediate the relationship between pre-consultation and response length. The positive coefficients of *Case_Len*$_{i,j,c}$ and *Case_Cog*$_{i,j,c}$ in Column (3) of show that the improvement in case comprehensiveness can explain the observed positive effect of pre-consultation on the informational support. Overall, these results support our prior conjecture that the case quality improvement in comprehensiveness or/and professionalism is an underlying mechanism that explains the positive effect of pre-consultation on online healthcare service quality.

Mediation Variables	(1)	(2)	(3)
	Sameday$_{i,j,c}$	*Len*$_{i,j,c}$	*Cog*$_{i,j,c}$
Case_Fac$_{i,j,c}$	-0.0003	1.572***	-0.004
	(0.0002)	(0.230)	(0.006)
Case_Flu$_{i,j,c}$	0.0003**	0.172*	0.001
	(0.0001)	(0.101)	(0.002)
Case_Len$_{i,j,c}$	-0.0002	4.663***	0.068***
	(0.0002)	(0.538)	(0.005)
Case_Cog$_{i,j,c}$	0.0001	-0.052	0.035***
	(0.0000)	(0.062)	(0.003)

Table 7. Mediation Effects of Case Information Quality

Discussion

This study investigates how pre-consultation influences online healthcare service quality and satisfaction. Using data on text consultations from a leading Chinese OHC, we consistently demonstrate that the pre-consultation conducted by an assistant physician can increase the service quality of the consultation provided by the attending physician. Specifically, after the adoption of pre-consultation, the attending physician responds faster and provides longer answers, which provides the patient with more informational

and emotional support. Despite the improvement in service quality, pre-consultation leads to decreased patient satisfaction of the online consultation services. The results of mechanism tests reveal that pre-consultation improves service quality by enhancing the professionalism and comprehensiveness of patient case information and reducing case information seeking and clarification of the attending physician with the patient.

Theoretical Contribution

Our study contributes to the healthcare literature on OHCs by examining a new service function, pre-consultation, which engages another physician to understand and document the patient's health conditions, medical history, and consultation objectives before the formal consultation with the attending physician. In contrast to prior studies mainly focusing on service functions used during the consultation (Chen et al. 2020; Huang et al. 2021; Yang et al. 2015), feedback functions (Peng et al., 2020; Wang et al., 2020; Zhao et al., 2022) or follow-up functions (Li et al., 2021) used in the post-consultation stage, we investigate pre-consultation prior to the formal consultation and examine its effect on service quality during the consultation and patient satisfaction after the consultation. By demonstrating the positive effect of pre-consultation on service quality and its negative effect on patient satisfaction, our study completes the current understanding of how OHCs and its innovations change the healthcare sector.

Our study also enriches the literature on medical pre-consultations that focuses on pre-consultations offered for offline patients and conducted via questionnaires (Jamal et al. 2019; Murphy et al. 2022; Rickenbach 2019; Zanini et al. 2016), interviews (Torres et al. 2021), or systems (Kocaballi et al., 2020; Petitgand et al., 2020; Qian et al., 2021; Zhang et al., 2022). Although the positive role of pre-consultation in offline healthcare service quality has been documented (Jamal et al. 2019; Murphy et al. 2022; Zanini et al. 2016), we extend this conclusion to pre-consultations offered for online patients, answering the call for research to investigate the effect of pre-consultation in complete telehealth services (Kocaballi et al. 2020). More importantly, whereas previous research mostly relied on subjective measures collected through questionnaires or interviews to assess healthcare service quality, our study utilizes more objective measures extracted from consultation records between patients and physicians for online service quality. Additionally, by examining how pre-consultations influence online healthcare service quality, we demonstrate the advantage of pre-consultation conducted by assistant physicians in enhancing the professionalism and comprehensiveness of patient case information and reducing case information seeking and clarification of the attending physician with the patient, which is one of the major limitations of pre-consultation systems (Qian et al. 2021). Offline patients using pre-consultations in the form of questionnaires are more satisfied with the consultation as they feel being listened to and taken seriously by the physician (Murphy et al. 2022; Torres et al. 2021). However, we find that pre-consultation significantly decreases the satisfaction of online patients when service quality actually improves. This may be caused by the additional costs for pre-consultation in online services, which raises patient expectations for consultation.

Furthermore, this study contributes to the literature on patient-generated feedback. In contrast to prior studies focusing on the patient reviews/ratings regarding offline healthcare services (Gao et al. 2015; Lu and Rui 2018; Okike et al. 2016; Saifee et al. 2020; Xu et al. 2021), we examine the reviews/ratings regarding online healthcare services. By looking into the effect of pre-consultation on both online healthcare service quality and satisfaction, our findings serve as a reminder that the provision of high-quality online healthcare service may not necessarily translate into higher online ratings, highlighting the limitation of patient-generated feedback given the credence nature of healthcare services (Okike et al. 2016; Saifee et al. 2020).

Practical Implications

Given the quite low adoption rate of the pre-consultation function by both physicians and OHCs, our findings provide guidance for physicians, patients, OHCs, and healthcare policymakers to improve online healthcare outcomes using this innovative healthcare tool.

For physicians, our results show that the adoption of pre-consultation is a double-edged sword. On one hand, pre-consultation can help to improve their online service quality and efficiency through enhancing the professionalism and comprehensiveness of the patient case information. Although they cannot choose

pre-consultation physicians, their consultations are not affected by the characteristics of pre-consultation physicians. On the other hand, the use of pre-consultation will decrease patient satisfaction towards the online service. Therefore, the adoption of the pre-consultation function is preferable for physicians aiming to be more efficient in online services rather than those prioritizing their online reputations.

For patients, they can choose physicians who have adopted the pre-consultation function to obtain better online services. This is particularly beneficial when patients are not concerned about the associated extra fee for utilizing the pre-consultation feature. Additionally, online reviews and ratings might not provide a comprehensive picture of a physician's online service quality. Therefore, patients are advised to seek out additional sources of information beyond just online reviews and ratings when evaluating and choosing physicians.

For OHCs, enabling the pre-consultation function for physicians creates positive effects on their online service quality, which can encourage more physicians to adopt this function in the OHC. However, the decreased patient satisfaction because of using this function may prevent some physicians' adoption. To address this reputational concern, OHCs could guide patients to improve their service evaluation with more detailed instructions and factual data. To better inform potential patients, OHCs can design and provide more objective measures for physicians' service quality based on their service records, instead of subjective feedback from their patients.

Our results also provide useful insights for healthcare policymakers. First, although the Chinese government has issued guidelines regarding pre-consultations for offline patients, no policy guiding has been made for online pre-consultations. Relevant policies can be made to encourage OHCs to enable the pre-consultation function to make online consultations more effective, especially for physicians in high demand. Second, as online reviews/ratings cannot truly reflect the online healthcare service quality, policymakers should not rely on public online reviews/ratings to close information gaps between patients and physicians. They should also educate patients about this and make more objective information of physicians' qualifications and services available. For example, relevant statistics on patient health outcomes, such as readmission rates and mortality risk, could be made widely available to the public.

Limitations and Future Research

Our work takes an initial step towards leveraging physician-conducted online pre-consultations in OHCs. First, because the research context is based on one OHC in mainland China, the findings may not be generalizable to OHCs based in other countries or with different structures. Second, while we contribute to the literature by considering online healthcare service quality based on online consultation records, future research may explore other quality measures such as health status of online patients. Third, without data on the interaction details between assistant physicians and patients during pre-consultations, we are unable to investigate whether their interactions affect the impacts of pre-consultation. Fourth, we only study pre-consultations conducted by assistant physicians. Future work might investigate and compare the different effects of AI-based vs. human-based pre-consultations on service quality and satisfaction. Finally, because the estimation window of this study is relatively short (i.e., four months), the effect of the pre-consultation function that dissipates with time cannot be fully examined. Future studies may probe the long-term impact of this service function.

Acknowledgement

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