Tele-Follow-Up and Outpatient Care

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Abstract

We examine the application of telemedicine for follow-up care (i.e., tele-follow-up). By collaborating with a large Asian hospital that sequentially adopted the tele-follow-up service in different departments, we leverage the difference-in-differences design and find that the adoption of telemedicine significantly increases the follow-up volume by 54%. Moreover, telemedicine generates positive spillover effects on onsite care provision, with onsite follow-up visits increasing by 10.7% and onsite initial visits increasing by 5.7%. The mechanism test shows that the treatment effect is heterogeneous by patients' cost sensitivity to onsite follow-up care. Finally, we show that tele-follow-up improves patient care quality, as evidenced by a significant reduction in the readmission rate, which reinforces the value of tele-follow-up applications.

Keywords: telemedicine, follow-up care, health information technology, health care access

1. Introduction

Follow-up care given to patients after an initial consultation or treatment is an indispensable part of the care process and carries various benefits. According to the Agency for Healthcare Research and Quality (AHRQ), appropriate follow-up allows physicians to clarify misunderstandings, monitor patient conditions, identify complications, make further assessments, and adjust treatments (AHRQ, 2022). Timely check-ups and assessments by physicians have been shown to improve care quality and patient health. For instance, Jackson et al. (2015) indicated that follow-up care in their study reduced readmission rates by 1.5% for patients in the lowest-risk strata and 19% for those in the highest-risk strata. Touching base with patients through follow-up appointments also helps improve medication adherence, which is a well-documented problem among discharged patients (Fischer et al., 2010; Lindquist et al., 2012).

Despite its importance, patients often lack access to timely follow-up care for various reasons, such as transportation issues, lack of health insurance, and limited assistance in scheduling outpatient follow-ups before discharge (Misky et al., 2010). Failures to follow up not only pose risks to patient health but also trigger potential negligence claims regarding healthcare practitioners' medical liability (Amednews, 2013). As such, healthcare organizations strive to encourage follow-up attendance, and the key is to ensure convenient access. For instance, Dennis McWilliams, former president of Apollo Endosurgery, said that "*Given the importance of patient engagement and follow-up care ... [we] needed to create a better process for follow-up care that was more engaging and convenient for the patient*" (Heath, 2016).

We propose telemedicine as a potential solution to encouraging follow-up attendance, for two reasons. First, telemedicine overcomes the transportation barrier by enabling two-way real-time interactive communication between patients and physicians at a distant site (Medicaid, 2022). This might promote patients' access to follow-up care, especially for those with transportation barriers, such as long travel distances to the hospital, lack of transportation, and inability to drive (Misky et al., 2010). Second, telemedicine eliminates travel and time costs, which may boost patients' willingness to access follow-up care. This especially appeals to patients who skip follow-up appointments due to time constraints related to work and family obligations. With telemedicine, time-sensitive patients can connect to care providers from work or home at their convenient time. Despite the feasibility of applying telemedicine in several clinical settings (Ekeland et al., 2010), the evidence regarding its impact on follow-up services is limited thus far. Only a few anecdotes have suggested that telemedicine could be feasible for follow-up services. For instance, a Wall Street Journal article indicated that "*specialists such as orthopedic surgeons are taking advantage of virtual visits for follow-up consults, even for seemingly complex issues like helping patients care for their incisions or surgical drains*" (Landro, 2021).

Given the limited empirical evidence and the promise of telemedicine in follow-up care from the anecdotes, our paper aims to provide more analytics regarding the impact of telemedicine application

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for follow-up care (hereinafter *tele-follow-up*). In particular, we aim to answer the following questions: *Does tele-follow-up improve patients' access to follow-up care*? *Will tele-follow-up affect patients' demand for initial care*? *If the answer is yes to the above questions, what are the underlying mechanisms*? Towards these goals, we collaborate with a children's hospital in Asia, which is the largest teaching hospital serving approximately 11 million people in the region. The hospital first adopted tele-follow-up service in the department of neurology on August 24, 2018, and subsequently extended the service to the department of primary care on March 11, 2019.

Leveraging the difference-in-differences (DID) design, we start by examining the treatment effects of telemedicine on patient access to care. We measure patient access by the number of patient visits per department per week. We distinguish between online and onsite service provisions and construct three outcome measures, including the total follow-up visits, onsite follow-up visits, and onsite initial visits.[1] The analyses yield two key findings. First, the adoption of the tele-follow-up service significantly increases the total follow-up volume by 54%, suggesting that telemedicine indeed improves patients' access to follow-up care. Second, the adoption of tele-follow-up service generates positive spillover effects on onsite care provision. In particular, among the adopting departments, onsite follow-up visits increased by 10.7% and onsite initial visits increased by 5.7%. Mechanism tests further show that the treatment effects are heterogeneous. In particular, the treatment effect is larger for patients who face higher transportation costs or have comorbid conditions. The findings corroborate the underlying mechanisms through which telemedicine works, whereby patients with a higher cost of accessing onsite follow-up care are more likely to value telemedicine, and their demand elasticity is thus larger. Finally, we show that better access to follow-up care improves the patient health outcome, as evidenced by a significant reduction in the readmission rate among adopting patients, which reinforces the value of tele-follow-up applications.

These findings contribute to the literature and practice from several aspects. The literature demonstrates the value of telemedicine in settings such as chronic and emergency care (Rajan et al., 2019; Sun et al., 2020). Our paper provides further evidence of the promise of telemedicine in follow-up care, which has so far received limited attention from researchers and practitioners. To healthcare decision-makers, our findings indicate that telemedicine not only improves access to follow-up care but redirects patients to the hospital for initial consultation and diagnosis. Moreover, the telemedicine channel designated for follow-up care enables task specialization and more focused operations, which improves physicians' working efficiency and helps address the unmet demand from the disadvantaged population.

[1]Initial visit refers to a patient's visit to the hospital for consultation, diagnosis, or treatment purposes

2. Literature Review

In recent years, the management literature has begun investigating the impact of telemedicine adoption in several clinical settings, such as primary care, emergency care, and teletriage (Bavafa et al., 2021; Çakıcı & Mills, 2021; Rajan et al., 2019; Sun et al., 2020). We aim to obtain a more comprehensive understanding of the telemedicine application for follow-up service. To our best knowledge, the literature on tele-follow-up care is limited, with only a few studies in the medical and public health domain. The primary focus of these studies is to compare the care quality between telemedicine and in-person visits for patients with specific health conditions (Faruque et al., 2017; Reider-Demer et al., 2018).

Our paper contributes to the literature in several aspects. First, our paper is among the first to study the impact of tele-follow-up services on patient behavior and hospital operations. Going beyond its direct impact on follow-up care, we also examine the impact of tele-follow-up service on the cross-channel and cross-service care provision, which we believe is informative to healthcare decision-makers striving to improve efficiency and care access. Second, despite its importance to patients and providers, outpatient follow-up services have rarely been studied. Our paper fills this gap by investigating health IT as a potential solution to improving patient access to follow-up care. Third, the literature generally believes that focused operations can improve performance in the hospital industry (Clark & Huckman, 2012; Kc & Terwiesch, 2011). Our paper points to health IT as a flexible way to improve focused operations, where hospitals can leverage telemedicine as a dedicated channel for follow-up appointments.

3. Hypothesis Development

When telemedicine becomes available for follow-up care, it may increase patients' access to follow-up services from two aspects. First, telemedicine alleviates the challenges associated with getting to an appointment. Since the transportation barrier is

a primary reason that prevents patients from getting follow-up care (Misky et al., 2010), patients who previously had difficulty reaching doctors' offices for follow-up appointments can now use telemedicine because of its minimal transportation costs. Second, telemedicine constitutes a simple, flexible, and convenient manner of delivering care. Unlike an onsite follow-up visit, where patients typically undergo a long and exhausting process from onsite registration, waiting for treatment, and checking out, the visit process is much smoother in the virtual space. For instance, telemedicine's "virtual waiting room" shortens patients' actual waiting time. When patients enter the virtual waiting room, they can see how many patients are waiting in the queue to estimate the waiting time. Patients are also notified of their turn through text messages and app notifications. Such features are especially beneficial for patients sensitive to the time costs of accessing onsite care. With telemedicine, they can flexibly get a follow-up appointment during breaks in the office or at home.

While telemedicine seems to have great potential in increasing patients' access to follow-up care, in practice, it may lead to unintended consequences due to possible friction. For instance, patients may hesitate to utilize telemedicine if they worry that virtual communication is less effective than an onsite face-to-face visit. Even if there is perfect compliance from patients and providers, technological glitches may disrupt treatment sessions and negatively affect patients' willingness to get tele-follow-up appointments. Therefore, whether telemedicine improves patients' access to follow-up care is ultimately an empirical question. We thus propose the following hypothesis for an empirical test.

Hypothesis 1: *The adoption of tele-follow-up increases patients' demand for follow-up care* (*measured by the volume of follow-up visits*).

The implementation of telemedicine may further affect onsite care provision. According to our collaboration hospital, physicians designate telemedicine to serve follow-up patients only. Thus, the hospital achieves higher focus and task specialization by separating patients based on the type of appointment. From the literature, because division of labor becomes only economic at scale, task specialization is a key mechanism through which scale improves outcomes and productivity (Kc et al., 2020; Narayanan et al., 2009). In the healthcare context, Ibanez et al. (2018) showed that radiologists take more time to read digital images (e.g., chest X-rays, head CT scans, and spine MRIs) when there is a greater variety of items in their queue. Using the empirical context of cardiovascular care, Kc and Terwiesch (2011) and Clark and Huckman (2012) found that focused operations generally have a positive effect on quality outcomes, such as lower length of stay and reduced mortality rates. In our setting, physicians can focus on quick checkups on follow-up patients, with no switching costs between initial and follow-up care, thereby increasing their service efficiency through telemedicine. Moreover, patients are required to pre-fill their health conditions when scheduling a tele-follow-up appointment. Due to the elimination of paperwork, physicians have minimal waiting in between visits compared to the office setting. Moreover, because of the efficient processing of tele-follow-up services via the telemedicine channel, physicians might have increased onsite service availability, and patients would then have better access to onsite care. Nonetheless, depending on the type of onsite visits, the patient choice may step in and affect the aggregated demand for care. Therefore, we separately elaborate on the possible changes in the department-level patient volume for onsite follow-up (Hypothesis 2) and initial care (Hypothesis 3).

From individual patients' perspectives, the tele-follow-up service may substitute or complement onsite follow-up service. In our collaboration hospital, telemedicine embeds real-time communications between patients and physicians through video conferencing tools, thereby essentially simulating the same scenario as an in-person visit. Given the significant convenience and cost reduction in transportation, patients may consider tele-follow-up service as a substitute for onsite follow-up service and switch from the onsite to the online channel, thus leading to a reduction in onsite follow-up visit frequency. On the other hand, tele-follow-up visits might complement the onsite follow-up care for two reasons. First, according to the literature, the use of e-visits (i.e., secure messaging) leads to more frequent onsite visits, because increased communication through e-visits creates more potential opportunities for a physician to feel obligated to see a patient in the office (Bavafa et al., 2018). Second, telemedicine functions as a gateway where patients can obtain timely feedback about their health conditions so that they can get more onsite appointments as needed for further evaluations. For instance, if a doctor notices any early complications for a patient with diabetes through a telemedicine follow-up, the patient may need an onsite follow-up visit for a plasma glucose test. Depending on the magnitude of the substitution and complementary effects, the impact of telemedicine on the onsite follow-up volume is unclear. Hence, we propose the following hypothesis for an empirical test:

Hypothesis 2: *The adoption of tele-follow-up increases patients' demand for onsite follow-up care*

(*measured by the volume of onsite follow-up visits*).

The tele-follow-up service may further generate positive spillover effects on the initial service provision. According to our collaboration hospital, patients hesitate to come to the hospital for even initial diagnoses because of the inconvenience of accessing follow-up care, particularly for whom the cost of an office follow-up visit is prohibitive. As such, even though the care quality from our collaboration hospital is higher, patients may instead go to a local clinic with lower quality for the sake of convenience. Since the cost to access follow-up care is much lower via telemedicine, adopting tele-follow-up may attract more patients to the department for initial care. Accordingly, we propose the following hypothesis for an empirical test.

Hypothesis 3: *The adoption of tele-follow-up increases patients' demand for onsite initial care* (*measured by the volume of onsite initial visits*).

If tele-follow-up service does affect patient behaviors in seeking onsite follow-up and initial care, the impact is likely contingent on the patient type. In particular, patients with a higher cost of accessing onsite follow-up care will be more likely to use telemedicine. Thus, their demand elasticity for tele-follow-up service will be larger. In particular, we consider two proxies for the access cost to onsite follow-up care: (i) the transportation cost and (ii) the presence of comorbid conditions. Patients with higher travel costs to onsite services, such as long travel distances or lack of transportation, will be more likely to factor in the costs of follow-up service in choosing whether to get the initial treatment. Similarly, routine follow-up appointments are often necessary for patients with comorbid conditions. Thus the long-term cost of follow-up care is likely a crucial consideration in their choices of providers for initial care. Hence, if telemedicine brings new patients to the hospital, the effect will be more salient for those with higher costs to access follow-up services. Accordingly, we propose the following hypothesis for empirical tests:

Hypothesis 4: *The effect of tele-follow-up is larger for patients with higher cost sensitivity to onsite follow-up care* (*measured by higher transportation costs or the presence of comorbid conditions*).

4. Research Background and Data

4.1. Research Background

We obtain visit-level data from a large children's hospital. The hospital is a leading teaching hospital that provides primary and specialty care in the area. The lack of follow-up attendance has been a longstanding issue in the hospital, even with providers informing patients about the necessity of follow-up appointments. Patients often ignore or skip such services due to various reasons, such as transportation barriers to accessing onsite service, lack of literacy regarding the importance of follow-up care, and insufficient assistance from front-desk receptionists in scheduling follow-up appointments upon discharge. To improve patients' access to follow-up care, especially for patients with chronic and non-urgent conditions, the hospital adopted telemedicine.

The hospital initiated the tele-follow-up service in the department of neurology on August 24, 2018, and subsequently, extended this service to the department of primary care on March 11, 2019. According to the hospital, as long as a department has patients needing routine follow-up service and telemedicine is unlikely to compromise care, it is eligible for adopting the tele-follow-up service. The hospital started its telemedicine program in these two departments because it considered telemedicine applicable to patients in these departments and that the use of telemedicine is unlikely to compromise care quality for patients with non-urgent follow-up need in these settings. No financial incentives were offered to patients or providers for using telemedicine, as the hospital set up the infrastructure and training for all patients and practitioners involved. Moreover, the cost to patients and the payment to physicians are the same per visit regardless of the modality (i.e., telemedicine or in-person visit).

Before telemedicine was adopted, follow-up service was available only through onsite visits. After telemedicine adoption, if a patient wants to schedule a follow-up appointment, they can decide on the visit modality by themselves. From a patient's perspective, the scheduling process of tele-follow-up appointments is no different from that of onsite follow-up appointments. When logging in to the hospital's app portal, both telemedicine and in-person appointments can be viewed, and patients can choose either option for follow-up care. Around the appointment time, patients are notified about the appointment through text messages and in-app notifications. After logging into the app, patients can check in real time the number of patients waiting in the queue. When it is their turn, the treatment session starts, and patients are connected to the physician using the video conferencing feature within the app portal. During this real-time interactive meeting, patients inform the physician of their symptoms, medication, and other relevant information. The physician accordingly adjusts treatment plans, administers medications, and orders lab tests if necessary. Upon completing the telemedicine

visit, patients can make an e-payment through the app portal, and the hospital fulfills any prescription orders and delivers them to the patients.

4.2. Data and Variable

Our primary variable of interest is *patient volume*, which has long been considered an important measure in healthcare research. We calculate patient volume as the number of outpatient encounters by department and week, which can capture changes in aggregated patient demand (i.e., care access) due to tele-follow-up adoption. Depending on the purpose of the visits, we distinguish initial visits from follow-up visits following the hospital's definition. More specifically, a *follow-up visit* refers to all follow-up appointments to the same department for the same diagnosis within a three-month window following an initial visit. Based on the modality of a visit, we further distinguish onsite from telemedicine visits. Before telemedicine adoption, there are two types of encounters: onsite initial and onsite follow-up visits. After telemedicine adoption, there are three types of encounters: onsite initial, onsite follow-up, and tele-follow-up visits. Correspondingly, we have three outcome measures for empirical tests—*Total Follow-up Visits*, *Onsite Follow-up Visits*, and *Onsite Initial Visits*—by department and week. Before telemedicine adoption, *Total Follow-up Visits* is equal to *Onsite Follow-up Visits*. After telemedicine adoption, *Total Follow-up Visits* comprises a mix of telemedicine and onsite follow-up visits for the treatment departments.

To examine the effect of telemedicine use on patient care quality, we construct measures for readmission risks following a visit. We track patients using their unique identifiers in the data and generate 7/14/30 day readmission indicators that equal one (and zero otherwise) if a patient revisits the emergency room (ER) or is readmitted to the hospital as an inpatient within 7/14/30 days of discharge. To control for the possible changes in patient mix, we construct a set of time-varying characteristics by department and time, such as patients' health conditions (Charlson comorbidity index [CCI]) and patients' demographics (age at admission and gender).

5. Tele-follow-up and Care Access

To test the impact of the tele-follow-up service on patient access, we conduct DID regression with multiple groups and time periods following the literature (Angrist & Pischke, 2009). We adopt the following specification using aggregated data at the department-week level:

$$Y_{it} = \alpha + \beta DepTeleAdoption_{it} + \gamma X_{it} + DepFE_i + TimeFE_t + \varepsilon_{it}, \quad (1)$$

where Y_{it} is the patient volume to department i at week t. Depending on the type of visits, Y_{it} can represent one of the following variables in log-scale: *Total Follow-up Visits*, *Onsite Follow-up Visits*, or *Onsite Initial Visits*. $DepTeleAdoption_{it}$ is a binary indicator of the telemedicine adoption status in department i at week t.[2] For treatment departments, $DepTeleAdoption_{it}$ equals zero in pre-adoption periods and one in post-adoption periods. For control departments, $DepTeleAdoption_{it}$ equals zero throughout the sample period. β captures the treatment effect on patient care access due to telemedicine adoption. We control for time-varying characteristics in X_{it}, including patients' demographics (i.e., age and gender) and health conditions (i.e., comorbidities). We also control for the department and time (i.e., week) fixed effects to capture cross-sectional and time-series unobserved heterogeneity.

Table 1 reports the regression results following the specification in Equation (1). Column (1) of Table 1 reports a significant positive coefficient estimate, suggesting that telemedicine adoption significantly increases follow-up volume. The DID estimate remains robust after accounting for changes in patient composition in Column (2). These results support Hypothesis 1, which states that telemedicine adoption increases patient access to follow-up care at the department-week level. In terms of magnitude, telemedicine increases follow-up volume by about 54.0% (i.e., $e^{0.432} - 1$). Interestingly, we also observe positive spillover effects on onsite care provision, which support Hypotheses 2 and 3. More specifically, following telemedicine adoption, the onsite follow-up volume increased by 10.7% (i.e., $e^{0.102} - 1$) (see Column 4) and the onsite initial volume increased by 5.7% (i.e., $e^{0.055} - 1$) (see Column 6).

These results have two implications. First, consistent with the hospital's initiative, telemedicine indeed enhances patient access to follow-up care. Since telemedicine reduces travel costs and increases time flexibility to getting care, patients who previously would not bother to come to the hospital for onsite follow-up appointments are likely to schedule tele-follow-up visits at their convenience. Second, apart from its direct impact on enhancing follow-up care, telemedicine

[2] $DepTeleAdoption_{it} = DepTeleAdoption_i \times Post_t$, where $DepTeleAdoption_i$ equals one for treatment departments and $Post_t$ equals one for post-adoption periods. In the estimation, the main effect of $DepTeleAdoption_i$ is absorbed by the department fixed effects and the main effect of $Post_t$ is absorbed by the time fixed effects.

Table 1: Effect of Tele-follow-up on Care Access

DV: Patient Volume	Total Follow-up Visits		Onsite Follow-up Visits		Onsite Initial Visits	
	(1)	(2)	(3)	(4)	(5)	(6)
DepTeleAdoption	0.533***	0.432***	0.102*	0.102***	0.087***	0.055**
	(0.079)	(0.054)	(0.054)	(0.039)	(0.033)	(0.027)
Patient Controls	N	Y	N	Y	N	Y
Department, Time FE	Y	Y	Y	Y	Y	Y
Observations	2,328	2,328	2,328	2,328	2,328	2,328
R^2	0.033	0.480	0.054	0.470	0.053	0.307

$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. Standard errors in parentheses are clustered by department.

unexpectedly generates positive cross-channel spillover effects, as evidenced by increased onsite visits.

To understand such spillover effects, we further interviewed practitioners of our collaboration hospital and learned the following channel through which telemedicine improves onsite operation. Before telemedicine adoption, patient encounters consist of a mix of initial and follow-up visits. After telemedicine adoption, the hospital redirects part of the follow-up appointments to the online channel, which makes the patient mix "purer" for both the online and offline channels. This eliminates possible interruptions and switching time between initial and follow-up visits, resulting in smoother workflow and reduced idle time between visits. The improved workflow further enables faster processing of follow-up visits, with physicians' average service time for follow-up service reduced from 39.6 to 21.6 minutes. When further decomposing onsite visits by modality, we find that: (i) the average service time is 12.4 minutes for tele-follow-up appointments, (ii) and that the onsite follow-up service time decreased from 39.6 minutes to 30.5 minutes. Hence, the efficiency improvement is primarily driven by the significant reduction of service time via telemedicine. In other words, the improved workflow via tele-follow-up facilitates service efficiency, thereby enabling physicians to serve more onsite patients.

6. Mechanism

The increased patient volume suggests the existence of unmet health needs before telemedicine adoption. To uncover what types of patients drive the increased demand, we perform additional mechanism tests by leveraging patients' heterogeneity. In particular, we examine patients' heterogeneous demand by their costs to access onsite follow-up care from two aspects.

6.1. Heterogeneity by Transportation Cost

Given that the long travel distance and the lack of reliable public transportation are two barriers to access care for the rural population (RHIhub, 2022), rural patients' demand is expected to be more elastic to the availability of the tele-follow-up service. As such, we distinguish rural from urban patients based on their home addresses. In our sample, the average travel distance to the hospital for rural patients (31.5 miles) is 2.6 times that for urban patients (12.2 miles). We then perform subsample analyses following Equation (1), with the dependent variables being the patient volume of rural and urban areas.

For rural patients, as shown in Column (1) of Table 2 Panel A, there is a significant increase in total follow-up volume. This finding is consistent with the main analysis finding presented in Table 1. However, despite a positive coefficient estimate, Column (3) shows that the treatment effect on onsite follow-up volume is insignificant. Connecting these two estimates, we can infer that the increased demand for follow-up care by rural patients is primarily driven by their uptake of the tele-follow-up service. The findings make sense as rural patients face higher transportation costs and are less likely to opt in for onsite follow-up care in the first place. Moreover, Column (5) shows a significant increase in rural patients' demand for initial care. Unlike urban patients who can plan for an onsite visit to hospitals at their convenience with or without telemedicine, rural patients often hesitate to come to the hospital for care. This is especially true for patients who need routine follow-up appointments. One of the example cases suggested by physicians is rural patients with pediatric epilepsy, who typically require long-term medication and consultation. Convenient access to follow-up care is thus critical in their choices of initial care. Before telemedicine adoption, they hesitated to come to the hospital for initial diagnosis, partly due to the high costs of accessing follow-up care. With the option of tele-follow-up, the hospital redirects such patients

Table 2: Heterogeneity of Treatment Effect by Patient Type

	Panel A - By Transportation Cost					
	Total Follow-up Visits		Onsite Follow-up Visits		Onsite Initial Visits	
DV: Patient Volume	Rural	Urban	Rural	Urban	Rural	Urban
	(1)	(2)	(3)	(4)	(5)	(6)
DepTeleAdoption	0.391***	0.468***	0.079	0.123***	0.091***	0.045
	(0.057)	(0.060)	(0.051)	(0.041)	(0.027)	(0.030)
Patient Controls	Y	Y	Y	Y	Y	Y
Department, Time FE	Y	Y	Y	Y	Y	Y
Observations	2,328	2,328	2,328	2,328	2,328	2,328
R^2	0.607	0.516	0.605	0.510	0.345	0.322
	Panel B - By Comorbid Conditions					
	Total Follow-up Visits		Onsite Follow-up Visits		Onsite Initial Visits	
DV: Patient Volume	CCI>0	CCI=0	CCI>0	CCI=0	CCI>0	CCI=0
	(1)	(2)	(3)	(4)	(5)	(6)
DepTeleAdoption	0.405***	0.594***	0.137***	0.016	0.126***	-0.034
	(0.053)	(0.074)	(0.041)	(0.042)	(0.030)	(0.035)
Patient Controls	Y	Y	Y	Y	Y	Y
Department, Time FE	Y	Y	Y	Y	Y	Y
Observations	2,328	2,328	2,328	2,328	2,328	2,328
R^2	0.475	0.606	0.464	0.607	0.292	0.479

$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. Standard errors in parentheses are clustered by department.

to seek initial diagnosis and follow-up care, thereby fulfilling the "unmet" demand from the disadvantaged group.

Comparatively, urban patients remain unaffected in their initial care decisions, as evidenced by the insignificant coefficient estimate in Column (6). This is because urban patients are less sensitive to travel costs than their rural counterparts, so the cost to access onsite follow-up services is less of a concern in their choices of initial care. Nonetheless, we do observe positive treatment effects of telemedicine on follow-up care for the urban population. As shown in Columns (2) and (4), telemedicine enhances urban patients' access to follow-up care via both online and offline channels. For urban patients, travel constraints may relate to time, parking, and other opportunity costs. Telemedicine offers them a convenient channel to access care during breaks in the office or at home. Moreover, as discussed in Hypothesis Development, timely tele-follow-up appointments enable physicians to detect early signals of changes in patients' conditions and thus create more opportunities for them to get onsite follow-up check-ups. Because urban patients are relatively less sensitive to the cost of traveling to the hospital, they are flexible about going for onsite check-ups when necessary.

6.2. Heterogeneity by Comorbid Conditions

Besides the transportation cost, patients might face other costs in accessing the follow-up service, such as time constraints and mobility issues associated with one's health conditions. Following a similar rationale regarding the demand elasticity to the transportation cost, the tele-follow-up service is expected to result in a larger demand shift for patients with comorbid conditions because of their higher intensity of follow-up needs. To empirically test this idea, we distinguish patients by the presence of comorbid conditions. Our rationale is that patients with comorbidities (CCI > 0) are more likely to need routine follow-up care. Thus, convenient access to follow-up service is critical for them in deciding where to seek initial care.

Panel B of Table 2 reports the results. For patients with chronic diseases (i.e., CCI > 0), their demand for follow-up and initial care increases significantly (Columns 1 and 5). The results thus support that the convenient tele-follow-up service attracts chronic patients who are in need of follow-up service to the hospital for initial care. The volume of onsite follow-up appointments by chronic patients also increases, probably because timely follow-up via telemedicine creates more opportunities for patients to get onsite examinations. In contrast, for patients without any comorbidities (i.e., CCI $= 0$), although they also use telemedicine for better follow-up care (Column 2), their onsite visit patterns remain unchanged (Columns 4 and 6). Because these patients are less impacted by chronic conditions, they might perceive a lower risk of missing follow-up appointments. Consequently, they are likely to skip the onsite service, which is often associated with transportation costs and long wait time. As a

result, patients without comorbidities are now willing to use telemedicine for follow-up care, yet they are still reluctant to use the onsite services. In sum, the findings from Table 2 provide supporting evidence for Hypothesis 4.

6.3. Effect on Care Quality

The literature shows that increased workload and speedup of service can lead to lower quality of care (Aiken et al., 2002; Oliva & Sterman, 2001). In our research context, the increased patient volume following telemedicine adoption may compromise the service quality if physicians speed up their service for a higher patient throughput yet spend less time taking care of patients per encounter. To check if this is the case, we examine the changes in readmission rate, a key measure of care quality in the literature (Lu & Lu, 2018; Senot et al., 2016; Zhang et al., 2016). To capture the all-cause readmission, we further collect all visits to the inpatient unit and ER. Leveraging individual patient records, we track patients' visits over time and generate a 7-, 14-, and 30-day readmission indicator that equals one if a patient was readmitted to the hospital as an inpatient or ER patient within 7/14/30 days following a discharge (and zero otherwise). This readmission measure captures all-cause readmission, including readmission through emergency care, ambulatory care, or direct admissions to the inpatient department. Table 3 reports the results. We observe a significant reduction in patients' readmission rates for all time windows, suggesting that the use of tele-follow-up service does not harm patient health.

The positive effect is feasible in our setting for two reasons. First, timely follow-up helps detect any early signals in patient health conditions, thus reducing the risk of hospital readmission (Brooke et al., 2014; Jackson et al., 2015). Second, physicians are able to speed up their services through improved workflow enabled by more focused operations rather than by squeezing the time needed to take care of patients. Our finding is also consistent with those of the healthcare literature demonstrating a positive association between patient volume and care outcome (Halm et al., 2002; Kizer, 2003).

7. Conclusion

Telemedicine is transforming the very nature of healthcare delivery, and increasing numbers of healthcare providers are making virtual visits available to their patients. According to the National Center for Health Statistics, between June 2020 and June 2021, over 30% of patients were offered telemedicine

Table 3: Effect of Tele-follow-up on Care Quality

DV: Readmission Rate	7-day (1)	14-day (2)	30-day (3)
PatTeleAdoption	-0.012**	-0.012**	-0.014**
	(0.005)	(0.005)	(0.006)
Patient, Department, Time FE	Y	Y	Y
Patient Controls	Y	Y	Y
Observations	371,018	371,018	371,018
R^2	0.0018	0.0017	0.0018

Notes. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. This table reports the DID estimates using the individual-department-episode level data. Therefore, the number of observations is much larger than the department-week level analysis. The dependent variables are the average 7-day, 14-day, and 30-day readmission rates by individual, department, and episode of care. We define the treatment status at the individual patient level. Standard errors in parentheses are clustered by department.

access by their providers (CDC, 2022). In this paper, we collect a unique dataset with visit-level information to evaluate the adoption of telemedicine in one important area of health care—that is, follow-up appointments for outpatients—and how this adoption affects overall outpatient care provision. The empirical results reveal that the availability of tele-follow-up not only significantly improves patients' access to follow-up care through the virtual channel but also generates positive spillover effects to onsite care provision.

On the academic front, this paper adds to the nascent literature on healthcare IT. While previous literature has highlighted how health IT applications can improve hospital operations in various settings, our paper further documents the telemedicine application to follow-up care. While there is no doubt about the value of telemedicine, practitioners often believe that telemedicine is only applicable to a few contexts (Krall, 2021; Rosner, 2021). Our paper demonstrates that tele-follow-up can be an integral part of the care process in improving patient health beyond the virtual channel and the follow-up service itself. Moreover, the heterogeneity analysis suggests that rural patients or patients with chronic conditions can benefit from tele-follow-up adoption, which contributes to the research aiming to address the disparity in healthcare access among the disadvantaged population.

Our study provides guidance for hospitals moving toward the era of adopting health IT for the provision of better care. Although follow-up care after an initial visit has long been recognized as an essential part of the care process, many patients lack access for reasons such as mobility or transportation barriers. Our results demonstrate the great potential of health IT initiatives in improving patient access to care (follow-up and initial visits) and physician productivity. Since timely follow-up care prevents a decline in a patient's health and reduces hospital readmission rates, tele-follow-up

adoption also carries long-term financial benefits for the healthcare system. To reap the full potential of telemedicine for outpatient care, our results suggest the following tactics in practice. First, hospitals should designate specific time slots for tele-follow-up care, as task specialization and focus on a single type of service can help improve physicians' service efficiency. Second, hospitals should consider adjusting physicians' schedules to cope with the increasing demand for initial and follow-up services, given that tele-follow-up services are likely to attract more patients through both online and offline appointments.

Our study also provides important implications for policymakers striving to improve care access and output quality, especially for the disadvantaged population. Our study can inform policymaking by demonstrating that the tele-follow-up service not only promotes access to follow-up care for all patients but also addresses the unmet demand of rural patients for onsite initial diagnostic services. More importantly, better access to follow-up care enabled by telemedicine further enhances patient health, as evidenced by a significant reduction in readmission rates. Therefore, along with other benefits of telemedicine (such as monitoring health indicators and improving medication adherence), wider adoption of the tele-follow-up service may ultimately lead to improved population health and reduced healthcare costs.

Our paper has several limitations that are worth noting and could motivate future work. First, the analysis is based on the context of pediatric care. Although the identified effects and mechanisms are not specific to pediatric care, future work may extend the setting to general care provisions. Second, we measure care quality using readmission rates. Future research could examine other dimensions of patient health outcomes, such as patient satisfaction following telemedicine visits. Third, apart from the analysis of the access and quality perspectives, it would also be interesting to explore the impact of telemedicine on patient no-show rates, medication adherence post-discharge, and the long-term financial impacts.

References

AHRQ. (2022). Health literacy universal precautions Toolkit, 2nd Edition. [https://www.ahrq.gov/health-literacy/improve/precautions/tool6.html (accessed December 30, 2022).].

Aiken, L. H., Clarke, S. P., Sloane, D. M., Sochalski, J., & Silber, J. H. (2002). Hospital nurse staffing and patient mortality, nurse burnout, and job dissatisfaction. *Journal of the American Medical Association*, *288*(16), 1987–1993.

Amednews. (2013). *Medical liability: Missed follow-ups a potent trigger of lawsuits* [https://amednews.com/article/20130715/profession/130719980/2 (accessed December 30, 2022).].

Angrist, J. D., & Pischke, J.-S. (2009). *Mostly Harmless Eonometrics: An Empiricist's Companion*. Princeton university press.

Bavafa, H., Hitt, L. M., & Terwiesch, C. (2018). The impact of E-visits on visit frequencies and patient health: Evidence from primary care. *Management Science*, *64*(12), 5461–5480.

Bavafa, H., Savin, S., & Terwiesch, C. (2021). Customizing primary care delivery using E-visits. *Production and Operations Management*, *30*(11), 4306–4327.

Brooke, B. S., Stone, D. H., Cronenwett, J. L., Nolan, B., DeMartino, R. R., MacKenzie, T. A., Goodman, D. C., & Goodney, P. P. (2014). Early primary care provider follow-up and readmission after high-risk surgery. *JAMA Surgery*, *149*(8), 821–828.

Çakıcı, Ö. E., & Mills, A. F. (2021). On the role of teletriage in healthcare demand management. *Manufacturing & Service Operations Management*, *23*(6), 1483–1504.

CDC. (2022). *Telemedicine access and use* [https://www.cdc.gov/nchs/covid19/rands/telemedicine.htm (accessed December 30, 2022).].

Clark, J. R., & Huckman, R. S. (2012). Broadening focus: Spillovers, complementarities, and specialization in the hospital industry. *Management Science*, *58*(4), 708–722.

Ekeland, A. G., Bowes, A., & Flottorp, S. (2010). Effectiveness of telemedicine: A systematic review of reviews. *International Journal of Medical Informatics*, *79*(11), 736–771.

Faruque, L. I., Wiebe, N., Ehteshami-Afshar, A., Liu, Y., Dianati-Maleki, N., Hemmelgarn, B. R., Manns, B. J., & Tonelli, M. (2017). Effect of telemedicine on glycated hemoglobin in diabetes: A systematic review and meta-analysis of randomized trials. *Canadian Medical Association Journal*, *189*(9), E341–E364.

Fischer, M. A., Stedman, M. R., Lii, J., Vogeli, C., Shrank, W. H., Brookhart, M. A., & Weissman, J. S. (2010). Primary medication non-adherence: Analysis of 195,930 electronic

prescriptions. *Journal of General Internal Medicine*, *25*(4), 284–290.

Halm, E. A., Lee, C., & Chassin, M. R. (2002). Is volume related to outcome in health care? A systematic review and methodologic critique of the literature. *Annals of Internal Medicine*, *137*(6), 511–520.

Heath, S. (2016). How health IT helps follow-up care, chronic disease management. [https://patientengagementhit.com/news/how-health-it-helps-follow-up-care-chronic-disease-management (accessed December 30, 2022).].

Ibanez, M. R., Clark, J. R., Huckman, R. S., & Staats, B. R. (2018). Discretionary task ordering: Queue management in radiological services. *Management Science*, *64*(9), 4389–4407.

Jackson, C., Shahsahebi, M., Wedlake, T., & DuBard, C. A. (2015). Timeliness of outpatient follow-up: An evidence-based approach for planning after hospital discharge. *The Annals of Family Medicine*, *13*(2), 115–122.

Kc, D. S., Scholtes, S., & Terwiesch, C. (2020). Empirical research in healthcare operations: Past research, present understanding, and future opportunities. *Manufacturing & Service Operations Management*, *22*(1), 73–83.

Kc, D. S., & Terwiesch, C. (2011). The effects of focus on performance: Evidence from California hospitals. *Management Science*, *57*(11), 1897–1912.

Kizer, K. W. (2003). The volume–outcome conundrum. *New England Journal of Medicine*, *349*(22), 2159–2161.

Krall, A. (2021). Wisconsin telemedicine improves care for some patients but not all. [https://www.wbay.com/2021/08/15/wisconsin-telemedicine-improves-care-some-patients-not-all (accessed December 30, 2022).].

Landro, L. (2021). *What Covid-19 taught us about telemedicine* [https://www.wsj.com/articles/what-covid-19-taught-us-about-telemedicine-11616932803 (accessed December 30, 2022).].

Lindquist, L. A., Go, L., Fleisher, J., Jain, N., Friesema, E., & Baker, D. W. (2012). Relationship of health literacy to intentional and unintentional non-adherence of hospital discharge medications. *Journal of General Internal Medicine*, *27*(2), 173–178.

Lu, L. X., & Lu, S. F. (2018). Distance, quality, or relationship? Interhospital transfer of heart attack patients. *Production and Operations Management*, *27*(12), 2251–2269.

Medicaid. (2022). Telemedicine. [https://www.medicaid.gov/medicaid/benefits/telemedicine/index.html (accessed December 30, 2022).].

Misky, G. J., Wald, H. L., & Coleman, E. A. (2010). Post-hospitalization transitions: Examining the effects of timing of primary care provider follow-up. *Journal of Hospital Medicine*, *5*(7), 392–397.

Narayanan, S., Balasubramanian, S., & Swaminathan, J. M. (2009). A matter of balance: Specialization, task variety, and individual learning in a software maintenance environment. *Management Science*, *55*(11), 1861–1876.

Oliva, R., & Sterman, J. D. (2001). Cutting corners and working overtime: Quality erosion in the service industry. *Management Science*, *47*(7), 894–914.

Rajan, B., Tezcan, T., & Seidmann, A. (2019). Service systems with heterogeneous customers: Investigating the effect of telemedicine on chronic care. *Management Science*, *65*(3), 1236–1267.

Reider-Demer, M., Raja, P., Martin, N., Schwinger, M., & Babayan, D. (2018). Prospective and retrospective study of videoconference telemedicine follow-up after elective neurosurgery: Results of a pilot program. *Neurosurgical Review*, *41*(2), 497–501.

RHIhub. (2022). Healthcare access in rural communities. [https://www.ruralhealthinfo.org/topics/healthcare-access (accessed December 30, 2022).].

Rosner, C. (2021). Telemedicine a blessing for some, inaccessible for others. [http://c-hit.org/2021/06/07/telemedicine-a-blessing-for-some-inaccessible-for-others (accessed December 30, 2022).].

Senot, C., Chandrasekaran, A., Ward, P. T., Tucker, A. L., & Moffatt-Bruce, S. D. (2016). The impact of combining conformance and experiential quality on hospitals' readmissions and cost performance. *Management Science*, *62*(3), 829–848.

Sun, S., Lu, S. F., & Rui, H. (2020). Does telemedicine reduce emergency room congestion? Evidence from New York state. *Information Systems Research*, *31*(3), 972–986.

Zhang, D. J., Gurvich, I., Van Mieghem, J. A., Park, E., Young, R. S., & Williams, M. V. (2016). Hospital readmissions reduction program: An economic and operational analysis. *Management Science*, *62*(11), 3351–3371.