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Systems Approach in Telemedicine Adoption During and After COVID-19: Roles, Factors, and Challenges

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ABSTRACT Telemedicine applications have received increasing attention with significant effects on the traditional mechanism of health care services, especially during the COVID-19 pandemic. This article investigates the values and barriers influencing the adoption and acceptance of telemedicine services during COVID-19 by a systems approach combined with a quantitative analysis. We developed a casual loop diagram showing the interactions between the factors, including technology, policymaking, patient, and care provider in the context of COVID-19. The feedback loops were thematically synthesized from the literature to demonstrate the attitude of adopting telemedicine services while considering the connections and causality of different factors. To further quantify how COVID-19 impacted the adoption of telemedicine, a National Electronic Health Record Survey 021 was utilized to test the usage, barrier, and trend of telemedicine. The results indicate that factors including ease of use, utilization, available tools, facilitating conditions, technology access, and quality of care influence the adoption and acceptance of telemedicine. The results also suggest that the challenges and opportunities associated with telemedicine adoption and use should be explored holistically from multiple perspectives and shed light on various stakeholders at different levels.

INDEX TERMS COVID-19, health services accessibility, regression analysis, systems theory, telemedicine.

I. INTRODUCTION

A. TELEMEDICINE IN THE COVID-19 PANDEMIC

With the outbreak of the COVID-19 epidemic, the demand for telemedicine has experienced a surge since March 2020 as a part of digital transformations in the healthcare system [1]. Telemedicine represents any medical activity involving telecommunication technologies with data transformation and communication, such as audio, video, web videoconference, etc. [2]. These tools enable care providers to offer consultation and monitoring to geographically remote patients and support the whole healthcare system by facilitating the wide dissemination of information, virtual meeting, and service delivery, including patients visit via digital platforms and telecommunications technologies over the pandemic [3].

COVID-19 exposed the vulnerability and fragility of the healthcare system, even the whole societal system, confronting this major disturbance [4]. The surge in the number of patients has placed a serious burden on the healthcare system, resulting in a shortage of supplies, hospital beds, medical equipment, and medical staff [5]. To slow and stop the spread of the virus, the main nonpharmaceutical interventions adopted in various countries and territories revolve around reducing the face-to-face contact rate and avoiding group gatherings, such as practicing social distancing and segregation policies. The utilization of digital health technologies can prevent cross-contamination of patients in hospitals as much as possible, thus reducing the pressure and avoiding overwhelming the capacity of the healthcare system to treat seriously ill patients. Moreover, the maturity and sophistication of information and communication technologies have substantially improved the efficiency and effectiveness of overall healthcare delivery [6].

Telemedicine-related technologies have been further adapted to avoid patients needing to visit the care providers physically but still receive virtualized treatment, tests, and medical opinions remotely. The epidemic provided an

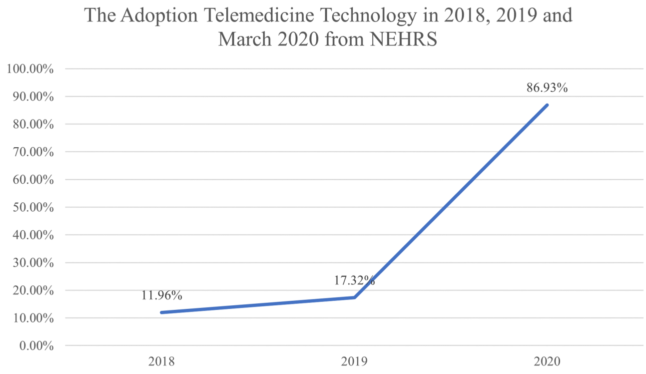

FIGURE 1. Trend in telemedicine use during 2018 and 2019, and March 2020 from NEHRS.

opportunity for the widespread use of telemedicine, which is driving the shift from traditional medical models to online/virtual care. The application of telemedicine relies on the coordination and interaction between technology, physicians, platforms, policymakers, and patients. According to 2018, 2019, and 2021 National Electronic Health Records Survey (NEHRS), telemedicine use surged to 86% after March 2020 compared to 12% in 2018 and 17% in 2019 [7], [8], [9]. Most outpatient and office-based care providers have quickly embraced telemedicine solutions as an alternative to in-person consultations. Fig. 1 displays the rapid increase of telemedicine during the pandemic era, showing that the utilization of telemedicine gradually increased from 2018 to 2019 but had a peak after Mar 2020, which is in line with the timing of the outbreak of COVID-19 in the United States.

The pandemic resulted in a paradigm shift in healthcare practice pushing the significant utilization rate of information technologies, including telemedicine. However, it might be short-sighted to assume that the widespread application of telemedicine technology would only be restricted in addressing the current crisis and overlook the long-term development [10]. Due to getting experience and lessons learned from the COVID-19 pandemic and the advantage of established cyber-physical infrastructures systems, this crisis can be identified as a potential opportunity for integrating telemedicine into the overall usual care process [11]. Furthermore, these experiences also provided knowledge and initial data to develop telemedicine technologies implementation in various healthcare settings considering the cooperation and interaction of care providers, technology transformation, policymakers, health systems, patients, and families, in society for long-term thinking.

B. OVERVIEW AND OBJECTIVE

To better understand the application trends of telemedicine in the current and postpandemic era, we conducted a two-phase study with a combination of qualitative and quantitative methods. There is a lack of publications examining the adoption process for telemedicine services in outpatient clinics influenced by certain variables and systems in the COVID-19 and post-COVID-19 period [1], [2]. In the first phase, we identify the different factors and systems that obstruct or contribute to the adoption of telemedicine, followed by a holistic analysis using a systems approach. Consequently, one purpose of this article is to analyze the application of telemedicine during the COVID-19 using a systems thinking approach. We aim to generate a comprehensive picture of the causal relationships between different factors and systems to uncover the dynamics of these relationships and interactions to expand on the existing literature on telemedicine. We employed a qualitative system dynamic model to investigate interactions among policymakers, technologies, patients, and care providers in COVID-19. In the second phase, this study utilizes nationwide public survey data from NEHRS (2021) to establish a binary logistic regression model to understand how telemedicine is used nationwide during the COVID-19 pandemic, recognizing the current status, barriers, challenges, and prospects. Our study covers regulatory, technological, governing, and healthcare domains. Findings from this study would assist stakeholders involved in the adoption of telemedicine to see the big picture of the current and future situation, serving as a foundation to be used in the potential expanded implementation.

C. RESEARCH QUESTIONS

This study addresses four research questions. The first two questions aim to identify the overall factors and interrelationships affecting the use of telemedicine, and explore the opportunities and challenges associated with telemedicine. To achieve this, we employ a systems thinking approach based on the published literature and analyze the usage, quality, satisfaction, and difficulty to use from multiple perspectives. The third question focuses on the empirical factors that could accelerate or impede the adoption of telemedicine during COVID-19 and its future trend. This is based on a nationwide survey of healthcare providers, and we consider factors such as technology, policy, and facilitation conditions. The fourth question examines the associations between physicians' current assessment of telemedicine and their perceived intention for future use of telemedicine after the pandemic. By using current satisfaction and quality achieved, we aim to reflect the future usage intention of telemedicine compared to conventional office visits. These questions provide insights into the adoption and use of telemedicine technology during and beyond the COVID-19 pandemic.

RQ1: What are the overall factors that may impact the use of telemedicine during the COVID-19 pandemic? And what challenges should be addressed to maintain the growth momentum?

RQ2: How the subsystems or factors affecting the use of telemedicine are interrelated and interacted in the context of the COVID-19 pandemic?

RQ3: What empirical factors would accelerate or impede the adoption of telemedicine during COVID-19 and its future trend in outpatient care?

RQ4: What are the associations between physicians' current assessment of telemedicine and their perceived intention to use in the future.

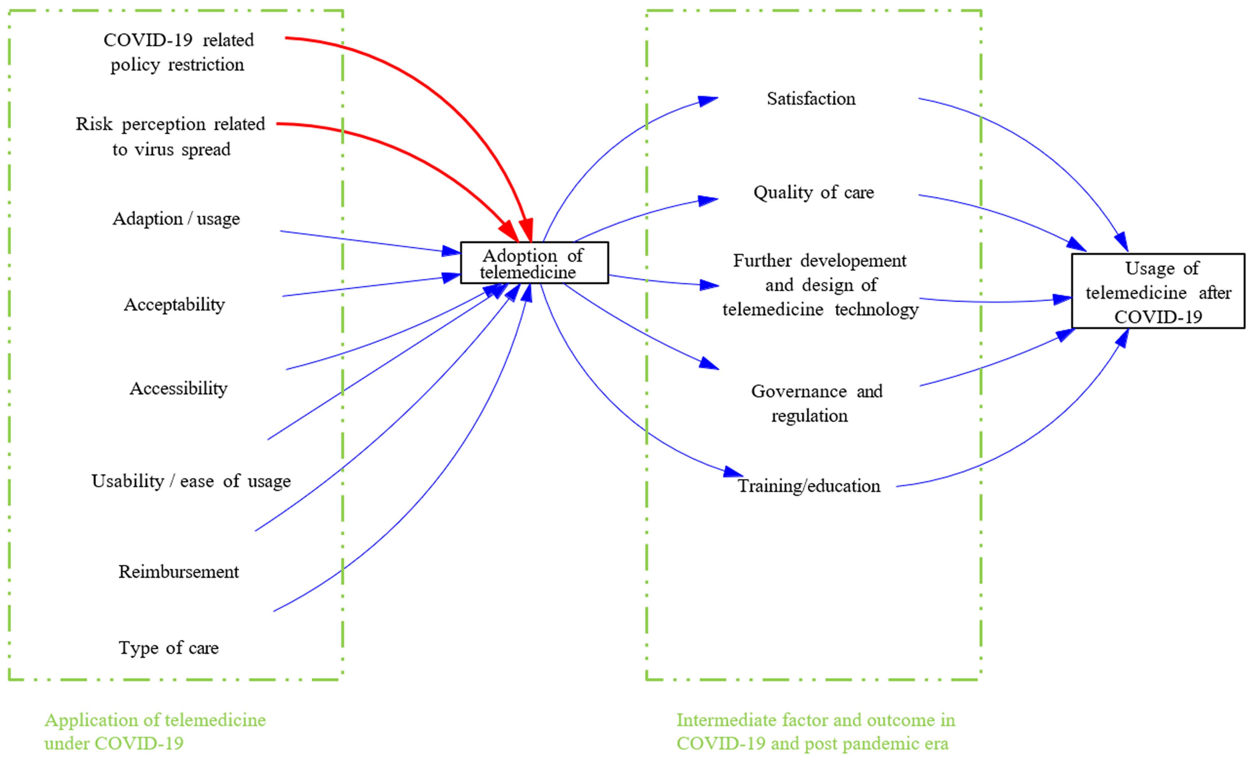

FIGURE 2. **Illustration of factors related to telemedicine adoption in COVID-19 and post-COVID-19 era.**

II. BIG PICTURE FROM SYSTEMS THINKING PERSPECTIVE

The pandemic has created unprecedented opportunities for telemedicine development. The challenge can be turned into an opportunity for healthcare researchers, technology providers, and policymakers to derive benefits from the crisis and build a better resilient system for the future [4]. Therefore, in this section, we carried out a system thinking approach to delineate the causal relationships of the factors that affect the adoption of telemedicine during and after the COVID-19 era (RQ1 and RQ2). We also identified the interactions with feedback loops among factors to describe the current telehealth implementation situations by highlighting the concerns and challenges.

A. METHODS FOR THE QUALITATIVE SECTION

This section is a qualitative analysis based on a systems thinking approach. The research setting includes a thematic synthesis of the literature related to the adoption and acceptance of telemedicine services during COVID-19. A causal loop diagram (CLD) is developed to depict the interrelationships and interactions between factors affecting the adoption and acceptance of telemedicine services during COVID-19 with addressing future challenges. The findings are synthesized thematically using the CLD developed in this phase.

B. SHIFTING THE CRISIS TO OPPORTUNITY

The systems approach provides a language suitable for tackling the complexities and interactions looking beyond a single factor and system and addressing the causalities and interconnections between paired factors and factors within the whole system [11], [12]. Systems thinking involves analyzing the relationships and feedback loops between various elements within a complex system, and understanding how changes in one element can impact the entire system [13]. By using a systems thinking approach, we were able to identify the various factors that impact the adoption and acceptance of telemedicine services, and how they are interconnected. After analyzing the current adoption situation of telemedicine from the literature, we developed a basic CLD with input, intermediate, and output. We also identified a list of potentially important factors associated with the different phases of the COVID-19 pandemic (see Fig. 2). CLD can uncover the casual relationships connecting by arrows and leverage points to describe the systems' shaping forces and overall structure [11]. After years of slow growth, the use of telemedicine has become widely available nationwide in a short time because of COVID-19. Implementation of telemedicine is a complex process, where multiple stakeholders are all accelerating or decelerating the process facing the systemic crisis at that particular time [14]. The two red arrows in Fig. 2 demonstrate that both policy restrictions on mobility and increased perceptions of risk from physicians/patients have contributed to the implementation of telemedicine. Moreover, the review process and regulation rules linked to the implementation of telemedicine have been simplified to reduce the furthermore risk of exposure to the novel coronavirus for both patients and care providers and potentially avoid overburdening and

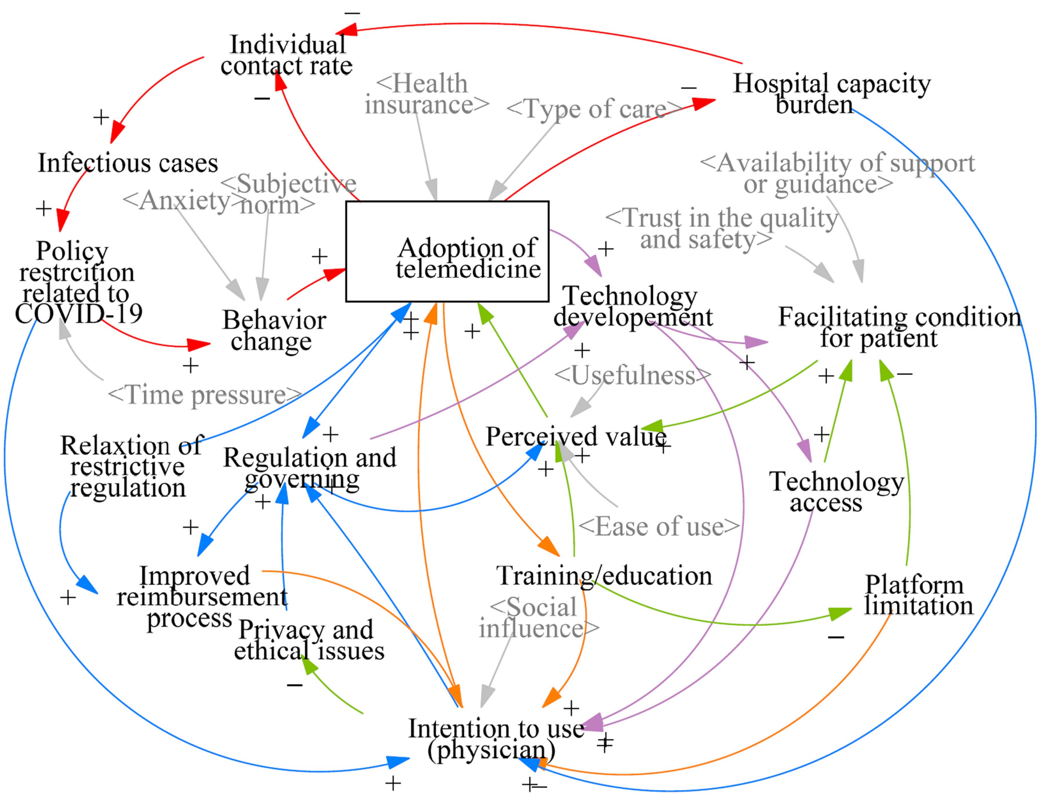

FIGURE 3. **Multiple loops and interactions in adopting telemedicine technology.**

overwhelming the healthcare system. Since human behavior and policymaking inherently [12] affect each other, people may choose telemedicine to protect themselves and save transportation time and cost. Besides, rapidly evolving technology provides a solid foundation to allow both patients and physicians to access the service [15].

The current telemedicine system is not still at the desired level [10]. In addition, there are various needs of stakeholders, including primary care, inpatient care, and specialties such as cancer and pediatrics, which makes it still critical to identify the unique needs of these care practices to reflect in the future redesign of telemedicine systems. These redesign activities will require interdisciplinary involvement and input to ensure that regulatory and policy gains are not withdrawn. The technological development would be compatible with patient and physician considerations to enhance the interactions among physicians, patients and technology, where the quality of care using telemedicine would be consistent with in-person care [16]. The stakeholders should clarify that the best approach and inappropriate usage to address telemedicine redesigning efforts is one of the priorities for the healthcare system's future, not just a flash in this crisis.

C. IDENTIFY THE INTERACTIONS AND FEEDBACK LOOPS IN ADOPTING TELEMEDICINE

CLD is a modeling approach widely used to reveal the interactions between systems and factors, and cascade the causality in complex systems, which is characterized by interdependency, interaction, and feedback loops [11]. The CLD helped us to identify the different feedback loops and themes associated with the adoption and acceptance of telemedicine, and how they were interconnected. The CLD also allowed us to identify potential unintended consequences of telemedicine adoption, which may have been overlooked using a traditional linear approach at system-wide. To determine the relationship between factors and systems that impact the adoption of telemedicine, a more comprehensive causal loop diagram was developed from five general perspectives: COVID-19 pandemic, policymaking, patient, healthcare provider and technology shown in Fig. 3. Factors and elements for the CLD were collected through the existing literature for available qualitative and quantitative analysis related to telemedicine services, policy documents, and other relevant studies in the context of the COVID-19 shown in Table 1 with a description of different issues labeled by colors. In the developed CLD, feedback loops are depicted, which are mainly focusing on the interaction and interrelationship of the factors and systems that may impact the implementation of telemedicine.

From the technological aspect, the lack of readily available infrastructure is an ever-present issue. Telemedicine cannot be effective without technological support and the availability of certain internet quality [2]. Limited internet access or speed issues will reduce the feasibility and motivation for the universal use of telemedicine. Besides, the novelty of the telemedicine platform may create potential uncertainty

TABLE 1. Descriptions of Causal Links and the Resources

Arrow colors in the CLD	Description	Sources
Red	The outbreak of COVID-19 makes telemedicine a critical role in emergency response and crisis management, interacting with different levels of subsystems and factors not only in the healthcare system but in the whole society.	[5], [13], [19], [20], [21]
Blue	Policymaking based on a systems approach would model potential change for both patients and physicians with different degrees of regulation and governing adjustment in accordance with the severity of COVID-19.	[4], [10], [22], [23]
Orange	Physicians' attitudes directly impact telemedicine use, so it is crucial to explore the perceived barriers and benefits that may interact with other factors and subsystems to see the big picture.	[13], [16], [24], [25]
Green	Patients, as end users and participants, are influenced by a variety of factors in behavior change, contributing to the complexity of managing the COVID-19 pandemic and the adoption of telemedicine.	[14], [23], [26], [27]
Purple	Integrating advanced technology into telemedicine creates the opportunity for current practice but also breeds a host of problems and risks that could be discussed from a broader range of interactions and interconnections among factors and subsystems.	[1], [3], [12], [19]

and difficulty for patients to use the platform without proper training, which may also lead to a lack of understanding of the new technology and thus diminish motivation and trust in adoption [17]. In addition, the regulation and standardization of the technology is also an issue that cannot be ignored in developing effective telemedicine systems [18].

For both patients and physicians, the issue of privacy and ethical concern always exists, which may influence telemedicine usage as well as the perception of its value [28]. Moreover, existing policies prior to the COVID-19 did not support telemedicine integration suffering both regulation and coverage/reimbursement problems [29]. However, the pandemic turned the tide. For example, the Centers for Medicare and Medicaid Services issued a waiver on March 17, 2020, and expanded telemedicine coverage for all Medicare patients during the COVID-19 pandemic, thus eliminating some of the current barriers [30]. During the COVID-19 era, a series of relaxed policies were introduced to promote the development of telemedicine, including streamlined reimbursement, providing online training, lifting licensing restrictions, and shorter review time [5], [10]. Accordingly, the Health Insurance Portability and Accountability Act (HIPAA) Security Requirement of the US Department of Health has indicated that there will be no penalties for providing telemedicine during the COVID-19 crisis without complying with HIPAA regulations and allow care providers to use digital tools such as Zoom, FaceTime, Skype, Google, and other digital tools to communicate with patients remotely [27]. Nevertheless, in the postepidemic era, privacy and ethical concerns should be given extra attention to maintain the positive development of telemedicine systems.

Besides, for physicians, a comprehensive platform should be established to increase their motivation to use telemedicine, which can potentially relieve pressure on the healthcare systems [31]. In order to improve communication efficiency and telemedicine utilization, training and education from both health providers and patients sides should be conducted to perceive the convenience and value of using telemedicine for themselves [32]. For patients, telemedicine can potentially reduce the risk of virus exposure in hospitals and clinics. Furthermore, the ease of use of telemedicine platforms and the overall quality of care heavily influence patients' acceptability and behavior [23]. Patients' perceptions will, in turn, influence the development of telemedicine and related technologies. At the same time, the governance system cascades all the factors related to the adoption of telemedicine and intertwines with the development of telemedicine to form a complex system. For example, relaxed rules may promote physicians' intention to use telemedicine and thus facilitate the regulatory process and alleviate patient concerns about privacy and abuse. Complementing training and education policies may also increase the perceived value of telemedicine usage, thus creating positive feedback loops to enhance the use of telemedicine.

III. UTILIZATION OF TELEMEDICINE DURING COVID-19 NATIONWIDE

To gain more insight into the specific application and implementation status of telemedicine during COVID-19 and illuminate future development trends, a nationwide public survey designed for physicians was employed to explore RQ3 and RQ4 for phase two analysis in this section.

A. METHODS FOR THE QUANTITATIVE SECTION

In the second phase, we conducted a quantitative analysis using survey data from NEHRS 2021 to identify the empirical factors that accelerate or impede the adoption of telemedicine services during COVID-19 and its future trend in the healthcare system.

B. STUDY SETTING

We conducted a quantitative study based on the 2021 NEHRS to further investigate factors that may impact utilization and adoption of telemedicine.

This nationwide public survey was sponsored by the Office of the National Coordinator for Health Information Technology, and conducted by the Division of Health Care Statistics, National Center for Health Statistics (NCHS). By targeting office-based physicians on their use of the electronic health record (EHR) system, NEHRS was designed to assist a policy goal of the Health Information Technology for Economic and Clinical Health Act (HITECH Act) [9], [33]. The survey was fielded from March 18, 2021 to July 26, 2021 and a total of 1875 providers (out of 10 302) completed questionnaires nationwide. The complete data was released by NCHS on May 6, 2022. The survey was completed by either electronic or mail submission method [34].

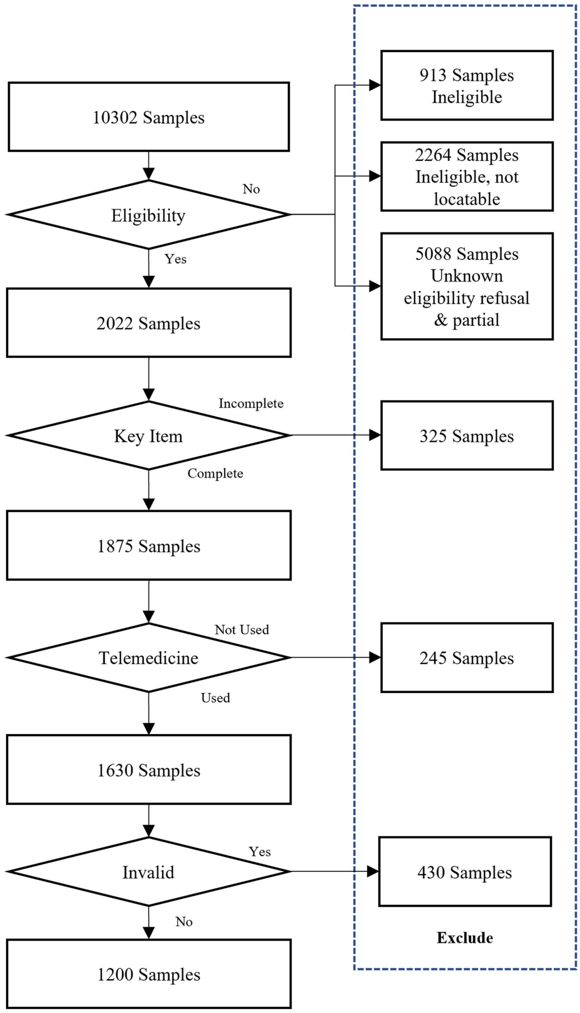

FIGURE 4. **Data filtering process.**

C. PARTICIPANTS

The original sample of 10 302 physicians was invited to answer eligibility questions to ensure they were eligible for the survey. Then, 913 physicians were ruled out for reasons such as retirement. Next, 2264 physicians were excluded because they were not locatable. And then, 5088 physicians were also excluded from the eligible sample because they either refused or partially completed the survey. Finally, 1875 physicians responded to all the key items and were selected for the final reporting by the NEHRS.

In our study, we were specifically interested in questions from the telemedicine section. The survey had one filtering question asking whether the physicians adopted telemedicine for patient care. After applying this filtering question, we had 1630 surveys remaining. Later eliminating missing and invalid data, this study used 1200 surveys for the final analysis. The data filtering process is shown in Fig. 4. The “telemedicine” section of the survey has seven questions, including Multiple-choice questions, Check-all-that-apply questions, Likert scale questions, and Polar questions [33]. These questions target the physicians’ usage of telemedicine technology, covering the following aspects: usage, tools/platform, barriers, quality concerns, satisfaction, and intention to use as shown in Table 2 as research setting. Question 1 is a demographic question that measures the size of the clinic. Question 2 shows the usage of telemedicine since the outbreak of COVID-19. Question 3 and 4 as categorical variables explore tools/platforms, and other variables (e.g., tech-related, policy-related issues) that may affect telemedicine usage. Question 5 and 6 are scale questions that assess the care providers’ consideration of quality of care and overall satisfaction during application. Question 7 as the output is coded as 0 or 1 (binary variable), where 1 indicates the willingness to continue using telemedicine after the pandemic is over and 0 represents the termination of telemedicine service after COVID-19.

D. DESCRIPTIVE STATISTICS

First, we ran descriptive analytics to show the overall distribution of the responses across all the questions (see Table 2). The analysis showed the current telemedicine use rate since March 2020, almost 50% of the participants used telemedicine in less than 25% of their visits, 28% of the participants used telemedicine in 25% to 50% of their visits, and 15% of participants used telemedicine in more than half of their visits. It is also interesting to see that only 30% of the participants used telemedicine integrated with their EHR systems. And 45% of physicians used a platform without EHR integration, meaning they had to process some of the clinical data manually. The findings also showed the common factors/issues to use telemedicine effectively from providers perspective. Two primary issues were related to patients’ access to technology (68%), and patients’ difficulties using the system (72%). In addition, physicians also experienced problems with network limitations (37%), as well as concerns about reimbursement and policy regulation. Furthermore, participants were asked to report the perceived quality of telemedicine visits compared to in-person visits. 30% of participants felt they could provide similar quality by using telemedicine; however, 23% felt the quality was not there as in-person visits. Finally, 62% of the participants were satisfied with the telemedicine systems they used, whereas 22% were not satisfied. The last question also showed that telemedicine would become the main component of the future healthcare system, as 83% of the participants stated that they would continue using telemedicine systems in the future.

E. RESULT

To further identify the factors that may impact the willingness to use telemedicine after COVID-19, we developed a binary logistic regression for the statistical analysis carried out by SPSS (Version 28). Variables used to build model are shown in Table 2 with a brief description to predict the impact of multiple aspects on intention to use telemedicine after COVID-19 pandemic (Yes or No) shown in Table 2. All statistical testing is two-tailed, with $p < 0.1$ designated as statistically significant.

TABLE 2. Practice Use Telemedicine Technology for Patient Visits

N		Variable name	Overall	Percentage
1	**How many physicians, including you, work at this practice (including physicians at the reporting location, and physicians at any other locations of the practice)?**	**PSIZECAT_P**	**Independent**	
	1 physician		190	15.833%
	2–3 physicians		203	16.917%
	4–10 physicians		399	33.250%
	11–50 physicians		240	20.000%
	More than 50 physicians		168	14.000%
2	**Since March 2020, what percentage of your patient visits were through telemedicine technology?**	**PERCENTAGE**	**Independent**	
	None		8	0.667%
	Less than 25%		666	55.500%
	25% to 49%		345	28.750%
	50% to 74%		105	8.750%
	75% or more		76	6.333%
3	**What type(s) of telemedicine tools did you use for patient visits? CHECK ALL THAT APPLY**	**TOOLS (1–5)**	**Independent**	
	Telephone audio		810	67.500%
	Videoconference software with audio (e.g., Zoom, Webex, FaceTime)		689	57.417%
	Telemedicine platform NOT integrated with EHR (e.g., Doxy.me)		544	45.333%
	Telemedicine platform integrated with EHR (e.g., update clinical documentation during telemedicine visit)		363	30.250%
	Other tools		25	2.083%
4	**What, if any, issues affected your use of telemedicine? CHECK ALL THAT APPLY.**	**ISSUES (1–6)**	**Independent**	
	Limited internet access and/or speed issues		443	36.917%
	Telemedicine platform not easy to use or did not meet our needs		227	18.917%
	Telemedicine isn't appropriate for my specialty/type of patients		303	25.250%
	Improved reimbursement and relaxation of rules related to use of telemedicine visits		594	49.500%
	Limitations in patients' access to technology (e.g., smartphone, computer, tablet, Internet)		816	68.000%
	Patients' difficulty using technology/telemedicine platform		871	72.583%
5	**To what extent are you able to provide similar quality of care during telemedicine visits as you do during in-person visits?**	**QUALITY**	**Independent**	
	Fully		44	3.667%
	To a great extent		331	27.583%
	To some extent		545	45.417%
	To a small extent		236	19.667%
	Not at all		44	3.667%
6	**Please rate your overall satisfaction with using telemedicine technology for patient visits?**	**SATISFACTION**	**Independent**	
	Very satisfied		233	19.417%
	Somewhat satisfied		517	43.083%
	Neither satisfied nor dissatisfied		190	15.833%
	Somewhat dissatisfied		184	15.333%
	Very dissatisfied		76	6.333%
7	**Do you plan to continue using telemedicine visits (in addition to in-person visits) when appropriate once the coronavirus disease (COVID-19) pandemic is over?**	**TELEMEDCONT**	**Dependent**	
	Yes		997	83.083%
	No		203	16.917%

Hosmer and Lemeshow Test (HL test) is a goodness of fit test for logistic regression that assesses the fitness of the data with the established model where the null hypothesis is the observed model fits well with the original data ($p > 0.05$ considered as a good fit of the model). In the observed logistic model, $p = 0.885 > 0.05$ with 89.1% correct classification of cases presented in Table 3, which demonstrates that the null hypothesis cannot be rejected, implicating the excellence and

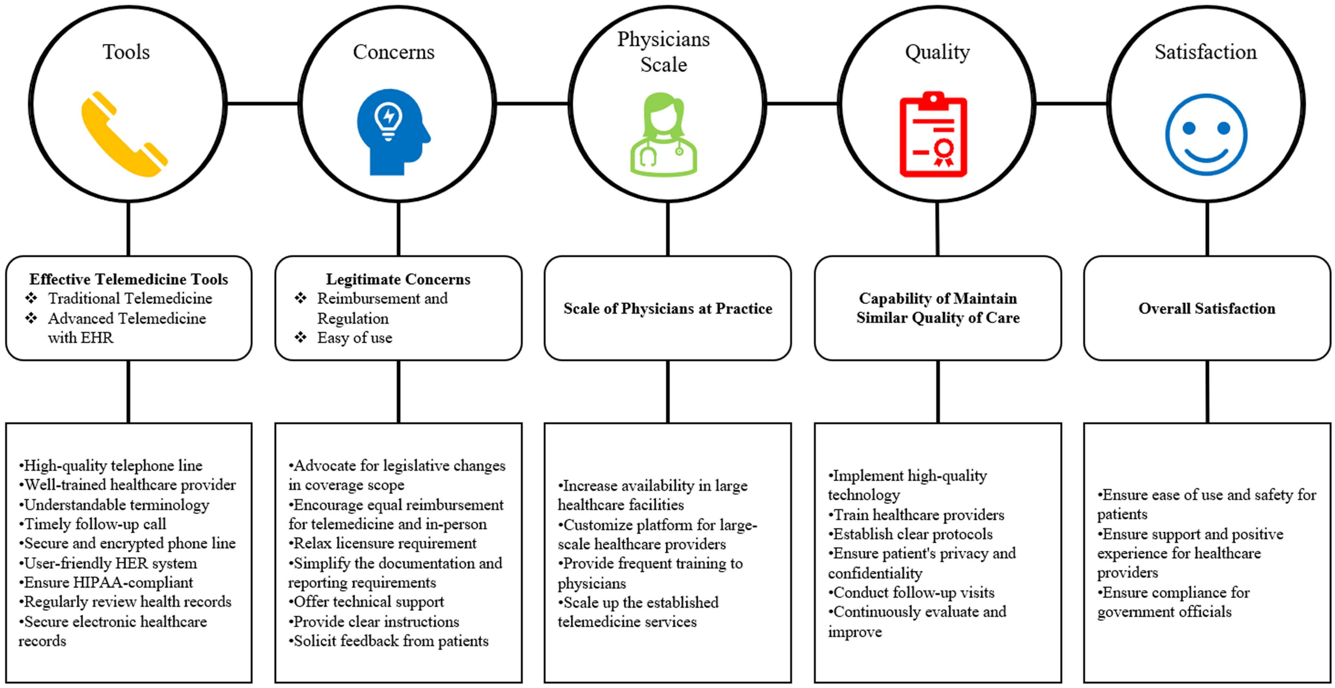

FIGURE 5. Visual summary of findings and recommendations.

TABLE 3. Hosmer and Lemeshow Test

Chi-square	Degree of freedom	Significance
3.683	8	0.885

reliability of the model. Table 4 shows the results of logistic regression with odds ratios (OR) and their confidence intervals (CI) regarding significant test results.

Seven variables are significantly associated with the intention of using telemedicine after COVID-19: the use of telephone audio ($p = 0.098 < 0.1$); the use of telemedicine platform integrated with EHR ($p = 0.098 < 0.1$); the improved of reimbursement and relaxation of rules ($p = 0.000 < 0.1$); the patients difficulty to use the technology($p = 0.087 < 0.1$); the similar quality of care during telemedicine as during in-person visits ($p = 0.000 < 0.1$); the overall satisfaction of use ($p = 0.000 < 0.1$) and size of the practice ($p = 0.017 < 0.1$) . Besides, limited internet access ($p = 0.141$) and the appropriation for the specialty ($p = 0.105$) also show slight significance to the usage of telemedicine after COVID-19.

IV. DISCUSSION

COVID-19 pandemic has dramatically impacted the mode of healthcare delivery, implying the relatively new treatment and communication method is becoming more widespread in a very short time. Telemedicine became one of the most popular substitutes for in-person care due to the mandatory mobility restrictions and the perceived risks to patients and physicians during the pandemic [20]. The unprecedented increase of telemedicine and the resulting concerns and challenges about regulation, safety, quality of care and effectiveness have attracted major attention from different stakeholders. This study utilized a systems thinking approach to indicate all the reported factors influencing the effective use of telemedicine in the healthcare system and also used a national database to identify the perception of providers in telemedicine use during and beyond the COVID-19 pandemic from a broader perspective. And then the quantitative factors that may impact the usage and adoption of telemedicine were identified by the survey-based study mainly focusing on physicians' perspective. Fig. 5 summarizes the key findings related to the factors that impact telemedicine adoption and usage with a brief discussion on how to promote the sustained adoption of telemedicine beyond the crisis. More specially, we classified the discussions in three main areas to address proposed three research questions: technology, policy, and care provider.

A. TECHNOLOGY

The increased usage of digital technology worldwide has become a key factor in the continued development of telemedicine. From the regression model, the result indicates that the selection of telemedicine tools also affects the usage of telemedicine. The doctors who use telephone audio (OR = 1.438, CI = 1.002–2.062) and telemedicine platforms integrated with EHR (OR = 2.038, CI = 1.289–3.222) were optimistic about the continued use of telemedicine tools. This may cause by the continued existence of telephone diagnosis in the early stages of medical treatment for a long history. In the meantime, the medical practice using the integrated platform, as an emerging technology, is continually improved based on the advanced technological platform, which to a

TABLE 4. Regression Result

Variable name	Coefficient	Standard Error	Wald Test	Significance	Odds Ratio	90% C.I. for EXP(B) Lower	90% C.I. for EXP(B) Upper
Telemedpct	0.234	0.164	2.046	0.153	1.264	0.965	1.655
Telemedtool1	0.363	0.219	2.741	0.098*	1.438	1.002	2.062
Telemedtool2	−0.076	0.227	0.112	0.737	0.927	0.638	1.346
Telemedtool3	−0.017	0.233	0.006	0.940	0.983	0.670	1.441
Telemedtool4	0.712	0.278	6.533	0.011*	2.038	1.289	3.222
Telemedtool5	−0.127	0.858	0.022	0.882	0.881	0.215	3.613
Telemedissues1	0.352	0.240	2.162	0.141	1.423	0.959	2.110
Telemedissues2	−0.088	0.264	0.110	0.740	0.916	0.593	1.414
Telemedissues3	−0.366	0.226	2.621	0.105	0.694	0.478	1.006
Telemedissues4	0.874	0.233	14.090	0.000*	2.397	1.634	3.516
Telemedissues5	−0.232	0.255	0.827	0.363	0.793	0.521	1.206
Telemedissues6	0.452	0.264	2.929	0.087*	1.572	1.018	2.427
Telemedqual	−0.906	0.180	25.263	0.000*	0.404	0.300	0.543
Telemedsat	−1.023	0.123	69.241	0.000*	0.360	0.294	0.440
Psizecat_P	0.205	0.085	5.739	0.017*	1.227	1.066	1.412
Constant	5.731	0.770	55.455	0.000*	308.224		

Note: "*" represents $p < 0.1$. The full questions and name for each variables is presented in Table II.

certain extent, can replace the traditional consultation model in medical treatment. Both tools mentioned above provide convenience to both patients and physicians, such as synchronizing patient consultation data by using the advanced platform. Our research results align with the technology acceptance model (TAM) emphasizing the importance of perceived usefulness and ease of use as crucial factors in determining physicians' attitudes and acceptance of telemedicine technology [23]. The ease of use of these tools, particularly in terms of their user interface and compatibility with existing workflows, can have a significant impact on healthcare providers' attitudes toward telemedicine adoption. Moreover, technology providers should consider the facilitating conditions in the continued usage of telemedicine technologies by healthcare providers. For example, healthcare providers may require technical support, training, and access to appropriate resources to effectively use telemedicine tools [25], [28].

When considering the barrier to telemedicine use, issues like internet access and/or speed on both sides of physicians and patients raise concerns. Even the society is moving into the industry 4.0 era, the imbalance between society and technology development still cannot be ignored (OR = 1.423, CI = 0.959–2.110). In addition, the difficulty for patients to use technology or telemedicine platforms and access to technology is a relatively significant barrier (OR = 1.572, CI = 1.018–2.427). Our study findings are consistent with the previous research [35], which highlights the persistence of inequalities and inequities in the distribution of healthcare resources from the patients' perspective of social economic disparities, despite the rapid growth of telemedicine applications. However, in our study, we mainly consider physicians' difficulty to use technology or telemedicine platform and their concern that patients may not have access to technology to maintain a high-quality care process, which still poses a significant barrier, further exacerbating the existing disparities. There are many chronic patients in the elderly population who needs ongoing care but are not familiar with the use of such technologies. The issue may need patients to adapt to telemedicine through continuous usage with relevant training and education. Simultaneously, technology providers should be aware of different usage scenarios and needs in system design to remove burdens for patients by developing the technology from the patient- and physician-centered orientation.

Besides, from a systems perspective, integrating telemedicine into the overall healthcare system increases system complexity, involving the interaction of multiple systems and interactions with patients and physicians in the complex cyber-physical infrastructure system. When considering the interrelationship within complex systems, factors such as function, integration, operation, security, technology management, assurance, certification, reliance on software, and usability should be addressed [36]. The integration of the telemedicine system requires the merging of the healthcare system with techniques, and a secure, reliable, and high-quality network connection is also required to improve the efficiency and effectiveness of the telemedicine system [26].

B. POLICYMAKING

Developing and using any technology including telemedicine requires regulation and supervision in healthcare. Followed by the widespread COVID-19, the urgently introduced policy related to telemedicine is involved accordingly, and different levels of governance systems have announced relaxing the limitation on the telemedicine rules process [27], [31] to promote its usage, which corresponds to the model result. One of the significant boosts to the adoption of telemedicine is improving reimbursement and relaxation of government rules (OR = 2.397, CI = 1.634–3.516). This finding is in line with the results of a previous study [20], which identified reimbursement policies as a critical factor affecting the future use and sustainability of telemedicine. However, whether the special exemption of telemedicine will continue during the postpandemic era might be physicians' concern about the future adoption of telemedicine [20]. Since it will be essential to have sufficient and sustainable coverage and convenient reimbursement policies in place, which can be considered as facilitating conditions to continually support the adoption of telemedicine. These policies can be seen as facilitating conditions, as highlighted in the TAM, corresponding to the previous study [23], which applied the TAM model to discuss the determinants of telemedicine usage under COVID-19. Furthermore, even if the policy of relaxation of telemedicine usage remains, the concern of ethical, privacy and data abuse will still exist [37].

Furthermore, maintaining patients' and physicians' interest in telemedicine after COVID-19 is also a forthcoming issue for policymakers and other stakeholders. Without continued beneficial policies and incentives, the scale of telemedicine use may stagnate with the end of the epidemic [37]. Policymakers urge to harness the potential of technology's digital capabilities to develop telemedicine technologies during and after pandemics [38]. Moreover, the quality of care directly determines if telemedicine will become a new normal rather than a temporary substitute for emergency situations. From the logistic regression model, it is obvious that whether telemedicine will maintain the same quality of care (OR = 0.404, CI = 0.300–0.543) compared to the in-person visit as well as the overall satisfaction (OR = 0.360, CI = 0.294–0.440) has a significant positive correlation with the intention of the future use of telemedicine. The outcomes of our study are parallel with the theory of planned behavior, specifically the construct of performance expectancy, which refers to the belief that using a particular technology will help physicians to perform tasks more effectively and efficiently to uphold the same level of care as compared to an in-person visit [13]. Policymakers should take this into account and focus on promoting telemedicine's potential to improve healthcare delivery and outcomes for both physicians and patients.

Governance system is central to regulate the utilization of telemedicine. In the increasingly connected healthcare system, the development of new technology and its adoption are deeply entwined within the governance system and healthcare system from the systems viewpoint. Recognizing the impact of adopting telemedicine during COVID-19 pandemic beyond the boundaries of the healthcare system itself [11] will help the policymakers find a clear path and make a quick decision toward regulation. The relaxation of regulatory and policies has facilitated physician adoption, thereby increasing physician interest in implementation. In the postepidemic era, improved and more transparent policies should be put in place to eliminate both physicians' and patients' concerns in the usage. Because it is not clear how much of the flourish in telemedicine is based on political demands (such as policy restrictions) and how much is based on empirical evidence (such as the perceived benefits of use without considering the epidemic element).

C. CARE PROVIDER/PHYSICIAN

In addition, physicians' willingness to accept telemedicine is also a critical integral part of the development. Physicians' acceptance of telemedicine highly depends on whether they perceive it to be effective, comfortable, safe and communicable [39]. Allocation of resources and political and regulatory support should ensure that physicians can provide similar service standards of care during telemedicine compared with in-person visits. Innovations in the digital era have led to physicians spending a longer time recording via the digital system. As telemedicine replaces large-scale in-person visits, interaction and communication between patients and physicians may be further compromised [2], [30]. Because there is no uniform integration or standardization of telemedicine platforms, where some platforms can only offer audio service while others can integrate medical documentation and record to better track patients' health. This also imposes an additional burden on the management of telemedicine and may indirectly aggravate the inequality in telemedicine.

Moreover, it is critical for physicians to integrate any new technology into their workflow efficiently [46]. Otherwise, it would slow down the adoption of that specific technology [25], [40]. Telemedicine might be complex and disruptive for some physicians, so it requires physicians to learn new methods as well as approaches [31], [41]. Therefore, necessary training and education are needed to lift the limitation of the platforms, while convenient usage models and user-friendly integration of the platforms would provide preliminarily technical support for telemedicine. In turn, when physicians perceive increased convenience and comfortability, their willingness to continuously use telemedicine is enhanced, thereby promoting the development of related technologies and creating a developed platform. These progressive facilitating conditions also stimulate patients intention to use by adding perceived value in this process to form a reinforcement loop in the adoption.

Similarly, a patient who is dissatisfied or has difficulty adapting to new technology will meet the same barrier. Therefore, the relationship between patient–physician–technology–policymaking has a joint effect on the adoption of telemedicine. The future expansion of telemedicine heavily relies on physicians' satisfaction with the use of the process and the assessment of the quality of use [42]. Quality and satisfaction are inseparable from the collaboration among technology, policy, patients, and physicians. Factors such as acceptability, convenience, efficiency, access, communication, governance, and platform choice have been identified to impact the usage and development of telemedicine [43]. Meanwhile, policymaking should explore the mechanisms during the adoption process by studying the interactions and cause-effect relationships of all the factors and elements from a global perspective.

V. CONCLUSION AND LIMITATIONS

One of the main lessons learned from the COVID-19 pandemic is that epidemics are widespread in complex networks and thus go far beyond the healthcare system to become a complex societal problem, where a small change can cascade in unpredictable ways. Telemedicine, as an alternative option in outpatient and office-based care, was employed to respond to the present COVID-19 pandemic. Suppose telemedicine is viewed only from a health system perspective rather than as a complex system with multiple intertwined factors. In that case, telemedicine adoption will be conflicted or hindered by ignoring the patient–physician–technology interactions. The development of telemedicine must consider each of the interrelated domains such as regulatory, financial, technological, medical, organizational, and human factors involving policymaker, patient, physician and technology provider [24]. Stakeholders in multiple systems at different levels should take advantage of technological change to create opportunities to meet people's health needs without compromising the quality of care to expand telehealth. Hope this research can serve as a foundation for telemedicine adoption and development from the systems perspective when we stand at the turning point in the postpandemic era.

Our study has several limitations. First, the survey is care provider-oriented, where the responses only include physicians and exclude patients. Furthermore, since the data is obtained from public databases, this means that investigations for specific groups or occasions cannot be conducted. Therefore, the analysis is done from a relatively macro perspective. Follow-up work will include more factors to explore patients' and physicians' attitudes and perceptions while considering the technology–policy–patient–physician interactions regarding telemedicine utilization in the complex healthcare system.

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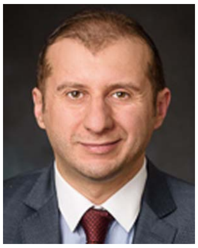

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