

Pereira, Francis; Fife, Elizabeth

**Conference Paper**

## Tele-health in theory versus practice: A comparative look at the United States and Singapore

23rd Biennial Conference of the International Telecommunications Society (ITS): "Digital societies and industrial transformations: Policies, markets, and technologies in a post-Covid world", Online Conference / Gothenburg, Sweden, 21st-23rd June, 2021

**Provided in Cooperation with:**

International Telecommunications Society (ITS)

*Suggested Citation:* Pereira, Francis; Fife, Elizabeth (2021) : Tele-health in theory versus practice: A comparative look at the United States and Singapore, 23rd Biennial Conference of the International Telecommunications Society (ITS): "Digital societies and industrial transformations: Policies, markets, and technologies in a post-Covid world", Online Conference / Gothenburg, Sweden, 21st-23rd June, 2021, International Telecommunications Society (ITS), Calgary

This Version is available at:

<https://hdl.handle.net/10419/238046>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

# Tele-health in theory versus practice: A comparative look at the United States and Singapore

Francis Pereira, Ph.D.  
Associate Professor of Clinical Data Sciences and Operations  
Marshall School of Business  
University of Southern California  
Los Angeles, California 90089.

Elizabeth Fife, Ph.D.  
Associate Professor, Technical Communications  
Viterbi School of Engineering  
University of Southern California  
Los Angeles, California 90089.

## ABSTRACT

A global and growing shortage of medical doctors and nurses, exacerbated by increasing life expectancy, is generating greater cost pressures on health care around the world. Many industry analysts and health care professionals have argued that early detection and preventive care, as well as education, is a solution to the escalating costs of medical care. In this respect, telemedicine can help alleviate these pressures, as well as extend medical services to under-served or unserved areas.

Despite rapid advancement in remote sensor technologies in the last 10 years, its relatively slow adoption suggests the presence of barriers and challenges. As such, while tele-health offers significant advantages, its limited use suggests potential divergences in “business models” of the key players in the health industry, specifically, health care providers and insurers, and other stakeholders. We identify the barriers or challenges that need to be addressed to facilitate tele-health’s adoption, widespread use and success.

Traditional discussions on e-health have revolved around the health provider, insurance company and patient. However, since the benefits of e-health accrue to other parties, other non-traditional stakeholders must be included. These would include national telecommunications service providers, equipment manufacturers, software services providers and major corporations, with one these stakeholders perhaps acting as a “keystone” player.

Thus, while tele-health offers significant advantages, its limited use suggests gaps between theory and practice in the U.S. health industry. This paper will elucidate the value proposition that e-health offers to both the U.S. healthcare and Singapore environment. More significantly, we identify the barriers that have been addressed in the Singapore Telehealth system, and how the SARS-CoV-2 pandemic has provided the conduit to bridge the gap between theory and practice to a large extent in Singapore.

As tele-health deployment in Singapore demonstrates, the successful deployment of e-health will revolve around a “keystone” player. In this case it is the Singapore government driving the initiative, identifying the revenue model, organizational structure and stakeholders in a comprehensive eco-system. This has led to relatively faster adoption of applications and services, and thus serves as a roadmap for successful deployment of telehealth applications in the U.S. and globally.

## INTRODUCTION

National health sectors, globally, have been experiencing substantial and ever-increasing costs, attributable to; i) a growing shortage of doctors and nurses relative to the population; ii) increasing life expectancy,<sup>1</sup> where each additional year of life expectancy is estimated to add 3% to total costs and iii) greater detection of diseases by patients. Total global expenditure on health is estimated at some \$7.83 trillion in 2013 and is expected to grow to \$8.8 trillion in 2021.<sup>2,3</sup> But by the end of 2016, in the United States alone, health care costs totaled some \$3.3 trillion dollars or some 17.9% of GDP,<sup>4</sup> with expenditures expected to reach \$5.7 trillion and comprise 19.7% of the U.S. economy in 2026.<sup>5</sup> It is estimated that by 2025, the shortfall in primary physicians in the U.S. could be between 12,100 and 31,500. Although the U.S. currently spends about 17.9% of GDP on healthcare, one of the highest in the world, many Americans, until only recently due to “Obama Care,” have been uninsured or under-insured. A solution to ever-increasing costs may lie in preventive care, early detection care and health maintenance, enabled by tele-medicine.<sup>6</sup>

Though the terms “tele-health,” “e-health,” and “mobile health” (m-health) may be relatively new, the antecedent concept and uses of telemedicine dates to the 1920s, where it was used for ship to land consultations. However, even with advances in medical technology over the years, the use of telemedicine in actual patient-doctor consultations remains low. Telemedicine is generally defined as “the use of telecommunications and computer technologies, including patient remote sensing and monitoring, and the use of telemetry devices, with medical expertise to facilitate health care delivery.”<sup>7</sup> However, this paper defines telemedicine more comprehensively, and subsumes tele-health, e-health and m-health under this umbrella. Telemedicine is currently also referred to as “tele-health” a term used interchangeably in this paper.

Many observers have long argued that telemedicine has significant potential to develop into an integral component of the global health care system and could provide better and more extensive access to healthcare through remote sensing, collaborative patient care, and access to medical databases and electronic libraries. The results would lead to lower medical costs and increased medical productivity. Similarly, mobile health applications can help manage chronic diseases, such as chronic obstructive pulmonary disease (COPD), diabetes mellitus, hypertension, and heart disease. Thus m-health, comprises a specific set of telemedicine applications, and is defined as the use of patient monitoring and communication applications and devices, using wireless transport technologies, to transmit patient health data and information over geographical areas.<sup>8</sup>

Telemedicine has the potential to address the cost pressures as well as the health availability issues facing the global health care sector. But a low adoption rate, despite rapid advancements particularly in the last 5-8 years in sensor and wireless technologies, suggests that despite significant potential, there may be differences in “business model” settings of the key players in the health industry eco-system, especially, health care providers, insurers and other non-traditional players.

Perhaps ironically, the SARS-CoV-2 pandemic has accentuated the value of tele-health and self-monitoring, as will be discussed below. The Centers for Disease Control (CDC) recently released data that showed for the causes of death in the United States, for which the CDC had full-year provisional data, nine registered increases were registered which arguably could have been mitigated with tele-health. These included Alzheimer's and Parkinson's disease, chronic liver disease, stroke and high blood pressure. After declining over the longer term, the heart disease death rate increased to 167 deaths per 100,000 population from 161.5 the previous year. This is only the second time in 20 years that the rate has increased. Diabetes deaths rose to 24.6 per 100,000 last year, from 21.6 in 2019. Again, the 14% increase was the largest rise in the diabetes death rate in decades. The death rate from Alzheimer's was up 8%, Parkinson's 11%, high blood pressure 12% and stroke 4%. Some experts believe one of the major reasons for this has been many patients did not seek treatment because they feared becoming infected with the virus.<sup>9</sup>

The SARS2-CoV-2 pandemic has highlighted barriers that need to be resolved to encourage tele-health's adoption, widespread use and success,<sup>10, 11</sup> in fact, demonstrating how some of these barriers were mitigated with appropriate, albeit temporary, policies.

### *The value proposition of Tele-health*

Past, and continuing research has validated telemedicine's effectiveness and usefulness when geography, distance, terrain, climate or other physical barriers, and climate has prevented or hindered direct contact between patient and clinician, or transportation of patients to clinician.<sup>12</sup> The accessibility of mobile phones and the ubiquity of cellular and terrestrial broadband networks provides the potential to greatly alleviate the cost pressures in health care management. These savings can be achieved from the reduced costs of patient care through i) better chronic disease management; ii) reduction in both travel and time for patients and doctors; iii) and from the provision of better health care, generating cost reductions from increased monitoring and early diagnosis of chronic diseases, such as hypertension,<sup>13</sup> diabetes, chronic obstructive Pulmonary Disease (COPD) and heart disease. COPD remains a leading cause of hospitalization for those over 65 years in the U.S. comprising some 65% of the annual 638,000 hospital discharges.<sup>14</sup> Also, some

20% of Americans will develop Congestive Heart Failure (CHF). Similarly, about 85% of African-Americans and 74% of Hispanics aged 65 years and older suffer from hypertension, which costs about \$47.5 billion in annual direct medical expenses.<sup>15</sup> But despite advances in medical care and pharmacological therapy, outcomes related to heart failure still remain relatively poor.<sup>16</sup> Given a six-month re-admission rate of some 44%, appropriate disease management for CHF patients is critical, and for people over 65 years in the U.S., it remains one of the leading causes of hospital admission. In both Europe and the U.S., the treatment of high-risk heart failure patients accounts for an estimated 1% to 2% of the total heart care budget. On the other hand, studies have shown that with tele-monitoring, survival rates have improved and there has been about a 26% reduction in number of days of in-hospital stays for patients.<sup>17</sup> The large number of internet-based wireless telemedicine applications, such as portable health monitoring devices and mobile health units, which seamlessly can connect wirelessly with a central service center, attest to the viability of this technology.<sup>18</sup>

Stroke is a leading cause of death and disability worldwide. Over 795,000 strokes occur in the U.S. every year or basically one person experiences a stroke every 40 seconds.<sup>19</sup> Studies have shown that the implementation and expansion of telestroke-networks over the past few years has improved access to stroke experts for patients living in rural areas.<sup>20</sup> Patients diagnosed with acute ischaemic stroke through telestroke consultation are typically evaluated for tissue plasminogen activator (tPA) treatment and are then either admitted locally or transferred to a primary or comprehensive stroke center for further care.<sup>21</sup> The Medical University of South Carolina (MUSC) established a dedicated teleneurology network as an ancillary network to its established telestroke network to provide care to patients with on-acute strokes, post tPA and non-mechanical thrombectomy patients, as well as those with various other neurological conditions. They evaluated the impact of establishing this teleneurology network on the transfer rate of stroke patients to the hub and the cost reduction associated with establishing the network. A total of 4,296 telestroke patients, were evaluated for concern for acute ischaemic stroke between January 2008 and March 2018. Of those patients, 2,493 acute stroke patients presented before the establishment of the teleneurology program, and 1,803 patients presented afterwards. Patients who presented after the establishment of the teleneurology

network were less likely to be transferred to the hub. The total cost reduction (including transportation cost, average length of stay for acute ischaemic stroke patients, and higher cost at the tertiary medical centers) for each patient that was able to avoid transfer was about \$4,997. If the rate of transfer to the tertiary medical center for acute stroke care was similar before and after implementing teleneurology consultation, an additional 173 patients would have been transferred. So, the total cost reduction for the avoided transfers for stroke-patients with the implementation of the teleneurology program was about \$864,481.<sup>22</sup>

Studies also have reported a lower cost of tele-rehabilitation for stroke survivors in Spain compared to center-based rehabilitation due to the reduced hours of supervision by physical therapists. It was found that in-clinic intervention required 8.3 physical therapist hours, whereas home-based tele-rehabilitation program required 1.6 hours. Besides savings due to reduced physical therapist hours, savings in travel expenses, which represent 88% of the total costs of in-clinic intervention, also contributed to the reduced cost of home-based tele-rehabilitation. Similarly, other studies have reported reduced costs of transportation for therapists to make home visits to provide in-person rehabilitation with the use of tele-rehabilitation.<sup>23</sup>

Systematic reviews have shown that stroke patients who completed home-based tele-rehabilitation achieved outcomes equal or greater to those of center-based patients in terms of physical function and participation in social activities.<sup>24,25,26</sup> Additionally, studies have shown that those who experienced tele-rehabilitation reported higher levels of satisfaction with tele-rehabilitation services compared to those who completed center-based rehabilitation.<sup>27</sup>

Thus, the value proposition of e-health and mobile health (and telemedicine) both in United States and in other countries is extremely high. The potential costs-savings from the deployment of various home-care e-health applications for monitoring is further illustrated in Table 1.<sup>28</sup>

Table 1

Cost of Inpatient Care (per patient per month) Compared to Home Care for Select Conditions			
Conditions	Hospital Costs	Home Care Costs	Dollar savings
Low birth weight	\$26,190	\$330	\$25,860
Ventilator-dependent adults	\$21,570	\$7,050	\$14,520
Oxygen-dependent children	\$12,090	\$5,250	\$6,840
Chemotherapy for children with cancer	\$68,870	\$55,950	\$13,920
Congestive heart failure in the elderly	\$1,758	\$1,605	\$153
Intravenous antibiotic therapy for cellulitis, Osteomyelitis, others	\$12,510	\$4,650	\$7,860

The savings notwithstanding, most of these applications have been deployed on a limited scope and scale. Tele-health, as such, remains very much in its infancy or “early adopter stage.”<sup>29</sup> Also, most companies are still in the testing stages for tele-health systems and their related technologies, and few long-term programs have been implemented. Much of the current impetus for mobile tele-health is being generated by technology companies who see the future revenue potential.<sup>18</sup>

Tele-health can also be used to increase healthcare at a reduced cost in federal prisons in the U.S., given the high costs of transporting prisoners to healthcare facilities. There are over 1.5 million persons in state and federal prisons in the United States and some 9% are estimated to have diabetes and perhaps other serious comorbid conditions. The rate of diabetes among prisoners in 2011–2012 (899 per 10,000 prisoners) has almost doubled since 2004 (483 per 10,000 prisoners) and is 1.5 times higher than in the general population. Many prisoners have had little or poor diabetes care before incarceration. Given the high costs of transporting prisoners to healthcare facilities, telemedicine can be used to help improve diabetes care for this vulnerable population. A recent analyses of prisoners’ retrospective charts from 15 correctional facilities who received televisits for diabetes from 2011 to 2014 showed that there had been improvements in glycemic, blood pressure, and lipid control for prisoners with diabetes.<sup>30</sup>

Next, follow-up care, particularly for medical conditions where the visual aspects, such as photographs, are critical to evaluate the medical status of the patient, such as in surgery after-care and chemotherapy, is another important area where tele-health could reduce costs and increase efficiency in the health system.<sup>31, 2,</sup>

<sup>33</sup> Pilot tests have been conducted for mobile phone-based follow-up care for patients in these areas.

Similarly, dermatology, where images and photographs are used extensively in diagnosis and treatment, is well positioned to exploit m-health.<sup>34</sup>

In rural health care, the use of mobile tele-health in rural healthcare looks promising. Although the ratio of doctor to patient ratio is relatively low in these areas compared to urban areas, most rural patients nonetheless have cell phones and are within the range of cell phone towers.<sup>18, 35, 36, 37</sup> Applications that increase or support doctor-patient communications, such as SMS text messaging systems that provide appointment reminders, have been the first types of applications downloaded to the mobile phone to support tele-health. Quantitative statistical studies show that these applications have had some success in countries such as New Zealand and the Philippines.<sup>37, 38</sup> M-health and e-health could also provide the platform for preventive medicine, and it is estimated that some \$500 billion could be saved in the U.S. by addressing obesity, smoking and other modifiable risks factors.

Other studies support the conclusion that most patients, even older patients, are generally satisfied with tele-home health services and tele-health, particularly in the treatment of COPD, CHF and chronic wound care, with patient satisfaction levels increasing with increased levels of tele-health care intervention<sup>39, 40, 41, 15.</sup>

Similarly conclusions can be drawn from a random survey conducted in North America involving over 5,000 respondents, which show high consumer interest in using both wireless technologies as well as the terrestrial internet to better manage their health care needs.<sup>42</sup> Over 60% of respondents find digital home health services, such as accessing medical records and test results, scheduling appointments, determining correct tests and treatments and direct access to online doctors as useful or very useful. A large and growing consumer interest in e-health indicates the viability of such services and applications.

## *Challenges to the “practice” of Telemedicine*

### *Interfaces for Tele-health*

The user interface experience while important for adoption of any good or service, specifically in terms of ease of use, simplicity, and convenience, it is particularly important for technology-enabled services, such as mobile health. Defined as the interaction between the customer and the service platform, this interface includes both hardware and software, and provides the bridge between the service platform and customer experience: it provides the “physical” link between the experiential or qualitative nature that the value proposition of the product or service provides, and the physical infrastructure that delivers it. The proliferation of smart phones, and their operating systems, the Internet and social media, and PC tablets offer yet new interfaces for customers to access digital products and services. Since most healthcare professionals currently routinely use handheld and wireless devices, training is not expected to be a major issue. Given the ubiquity of cell phones among patients, it is the obvious platform for application developers, who have created, among other applications, insulin, and heart rate monitoring functions, for cell phones, and are beginning to develop applications that support tele-monitoring and remote patient education in the home. Small-scale clinical trials repeatedly find that “extreme” simplicity is needed in for home health applications, since most of patients who have been released from the hospital and expected to use these applications are generally older and may have limited experience with computers. Furthermore, from a user interface perspective, these applications must account for potential physical limitation of patients due to medical conditions, such as rheumatoid arthritis, vision and other problems.<sup>43</sup> This is a critical requirement, and devices and their interfaces must be designed to adapt to a patients’ limited capabilities, including dementia, or lack of stamina, or disabilities.<sup>42</sup> A potential solution to this problem of limiting and changeable usage abilities may lie in intuitive interfaces that can learn and adapt to an individual’s capability. Studies suggest that even non-technical individuals are interested in learning how to use mobile and wireless services if they provide them with more independence.<sup>44</sup>

### *The Delivery Platforms Necessary for Tele-health*

Potential economic benefits from use of telemedicine are numerous, nonetheless, deployment and adoption of remains low, principally due to several technical, structural and social constraints. Many of these constraints, including low compatibility with how medicine is practiced, the complexity of telemedicine equipment interfaces, and at times, use of the equipment itself, the prevalence of multiple technical standards<sup>45, 46</sup> physicians' unfamiliarity with the technology, and ineffective training and change management still persist today.<sup>47</sup> Furthermore, with the availability of new wireless technologies and standards for mobile tele-health, such as GSM, GPRS, 4G, Bluetooth, WiFi and Zigbee, these interoperability issues may have been exacerbated.<sup>48</sup> Also, given the recent data breaches in the health sector, network security has become a primary concern. Thus, a high level of security, characterized in part by encryption, authentication, and controlled access, to protect health care data, are necessary and critical for mobile tele-health.<sup>44</sup> Because of the current state of the network, most of the wireless tele-health applications used today are considered "low risk" and involve only text messaging, simple patient data and checking prescriptions.<sup>49</sup>

Deploying a multi-network approach may provide a solution to current wireless network challenges. Specifically, Varshney asserts that the current cellular networks, used in conjunction with wireless LANs and satellites to help provide coverage, redundancy, and reliability, could form the bases of a reliable and usable wireless infrastructure that affords easy access and support prioritized communications.<sup>44</sup> Additionally, a potentially higher degree of service quality and scalability could be achieved by switching between multiple networks, which would help overcome the limitations in current wireless networks. But technical interoperability between tele-health devices remains a significant obstacle. Thus, while the use of mobile phones are ubiquitous, the rate of adoption of mobile tele health applications and services, using the cellular platform, will depend on how successful telecommunication network providers will be able to integrate their platforms with hospital and other health-related IT systems as well as other medical devices and interfaces.<sup>50</sup> Specifically, with mobile tele-health, in order to preserve the integrity of data and appropriate patient care, it is extremely important to seamlessly integrate new tele-health data into existing hospital records systems. Interoperability of access devices is crucial for rapid adoption and to ensure medical applications will not fail on different devices.

One of the most significant challenges related to adoption of tele-health is not technology-based but “people-based” and involves integration with current workflows. In the case of a mobile tele-health system, this would require the integration of e-health applications with traditional workflows (or replacement of some activities). While patients have found the use of mobile phones in healthcare to be relatively easy,<sup>32</sup> healthcare providers on the other hand, have been confronted with scalability issues, the need for meticulous planning, strategic phasing and ongoing assessments in deployment of the system. These issues are likely to remain immense challenges.

### *Organizing Structure and Eco-system*

In many countries, the medical health eco-system system is very complex and structured, none so perhaps as in the United States. Specifically, in the United States, at least twelve Federal and State Agencies regulate the health industry, including the Department of Health and Human Services, the Drug Enforcement Agency (DEA), and the Food and Drug Administration (FDA) at the Federal Level.<sup>45</sup> However, in the case of mobile tele-health, since health applications will use the cellular networks, oversight would also have to be provided by the Federal Communications Commission. From a medical health eco-system perspective, with the exception of perhaps the American College of Radiology, there has been ambivalent support for telemedicine, from the leading U.S. medical institutions, particularly the American Medical Association, and most medical schools and college, as well as the majority of doctors and hub hospitals.<sup>51</sup> Several key societal impediments to the use of telemedicine can account for this ambivalence, most significantly the tension between state laws on medical licensure telemedicine<sup>52</sup> which, under the present individual state licensure system, requires physicians to be medically certified and licensed in each state in which they tele-consult with their patients. This practically limits telemedicine to state borders and as such curbs the potential geographic benefits that mobile tele-health solutions can provide.<sup>53</sup> Furthermore, ambiguity exists as whether telemedicine services are covered under malpractice insurance policies.<sup>54</sup> These legal malpractice issues and challenges are compounded when these services extend beyond individual state borders.<sup>55</sup>

Furthermore, as discussed above, technical security protocols in the networks are needed to ensure the confidentiality of patient medical information and record for mobile telehealth,<sup>56</sup> perhaps more so than for other types of personal information. 3G networks however, remain vulnerable to malware attacks. Medical history and records, if used inappropriately used can be severely detrimental to the patient. The challenge remains to include security and privacy protocols into mobile tele-health applications since mobile networks may not be 100% secure.

Perhaps one of the most critical factors for the success of tele-health is the necessity of identifying all the stakeholders in the tele-health system and establishing an alliance structure.<sup>57</sup> Traditionally the health ecosystem has been narrowly defined to include only the health provider, insurance company and patient. However, since the benefits of telemedicine accrue to many other entities beyond these traditional stakeholders, these new parties have to be included. At the very least, these would include the national telecommunications service providers, equipment manufacturers, software services providers, major corporations and state agencies.

The technical complexity in the delivery of e-health services requires the active participation of network service providers. In the U.S. market, network service providers are now just beginning to explore e-health. Network service providers also offer the advantage of being able to set and/or establish standards and protocols.

The importance of identifying and including stakeholders in any deployment of tele-health is perhaps best illustrated in a recent study of TeleMental Health. Mental health conditions (MHCs) affect 44.7 million adults in the US and it is reported that one in five adults experience an MHC in a given year.<sup>58</sup> MHCs can be highly disabling, but with proper treatment, can often be managed.<sup>59</sup> Despite policy changes to increase mental health parity and integrate mental and physical healthcare, 50% of adults with MHCs remain untreated. Untreated MHCs can impose a heavy burden on individuals, their families, payers, and society. The shortage of mental health providers remains a significant barrier to mental health treatments. As of 2017,

there were 5,042 designated Mental Health Care Health Professional Shortage Areas in the U.S. Telemental health (TMH), the delivery of mental health services through remote technologies (e.g. video-based conferencing), has emerged as a promising solution to the shortage of providers.<sup>60</sup>

In a retrospective, cross-sectional study to linked data for 2016 from the National Mental Health Services Survey (of some 11,800 records), Area Health Resources File, and national reports for broadband access and telehealth policies, Zhao et al. found that only 26% reported using TMH as a treatment approach in 2016. This adoption was much lower than the prevalence reported for general tele-health (42%) in acute care hospitals in the American Hospital Association Annual Survey of Hospitals, but parallel to findings from the American Medical Association's 2016 Physician Practice Benchmark Survey indicating that 27.8% of psychiatrists had used telemedicine to interact with patients. One reason for the discrepancy in adoption prevalence may be the high need in acute care hospitals for tele-health services such as teleradiology, teledermatology, teleophthalmology, and telecardiology.<sup>60</sup>

The study found that the adoption of TMH by a mental health facility could be influenced by several factors including the type of facility, mental health treatment capacities, IT capability, QI practice, and payer and case mix of the facility. Specifically, the study found that:

- i) TMH adoption was significantly higher in Veteran Administration Medical Centers (VAMCs) and facilities that had higher proportions of veteran patients. As the nation's largest health care system, the VA has been the leader in tele-health in the US since 2003. In addition to the VA's continuous commitment to telehealth and mental health, the integrated nature of the VA system may also contribute to the adoption of TMH.<sup>20,31</sup>
- ii) Mental health facilities that included outpatient settings were also more likely to have TMH, likely reflecting the fact that most mental health services adapted to TMH are provided in outpatient settings.
- iii) Public mental facilities were more likely to adopt TMH as compared with private for-profit facilities, perhaps due to differences in fiscal incentives.

- iv) Higher IT capacity was associated with higher TMH adoption. This association may in part reflect differences in infrastructure. For example, facilities with higher IT capacities are likely to be those with a patient referral system and health records.
- v) Facility payer type and patient mix were also significantly associated with TMH adoption. Facilities treating patients insured by Medicare, VHA, and private payers were more likely to adopt TMH. Facilities treating elderly patients were more likely to have TMH as compared with those who did not.
- vi) TMH adoption varied substantially across states, and the variation was primarily driven by differences in telehealth policies and level of rurality. TMH adoption was more likely in states with a higher percentage of rural counties. Higher telehealth/TMH adoption in rural areas might be a result of financial incentives provided by federal and foundation funding that focuses on rural health.
- vii) Mental health facilities located in states that had a special application process for licensure for providing interstate tele-health services were twice as likely to have TMH than those in states without specific licensure requirements. Medical boards in nine states had established processes to issue tele-health-specific licenses to allow out-of-state providers to provide tele-health services. Twenty-two states had adopted the Federation of State Medical Board's Interstate Medical Licensure Compact to allow an expedited process of applying for licenses in other states.<sup>60</sup>

### *Cost-structure for Tele-health*

Both in the U.S. and Europe, the deployment costs of a mobile tele-health or telemedicine infrastructure, and the reimbursement of services provided over this network, remain two major impediments to the rapid deployment of telemedicine applications.<sup>61, 62</sup> Currently, most of the technology costs and the consultations carried out through telemedicine are not reimbursed.<sup>63</sup> Most telemedicine initiatives are run by organizations which are usually financed by demonstration grants, like the military, research centers, or state-owned hospitals, and, as such, are not overly concerned with the revenue model or reimbursements. Grant funding has been crucial for the development of many telehealth centers that still rely on grant funding as a major source of financial support.<sup>64</sup> Although studies have shown the viability and profitability of telemedicine,

through out-patient clinics associated with hospitals in non-rural areas, only a small number of these for-profit medical centers are involved in telemedicine and many of these, like the Mayo Clinic, are deploying closed telemedicine systems.<sup>65,66</sup> Furthermore, out of fear that the telemedicine equipment will be fast outdated, medical organizations are reluctant to purchase such equipment.<sup>51, 67</sup>

While the many studies conducted show the potential cost savings due to tele-health and remote monitoring, both in the U.S. and in other countries, the fact that most of these studies still involve small sample sizes with diverse types of tele-homecare intervention for select chronic illnesses, such as heart failure and COPD questions remain around the revenue model<sup>15, 68, 69, 70, 71, 72</sup>. Also, other studies argue that the outcome of telemedicine in these areas is not conclusive due to definition and measurement issues.<sup>73</sup> A 1992 study by the Arthur D. Little Consulting Company which estimated then, that telemedicine would have resulted in savings of \$36 billion annually, was perhaps the first, and one of the few, comprehensive studies that tried to estimate the potential savings from telemedicine.<sup>74</sup> However, a more recent study estimates increases in efficiency in health care from wireless telecom solutions alone, would increase from almost \$4.5 billion in 2005 to \$29.2 billion in 2015.<sup>75</sup>

The introduction of telemedicine in China, linking highly specialized major hospitals (hub) with hundreds of small rural hospitals (spoke), has shown great improvements to the quality, efficiency, and cost effectiveness of healthcare delivery and utilization. Specifically, between 2002 and 2013, data from 11,987 consultations conducted at West China Hospital using the telemedicine network, a government-sponsored major telemedicine program, in 2002 by the West China Hospital of Sichuan University (hub), covering 249 spoke hospitals in 112 cities throughout western China and in 40 medical expertise areas, was analyzed. The results show that neoplasms (19.4%), injuries (13.9%), and circulatory diseases (10.3%) were the three most common diagnoses. Teleconsultations resulted in a change of diagnosis in 4,772 (39.8%) patients, and 3,707 (77.7%) of them underwent major diagnosis changes. Moreover, this led to a change of treatment in 6,591 (55.0%) patients, including 3,677 (55.8%) changes not linked to diagnosis changes. The telemedicine

network resulted in an estimated net savings of \$2,364,525 and \$3,759,014, depending on whether the patients traveled to the hub or the specialist to the spoke hospitals, respectively.<sup>76</sup>

Similarly, in Brazil, the Telehealth Network of Minas Gerais (TNMG), a public telehealth initiative that supports primary healthcare (PHC), performing teleconsultation and telediagnosis (electrocardiogram [ECG], Holter, ambulatory blood pressure monitoring, spirometry, and retinography analysis) initially for 82 small and remote cities in the state of Minas Gerais, Brazil was created in 2005. Currently the network provides support to 750 cities and covers 88.0% of the Minas Gerais state. An analysis of the system shows that by December 2015, 2,464,999 ECGs and 73,698 teleconsultations had been performed: on average, 2,000 ECGs and 40 teleconsultations per day in 2015. More than 95% of users have declared to be satisfied or very satisfied with the service. A recent cost-benefit analysis of the project showed that for each dollar invested, 6.1 dollars are saved as a consequence of patient referral reduction.<sup>77</sup>

The potential economic returns and benefits to employers that tele-health applications can provide is another area of economic analyses that is lacking. For examples, employees who are also primary health-care givers, may enjoy “ease of mind” as they are able to monitor their loved ones, and thus companies may not experience any loss of productivity. There are no studies in this respect that analyze the productivity effects. Similarly, there is a dearth of comprehensive studies that enumerate the research benefits accruing to continuous access to electronic patient health data, and real-time analyses of possible effects of medication and other treatment. Such studies could help both in refinement or development of new medical procedures and medications.<sup>78</sup> No comprehensive studies have been done to estimate the economic benefits of tele-health to society in general, and the cost reductions to national health-care spending, both private and public, specifically, as several reports have re-emphasized the need recently.<sup>79, 80</sup> Furthermore, two aspects that currently are not included in these analyses are i) the economic savings from early detection and monitoring of infectious diseases: it has been estimated that Hong Kong’s GDP contracted by 1.8% in 2003 due to the SARs outbreak and; ii) productivity increases in businesses from wellness programs. As discussed above, most studies deal with only chronic diseases, and involve small number of patients. Since the potential

economic benefits of tele-health accrue to employers and the government, they are relevant stake-holders that have to be included.

The costs saving estimates from telemedicine today are not very different from the estimates made in 1992, attesting to the lack of progress in trying to quantify the economic benefits in the United States over the past twenty years or so.<sup>81</sup> However, in this respect, some work has been done in areas like electronic records by the largest of the integrated medical groups (i.e. the Mayo Clinic, Kaiser Permanente, the University of Pittsburgh Medical Center among others).<sup>82</sup> While large medical groups have been generally quick to adopt electronic record systems, smaller practices however, among other issues, have found the initial set-up costs of these systems to be high and that they are tailored to larger entities. In this respect, web-based services offer promising alternatives; Internet-based service providers are seen by many as the emerging players in healthcare provision,<sup>83</sup> such as patient access and transfer of medical records which is currently offered by Google and Microsoft.

Although the overall cost of tele-health systems has yet to be established, it is expected that the greatest costs will accrue to human resource implementation and training, since hardware costs, such as mobile phone devices are relatively inexpensive, and mobile networks have already been deployed. There are expected cost savings based on the pilot tests done in certain countries.

### *Tele-health in the U.S During the SARS-CoV-2 Pandemic*

While there has not been any reported widespread deployment of tele-health in the U.S., the Centers for Disease Control found that during the first quarter of 2020, the number of tele-health visits increased by 50%, compared with the same period in 2019, with a 154% increase in visits noted in surveillance week 13 in 2020, compared with the same period in 2019. During January–March 2020, most encounters were from patients seeking care for conditions other than COVID-19. However, the proportion of COVID-19–related encounters significantly increased (from 5.5% to 16.2% during the last 3 weeks of March 2020--surveillance weeks 11–13). This marked shift in practice patterns has implications for immediate response efforts and

longer-term population health. Continuing tele-health policy changes and regulatory waivers might provide increased access to acute, chronic, primary, and specialty care during and after the pandemic.

More importantly, it argues that the increased number of visits in the latter weeks in March 2020 might also be related to the March 6, 2020 policy changes and regulatory waivers from the Centers for Medicare & Medicaid Services (1,135 waivers) in response to COVID-19 and provisions of the U.S. Coronavirus Aid, Relief, and Economic Security (CARES) Act, effective March 27, 2020. These emergency policies included improved provider payments for tele-health, allowance for providers to serve out-of-state patients, authorization for multiple types of providers to offer tele-health services, reduced or waived cost-sharing for patients, and permission for federally qualified health centers or rural health clinics to offer tele-health services. The waivers also allowed for virtual visits to be conducted from the patient's home, rather than in a health care setting.<sup>84</sup>

Similarly, Frost and Sullivan found, in an initial reforecast of the tele-health market, a significant spike in usage in 2020. They project that the full virtual care market in the U.S. will grow at a compound annual growth rate (CAGR) of 38.2% between 2019 and 2025. The pre COVID-19 CAGR was 28.2%. The most noticeable change has been the year-over-year growth in 2020 with an estimated 64.3% growth in 2020. It estimated that remote patient monitoring (RPM) has grown by 150.3% in 2020, while virtual visits are forecast to grow by 124.2% in 2021<sup>85</sup>.

Other contributing factors that could have affected utilization of services include state-issued stay-at-home orders<sup>86</sup> states' inclusion of tele-health as a Medicaid covered benefit and the CDC's guidance for social distancing and increased use of virtual clinical visits. Tele-health might have multiple benefits for public and individual health during the pandemic. During the latter weeks in March 2020, remote screening and management of persons who needed clinical care for COVID-19 and other conditions might have increased access to care when many outpatient offices were closed or had limited operating hours. The increased availability of tele-health services also might have reduced disease exposure for staff members and patients, preserved scarce supplies of personal protective equipment, and minimized patient surge on facilities. In addition, most patients seeking tele-health in the early pandemic period were managed at home, which might

have reduced large volumes of patients seeking care at health care facilities. Access to tele-health services might have been particularly valuable for those patients who were reluctant to seek in-person care, had difficulty accessing in-person care or who had chronic conditions that place them at high risk for a severe COVID-19 infection.<sup>84</sup>

### *Tele-health in Singapore*

In Singapore, video consultations and telemedicine pilots began at six public health institutions as early as 2017. Telemedicine has been seen as a way to help tackle the problem of Singapore's overcrowded hospitals and specialist outpatient clinics, saving patients commuting and appointment waiting time. Apart from public hospitals, private sector healthcare providers are offering telemedicine as an option. Even Traditional Chinese Medicine (TCMs) firms acknowledge that the pandemic has disrupted the way they do business. They already sell products online but are now also offering teleconsultation services.<sup>87</sup>

In the past, telemedicine was employed for review consult cases which were stable, where physical checks and tests were not required, and where patients had access to the appropriate devices and connectivity. The initial pilots were for disciplines such as mental health, renal medicine, pharmacy, epilepsy, and dementia. But only 1,947 patients used the service between 2017 and the start of 2020. Singapore has been able to reap some of the benefits of tele-health. For example, Singapore's Ministry of Health (MOH), reported 7,413 cases of stroke treated in the nation's public hospitals in 2016. Stroke survivors often experience physical limitations (such as loss of balance, mobility and dexterity) and require rehabilitation from health care professionals, to regain their functional independence during and after hospitalization. Rehabilitation at both inpatient and outpatient settings can facilitate these individuals to achieve their goals of regaining and/or maintaining functional independence and potentially lower long-term health-care costs. However, it has been reported that a significant number of participants choose not to continue their rehabilitation after hospital discharge due to functional, financial and social barriers such as mobility and transportation problems, as well as the cost of treatment. In a recent study 124 eligible individuals were

recruited into the trial between 2013 and 2016 from two participating hospitals in Singapore. Sixty-one individuals were randomly allocated to the tele-rehab group and 63 to the control group. Patients in the intervention group who had access to tele-rehabilitation and patients in the control group who had access to usual care (i.e. center-based rehabilitation) presented similar improvements in functional outcomes while self-reporting a similar amount of time spent on rehabilitation and exercise over the three-month trial period. Tele-rehabilitation may be a viable option for providing rehabilitation services in Singapore to reduce health services utilization barriers and nurture continuous participation in rehabilitation after discharge from hospital post stroke.<sup>23</sup>

However, video consultations in telemedicine in Singapore rose throughout 2020 amidst the COVID-19 pandemic lockdown and by January 2021, 36,000 patients had sought medical help via video consultations.<sup>87</sup> The response by the Nephrology Division at Singapore's the National University Hospital (NUH) illustrates how various medical groups adapted to the pandemic, in this case, to make an urgent and wide-scale transition to tele-health services in a 10-week timeline. In Singapore, the Nephrology Division is an academic practice at the National University Hospital (NUH) of Singapore with a 1,160-bed tertiary hospital serving more than 670,000 outpatients and 49,000 inpatients a year. It has a collaborative service model with the National Kidney Foundation (NKF) with seven nephrologists perform monthly rounds on 960 HD patients across seven satellite community dialysis centers (DCs). The traditional model of care in community dialysis is nephrologist-driven. Frequent in-person rounds at DCs were mandatory before the pandemic. Inpatients at regional hospitals are reviewed by separate attending nephrologists.

In November 2018, NKF established an electronic medical record (EMR) for each HD patient, with integrated computerized physician order entry and task management tools. Physicians were given remote access via password-secured virtual private networks (VPN) on tablet computers, but many preferred paper documents. However, on February 7, 2020, after local authorities raised the risk posture of Covid-19, in-person dialysis rounds were ceased and one day later, replaced by remote review of dialysis treatment records and telephone discussion with dialysis nurses for all patients. However, a complete telemedicine practice was not possible, as on-site nurses were required for connecting patients to dialysis and monitoring purposes.

In a subsequent analysis, NUH found that overall outcomes and patient satisfaction with the rapid adoption of telemedicine to continue providing care to patients. It found that key biochemical performance indicators had been unaltered by reduced physician presence. Also, unpublished audit data in March 2020 revealed that serum hemoglobin, albumin, and dialysis dose targets continue to be achieved in 85%, 91%, and 93% of patients respectively, unchanged from 6 months pre-Covid-19 at 86%, 90% and 92% respectively. It found no significant difference in hospital admission rates for cardiovascular disease or vascular access complications. Similarly initial feedback through an informal survey of patients at one DC found that most expressed satisfaction with the experience: 13 of 18 patients agreed that the telemedicine service had benefited their care, and 11 of 18 agreed that telemedicine offered a near-equivalent to in-person physician rounds.<sup>88</sup>

However, the ability of health-care providers in Singapore to rapidly switch to tele-health as an alternative delivery system was made possible through two major government programs, the first initiated nearly 2 decades ago, and exemplify the infrastructure and service platforms requirement discussed above.

In 2014, Singapore launched the Smart Nation Program, designed to harness ICT, networks and data to improve the quality of life of its citizens, strengthen businesses, and help government agencies serve citizens better, particularly in the face of increasing urban density and as aging population.<sup>89</sup> The Smart Nation program was the planned extension of Singapore's 10-year Intelligent Nation masterplan (iN2015) begun in 2004 to develop the infocomm infrastructure to support the Internet of Things (IoT) and enable cyber physical systems (CPS). iN2015 was thus designed to use infocomm technologies to enrich lives, enhance the growth, competitiveness of and innovation in key economic sectors and build a well-connected society.<sup>90</sup> Based on iN2015, 9 out of 10 Singapore homes have broadband and soon every home will have fiber. Singapore's smart phone penetration is one of the highest in the world at 85%.

Integrated Health Information Systems (IHIS) is the technology agency for the public healthcare sector. It was formed in Singapore in 2008 as a cohesive approach to the development and management of IT systems

in public healthcare with the objective of improving the Singapore population's health and health administration by integrating intelligent, highly resilient, and cost-effective technologies with process and people.

Currently, IHiS supports the operations of 46 public healthcare institutions including acute hospitals, specialty centers, and polyclinics, as well as over 1,400 partners such as community hospitals, nursing homes, general practitioner clinics and voluntary welfare organizations. In November 2016, it merged with Singapore's Ministry of Health (MOH) Holding's Information Systems Division essentially assuming the role of the technology agency for Singapore healthcare.<sup>91</sup>

### *LEAP in Tele-health in Singapore*

Recognizing some of the legal and structural challenges to the deployment of tele-health services, Singapore's Ministry of Health (MOH) launched a new Licensing Experimentation and Adaptation Program (LEAP) beginning with telemedicine services, with the objective of identifying new and innovative models and services that have the potential to bring significant benefits to patients and support healthcare transformation. LEAP will provide regulatory sandboxes that enable new and innovative models and services to be developed and refined in a safe and controlled environment. Participating providers and MOH will achieve this through clear boundary conditions, data governance measures and risk mitigation strategies.

Singapore's MOH hopes that under LEAP, patients and caregivers will benefit from early access to new healthcare models while being assured that essential safety and risk mitigation measures are in place. Being able to develop an appropriate and clear regulatory regime with LEAP will enable the growth of these services that can bring benefits to more patients and caregivers, while safeguarding their interest. For health care providers, it hopes that participating in the regulatory sandbox will be able to introduce new healthcare models or evolve their current models in a safe manner, with early visibility over the eventual regulatory environment. This positions them to transit more seamlessly into the eventual regulatory framework and meet patient safety and welfare requirements.

From LEAP, the Singapore Ministry of Health (MOH) hopes to better understand the risks associated with telemedicine and as of February 2021, are satisfied that it had achieved the objectives. It had in the interim, introduced a voluntary listing of direct telemedicine providers that have agreed to comply with the MOH telemedicine e-training. Currently, there are more than 600 telemedicine providers on the list including public hospitals, clinics and telemedicine firms. Only registered providers can offer consultations to patients under the Community Health Assist Scheme (CHAS) and tap Medisave (Singapore's compulsory national medical savings plan), for video consultations for follow-up of certain chronic conditions. As of October 2021, twenty chronic conditions, including osteoporosis, psoriasis, rheumatoid arthritis and ischemic heart disease, were added to the list.<sup>92</sup>

MOH aims to license telemedicine services in mid-2022 as part of the phasing in of the upcoming Healthcare Services Act. The Health Services Bill was approved by Parliament in January 2020 and was supposed to be implemented in three phases, from early 2021 to end 2022. However, last year's pandemic derailed this and the new timeline is now scheduled for September 2021 to March 2023.

## Phased Implementation to ensure smooth transition for licensees

Implementing HCS Regulations in Phases		
Phase 1 September 2021	Phase 2 June 2022	Phase 3 March 2023
1. General Regulations 2. Advertisement Regulations <u><b>Clinical Support Services</b></u> 3. Clinical Laboratory Service 4. Radiological Service 5. Blood Banking Service 6. Tissue Banking (cord blood) Service <u><b>Special Services</b></u> 7. Nuclear Medicine Imaging Service 8. Nuclear Medicine Assay Service <u><b>Non-Premises Based Services</b></u> 9. Emergency Ambulance Service 10. Medical Transport Service	<u><b>Non-Premises Based Services</b></u> 11. Telemedicine Service <u><b>Ambulatory Care Services</b></u> 12. Medical Clinic (including Mobile Medicine) Service 13. Dental Clinic Service 14. Health Screening Service 15. Ambulatory Surgical Centre Service 16. Renal Dialysis Centre Service <u><b>Special Services</b></u> 17. Assisted Reproduction Service 18. Radiation Oncology (including Proton Beam Therapy) Service 19. Blood Transfusion Service 20. Nuclear Medicine Therapy Service <u><b>Clinical Support Services</b></u> 21. Tissue Banking (human tissue; reproductive cell and/or embryo) Service	<u><b>Hospital Services</b></u> 22. Acute Hospital Service 23. Community Hospital Service <u><b>Long Term Care Services</b></u> 24. Nursing Home Service 25. Inpatient Palliative Care Service <u><b>Special Services</b></u> 26. Cell, Tissue and Gene Therapy Service 27. Clinical Genetic and Genomic Service 28. Organ Transplant Service 29. Specialised Interventional Procedures Service

This will replace the Private Hospitals and Medical Clinics Act of 1980 which was last amended in 1999.

The broadened scope of the new Healthcare Services Act will include healthcare services, allied health and nursing services, traditional medicine and complementary and alternative medicine. It aims to better safeguard the safety and well-being of patients amidst the changing healthcare environment while enabling the development of innovative services that benefit patients. It will also strengthen governance and regulatory clarity for better continuity of care to patients and address wider issues of patient welfare.

## CONCLUSIONS

Analyses of telemedicine and mobile tele-health illustrate that, while technology issues, such as security and privacy considerations remain key factors that will determine the rate of adoption of telehealth, the non-technological challenges, are equally, if not more, important. In the U.S. health eco-system, these include

organizational, including regulatory, and revenue-model issues. The above analyses thus suggests that rapid mobile healthcare adoption can only be achieved when, on the one hand, the service platform, (perhaps more importantly) the organizational and revenue model, and on the other the interface and to a lesser extent the value proposition are all adequately addressed.

While traditional discussions on the cost and benefits of tele-health have been focused on the health provider, insurance company and patient, as the benefits of tele-health accrue to other potential parties, as this paper has argued, these non-traditional stakeholders must be included. These would include the national telecommunications service providers, equipment manufacturers, software services providers, major corporations and the state, with one these stakeholders perhaps acting as a “keystone” player.<sup>93</sup> In the case of Singapore, the government has adopted this role. However, there is currently relatively little federal government financial support in the U.S. to facilitate either mobile health or telemedicine.

Ironically, the SARS-CoV-2 pandemic accentuated the value of tele-health and self-monitoring, as previously discussed. The Centers for Disease Control (CDC) recently released data showing that the significant increases in deaths in the United States due to Alzheimer's and Parkinson's disease, chronic liver disease, stroke, high blood pressure and diabetes, could have been avoided if a tele-health system had been in place.

## REFERENCES

1. Darkin A, Ryan P, et. al. Care Coordination/Home telehealth: The systematic The Systematic implementation of health informatics home telehealth, and disease management to support the care of veteran patients with chronic conditions. *Telemedicine and e-Health*. 2008;14(10):1118-1126.
2. Institute for Health Metrics and Evaluation, "National spending on health by source for 184. countries between 2013 and 2040," <http://www.healthdata.org/research-article/national-spending-health-source-184-countries-between-2013-and-2040>
3. Centers for Medical and Medicaid, Health Expenditures, <https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/NationalHealthAccountsHistorical.html>
4. HIS Market: Global healthcare spend to remain stable. <https://ihsmarkit.com/research-analysis/global-healthcare-spend-to-remain-stable.html>
5. Reuters, "Heath care spending to climb 5.3% in 2018", <https://www.reuters.com/article/us-usa-healthcare-spending/u-s-healthcare-spending-to-climb-5-3-percent-in-2018-agency-idUSKCNIFY2ZD>
6. Bashur et. al. The empirical foundations of Telemedicine interventions in primary care. *Telemedicine and e-Health*. 2016;22(5):342-374
7. Donlok K, James E. Cabral Jr. and Yongmin Kim. 1995. Networking requirements and the role of multimedia systems in Telemedicine. <http://icsl.ee.washington.edu/projects/gsp9/spie1095>
8. Teyhen D, Edinborough E, et. al. Leveraging technology: Creating and sustaining changes for health. *Telemedicine and e-Health*. 2014;20(9): 835-848.
9. Stobbe, M US deaths from heart disease and diabetes climbed amid COVID, Associated Press, 6/9/2021. <https://www.msn.com/en-us/news/us/us-deaths-from-heart-disease-and-diabetes-climbed-amid-covid/ar-AAKSmau?li=BBnb7Kz>
10. Chen S, Cheng BS, K Mehta. A review of business models. *Telemedicine and e-Health*. 2013;19(4):287-297
11. Rogove H, McArthur D, Demaershalk B, Vespa P. Barriers to telemedicine: Survey of current users in acute care units. *Telemedicine and e-Health*. 2012;18(1):48-53.
12. Larsen D, Hudnall Stamm B, Davis K, Magaletta P. Prison telemedicine and teleHealth utilization in the United States. *Telemedicine Journal and e-Health*. 2004;10(2):S81-S89.
13. Bin-Abbas B, Jabbari M, Al-Fares A, El-Dali A, Al-Orifi F. Effects of mobile phone short text messages on glycemic control in children with type 1 diabetes. *Journal of Telemedicine and Telecare*. 2014;20(3):153-156.
14. American Lung Association, [www.lungusa.org/site/pp.asp?c=dvLUK9O0E&b=35020](http://www.lungusa.org/site/pp.asp?c=dvLUK9O0E&b=35020), 2007.
15. Czaja S, L CC, Arana N, Nair S, Sharit J. Use of telehealth systems by older adults with hypertension. *Journal of Telemedicine and Telecare*, 2014; 20(4):181-191.

16. Seibert PS, Whitmore T, Patterson C, Parker PD. Telemedicine facilitates CHF home health care for those with systolic dysfunction. *International Journal of Telemedicine and Applications*, 2008.
17. Phillips Medical System. Ten-HMS Study Demonstrates Clinical and Financial Efficacy of Home Monitoring Phillips Medical Systems, 2003.
18. MIT MoCa Team. MOCA: Mobile Telehealth for Rural Communities, 2009.
19. Thrift AG, Thayabaranathan T, Howard G, et al. Global stroke statistics. *Int J Stroke*. 2017;12: 13–32.
20. Benjamin EJ, et al. Heart disease and stroke statistics – 2017 update: a report from the American Heart Association. *Circulation* 2017;135: e146–e603.
21. Chalouhi N. et al. Intravenous tissue plasminogen activator administration in community hospitals facilitated by telestroke service. *Neurosurgery* 2013; 73: 667–671.
22. S.Kasab et. al. Beyond acute stroke: Rate of stroke transfers to a tertiary center following the implementation of a dedicated inpatient teleneurology network. *Journal of Telemedicine and Telecare* 2021; 27(4): 239–243.
23. M. Asano et. Al. Home-based tele-rehabilitation presents comparable positive impact on self-reported functional outcomes as usual care: The Singapore Tele-technology Aided Rehabilitation in Stroke (STARS) randomized controlled trial. *Journal of Telemedicine and Telecare, Journal of Telemedicine and Telecare* 2021, Vol. 27(4) 231–238.
24. Bjorkdahl A, Nilsson AS, Grimby G, et al. Does a short - period of rehabilitation in the home setting facilitate functioning after stroke? A randomized controlled trial. *Clin Rehabil* 2006; 20: 1038–1049. 11.
25. Roderick P, Low J, Day R, et al. Stroke rehabilitation after hospital discharge: a randomized trial comparing domiciliary and day-hospital care. *Age Ageing* 2001; 30: 303–310. 12.
26. Sarfo FS, Ulasavets U, Opare-Sem OK, et al. Tele-rehabilitation after stroke: an updated systematic review of the literature. *J Stroke Cerebrovasc Dis* 2018; 27: 2306–2318.
27. Johansson T and Wild C. Telerehabilitation in stroke care – a systematic review. *J Telemed Telecare* 2011; 17: 1–6.
28. National Association of Home Care and Hospice, Basic Statistics About Home Care, 2010. [http://www.nahc.org/facts/10HC\\_Stats.pdf](http://www.nahc.org/facts/10HC_Stats.pdf)
29. Pinnock, H. et. al. Professional and patient attitudes to using mobile phone technology to monitor asthma. *Primary Care Respiratory Journal*. 15:237-245.
30. Kassir K. et. al., Use of Telemedicine for Management of Diabetes in Correctional Facilities. *Telemedicine Journal and e-Health*, 2017;23(1):55-59.
31. Martinez-Ramos C, Cerdan MT, Lopez RS. Mobile phone-based telemedicine system for the home follow-up of patients undergoing ambulatory surgery. *Telemedicine and e-Health*. 2009;15(6):531-537.

32. Kerney, H. et. al. Evaluation of a mobile phone based, advanced symptom management system (ASmMSC) in the management of chemotherapy-related toxicity. *Supportive Care in Cancer*; 17(4); 437-444
33. The Economist. The doctor in your pocket. *The Economist*. 2005; 376 (8444); 8
34. Mort M, May CR, Williams T. Remote doctors and absent patients: acting at a distance in telemedicine? *Science, Technology & Human Values*. 2003; 28(2); 274-295.
35. Kulkarni S, Agrawal P. Smartphone driven healthcare system for rural communities in developing countries. *Proceedings of the 2nd International Workshop on Systems and Networking Support for Health Care and Assisted Living Environments*, 2008.
36. Luk R, M. Ho M, Aoki PM. Asynchronous remote medical consultation for Ghana, CHI 2008 *Proceedings. Healthcare in the Developing World*, 2008.
37. Wootton R. *Telehealth in the Developing World*, London. UK: Royal Society of Medicine Ltd; 2009.
38. Jubbawey A. The potential of person centric wireless mobile devices and telehealth solutions: Sustaining rising healthcare costs and providing quality care. Paper presented at the *Proceedings of Health Informatics New Zealand*, 2009.
39. Agrell H, Dahlerg, S, Jerant AF. Patients' perception regarding home telecare. *Telemedicine Journal and e-Health*. 2000; 6 (4): 409-415.
40. Rahimpour M, Lovell N, Celler B, McCormick J. Patient's perception of a home telecare system. *International Journal of Medical Informatics*. 2007;77(7): 486-498.
41. Demiris G, Rantz MJ, et al. Older adults' attitudes towards and perceptions of "smart home" technologies: A pilot study. *Medical Information*. 2004; 29 (2): 87-94.
42. Pereira F. *Digital Home Survey, 2008-2011*. Institute for Communications Technology Management, University of Southern California, Los Angeles, 2011.
43. Gardner-Bonneau D, "Untapped Potential: Speech Technologies and the Home Health Care Market," *Speech Technology*, March 1, 2006, <http://www.speechtechmag.com/Articles/ReadArticle.aspx/ArticleID=30071>
44. Varshney U. Pervasive healthcare and wireless health monitoring. *Mobile Network Applications*. 2007;12:113-127.
48. Lewis C. My computer, my doctor: A constitutional call for Federal regulation of cybermedicine. *American Journal of Law and Medicine*. 2006;32(4):585-609.
46. Charles B. Telemedicine can lower costs and improve access. *Healthcare Financial Management*. 2000;54(4): 66-69.
47. Wasley TP, What has government done to our health care? Washington, DC: Cato Institute, Washington D.C., 1992.
48. Garcia C, Urdiales F, et al. On practical issues about interference in telecare applications based on wireless technologies. *Telemedicine and e-Health*. 2007;13(5):519-533.

49. Lunden I. Plenty of scope for networking in healthcare industry. Financial Times, February 11, 2008, pp 6.
50. Wartena F. The impact of a personal telehealth ecosystem. Paper presented in the Proceedings of International Conference on eHealth, Telemedicine, and Social Medicine (eTELEMED), 2009.
51. National Institute of Justice, Implementing telemedicine in correctional facilities, 2002. Report no. NCJ 190310. Washington, DC, U.S. Department of Justice.
52. Uscher-Pines L, Kahn M. Barriers and facilitators to pediatric emergency telemedicine in the United States. *Telemedicine and e-Health*. 2014;20(11):990-996.
53. Hammack G. Redefining Telemedicine. September 20, 2006.  
[http://www.healthmgttech.com/archives/1006/1006redefining\\_telemedicine.htm](http://www.healthmgttech.com/archives/1006/1006redefining_telemedicine.htm)
54. Smith, D. The influence of financial factors on the deployment of telemedicine. *Journal of Health Care Finance*. 2005;32(1):16-27.
55. Gagnon M, Lamothe L, Fortin JP, Cloutier A, Telehealth adoption in hospitals: An organizational perspective. *Journal of Health Organization and Management*, 2005;19 (1): 32-56.
56. Yang X, Hui C. *Mobile telemedicine: A computing and networking perspective*, Boca Raton, Florida: CRC Press, 2008.
57. LeRouge C, Tulu B, Forducey P. The business of telemedicine: Strategy primer. *Telemedicine and e-Health*. 2010;16(8):898-909.
58. Ahrensbrak R, et al. Key substance use and mental health indicators in the United States: Results from the 2016 National Survey on Drug Use and Health. Center for Behavioral Health Statistics and Quality, Substance Abuse and Mental Health Services Administration: Rockville, MD, USA. 2017.  
<https://www.samhsa.gov/data/sites/default/files/NSDUH-FFR1-2016/NSDUH-FFR1-2016.htm#summary>
59. Mental Health America. Mental health treatments.  
<http://www.mentalhealthamerica.net/types-mental-health-treatment>
60. Zhao, X et al. Facility and state-level factors associated with telemental health (TMH) adoption among mental health facilities in the United States. *Journal of Telemedicine and Telecare* 2021, Vol. 27(4) 244–257
61. Statura M. Telemedicine/tele-health: A national development tool and economic engine. *International Journal of Economic Development*, 2006;18 (3): 679-681.
62. Hoppszallern S. Bridging the Distance. HHN Most Wired Magazine, April 2007.  
[http://www.hhnmostwired.com/hhnmostwired\\_app/jsp/articledisplay.jsp?dcrpath=HHNMOSTWIREDPubsNewsArticlesMostWired/data/07/Winter/07MW\\_Winter\\_DataSet&domain=HHNMOSTWIREDD](http://www.hhnmostwired.com/hhnmostwired_app/jsp/articledisplay.jsp?dcrpath=HHNMOSTWIREDPubsNewsArticlesMostWired/data/07/Winter/07MW_Winter_DataSet&domain=HHNMOSTWIREDD)
63. Nagy, B. Telemedicine's depth now going beyond rural areas. *Managed Healthcare Executive*, 2006; 16 (9): 62-64.

64. Effertz G. et. al. Sustaining and expanding Tele-health: A survey of business models from selected prominent U.S. Telehealth centers. *Telemedicine and e-Health*. 2017; 23(2):137-142.
65. Tangalos EG. Telemedicine: An information highway to save lives. Written testimony to the Telemedicine hearing before the Subcommittee on Investigations and Oversight, Committee on Science, Space and Technology, U.S. House of Representatives, 103<sup>rd</sup> Congress, 1994, U.S. Government Printing Office.
65. McCue M, Palsbo S. Making the business case for telemedicine: An interactive spreadsheet. *Telemedicine and e-Health*. 2006;12(2):99-106.
67. Muirhead, G. An update on telemedicine. *Patient Care*, 2000; 34 (6): 90-109.
68. Bowles K, Baugh A. Applying research evidence to optimize telehomecare. *Journal of Cardiovascular Nursing*, 2007; 22 (1): 5-15.
69. Jodar-Sanchez F, Ortega F, et. al. Implementation of a telehealth programme for patients with severe chronic pulmonary disease treated with long term oxygen therapy. *Journal of Telemedicine and Telecare*, 2013; 19(1):11-17.
70. Kothapalli P, Bove A, Santamore W, Homko C, Kashem A. Factors affecting frequency of patient use of internet-based telemedicine to manage cardiovascular disease risk. *Journal of Telemedicine and Telecare*. 2013; 19(4):205-208.
71. Chen MJ, Chen KY, et. al. A telehealth service model for the treatment of hypertension. *Journal of Telemedicine and Telecare*. 2013; 19(5):238-241.
72. Sorknase A, Bech M, et. al. The effect of real-time teleconsultations between hospital-based nurses and patients with severe COPD discharged after an exacerbation. *Journal of Telemedicine and Telecare*. 2013;19(8) 466-474.
73. Alcherod, D. Policy expectations and reality of telemedicine – a critical analysis if health care outcomes, costs and acceptance for congestive heart failure. *Journal of Telemedicine and Telecare*. 2014; 20(4):192-200.
74. Shoor R. Long-distance medicine: Telecommunication promises to deliver better care. *Business and Health*. [http://findarticles.com/p/articles/mi\\_m0903/is\\_n6\\_v12/ai\\_15496262](http://findarticles.com/p/articles/mi_m0903/is_n6_v12/ai_15496262) June 1994
75. Entner R, Lewin D. The impact of the US wireless telecom. Ovum, September 2005.
76. Wang T, et. al. Assessment of utilization and cost-effectiveness of Telemedicine program in Western regions of China. *Telemedicine and e-Health*, 2016; 22(11):909-920
77. Marcolino M. et. al. The experience of a sustainable large scale Brazilian Telehealth network. *Telemedicine and e-Health*, 2016; 22(11): 899-908
78. Davalos M, French M, Burdick A, Simmons S. Economic evaluation of telemedicine: A review of the literature and research guidelines for cost-benefit analysis. *Telemedicine and e-Health*. 2009;15(10):933-948.
79. Schweitzer J, Synowiec C. The Economics of eHealth. Results for Development Institute, 2010.

80. OECD. Improving Health Sector Efficiency: The Role of Information and Communication Technologies. Paris, OECD, 2009.
81. Healthcare Business Market Research Handbook, Pharmalicensing Limited, 2006, Retrieved February 11, 2007.  
<http://pharmalicensing.com/intelligence/reportsearching.php?action=toc&productID=1211311>
82. Lohr S. Most doctors aren't using electronic health records. New York Times, June 19, 2008.
83. Latifi R. Current principles and practices of telemedicine and e-health. The Netherlands: IOS Press, 2008.
84. Koonin L. et al. Trends in the Use of Telehealth During the Emergence of the COVID-19 Pandemic — United States, January–March 2020. Centers for Disease Control.  
<https://www.cdc.gov/mmwr/volumes/69/wr/pdfs/mm6943a3-H.pdf>
85. Frost and Sullivan, Telehealth—A Technology-Based Weapon in the War Against the Coronavirus, 2020
86. Moreland A, et al. Timing of state and territorial COVID-19 stay-at-home orders and changes in population movement. Centers for Disease Control, Morbidity and Mortal Weekly Report 2020;69:1198–203. <https://doi.org/10.15585/mmwr.mm6935a2>
87. International Trade Administration, Singapore Licensing of Telemedicine. ITA, Department of Commerce, International Trade Administration, 4/26/21 <https://www.trade.gov/market-intelligence/singapore-licensing-telemedicine-1>
88. Ngoh CL et al. Rapid Transition to a Telemedicine Service at Singapore Community Dialysis Centers During Covid-19. *NEJM Catalyst* May28, 2020.
89. Chia, ES. Singapore's Smart Nation Program – Enablers and Challenges  
[https://www.researchgate.net/publication/306113634\\_Singapore%27s\\_smart\\_nation\\_program\\_-\\_Enablers\\_and\\_challenges](https://www.researchgate.net/publication/306113634_Singapore%27s_smart_nation_program_-_Enablers_and_challenges)
90. Infocomm Development Authority of Singapore, 2010. iN2015 Masterplan,  
<http://www.ida.gov.sg/Tech-Scene-News/iN2015-Masterplan> accessed 4 May 2015.
91. iHIS Integrated Information Services Annual Report 2018,  
[https://www.ihis.com.sg/About\\_IHIS/Documents/IHIS0110\\_18%20Annual%20Report%202016\\_17\\_05Dec18\\_FA.pdf](https://www.ihis.com.sg/About_IHIS/Documents/IHIS0110_18%20Annual%20Report%202016_17_05Dec18_FA.pdf)
92. Ministry of Health, Singapore. MOH Launches First Regulatory Sandbox to Support Development of Telemedicine <https://www.moh.gov.sg/news-highlights/details/moh-launches-first-regulatory-sandbox-to-support-development-of-telemedicine>
93. Iansiti M, Levien R. Strategy as ecology. Harvard Business Review, 2004. March: 68-78.