

TELEMEDICINE PRE AND POST COVID-19: LESSONS FOR COMMERCIALISATION BASED ON PREVIOUS USE CASES

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Abstract

Telemedicine used to be slow, difficult, expensive and widely neglected by doctors and patients. COVID-19 changed everything; telemedicine is entering a period of rapid economic and business growth. This paper discusses the reasons for change in telemedicine over the last 20 years, through real-life medical technology projects, telemetry, ehealth and health IT. Our methods are based on the analysis of telemedicine projects we have implemented and characteristic historical data. The results of our investigation demonstrate a clear increase of significance in telemedicine in the present and near future. We envision the evolution of mobile phones to personal telehealth monitors. Prior to COVID-19, market penetration and economic factors of telemedicine evolved slowly and in an uneven manner on a global scale. Many of the projects remained active only as long as the grant or corporate or national support was provided. The age of novel globally spreading infectious diseases, exemplified by COVID-19, has created an unusual, different setting. Recent pandemics and epidemics have changed global economics significantly and generated a new motivation and a new market with a projected trillion-dollar market value. Post COVID-19, regular and periodic epidemics and pandemics are expected to continue to occur. This will generate an enormous global market for isolated high-tech services, including telemedicine and telemetry.

Keywords: COVID-19; telemedicine; health system; respiratory diagnostics; cardiology

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Introduction

We have been observing secure telemedical systems since 1999^{1,2} and have initiated and participated in a number of telemedical projects, including IsfTeH (International Society for Telemedicine and eHealth) driven projects³ and national programmes.⁴⁻⁸ After 20 years, we have to admit that telemedicine so far had a slower growth than expected during its inception, as we will demonstrate with examples mainly from Europe, USA, and Australia. Even though some areas were relatively successful, many of the general concepts turned out to face obstacles in the highly conservative medical community as there was a lack of financing from the public sector.

In this paper we address some of the economic, administrative, legal, security and other reasons of the slow progress so far.⁹⁻²⁹ In addition, we elaborate on the effect of the expected impact on the telemedical services industry of the recent global virus outbreaks, epidemics and pandemics.³⁰⁻³¹

State of the art

Telemedicine can provide medical care from a distance.^{8,27,31} It also helps in the integration of healthcare data and services.²⁵ Moreover, the technology cuts the cost of care.^{12-14,28,32-37} Telemedicine has an invaluable role in case of emergencies in remote settings.²⁷ Telemedicine also offers benefits to the remote or rural areas where there are relatively few doctors.³⁸ In this situation it improves access to health care, reducing the need for patients or doctors to travel. Even in urban areas, introduction of telemedicine has been shown to speed up the referral process, to reduce unnecessary referrals, and to improve the consistency and quality of health care. Early advice from a specialist in an emergency improves the care of sick and injured patients.^{20,39} Telemedicine also offers advantages in cases where moving a patient may not be desirable.⁵ Telemedicine allows the possibility of changing the mix of skills in remote areas, such as by means of nurse practitioners.³¹ A small proportion of the workload can be utilised by installing a low-cost telemedicine link. Finally, telemedicine can be used to care

about isolated, infectious patients or when the doctors themselves are in isolation and to share data by electronic means with effective infection control.³¹

A range of standards exists for data sharing among medical professionals,^{4,40-42} stemming from medical data storage and from telecommunications. Data security, efficiency, availability and compatibility are all high priorities in telemedicine.^{40,43}

Barriers to commercialisation

Telemedicine technologies are abundant and well developed in some parts of the world, yet, they have not managed to spread globally, for the following reasons.

Economic factors: Healthcare financing is distributed unevenly: On the global scale, notably in the developed world, Big Pharma receives a large ratio of public funding, government support is usually less for medical devices, and typically very little for home care medical technology products.⁴⁴

Administration and bureaucracy: certificate requirements make medical devices expensive and thus difficult to pay for out-of-pocket by the end users, telemedical data processing is rarely supported by local healthcare administration, healthcare specialist resources are scarce and primary care centres are typically overloaded. A rare positive example used to be Australia where a limited niche of the healthcare sector used to be available for telemedical data processing. At the time of writing, there is a lot of uncertainty in the continued Medicare financing of telemedical services in Australia.

Data protection and security: Data security is always an issue in all online services, however, we intend to contribute in providing solutions on data security for telemedicine⁴³ to provide a secure access to underlying data in a relational database. We have experienced a number of data security challenges in telemedicine. A characteristic example was in telerespiratory diagnostics.^{21,29,45,46} (Table 1)

In particular, a telemedicine implementation in France had to avoid transferring any patient information over the

Internet. This raised a challenge, which was solved in the pilot project by filling up the patient database on an alternative communication channel on both sides and sending only a unique, encoded patient ID over the network, togetherwith the encoded measurement.^{47,48} Data security remains a key challenge in all telemedical applications, the reason for potential hazards is increasingly human error, and not due to technology limitations. Encryption technologies have evolved with the availability of computation power and cloud computing resources. In addition, higher data transfer speed including introduction of 5G technology enables an increased use of telemedicine even in remote areas where traditional land-based Internet connections are not feasible.

Legal framework: medical data security, legal responsibility, lack of regulation in electronic prescriptions and remote diagnostics and therapy are all barriers to telemedicine. However, with the recent retraction of globalisation and decoupling of economies the legal settings are also getting more disjunct. There is an increasing opportunity for cross-border services to decouple jurisdictions and therefore use legal backdoors to spread the use of telemedicine.²⁷

Lack of motivation: patients, healthcare systems, and medical service providers need to be incentivised by economic and other factors. A positive example is the private insurance sector; objective health data can define risks and therefore limit costs of the medical insurance. A number of private insurance targeted projects have been implemented in the USA, Germany, South Africa.^{31,44,49}

Use case scenarios

Telerespiratory diagnostics

In this section, we present real-life scenarios of various telemedicine projects including telepulmonary diagnostics, telecardiology and teleradiology, that underpin earlier efforts and the observed barriers to commercialisation.

In 2009, a large study was conducted with home pulmon-

Table 1. Evolution of telerespiratory diagnostics.

	Date of implementation	Level of telecommunications	Region(s)	Project funding	Illustration
Tele-pulmonary diagnostics POTS	1999-2002	Plain Old Telephone System, modem service level protocol	Italy, USA	Grant, private investment	
Bluetooth respiratory diagnostics + JAVA software	2003-2006	JAVA app running on PDA or Nokia 3310, communication via SMS, MMS.	European Union only.	eHEALTH8, EU + national grant	
BLE 4 respiratory diagnostics	2010-2012	TCP/IP over GSM, WIFI, 3G, 4G+.	Global	National grant+ private funding	

ary diagnostic devices deployed at patients' homes.^{1,2} The data were transmitted to a central server by means of telecommunications. The following main barriers were observed:

1.) The devices require patient compliance. A large number of the tests were unusable due to misuse and mishandling of the devices or incorrect use. This issue was addressed and later more advanced devices were developed which could train the patients for their own use, and an intelligent algorithm was developed to automatically correct identified patient mistakes. However, this made the device relatively expensive and thus an additional barrier to home care distribution.

2.) The incoming amount of data was very large and difficult to manage. Medical staff typically have a very limited amount of time available especially for administration, therefore the manual processing of the data was expensive and seriously limited. To overcome this issue, a medical decision support system was developed which speeded up the data management. Automated notifications were introduced with pre-defined thresholds. However, this introduced false positive notifications and warnings. The implementation of artificial intelligence (AI) methods was initiated to process the data and to generate an automated diagnosis. This, however, raised a number of potential legal issues and led to strong resistance from medical professionals. This issue reached the levels of the central administration in the EU. Without proper legislation, it will not be possible to introduce such methods. Regulations have evolved since then and this obstacle is increasingly addressed globally.

3.) The underlying telecommunication technology has evolved rapidly and significantly in the last 20 years. An early telepulmonology solution was implemented with POTS (Plain Old Telephone Systems) with a low-level modem protocol.¹ With the rapid spread of the GSM systems, this quickly became obsolete. The first GSM application was developed on Nokia mobile phones running the Symbian operating system and the application was written in JAVA. The communication protocol between the medical device and the mobile phone was by Bluetooth. The Symbian operating system soon became obsolete and the next application had to be developed on the Microsoft mobile operating system (an interim application was developed for the GEOS on the Nokia Communicator). The Bluetooth standard evolved later with Low Energy and other extensions, as well as ZIGBEE and other interim protocols were developed in consecutive applications. Now, the current ANDROID operating system, as well as Apple IOS and the rising Huawei operating systems are dominant; however, the situation is changing rapidly. Such quick changes in the underlying environment require continuous development and frequent software releases, which in turn requires an expensive infrastructure. Due to the fact that medical devices are relatively niche markets with relatively low sales quantities compared to telecommunications equipment, and that medical devices

sometimes require more stringent quality control than telecom equipment, it is obviously difficult to follow the extreme speed of evolution in telecommunication interfaces and standards and their implementation in medical devices.

4.) Centrally financed studies were successful; however, there was little organic progress driven by the open markets. Patients have a psychological limit up to which they are willing to pay for a medical device, and this limit is heavily defined by the general living standard of the observed region. So far, the dominant markets were developed in democratic countries with advanced social security systems. A large number of patients demand comprehensive medical services from the state or by their primary insurer. They are unwilling to pay extra out of their own pocket, especially for diagnostics and monitoring. This situation is changing due to the rise of China, which has a very different medical system and rapidly evolving centrally governed healthcare services, with a large gap in primary and home care services, which are evolving in an organic manner. Another driving factor is the combination of telemedical devices with novel drugs. Proper drug administration may be a driving force behind distributed telemedical services on advanced markets, if the solution is picked up and supported by large pharmaceutical companies like Novartis, GSK or Pfizer. A number of telemedical, drug administration and drug compliance start-ups have been acquired by major pharmaceutical companies recently, a clear sign of their expectation to see this market grow (e.g. Teva acquired Amwell, Novartis and Roche invested in Nuvoair, Novartis acquired Amblyotech, Optum acquired naviHealth, Resmed acquired Propeller Health, etc).

5.) Bureaucratic red tape often impedes innovation. All aspects of medical device development, manufacturing, quality control, certification, international sales and distribution have become significantly more bureaucratic in recent years. This is said to be driven by the spread of unsafe methods and devices, but to a large extent, the real reasons include market protection and the dominance of large organisations defining the standards. Overly excessive requirements for medical device certificates make the devices expensive and projects impractical unless they are large scale and global. It does not make sense to manufacture only a few hundred devices dedicated to a limited market, because due to the small scale production and the excessive bureaucratic overhead the outcome would be too expensive and cost-prohibitive for patients as explained above.

Pharmaceutical testing

Telemedical technologies have been applied successfully in pharmaceutical testing studies, including validation of asthma drugs.⁵⁰ Childhood asthma ranges from a very mild chronic condition, which may disappear almost completely by the time the subject grows up, to a serious, life-threatening disease. Some of the drugs, including bronchodilators, are administered by metered dose inhalers (MDI), and the dosage is static, and rarely adjusted properly. Some of the side effects may include cardiovascular morbidities, the effects of

which need to be minimised and also closely monitored.

During a pilot project in 2007, home monitoring medical devices were supplied to the parents of the children taking certain novel respiratory drugs.⁵¹ The devices included a home respiratory diagnostic system with an embedded proprietary sensor technology^{52,53} and later a nitric oxide (NO) diagnostic system. The drug was typically administered in the evening, before the child went to sleep. The parents were instructed to perform the measurements on their child with the provided medical devices. Using a GSM protocol, the data were sent to a doctor / medical professional who reviewed it and instructed the parents whether the drug was to be taken for the night or not. Should the child take the drug for the night with no actual need for it, the side effects could do more harm than good. On the other hand, should the child not take the drug when there was a real need for it (e.g. due to a low FEV1/FVC value or poor lower airways parameters or an increased NO level indicating acute inflammation), the exacerbation may have caused lung tissue damage. Therefore, the direct and immediate feedback indicating whether to take the drug or not may limit morbidity, even be life-saving for certain children.

Long term monitoring for the effects of baby formula

A comparison study was implemented to understand the development of childhood asthma and allergy by monitoring the immune system of infants and children.^{39,54,55} A large pan-European study, with an operation centre in Germany was extended with telemedical means. The study observed the effects of baby formula on the development of the immune system of children. Danone Corp (Milupa) was actively seeking the latest technologies to monitor the development of children, including allergy and asthma. The Frankfurt operational centre introduced telemedicine, including telepulmonology,^{52,53} to collect the data from participants. The data were stored and processed for 15 years. A network edition of a medical monitoring software system was developed to support the distributed collection of data from various sites.

Telemedical gateways

Classic telemedical gateways have been around since the birth of telemedicine. This is an early scenario, which is still viable and has been implemented in a number of projects. Yet, still, its global use is limited, mainly due to the reasons already elaborated above.

Denmark was a first mover in the development and introduction of telemedical hubs. A dedicated telerespiratory diagnostics interface was provided for the MedCom Hub in 2009 to monitor 800,000 unstable chronic obstructive pulmonary disease patients from their homes and a project for tele-wound management has also been initiated.⁵⁶ Denmark introduced Electronic Health Records in 1996, and initiated a national eHealth strategy in 2003.⁵⁶ Plans were made for the extension of the ePrescribing system to arrive at a personal medication profile stored on a national prescription server, and 29 individual initiatives in the

eHealth domain were agreed on. Initially, a simple medical device interface was implemented via a serial RS232 connection and a dedicated software which transferred only three main parameters: FVC, FEV1, PEF. The communication interfaces between the telemedical gateway and the diagnostic and monitoring devices have evolved significantly since then.

Telemedicine Australia Corp. was established by Dr. Ash Collins in Temora, NSW. Dr. Collins, a medical doctor, was a first mover in telemedicine in rural New South Wales. Temora is an optimal location to start a telemedical centre: it is located in a rural area of the continent, it is conveniently far from main capital areas, yet it is accessible within a reasonable time (about 5 hours drive) from Sydney. Dr. Collins influenced the developments of Insung, a Korean manufacturer of a telemedical hub, in integrating a number of TGA (Therapeutic Goods of Australia) approved medical devices to the central hub. One of them was a respiratory diagnostic device^{48,52} designed for easy remote use and another was a professional ECG. Later the project evolved into My Online Clinic, an online platform for telemedicine in Queensland and New South Wales. The use case of this Australian telemedical system was built on pharmacies: a patient may go to a nearby pharmacy, where the complex telemedical station is installed. The patient may initiate a consulting session with a remote doctor, who may be in a rural area and may have more time available than local doctors. The doctor instructs the patient (via video link) to use the medical diagnostic devices attached to the telemedical station and perform self-diagnostic manoeuvres. The results are displayed on the remote doctor's monitoring station. The doctor may prescribe medication and the prescription is transferred to the telemedical hub, which prints it and the patient may purchase the drug right at the pharmacy. The same model was placed on offer in a major project in France, and Insung has since built it into their global offerings.³⁸

In the U.S.A, the Veterans Affairs (VA)⁵⁷ supported and funded a large scale national telemedical system, a selected respiratory diagnostic and monitoring technology was integrated, and a pilot study was implemented involving over 2,000 veterans in age care centres and in their own homes. The key reason was to save on the cost of medical staff (community nurses) spending time with the veterans in their homes, with the veterans using videoconferencing to connect to their healthcare providers and monitor themselves for their chronic diseases in their own home.

Barriers included the fact that the projects were selected based on a national tendering process, which included a large number of telemedical stations and accessories to be deployed in one tender; however, in an eventual tender a completely different set of devices were acquired and deployed, which were usually incompatible with the previous ones, due to the lack of standards and exact national regulations at that time. Also, the entire system was available

only for U.S. army veterans, and there was no spin-off to the public. Unfortunately, the project administration was managed according to the requirements of the military administration. It was a closed system without any chance to evolve into a publicly available service.

Telemedicine Australia³⁸ was initially supported by Mark Powley as well in New Zealand. Powley came from telecommunications and started a number of rural medical technology projects prior to engaging in telemedicine. Later, he moved on to support a platform by Embedded Wireless Systems (Malaysia), and low level interface protocols were implemented to comply. The Embedded Wireless telemedical hub systems required a low level communication protocol which was hard to implement and negotiate by medical device suppliers. In parallel, Insung's technology evolved further with intelligent, cooperative protocols. Hence, over a hundred medical devices of all kind have been integrated with Insung, and later, the New Zealand based system returned to support the Insung solution. Powley expanded the telemedical services later to Thailand, where the local government was less generous in their technical and financial support to remote communities. Recently he returned to New Zealand and continued his work on supporting rural areas with government financed telemedicine solutions.

Several pilot projects were prepared in Europe under the AAL (Ambient Assisted Living) framework, supported by European Union grants. In our experience, many of such projects lasted as long as the government funding was there, eventually either the consortiums and disseminations discontinued or continued on a very small scale.⁵⁹ Several projects in the field of dementia home monitoring were implemented by the Zoltan Bay Institute, the Austrian Institute of Technology, Bayern Innovative, Fraunhofer Institute, Ludwig Boltzmann Institute, Karolinska Institute, University of Munich, Coventry University, and various other European universities and institutes.^{3,58}

A key area was monitoring and caring for people with dementia, which used to be a heavy burden in Europe and most of the developed world. Cost-efficient technologies and remote monitoring are now widely implemented, however, the bottleneck is usually the monitoring itself. Major issues in the penetration of telemedical technologies included the cost of maintenance, false alarms, the cost of monitoring and action.

Telecardiology,⁵¹ including home care ECG is spreading in telemedicine, however, the issues are similar to those in telepulmonology; mainly expense, central processing, bureaucracy and central administration. A promising trend is the spread of fitness trackers which are not considered to be medical devices, and hence they do not require the stringent certification procedures that make medical devices generally expensive and hard to sell. However, the issue with these relatively cheap devices is that the data they generate cannot be used for serious medical-grade monitoring. There is an

interim grade of devices evolving, the technologies supported by global electronics companies like Analog Devices. A research and development project was initiated regarding ambulance based high-end cardiac diagnostics. In this project the data were sent ahead from the ambulance to the hospital and by the time the ambulance arrived, the cardiologist was ready for any intervention.⁴⁹ Mahmood et. al⁵⁹ demonstrated an algorithm to detect cardiac abnormalities from compressed ECG data which can be useful in case of transferring large amount of data e.g. from an ambulance on the way to the hospital.

An EU grant-supported telecardiology project was about automation of objective health assessment data in sub-Saharan countries for patients seeking private insurance. The ECG was recorded in Africa and evaluated in Europe, the results were returned to Africa with recommendations.⁵¹

Teleradiology is a very successful subcategory in telemedicine as the market has evolved by itself. Some of the prominent examples are:

1. Teleradiology from Eastern Europe to the United Kingdom used to be a very lucrative business prior to BREXIT; however, the future of the project after the UK's exit from the EU is uncertain. One example of such a scenario used to be low paid but highly educated Eastern European doctors assessing DICOM data of UK based medical imaging scans.
2. PET-CT imaging is increasingly evaluated within a distributed setting, the evaluation is increasingly supported by sophisticated medical decision support systems.
3. Teleradiology is increasingly used in Australia (as well as in other regions around the World), with a large number of private teleradiology groups operating nationwide and the network is growing (Everlight, I-Telerad, Vision XRAY, TMC, PRESCRIPT, Telerad, Intellirad, etc).

The Latest Use Case Scenario: COVID-19

The economic impact of the COVID-19 epidemic was unexpected and unprecedented.³⁰ As shown in Table 2, global media coverage of epidemics has never been so interconnected. This has created an unprecedented scenario: travel restrictions and quarantines were introduced within days or hours upon receipt of information, and the spread of the epidemic was slowed down by governments around the World. However, the corresponding upheaval also had unprecedented impact on diverse areas of economics and services. Eventually the entire western world became virtually closed and supply chains were disrupted everywhere. Such disruption creates an opportunity to overcome the comfortable and extremely powerful dominance of the current main stakeholders in global healthcare, which we believe is one of the main reasons of the slow spread of modern technologies and services, including telemedicine. In addition to the previous advantages of telemedicine, there is yet another one, and this

Table 2. Epidemics and telemedicine.

	Timeframe	Level of telecommunications	Global spread	Economic impact	Funding of healthcare
Spanish Flu	1918-1920	Plain Old Telephone System	Global, uncontrolled, 50 million deaths	Added to the effects of the 1st World War	Limited, extreme lack of workforce nurses doctors
SARS-1	2009-2010	Dawn of smart phones, mobile data limited	Stopped relatively fast. Vaccine readily available	Limited, mostly Asia.	Relatively well controlled
COVID-19	2019-2020	Unlimited mobile data, 4G/5G, as well as other sophisticated high speed data communications	Global, currently uncontrolled, no vaccine yet	Global, predicted to be catastrophic, killing entire industries	Vast resources available Technology, funding, HR available

one comes now with a trillion dollar label:⁶⁰ physical isolation among the players in medical services, namely the patient and various levels of healthcare providers.

The best-case scenario in a biological pandemic situation is ultimately infection control:

1. use of single use or fully disinfectable medical devices, which can be cleaned by automated means with or without very limited human interaction,
2. operated by protected first level support personnel (not by doctors or high-level operators, whose time is expensive and they may not be replaceable)
3. the medical devices and their disinfection procedure should be fully automated,
4. or the patient himself may be involved in supporting some of the disinfection procedure,
5. use the devices in a distributed manner, by means of telecommunications,
6. the data should be evaluated at a central location by professional medical personnel in a highly protected area, and especially with the means of decision support systems, involving the implementation of artificial intelligence and machine learning.

At the time of writing, one home care test has been approved in the U.S. and there are no approved home care COVID-19 tests in most of the democratic western countries. The Chinese developed and made rapid antibody tests are forbidden in many jurisdictions, including Australia. Test results are mostly communicated by using telemedical means and an increasing level of sophistication is being implemented in monitoring symptoms. It is widely expected that the use of telemedicine will prevail in this field as well, especially due to the very large number of tests and patients to care for World-Wide. General Practitioner consultancy via video link is experiencing a renaissance, as the motivation of the doctor to be away from the patients is stronger than being close to them. However, audio and video are insufficient information for a medical diagnosis. Telemedical monitors need to be equipped with novel sensors to be able to measure the most common vital signs parameters as well as, perhaps, basic point of care data. The key to the delivery of medical

sensors to the patients is in the hands of mobile phone manufacturers.^{61,62} Mobile phones are key products which are manufactured in sufficient quantities to reach a level of cost efficiency affordable for home care (in comparison to the often high costs of stand-alone digital electronic medical devices). Also, mobile phone makers can fulfil the stringent certification and quality control measures required to market medical-grade devices. Ferenczi predicted in 1999, that mobile phones will be used to monitor human healthcare.⁶³ We believe that mobile phones will evolve in time to be lifesaving and life support systems for everyone. We are surprised this still hasn't happened on a large scale, but we believe COVID-19 will speed up such evolution.

The Spanish flu

One hundred years ago, the Spanish influenza pandemic swept the globe, infecting an estimated 500 million people, one-third of the world's population, and killing at least 50 million people, a death toll was greater than the total number of military and civilian deaths from World War I.^{64,65} The cause was an influenza A (H1N1) virus, but at the time, influenza viruses had not yet been discovered. Key issues included: lack of advanced communications; no contact tracing; the uncontrolled spread of the infection by soldiers returning to their homes; and several European countries reshuffling their population due to the relocation of borders. The 1918 pandemic actually caused the average life expectancy in the United States to drop by about 12 years for both men and women. Improvements in medical care and technology since the last pandemic may reduce the impact of the next. Developments since the 1918 pandemic include vaccines to help prevent flu, antiviral drugs to treat flu illness, antibiotics to treat secondary bacterial infections such as pneumonia, and a global influenza surveillance system with 114 World Health Organization member states that constantly monitor flu activity.⁶⁵

The economic impact of SARS-1

The cost to the global economy of SARS is estimated to have been \$54 billion, according to the World Bank, while the organisation estimated that an upcoming 'severe flu pandemic' could cost over \$3 trillion, nearly five percent of

global GDP.

The economic impact of COVID-19

Economic estimates of the likely global impact vary markedly. Orlik and others at Bloomberg hypothesise \$2.7 trillion in lost output.⁶⁵ The Asian Development Bank has released scenarios from \$77 billion to \$347 billion, and an OECD report suggests halving of the global economic growth. The latest report from the United Nations estimates the overall burden is even higher, in the range of \$8.5 trillion.³⁰ The full scale of the economic impact is not yet known, but will be significant. According to WHO, the average lost lifetime of COVID-19 casualties is 11.5 years.

Summary

A number of earlier cases of telemedicine applications and the economic factors and assumptions on possible issues and obstacles to the sustainability and upscaling of projects after initial funding have been described. The economic impacts of global pandemics, namely the Spanish Flu, SARS-1 and the current COVID-19 pandemic have been estimated and the evolution of available technologies at the time of the pandemics described. We have concluded that telemedicine has a significant role in combating global diseases. So far, in telemedicine, there have been many tools, methods and technologies available, but the economic and administrative factors were not adequately present. This time the economic factors are clear. The administrations in China, Europe, USA, and Australia etc. also seem to be very motivated to implement whatever it takes to control the situation. If this involves the introduction of high-level technologies, the Chinese and other administrations will be even more motivated. Huawei, for example, is in a very different environment from Nokia and Samsung.

Conclusion

We predicate that mobile phone makers hold the key to telemedicine. To pass the market entry barriers in terms of price, functionality, quantities and customer reach medical sensors should be integrated in or linked to the mobile (smart) phones, in one way or the other.^{61,62} We also predicate that whichever mobile phone implements this first, will be the absolute market leader on the medium-long term. According to a 2014 analysis, the market for telemedicine technologies is predicted to grow at a compound annual growth rate of 18.4 percent through the year 2020. This prediction was made before the COVID-19 crisis unfolded. We believe the growth is now significantly faster.

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References

1. Bonavia M, Averame G, Canonica W, et al. Feasibility and validation of telespirometry in general practice: The Italian "Alliance" study. *Respir Med* 2009;103(11):1732-1737. DOI:10.1016/j.rmed.2009.05.006
2. Maiolo C, Mohamed EI, Fiorani CM, De Lorenzo A. Home telemonitoring for patients with severe respiratory illness: the Italian experience. *J Telemed Telecare* 2003;9(2):67-71. DOI:10.1258/135763303321327902
3. Roze R, Fisk M TeleSCoPE. (2013). Telemedicine Coventry University. Available at: <https://www.coventry.ac.uk/business/our-services/health-design-technology-institute/health-design-technology-institute-research-projects/telescope/> accessed 6 December 2020.
4. Daragó L, Jávora A, How to make eProtocol? In *Telemedicine and eHealth ICT Forum for Education, Networking and Business*, Luxembourg, 2010, 203-206. ISSN:1818 - 9334,
5. Reding V, eHealth - Regional case studies. (2006). Available at: http://ec.europa.eu/information_society/newsroom/cf/itemlongdetail.cfm?item_id=2892 accessed 6 December 2020.
6. European Commission. (2020). *eHealth : Digital health and care*. Available at: https://ec.europa.eu/health/ehealth/policy/network_en accessed 6 December 2020.
7. European Commission (2020). *Shaping Europe's digital future* Available at: https://ec.europa.eu/health/ehealth/policy/network_en accessed 6 December 2020.
8. Ferenczi G, Vass D, P. I, Csaba E, Darago L, eHealth8 Project: A complex telemedicine system implemented in Hungary, 2008. Available at: <http://ehealth8.bzlogi.hu/index.php?lang=en> accessed 6 December 2020.
9. WHO Macroeconomics and health : investing in health for economic development : executive summary / report of the Commission on Macroeconomics and Health, World Health Organization, 2001. Available

- at: <https://apps.who.int/iris/handle/10665/42435> accessed 6 December 2020.
10. Australian Government. (2018) *Australian entities and the EU General Data Protection Regulation (GDPR)*, Available: <https://www.oaic.gov.au/privacy/guidance-and-advice/australian-entities-and-the-eu-general-data-protection-regulation/> accessed 6 December 2020.
 11. European Parliament. *General Data Protection Regulation (2016/679 EC)*, 2016. Available at: <http://data.europa.eu/eli/reg/2016/679/oj> accessed 6 December 2020
 12. Bergmo TS. An economic analysis of teleradiology versus a visiting radiologist service. *J Telemed Telecare* 1996;2(3):136-142. DOI:10.1258/1357633961929952
 13. Bergmo TS. Can economic evaluation in telemedicine be trusted? A systematic review of the literature. *Cost Eff Resour Alloc* 2009;7(1):18. DOI:10.1186/1478-7547-7-18
 14. Bergmo TS. Economic evaluation in telemedicine - still room for improvement. *J Telemed Telecare* 2010;16(5):229-231. DOI:10.1258/jtt.2010.009008
 15. Davalos ME, French MT, Burdick AE, Simmons SC. Economic evaluation of telemedicine: review of the literature and research guidelines for benefit-cost analysis. *Telemed J E Health* 2009;15(10):933-948. DOI:10.1089/tmj.2009.0067
 16. Ekeland AG, Bowes A, Flottorp S. Effectiveness of telemedicine: a systematic review of reviews. *Int J Med Inform* 2010;79(11):736-771. DOI:10.1016/j.ijmedinf.2010.08.006
 17. Himpens B. The Pentalfa project. 4: educational aspects. *J Telemed Telecare* 2003;9(3):171-175. DOI:10.1258/135763303767149997
 18. Himpens B. The Pentalfa project. 3: participant evaluations of the interactivity of the educational videoconferences and the effectiveness of project promotion. *J Telemed Telecare* 2003;9(3):167-170. DOI:10.1258/135763303767149988
 19. Himpens B. The Pentalfa project. 2: profile of participants and economic aspects. *J Telemed Telecare* 2003;9(2):104-108. DOI:10.1258/135763303321327975
 20. Himpens B. The Pentalfa project. 1: the development of distance continuing medical education via videoconferencing in the Dutch-speaking region of Belgium. *J Telemed Telecare* 2003;9(2):99-103. DOI:10.1258/135763303321327966
 21. Jaana M, Pare G, Sicotte C. Home telemonitoring for respiratory conditions: a systematic review. *Am J Manag Care* 2009;15(5):313-320. PMID: 19435399.
 22. Jennett PA, Affleck Hall L, Hailey D, et al. The socio-economic impact of telehealth: a systematic review. *J Telemed Telecare* 2003;9(6):311-320. DOI:10.1258/135763303771005207
 23. Miyahara S, Tsuji M, Iizuka C, et al. An economic evaluation of Japanese telemedicine, focusing on teleradiology and telepathology. *J Telemed Telecare* 2006;12(Suppl 1):29-31. DOI:10.1258/135763306777978579
 24. Mladek T, Stroetmann KA, Bartova S, et al. An economic evaluation of a Web-based national patient records system. *J Telemed Telecare* 2007;13(5):40-42. DOI: 10.1258/135763307781645185
 25. Moreno-Ramirez D, Ferrandiz L, Ruiz-de-Casas A, et al. Economic evaluation of a store-and-forward teledermatology system for skin cancer patients. *J Telemed Telecare* 2009;15(1):404-5. DOI:10.1258/jtt.2008.080901
 26. Schaafsma J, Pantazi SV, Moehr JR, Anglin CR, Grimm NA. An economic evaluation of a telehealth network in British Columbia. *J Telemed Telecare* 2007;13(5):251-256. DOI:10.1258/135763307781458877
 27. Schemken H-W, Au H, Dobrev A, et al. Access to efficient health services for tourists an evaluation of the economic benefits. *J Telemed Telecare* 2007;13(5):52-55. DOI:10.1258/135763307781645211
 28. Stroetmann KA, Jones T, Dobrev A, Stroetmann VN. An evaluation of the economic impact of ten European e-health applications. *J Telemed Telecare* 2007;13(5):62-64. DOI:10.1258/135763307781645167
 29. Wainwright C, Wootton R. A review of telemedicine and asthma. *Dis Manag Health Out* 2003;11(9):557-563. DOI:10.2165/00115677-200311090-00003
 30. United Nations. (2020). *COVID-19 to slash global economic output by \$8.5 trillion over next two years*. Available at: <https://www.un.org/development/desa/en/news/policy/wesp-mid-2020-report.html> accessed 6 December 2020.
 31. AllegraHMS. (2017). *Telemedicine Keeps the Doctor Away* Available at: .accessed 6 December 2020.
 32. Szabo B. Development and further improvement of the hungarian national ehealth platform. ed. Human Resources Development Operational Programme: National Healthcare Service Centre (AEEK), 2013. Available at: <http://esifundsforhealth.eu/sites/default/files/2018-05/HU%20EESZT.pdf> accessed 6 December 2020.
 33. Bolte R, Walz M, Lehmann KJ, et al. Teleradiology: results of a questionnaire of German radiologists. *J Telemed Telecare* 1998;4(1):169-171. DOI:10.1258/1357633981931524
 34. Bolte R, Lehmann KJ, Walz M, et al. Radiologic medical desktop conferences--clinical evaluation of the KAMEDIN teleradiology system in routine

- practice of a radiologic institute. *Aktuelle Radiol* 1996;6(4):199-202. PMID: 8924455.
35. Lehmann KJ, Walz M, Bolte R, et al. Possible applications of the KAMEDIN teleradiology system with special reference to an economic analysis. *Radiologe* 1997;37(4):278-284. DOI:10.1007/s001170050212
 36. Walz M, Bolte R, Lehmann KJ, Lutgemeier J, Georgi M. Economic analysis of teleradiology applications with KAMEDIN. *Stud Health Technol Inform* 1999;64:208-216. DOI: 10.3233/978-1-60750-908-0-208
 37. McIntosh E, Cairns J. A framework for the economic evaluation of telemedicine. *J Telemed Telecare* 1997;3(3):132-139. DOI:10.1258/1357633971931039
 38. Collins A. (2017). Funding for telehealth. Available at: <https://nadc.net.au/wp-content/uploads/2019/08/3.1-Ash-Collins-Funding-for-Telehealth.pdf> accessed 6 December 2020.
 39. Bush A, Saglani S. Management of severe asthma in children. *Lancet* 2010;376(9743):814-825. DOI:10.1016/S0140-6736(10)61054-9
 40. Ferenczi G. Mobile IP. Report at: Nokia Wireless Business Communication and the Tampere University of Technology Tampere, 1999.
 41. Latifi R, Weinstein RS, Porter JM, et al. Telemedicine and telepresence for trauma and emergency care management. *Scand J Surgery* 2007;96(4):281-289. DOI: 10.1177/145749690709600404
 42. Weinstein RS, Lopez AM, Krupinski EA, et al. Integrating telemedicine and telehealth: putting it all together. *Stud Health Technol Inform* 2008;131: 23-38. PMID: 18305320
 43. Ferenczi G. Advanced Security Database access with Security Solutions Simulation in Java, M.Sc., University Tampere, Tampere, 1998,.
 44. Melvin E, Cushing A, Tam A, Kitada R, Manice M. Assessing the use of BreatheSmart(R) mobile technology in adult patients with asthma: a remote observational study. *BMJ Open Respir Res* 2017;4(1):e000204. DOI:10.1136/bmjresp-2017-000204
 45. Liu WT, Huang CD, Wang CH, et al. A mobile telephone-based interactive self-care system improves asthma control. *Eur Respir J* 2011;37(2):310-317. DOI:10.1183/09031936.00000810
 46. McLean S, Chandler D, Nurmatov U, et al. Telehealthcare for asthma. *Cochrane Database Syst Rev* 2010;(10):CD007717. DOI:10.1002/14651858.CD007717.pub2
 47. Ferenczi G. Method of transmitting results of diagnostical measurements in MMs via GSM network, Patent Appl. P1100371/8, A61B 5/00, H04W 4/12, 2011.
 48. Ferenczi G. Method of compressing and restoring pulmonological FVC graphs Patent Appl. P1100370/9, A61B 5/08, H03M 7/30, 2011.
 49. Glatte GC. (2018). Fundamentals and Aspects of Telemedicine ECG Transmission (TET) in combination with Telematic Heart Disease Support (THDS) including General Considerations concerning structure of Telemedicine frameworks and adding other relevant parameters as lung function testing provided by PC based spirometers. Available at: <https://www.mesamed.de/mesa-ftp/pdf/eng/Fundamentals-and-Aspects-of-%20ECG-and-Lung-Function-Telemedicine-Glatte-et.al.pdf> accessed 6 December 2020.
 50. Chan DS, Callahan CW, Hatch-Pigott VB, et al. Internet-based home monitoring and education of children with asthma is comparable to ideal office-based care: results of a 1-year asthma in-home monitoring trial. *Pediatrics* 2007;119(3):569-78. DOI:10.1542/peds.2006-1884
 51. Moga VD, Moga M, Avram R, Ciocarlie T, Bosneag L. Telecardiology in Clinical Practice: A One Decade Experience. in *Med-e-Tel 2010*, Luxembourg, 2010: International Society for Telemedicine & eHealth (ISfTeH), ISSN 1818 - 9334
 52. Ferenczi G. Method for diagnostic measurement of respiratory function and apparatus for carrying out said method. Patent Appl. P0500517, 2005.
 53. Ferenczi G, Method and apparatus for determining the flow parameters of a streaming medium, Patent Appl. WO/2009/071960, PCT/HU2008/000146, 2009.
 54. Bergman DA, Sharek PJ, Ekegren K, et al. The use of telemedicine access to schools to facilitate expert assessment of children with asthma, *Int J Telemed Appl* 2008;159276. DOI:10.1155/2008/159276
 55. von Berg A, Filipiak-Pittroff B, Schulz H, et al. Allergic manifestation 15 years after early intervention with hydrolyzed formulas--the GINI Study. *Allergy* 2016;71(2):210-9. DOI:10.1111/all.12790
 56. Doupi P, Renko E, Hämäläinen P, et al. eHealth Denmark : eHealth Strategies, Denmark, in "DG Information Society and Media, ICT for Health Unit" European Commission, 2010. Available at: <https://docplayer.net/1290201-October-2010-european-commission-dg-information-society-and-media-ict-for-health-unit.html> accessed 6 Dec 2020.
 57. Darkins A, Ryan P, Kobb R, et al. Care Coordination/Home Telehealth: the systematic implementation of health informatics, home telehealth, and disease management to support the care of veteran patients with chronic conditions. *Telemed J E Health* 2008;14(10):1118-1126. DOI:10.1089/tmj.2008.0021
 58. AAL Association. (2020). *Active Assisted Living Programme (AAL)*. Available at: <http://www.aal-europe.eu/> accessed 6 December 2020.

59. Sufi F, Khalil I, Mahmood A. A clustering based system for instant detection of cardiac abnormalities from compressed ECG. *Expert Syst Appl* 2011;38(5):4705-47113.
DOI:<https://doi.org/10.1016/j.eswa.2010.08.149>
60. Orlik T, Rush J, Cousin M, Hong J. (2020). *Coronavirus Could Cost the Global Economy \$2.7 Trillion. Here's How*. Available at: <https://www.bloomberg.com/graphics/2020-coronavirus-pandemic-global-economic-risk/> accessed 6 December 2020.
61. Project ARA. (2020). Available at: https://en.wikipedia.org/wiki/Project_Ara accessed 6 December 2020.
62. Pensworth L. (2020). What Happened to Project Ara? Available at: <https://dailywireless.org/mobile/what-happened-to-project-ara/> accessed 6 December 2020.
63. Orosz G. Design and development of a compact lung function monitoring device, M.Sc., Technical University of Budapest, Budapest, 2009.
64. Garrett TA. Economic Effects of the 1918 Influenza Pandemic. Implications for a Modern-day Pandemic, Federal Reserve Bank of St. Louis, St. Louis, 2007. Available at: https://www.stlouisfed.org/~media/files/pdfs/community-development/research-reports/pandemic_flu_report.pdf accessed 6 December 2020.
65. CDC. (2018). The 1918 Flu Pandemic: Why It Matters 100 Years Later. in *Public Health Matters Blog*. Available at: <https://blogs.cdc.gov/publichealthmatters/2018/05/1918-flu/> accessed 6 December 2020.