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ACEE ISSN 2574-0350 ANNALS OF CIVIL AND ENVIRONMENTAL ENGINEERING

Review Article

Telemedicine on Earth can learn from Spaceflight

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Submitted: July 01, 2025
Approved: July 14, 2025
Published: July 15, 2025

How to cite this article: Brigitte G. Telemedicine on Earth can learn from Spaceflight. Ann Civil Environ Eng. 2025; 9(1): 018-032. Available from: https://dx.doi.org/10.29328/journal.acee.1001076

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Keywords: Telemedicine; Telehealth; Remote real-time; Data; Safety; Security; Training; Spaceflight; Microgravity

Abbreviations : AI: Artificial Intelligence; ARED: Advanced Resistive Exercise Device; BC: Blockchain; CAIM: Complementary and Integrative Medicine; CCMM: Centre de Consultation Médical Maritime; CM: Crew member; CMO: Crew Medical Officer; CO2: Carbon dioxide; CPR: Crew pulmonary resuscitation; DCS: Decompression Sickness; ECG: Electrocardiogram; ESA: European Space Agency; EVA: Extravehicular Activity; FS: Flight surgeon; GP: General Practitioner; GDPR: General Data Protection Regulation; ICT: Information and communication technology; ISS: International Space Station; LEO: Low Earth Orbit; NASA: National Aeronautics and Space Administration; OCT: Optical Coherence Tomography; PMC: Private Medical Conference; PPC: Private Psychological Conference; PEC: Private Exercise Conference; SANS: Spaceflight-Associated Neuro-Ocular Syndrome; TDRS: Tracking and Data Relay Satellite; LDF: Long Duration Flight

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Executive summary

Telemedicine has become widely used, primarily following or during the COVID pandemic.

However, it was used a long time ago in specific cases, like submarines and space. Telemedicine has been developed to facilitate diagnosis and treatment in areas without physicians, either because the area is isolated without a medical doctor (as in submarines and space) or because we need expertise.

This article is a review using studies selected via PubMed to collect generic knowledge on some technical details on both sides: Earth and Space, where telemedicine activity is regularly provided. The goal was to compare tools, data collected, and ways of improvement in each area. As experienced on both sides, indeed, the author has already worked in the spaceflight area with astronauts as well as doing teleconsultations with patients nowadays, which allows us to see how we could improve the way we are doing teleconsultation on Earth by teaching the users as done with the astronauts in the pre-flight period. It seems telemedicine will still be mandatory for a while because as seen in many countries even out of the scope of isolated area (or very difficult to be accessed (like mountains, desert ...), more and more small cities and even bigger are lacking general practitioner (GP) as well as some specialists. Taking into account the time needed to have a functional doctor (for a GP mainly 8 years and for specialists longer, up to 12 years), telemedicine should improve and take a real place in the health system.

This review gives a few definitions, also the term telehealth or e-health is widely used. It refers to the use of an internet communication system to transmit data, receive data, communicate in real time, and guide and provide healthcare services to the patient remotely.

Improvements in technologies have mainly been done for Earth applications, and tools are becoming smaller and more resistant. The different purposes of using telemedicine are increasing nowadays, and it is not used only because of a lack of physicians but to teach remotely and avoid travel, as well as to have direct access /advice with a specialist. We can find a lot of reasons to use it.

Living in space is a real challenge for the human body used to gravity. As explained in a lot of reviews, the body in space loses bone, muscle, and has changes in heart volume and excitability. All the body systems will suffer from microgravity. Other factors impacting the body in space are the high level of ionized radiation, plus isolation. This is why, since the beginning of space flight, the so-called flight surgeon (more GP of the astronaut than a surgeon) is using telemedicine with the astronauts to prevent disease and, in case a medical event happens, to help the astronaut receive a diagnosis and efficient treatment. The actual ISS, International Space Station, allows real-time communication with the astronauts. This will be used for direct discussion or conferences to check the medical/psychological/fitness status. In other cases, remote access can always be done to communicate pictures or movies to provide advice on health or science. Furthermore, some medical tests will be done to guide the astronauts because some tools need real expertise to be interpreted correctly. In that case, eye exam is a good example: an astronaut uses devices following the recommendation of the specialist based on the NASA Console in Houston.

Of course, new improvements are needed to facilitate the next challenges of spaceflight, also going a step further beyond LEO (Low Earth Orbit), like doing an interplanetary trip and going to Mars. In that next scenario, to allow the mission where the Earth will not be seen anymore, when the real-time exchange will not be feasible, a new autonomy of the astronauts will be required.

As on Earth, space with all technologies like satellite is not only used as for direct health care facility with the astronauts but also in a more preventive way. It is possible to follow changes on the ground, climate changes too, as a witness to a possible new epidemic, and another specific use is to help in locating people.

Finally, we see how the way telemedicine is done in space could help improve telemedicine on the ground. First of all, we could improve telemedicine in many ways on Earth for classical consultation by increasing the utilization of simple tools like otoscope and… more in that case we need to train the patient like the astronauts are trained on ground before flying, this has a huge positive effect in allowing easier diagnostic and then better treatment for example when good pictures are provided.

The new tools as Artificial Intelligence (AI) or Virtual Reality (VR), on trial if needed for long-duration missions and specifically for missions beyond low Earth orbit, should be beneficial as well on Earth.

Maybe the big challenge for Earth's Telemedicine is increasing the trust in practitioners who are still convinced that this way of providing medicine could be a competitor, and for that reason, they are reluctant to use it.

Nowadays, it should become more and more obvious that we need to work on some specific weak points, like security, training in using tools to make sure telemedicine is efficient and useful, where we have a lack of physicians.

Introduction

Spaceflight is still fascinating for most of us on one hand, and is sometimes seen as useless for some others. Since the beginning of the space era, a lot has been learnt, and finally, most of the knowledge acquired can be used on Earth, like a lot of technologies have been developed to be used in a small environment as the space station and it is used today, the good example is the Holter.

The ISS is considered nowadays as the biggest challenging laboratory where, every day since 1998, the time when ISS was built, as an international partnership between the five following big nations, North America, Russia, Canada, Japan, and Europe, science is done and increases our knowledge about microgravity, radiation…

The first two places where telemedicine was done are space and submarines. These two environments are very good examples of telemedicine for two main reasons, the first one in areas far away from a clinical center, and the second for lack of physicians, as we experienced nowadays at least in France.

In 1968, Professor Louis Lareng, Professor of Anesthesia and Intensive Care, created the first SAMU in Toulouse, and in the following years, the presence of a regulating physician was established. This was the start of telemedicine with submarines in France. The regulating doctor was regularly called to give advice as soon as the Radio operators had efficient communications. This service via the intensive care was the main reason why, later on, the "Centre de Consultation Médicale Maritime" was created in 1983 [1].

Since the beginning of space, astronauts have been monitored from ground stations via telemetry using one of the world's first miniaturized electrocardiographs (Mercury Project, NASA, 1961). Before, in 1957, Russia monitored dogs in space, and the USA monitored monkeys. The first man to be monitored was Yuri Gagarin in April 1961 [2].

In space, we need telemedicine because astronauts are not physicians most of the time, and despite the fact that they are selected among a huge number of applicants, also they are perfectly healthy, we still have two reasons to closely monitor them. The first reason is, it is not uncommon for the astronaut you selected in the past is become sick or have some issues because a long gap has been made in between her/his selection process and her/his assigned flight; it could be 10 years. Indeed, in such amount of time, a lot can happen. What do we do? Do we need to disqualify her/him? Not at all, this is exactly the other way round, we will try to do our best to make her/him fly so a lot of medical exams can be done.

The second reason is that the space environment is extreme for the human body, not adapted to such a level of constraints. Staying in space for at least 6 months and sometimes, one year, requires one to be very well prepared. Why, because space is a unique, unhostile environment. Three main constraints and even more have to be taken into account to ensure the safety of the flight, the safety of human health, and of the mission (in other words, that the work/trip will be feasible without too big consequences on the human body). These three constraints are the radiations [3], the microgravity [4] and the confinement [5] plus, we need to add some specific conditions linked to the life on board the ISS: high level of CO_2, [6] high level of noise [7], changes in the circadian rhythms because of the light/darks changes every 90 minutes, risks of collision with debris, EVA (Extra Vehicular Activity) constrains on the human body (change in pressure, temperature, duration, high level of work, energy consumed…) [8], busy planning … [9].

The consequences of the previous factors, radiation, microgravity, and conditions in the ISS, like isolation and specificities on board, can be found in many reviews. This is not the goal of this review but to summarize we can say that the major impact of the microgravity is simulation of elderly with osteoporosis [10], muscle atrophy [11], cardiopathy disorders [12], immune deficiencies [13], hormonal changes [14], visual impact [15], taste and smell discrepancy [16], nutrition impact with microbiota changes [17]. This is why scientists and doctors are working together to avoid too big impact on the astronaut's health and have developed what they are calling a countermeasure. The two most well-known and used countermeasures nowadays are physical exercise to avoid losing too much bone and muscle, and adequate nutrition and calorie intake [18]. Astronauts are doing three types of exercise: treadmill, velo, and resistive exercise, 1h30 to 2h daily.

In this review, we first take a look at the telemedicine itself, going from the beginning until now with definitions evolution of the tools, communications system. In a second part, we show examples of how telemedicine is done on the ground, with its advantages and disadvantages. Lastly, the example of space using the actual setup with ISS (International Space Station) will show how we can take advantage of space for the Earth. And we finish with the next steps still to be done to improve for an interplanetary mission, which at the end would be beneficial on Earth, and will show the actual gaps.

Microgravity can be defined by the feeling of free floating, lack of gravity. Experience during parabolic flight or in the ISS Or called weightlessness	Osteoporosis is a disease characterized by like of bone density. It affects physiologically all human body at elderly, but seen on all astronauts after long time in space. But they usually recovery post-flight
Microbiota is the full micro-organism like bacteria living in our body from skin to the gut. Our body contains more bacteria than cells. Each organism has his own microbiota	Countermeasure developed to counteract the secondary effects of space flight, it can be exercise, nutrition, medications or others...

Telemedicine

Definition of telemedicine: Telemedicine is the delivery of health care and the exchange of health-care information across distances. The prefix 'tele' derives from the Greek for 'at a distance'; hence, more simply, telemedicine is medicine at a distance. Telecare is a related term and refers to the provision, at a distance, of nursing and community support to a patient. Similarly, telehealth refers to public health services delivered at a distance, to people who are not necessarily unwell, but who wish to remain well and independent [19].

Another definition for telehealth is more generic and refers to the use of telecommunication in health care delivery and information, according to the Health Resources and Services Administration. Both telemedicine and telehealth cover the same services. To summarize, telemedicine, telehealth, and eHealth refer to technology used to provide healthcare services to patients remotely [20].

The World Health Organization (WHO) defines telemedicine as "an interaction between a healthcare provider and a patient when the two are separated by distance", and this communication may be synchronous (as in telephone or video consultations) or asynchronous (when data, queries and responses are exchanged by email or short message service) [21].

The term e-health more generic has been used by WHO in their global survey of 2005, they mentioned "eHealth is the cost-effective and secure use of ICT in support of health and health-related fields, including health-care services, health surveillance, health literature, and health education, knowledge and research" [22]. Furthermore, the last Global survey made by WHO in 2015 stated that more members are interested in e-Health, which reflects growing interest by countries in this issue and eHealth's increasingly ubiquitous role in health care [23].

The Department of Health and Human Services estimates that more than 60% of all health care institutions and 40 to 50% of all hospitals in the United States currently use some form of telehealth [24].

What are the data and the tools in telemedicine

The tools: The tools are very numerous, depending on the type of telemedicine.

It could be a range from phone nowadays PC, Smartphone. as basic tool to do the classical consultation but of course depending on the reason to do this teleconsultation can be connected to a variety of medical object like blood pressure device, oximetry device, otoscope, dermatoscope (like one of the platform of telemedicine connected via pharmacy where the patient as soon as he is connected can use these tools which will be connected with the physician through the application platform [25].

Most of the medical devices are certified for outdoor use, but the performance in real environmental conditions is often not satisfactory; this is an even stronger statement for space usage. This equipment should be compatible with the telecommunication equipment.

The telecommunication system: In the past era, it was based on radio contact or messages in Morse code and two-way communication at low bandwidth, like the first communication mentioned earlier with the ship [1]. Nowadays, data are transmitted through terrestrial digital and analogue telephone networks or Global System Mobile, either directly or via the Internet, and the remote sites usually rely on satellite links.

Some parameters have to be defined clearly, like the coverage, availability (permanent or temporary), mode of transmission (real-time or store and forward), minimal and maximal up-link/down-link bandwidths, transmission protocols, data encryption and safety, cost per info transmitted, and the overall system costs.

The mobile satellite communication terminals can be conveniently categorized according to their operational bandwidth (From Low 2,4 - 9,6 kps, Medium (64 - 400 kps to high) [2].

The data: Regarding the data, the generic system architecture used for remote telemedicine consists of peripheral data sources, on-site processing and storage units, telecommunication links, and dispatch facilities.

The signals are typically simple data like temperature, pulse oximetry, audio (voice), still or moving images (ultrasounds), or a combination of all these data. These signals will be acquired and transmitted.

New way to do medicine

Nowadays, general practitioners have changed their practice, and this has been first challenged during the COVID pandemic. Because the level of risk was not well known, it was recommended to stay home, and several telemedicine platforms started to work a lot during that time. It will be focused, as well, in this review on France, where the author used to practice telemedicine.

The users of telehealth (choosing this word to be more generic) are increasing regularly, and among the most frequent are the clinicians with patients, as well as the services in hospitals and new domains are the ones for education and training. Depending on the area of medicine, we can differentiate:

-Clinicians and consumers expanded their use in numerous areas: real-time video consultations with off-site specialists in fields such as cardiology, dermatology, psychiatry and behavioral health, gastroenterology, infectious disease, rheumatology, oncology, and peer-to-peer mentoring; telephone, e-mail, and video visits for primary care triage and interventions such as counseling, medication prescribing and management, and management of long-term treatment for diabetes, chronic obstructive pulmonary disease, and congestive heart failure; technologies for transferring imaging data for off-site radiologic review;

-Hospital-based services, such as emergency and trauma care, stroke intervention, intensive care, and wound management, that are supported by specialty consultations through videoconferencing and securely transmitted high-resolution images; post discharge coordination and management of chronic and other illnesses in home and community-based settings, supported by remote monitoring capabilities, improved resolution of smartphone cameras, and growing consumer familiarity with video interactions;

-Out of the real medical scopes, other centers like fitness and wellness centers, in areas such as health education, physical activity, diet monitoring, health risk assessment, medication adherence, and cognitive fitness, use video channels, smartphone apps, and texts, and Web portals [24].

Why do we need telemedicine

There are two reasons why telemedicine should be used: first, there is no alternative to telemedicine; second, telemedicine is better than existing conventional services.

For the first point, Telemedicine has a role in the case of emergencies in remote environments such as the Antarctic and in ships or airplanes, where it may be difficult, if not impossible, to get medical care to the patient in time. In countries with unstable or weak economies, however, where health-care services are often not a priority, telemedicine also permits access to services that would not otherwise be available. Space is among those, too.

For the second reason, Telemedicine has obvious advantages in remote or rural areas where it improves access to health services, obviating the need for patients and healthcare workers to travel. Even in urban areas, however, telemedicine can improve access to health services and information.

Of course, in all remote or rural areas, however, telemedicine could have a great impact, permitting, among other opportunities, better diagnostic and therapeutic services, faster and easier access to medical knowledge, and enhanced communication between health-care workers [19].

As time goes on, we see more and more specialties using telemedicine like dermatology, ophthalmology, mental health, heart, pregnancy, cancer, neurology (sleep insomnia), nursing, and even dentistry [20].

Maybe another emerging reason would be the lack of physicians in some countries. For the author practicing in France it has been obvious that more and more patients have no more GP (General practitionners), this is becoming a huge problem since the COVID pandemia, the retired physician are not replaced anymore, and probably more than a third of patients using telemedicine platform are missing a referent GP.

This lack of GPs and some other specialists is worldwide. We mentioned earlier the Missouri area in US in Europe, the proportion of citizens aged 65 and over has increased from 16% in 2000 to 21% in 2023, and is likely to reach around 30% by 2050. This is a result of longer life expectancy and lower fertility rates, which are causing a major shift in the demographic composition of countries. Doctors across all specializations are ageing as well, and they are getting closer and closer to retirement. However, the influx of young doctors into healthcare systems is not sufficient to compensate for the large number of doctors who are going to retire. Today, it is estimated that it will take two young doctors to replace every retiring one (https://www.europeandatajournalism.eu/lack-of-general-practitioners-in-europe/).

And, in the Netherlands, they have a huge concern about the continuity of GP care. Regarding the number, it was mentioned in 2021 that 1 in 20 people were currently seeking to register with a GP or to change their GP, and this is still increasing (Focus+on+shortage+of+general+practitioners.pdf).

Advantages and disadvantages of telemedicine

Advantages of telemedicine?

- *Quick access to health facilities*
- *Save time for medical doctors and patients*
- *Reduce costs*
- *Reduce the spread of diseases*
- *Exchanges between professionals* regarding audio, video, lab results, and radiology images allow as well support of specialists, nursing, psychologists, exchanges of new medical findings between doctors around the world, and help in solving complicated medical cases between specialists.
- *Reduce stress and prolonged hospitalizations*

Disadvantages of telemedicine activities?

To practice telemedicine, we need to be aware of its limits. Indeed, the major and first limitation of it is the lack of physical examination and consequently missing an event that needed surgery or emergency care. This has to be clear between the patient using the platform and the doctor. Coming from this, the author discovered that we need to explain very well and be very knowledgeable about our tasks.

- *Clinical exam is missing.*
- *The possibility of a decrease in the quality of healthcare*
- *The possibility of a technical problem*: needs good network connectivity and needs real-time communications
- *Need the same quality of care and a strong legal aspect*
- *Need to have a national health ICT (*Information and communication technology) *index* (it will include ICT infrastructure and access, ICT usage level, and ICT skills [26].
- *Lack of a comprehensive and universal telemedicine guideline* for each country to ensure uniformity of telemedicine services and patient safety
- *High cost of infrastructure*
- *Lack of available equipment, such as high-speed internet and lack of training, and lack of skilled labor*
- *Data security and privacy*

We will detail below the three important points

Clinical exam is missing: Consequently, you can't offer a medical certificate. It looks like the patient is very surprised when you announce you cannot do it! It seems to them just a paper. The patient is telling you. "I am doing well… I just need it to do sport ...." And the physician answered OK, but I need to do your clinical exam because this is the way to discover a latent or a quiet disease. Of course, this is a basic legal act.

The medical certificate might be the major point on the telemedicine restriction; the only authorized certificate is for the parent of a sick child, and it makes a lot of sense that we cannot offer another certificate.

Need the same quality of care and a strong legal aspect: Missouri's experience is a good example of telemedicine and telehealth with clear regulations and rules. Missouri is a national leader in Telemedicine, and the Missouri Telehealth Network has led operational, legal, and regulatory, and research and evaluation efforts since 1994. Missourians have an increase in elderly people expected to still increasing, and more than 30% live in rural areas with fewer physicians. In total, they have no access to timely and quality care in these rural areas, which is why, since the 90s, telemedicine and telehealth have been promoted and intensively used. They started from just a connection between rural patients with specialty care, and nowadays the uses are myriad and include telehealth of the tele-ICU and emergency departments, even telehealth in schools, hospitals, to hospitals. The Missouri Telehealth Network (MTN) was a pioneer in this field since 1994. Due to its experience, MTN is a trusted expert partner with expertise in legal and regulatory telehealth for state agencies designing telehealth policies and regulations.

Of course, they have restrictions like the fact that telehealth prescription and treatment may only be delivered within an established patient-physician relationship as regulated by the Missouri Board of Registration.

This is not what is done in fine, so the Direct-To-Consumer Telemedicine refers to patient-initiated on-demand health care with their physician within the same practice, or more commonly, a physician with whom the patient has no existing relationship. In this late example, some studies show a lack of quality care [27].

Even with the best of intentions, prescribers may be more likely to overtreat minor complaints. Furthermore, telehealth technology is well-suited to deliver complementary and alternative therapies such as yoga and mindfulness. Of course, this may lead to an increase in the opportunities for misuse and fraud. The Complementary alternative and Integrative medicine (CAIM) could be beneficial for the patient living in remote areas or with accessibility challenges. A recent review in 2023 showed that if the practitioner was favorable because among the positive sides, it was reducing the times improving hospital storage problems and reducing the workload burden of health care staff. Regarding CAIMS, the practitioner was also favorable this has positively impacted the course of the illness. From the patient's point of view, it was not so clear (they found it challenging to form meaningful connections with the CAIM practitioners using telemedicine and found less follow-up with remote-based interventions and a lack of feedback on their performances. Of course, in fine, the telemedicine approach cannot replace human connections formed with face-to-face conversation. Some limitations are well recognized, like special populations such as older adults, patients with disabilities, who may face additional barriers. Training both care providers and patients is mandatory to improve the delivery of CAIM via telemedicine [28].

The experience acquired in Missouri has a strong positive point by empowering patients to take a more active role in their health care and be more proactive [27].

Data security and privacy: One of the most important challenges in telemedicine is the preservation of patients 'privacy during transmission and processing. One of the key points in privacy is the method to preserve privacy. In a recent article, Ansarian et Baharlouie identified different methods for privacy with advantages and disadvantages, like Blockchain-based, Graph-based, Watermarking algorithm, Homomorphic, and attribute-based signature. Depending on the mean, it can be more or less expensive and more or less time-consuming [20].

Another reason for failure in security can also be the lack of training and competencies to manage patients remotely. Of course, Healthcare organizations must increase their security by updating the device's software.

Risks of privacy vulnerabilities can come from the utilization of a large number of devices like smartphones, smartwatches, or other smart sensors with a low level of security. If the physician protected his internet access on such a device, some patients might fail to protect it [29].

Limitations

To do a good telemedicine exchange, we need only two things: good internet connectivity, audio and video, and of course, the tool in between we exchange with the patient, this can be an iPad Mobile Phone, or a computer with a screen. Because the physician cannot do the clinical examination, he needs to at least sometimes have the patient do a minimum check, which will really help in making the diagnosis. This is mainly the major difference between what is done in some areas where physicians are missing, but still a nurse is acting as the mediator between the patient and the telemedicine platform (Guyana project).

Why do we still need to use this way of practicing medicine after the pandemic, when we all agree to say that nothing can replace the relationship between physician and patient? Because the number of physicians (speaking for France) is too low. Not enough open positions for medical studies have been available. Also, not only are a large number of retired doctors doing these activities, but it is also helping them to keep a small social activity; however, a lot of physicians, after their activities, are participating in this new way of doing medicine. In the countryside, it is obvious that the number of physicians is too low, but the number of patients is really increasing, and some practiced are really busy with only big, medically challenging diseases. Nowadays, physician will have in his/her practice less and less time for what we could call the "bobology" (very basic and not urgent medical issues). This type of issue is the one clearly the best for such telemedicine.

Probably this tendency will not decrease but instead increase, so we really need to help the patient more and more to become autonomous.

In that case, we can learn from what is done with astronauts, which will be seen in the next chapter.

Telemedicine, and Space

The difference in telemedicine for earth and space: The main difference is the altered gravity exposure. It is well known that a lack of gravity influences the physical properties and processes, as it has been described in the Cemack review 2006.

Continuous monitoring of astronauts is not practiced today.

At the beginning of telemedicine utilization, NASA supported the use of space-based communication facilities to facilitate international telemedicine in different cases, bringing medical care to remote locations, supporting the people during the Armenian Earthquake. After that, NASA developed the Telemedicine Instrumentation Pack (TIP) to connect with the Space Shuttle and the ISS KuBand downlink communications capability. It was the first step to support telemedicine at the beginning of space flight.

Telemedicine in space has not evolved as fast as on the ground due to the need to develop flight-certified clinical equipment [30].

The actual setup for communication between ISS and the ground (Mission Control Centre in Moscow or Houston) is either through the geostationary TDRS system or through direct downlink to the ground station as the spacecraft passes by. The telecommunication system signal delay within the system is in the order of 2 seconds, which is quite acceptable for remotely supervised procedures. The communication between ISS and the ground is not 24/24h there are only open windows for communication.

For an interplanetary mission, it will not be feasible to use such telemonitoring due to the distance and the increased delay in communication. This prevents real-time communication, but the delay (20 to 40 minutes round-trip) will not affect the data transfer. Also, if a real emergency were to occur, it could only be by the astronauts. This is the reason why we have always had 2 to 3 CMO (Crew Medical Officer) for 6 members on board. The CMO has been intensively trained on medical procedure and, if possible, as well medical doctor. For all other non-emergencies / medical issues, an expert opinion would always be feasible [2].

Table 1 shows the similarities and discrepancies between communication tools, medical tools, Data collected, and safety on the ground on one hand and in space on the other hand.

For each side, the reason for using telemedicine is briefly reviewed.

The telemedicine used for space activities

Epidemiology and follow spread of diseases: Regarding space Telehealth or monitoring, we need to explain that the telehealth care system could be extended not only to human spaceflight but also to all other space programs, such as satellites and all space technologies. Indeed, in 2018, the UNISPACE + 50 conference took place and marked the 50th anniversary of the start of the United Nations (UN) conferences that engaged states to cooperate in their outer space engagements. An expert group on Space and Global Health of the UN Office from Outer Space was in charge of identifying key applications of space technologies to global health to report the gap challenges and perspectives. From this work, it is interesting to note that all communication networks and satellites still have a big role to play not only in telemedicine but in infectious diseases. Also, it is feasible to predict the evolution of the extension of infectious diseases as well as environmental pollutants by using remote sensors. In addition to the use of remote sensors, GNSS (Global navigation satellite system) can be of great help in epidemiological studies too as well as in promoting health care access in different settings via Geolocalization or locating subjects after a disaster. The use of

Table 1

	On the Ground	Need to Improve to fully use platform	In Space (ISS)	Need to Improve for LDF and Beyond LEO
Communication Tools				
Satellite		In some isolated area: very bad internet connection	+	Direct comm not acceptable (more than 20 min delay in one direction)
GSM	+		+	
Internet	+		+	
Real-time	+		+	
Remote and storage	+		+	
Remote Guided	+/-		+	
Tools				
Phone	+	When tools are used on platform,need to increase the performance of the tool, stethoscope	+/-	Develop autonomy of crew using IA and VR
I-PAD	+		+	
Computer	+		+	
Medical Tools	+/-			
Temperature	Yes on the platform		+	
Oximetry			+	
Blood pressure	+		+	
Heart rate	+		+	
Stethoscope	+		+	
Otoscope	+		+	
Ultrasounds	+	Training of the patient or the one guiding the platform	+	
Laboratory			+	
EYES devices (IOP, OCT, Fundioscope)			+	
			+	
			+	
Data Collected/Transmitted		A good picture is recommended		
Audio	+	Need training	+	Usually good well trained
Visio	+		+	
Pictures	+		+	
Movies			+	
Safety / Security	- Blockchain	Costly	Advances encryption techniques (encryption algorithm or key encryption)	
	- Graph based	Time consuming		
	- Watermarking algorithm	Increase security		
	- Identity based	Secure, efficient		
	- Homomorphic	Time consuming		
	- Attribute based signature	Heavy computation		
Reason of Utilization	- For consultation because lack of physician (GP and specialists) or isolated area) - By GP for advice - Teaching (school or other professionals) - Fitness			- Preventive and curative health of the astronaut
				- Check-up before EVA
				- Social and family events
				- Education with school
				- Psychology

LDF: Long Duration Flight

satellite communication will have the same application as our telemedicine when we use the internet, in case the internet is available. This is foreseen with the ships, as has been shown, it can decrease the number of unnecessary medical evacuations because of telemedicine capabilities.

Education: The same it is used as described earlier for education.

The "health-on-the go": Finally, the last application of satellite communication is the so-called "health-on-the-go". It is a subpart of telemedicine. In some areas without traditional communication systems, it is the usage of mobile medical units that provide treatment and can transmit health information. We can see as well a Trauma station, such as a device which carries an ultrasound, electrocardiogram, blood analyzer…. Emergency patient transportation can also belong to this means. So, before the patient arrives at the hospital, he might have already received treatment and management remotely.

Spaceflight telemedicine: Of course, the last but not least major domain is human space flight, where telemedicine, as reported in this review, is at the core of global health. Space will widely use ultrasounds, and space will use knowledge from telesurgery too.

Actual data collected in space

Of course, this setup is working with ISS, where we still have real-time communication and no delay, which allows us to collect [31].

Depending on the real need or not, and on the communication status, we need to differentiate:

Via live remote guidance: These are the data the crew member collects on board the station in real time with the help of a guide on the ground. These exams are complicated enough to have the help of the ground and to have direct feedback, for example, to make more picture changes in the orientation, because the guide on the ground can compare with the exam done in pre-flight. In that case, the communication must be real, and no big lapses in communication.

Eyes follow up with Intra ocular pressure, Ultrasounds, OCT, Fundoscope are needed to follow the ocular issue discovered in space in 2011 even though this was existing before but not discovered [32,33] and as well for duration mission we will repeat assessment of exercise fitness to check the status of the crew member.

Via live monitoring: In real time, the crew member will participate to Private conferences we have few types, the conference with her/his physician (PMC) 15 minutes weekly, conference with the psychologist (PPC) every two weeks, conferences with the Exercise team (PEC) monthly and a session to practiced and check the good way of using the device with Exercise team and support of the physiotherapist (this should be done as soon as possible in flight to be sure of the good practice of the crew on the ARED device (because of changes due to lack of gravity) (ARED PTV).

Of course, an unexpected PMC or PPC can always be done in case emergency and real-time communication is available.

Other conferences can be scheduled in the same way, but are not regular for social events and with a school in an educational program. These events will not be for medical reasons, but the last one can be for educational purposes, always useful for the ground community to learn about space and have a real-time communication link that allows people to see what life is like onboard the ISS.

Via store and forward: For some exams performed in space, the astronaut can do it on his own, and the data will be sent to the ground and analyzed later. Among those are: audiometry, exercise, and nutrition survey, plus others.

Audiometry: It was mentioned earlier that due to the life on board with a lot of noise, it is necessary to check the audiometry regularly [34,35].

Exercise monitoring: In the same way, the sports activity will be recorded to allow the exercise team to provide good recommendations and to adjust the fitness level of the crew as long as the mission is going ahead [36-38].

Nutrition: As mentioned, nutrition is among the proven efficient countermeasures in line with daily exercise. This is why we need to monitor it closely and be able to give feedback to the astronaut.

In that way, the crew will send their detailed food table record with the description of the meal and receive recommendations from the diet [39,40].

Pictures for skin or other issues: Among all medical issues that can affect the crew members, skin disorders are often reported. It is always very useful to have a good picture, which helps to have a good diagnosis and, in the end, good treatment [41].

For the preparation of EVA: Tympanic membrane picture, vital parameters.

Before doing an EVA, the flight surgeon must be sure about the health of the astronaut, and among the parameters checked will be the tympanic membrane and vital parameters. Also, a picture of good quality of both tympanic membranes will be sent to the ground.

Psychology and cognition: Cognition is a psychological test that will be repeated regularly on board, of course, it is done in preflight in order to compare and be able to depict any problem as soon as possible [42].

To be able to use telemedicine in space, astronauts and their flight surgeon and all other specialists involved in the follow-up need to be trained [43,44].

ISS telemedicine training is scheduled for all crew members, and of course, increase time for the CMO. This will represent a big number of hours to make sure they are confident in using the tools.

The following training is done in pre-flight, and some practices will be repeated in flight

For the crew members

– The training done in preflight is:

- Initial, for crew member CPR (Cardiac Pulmonary Resuscitation), DCS(Decompression Sickness), field training
- For the ground Crew: Emergency and Specialists Operations – Ultrasound for Eye (SANS) – Spinal – Medical event

Training will be added in-flight for the crew member to make sure they are keeping their skills:

- Emergency drill (4-6 weeks of arrival, 45 min)
- Computer-based training (30 days/25 min)

The future challenges in space for missions beyond Leo

Increase the autonomy of the crew: No real-time communication is a major change for spaceflight. The delay will be too long to allow the help of the ground, and it will change the way of doing medicine on board in case of an emergency.

If telemedicine is still needed, this is acceptable, even with a delay in the answer.

But a real medical emergency will have to be treated by the crew. We need to increase the level of medicine. Nowadays lot of tools can be of help, like AI and VR.

Some other tools are still in development and could help. For example, we need to be able to treat SANS and other ocular damage. In space few ocular diseases might happen, such as corneal abrasion, infections, and trauma damage.

We should prevent or treat. A few ways are considered, like 3D printing or using stem cells, or other alternatives enabling on-demand tissue fabrication. But these means still need to improve, and they include the need for sophisticated ocular facilities and good surgery skills in microgravity. This is why telemedicine and AI-driven diagnostic tool seems the best immediate solutions. This will be associated with training using VR. Virtual reality can help astronauts provide hands-on training. All together, VR and AI-driven tools should help astronauts to manage ocular conditions autonomously. Furthermore, these technologies will improve healthcare on Earth [45].

For cardiac issues, tele-echography has been widely used on ISS. The tool has evolved such the Tessa technology. In that condition, the astronaut doesn't need any more the real remote guidance. This is nowadays used in France hospital in isolated area so we don't need the specialist either the technician is guided by the specialist using even a joystick which can be manipulated by the specialist from his own computer and area if the specialist is not accessible like would do astronaut on board the station, the technician can do picture stored and have later the diagnosis of the specialist [46].

A new tool to optimize sport in flight when real-time communication is not available is being developed to give autonomy to the crew. A recent study showed that the wearable IMU based biofeedback system could monitor astronauts efficiently in flight, displaying real-time feedback while the crew is doing exercise. Of course, these Inertial Measurement Units need to be tested in microgravity. This tool would have a potential extended application for subjects on the ground at home and for elderly patients as well. This would allow for improved exercise to be done and receive correction without the physiotherapist [47].

What do we learn from spaceflight

How can we use what we learnt from space telemedicine to apply it to telemedicine on the ground? This time, not only in an isolated area where it has been developed for a long time, but in an area where we used to have a physician, but since COVID-19, it seems a new era is coming. General practitioners and some specialties in medicine are really missing more and more medical doctors are doing telemedicine work, even retired physicians, to help [48].

From the previous chapter, we could use the training of the crew and help the patient become more autonomous.

Training as the crew is doing for using the tools

Training on doing and sending good pictures: Another topic where we can learn is regarding dermatology and the use of pictures. Dermatologic diseases happen very often in flight for many reasons among those: lack of water and hygiene (no shower on board!), changes in the station with dryness, small dust because of lack of gravity such small particles/dust are flying around, very small traumatism on the hand and arm (because, they are using much more the upper part of the body to move ....). They can choose to show their flight surgeon during the Private Medical Conference, but it comes only once per week for 15 minutes... in case the days of the PMC are far away, the best way to do it is to send a picture of their skin issue.

The same for telemedicine on the ground, we need to teach patient how to take their blood pressure, how to check their ears. On some platforms, several small devices have been developed and connected between the patient and the physician. But of course, the first time a patient is using it, you need to take time to explain. Also, this is a unique opportunity to teach the patient about his body.

For example, you can show him both sides of the ear, the tympanic membrane, which may be the best example of the differences between right and left sides (in case otitis in one ear only), and next time he will be doing it easily. And this is helping as well in making your decision to take or not take medication or antibiotics. Of course, you, as a practitioner, need to take the time to explain how to proceed. Like we do with the astronaut on the ground during his medical training. But next time, they will do it easily.

Pictures are always beneficial for us medical practitioners, in case it is done with high quality: What we need to develop more on telemedicine, as on ISS, is the systematic utilization of pictures. You really need a very good quality screen most of the time for dermatology issues. Some platforms have developed as mentioned several tools, among them the dermatological tool. This tool offers a very big zoom, but this is even too much. If too enlarged, it can really affect you and change your interpretation. Instead, as we do for spaceflight a picture on all side of the skin part affected might be very helpful, for astronauts usually they are using it for their ears before and after EVA and for all dermatologic issues they might have it has been always a nice way to be more efficient and tell him what disease it is? How to treat?

Autonomy

Helping the patient to become autonomous: Doing telemedicine is a big chance to help those patients become autonomous and give recommendations on what to do to become healthier. You probably have no time in practice to do that. We really need to have the patient become more and more responsible for their health, this is via going through the process of feeling to trust themselves and not to obey 100% to what the practitioner is telling them.

Using the new technologies developed for space

A lot of technologies are transferred to Earth. It is expected that spaceflight with humans will promote global health. For example, new medical procedures for long-term spaceflight are ongoing and should be useful on Earth too. In 2004, a new concept of training was tested. It is based on the combination of on-site CD-ROM tutorials with real-time teleguidance from the ground expert center (It was applied to ultrasound teleguidance). This should be widely developed and used for a telemedicine platform as mentioned thereafter [2].

Space being a good model of aging, we expect new countermeasures to prevent adverse effects on bones, microbiota, and radiation, and we expect such countermeasures to be beneficial on the ground. The next challenge is being able for an astronaut to be fully autonomous. We expect a lot from personalized space medicine and new technologies, which are under development and would contribute to Global health as well [49].

How can we implement data/tools/techniques from space to ground

Example of specific case studies of Space-to-Earth technology transfer:

AI (Artificial Intelligence): Artificial Intelligence is more and more used nowadays to help people by saving time and replacing people.

For astronauts, they are training via AI. We should implement the tools for the patient. For example, they could learn how to put on the blood pressure cuff and be autonomous in taking their blood pressure. Usually, the physician on the other way explains to the patient how to put the cuff for some patients they have already done it and how to do it, but for some others, in my experience, we could easily lose five minutes explaining. A good program on the screen, even in 3D, could easily replace even a simple picture.

The same could be done for all the tools we are using on such a platform.

VR (Virtual reality): Virtual reality could be a secondary tool used as well for some training. For some tools like the otoscope, VR should really be developed and used connected to the real-time physician, such that with simply putting a captor in the ear, the physician could see as if he was doing the exam himself.

We could imagine having this tool to improve performance and even train the brain, and avoid alterations in memory. Repeating exercises in the elderly will improve the brain connections.

Another usage of VR could be using it for disabled people, which will give them a new feeling and at least increase their mood and mental health. But we are exceeding the limits of telemedicine.

Remote guiding: Nowadays hospital without specialists can be helped via remote guidance, as we do for eye exams and astronauts. This is something which could be developed as well for teleconsultation using an equivalent of a sonde which is used for ultrasounds, manipulated remotely by the physician. In that case, we could even imagine doing a clinical examination… placing the probe on part of the body and checking if painful or not. From my side, when I have a suspicion of appendicitis, which is not rare, I always try to use a member of the family (parents usually) and explain to them what and how to do it, such could be quickly done via such a probe.

Critical care autopilot: Cermack, in his review from

2016, mentions that the crew going on an interplanetary mission should benefit from an automated medical support, which would allow them to keep a critical astronaut's status constant under variable conditions. This kind of critical care pilot should be developed and tested on the ground in an isolated area, which would allow for waiting for medical care.

Predictive modelling: Modal to use the critical care autopilot on the ground, and to use not for critical injury but for any kind of disease.

- Use of the previous result obtained during the flight.
- Prepare data for the patient on the ground, remove what is not needed from microgravity (for example should be easier on Earth than in microgravity). As well, remove the effects of radiation so robustness of the device should not be so strong. Remove the more complex dizziness in a first step, or not linked to space (like EVA activity, depressurization ...)
- Train the tool on the patient: utilize the data extract and prepare a frame for the patient on Earth: add an algorithm combining symptoms to define the final disease, and choose treatment linked to it.
- Test data and results from the test: adjust and monitor
- Implement as a test tool in a telemedicine platform

Challenges expected

- Not possible to be exhaustive. It will be difficult to think about all pathologies: we could start from the NASA recommendation (they designed in the past 100 pathologies susceptible to happen in flight) and all data linked to bone, muscles, and the cardiac system shall be used, because space is a good model of ageing.
- **Training:** as already mentioned, astronauts have specific training as soon as they are selected, even good basic medical knowledge, which we do not have for the patient
- **Level of skills:** the patient, depending on his background, could have more or fewer difficulties understanding the requirement. So we would need to prioritize or adjust on a few levels, from basic knowledge to the most cultivated people.
- **Time:** This will probably increase the time lapse, which is not the goal in telemedicine; we always need to save time. To avoid a phase of learning and training, most likely to be done with a pilot study on a sample of 50/100 patients, with the physician voluntarily testing and able to improve the tool.
- **Intercultural knowledge:** The work should be done with a team in different areas of knowledge. It is needed to combine a medical doctor, engineers, and even scientists to increase the level of expertise and improve the tool.

Figure 1 summarizes the telemedicine activities on Earth and the ISS. It shows the variety of usage and still needs to improve the knowledge for using tools on the ground and increase the level of autonomy for interplanetary missions.

On the left side is way doing globally e-Health on Earth, via hospital, Health on the go (means that a specific car with a lot of tools will be visiting the patients and transmit data to the hospital), e-learning is another way to teach using e communications and telemedicine can be done via platform with some tools used by the patient to have advice given by the doctor. It can be a teleconsultation via Visio only without tools, and finally, the communication can be established for expertise, which means to allow doctors to discuss between themselves about difficult cases or simply to have advice from a specialist.

On the right side is the astronaut's communication with the ground. As described in the article, the astronauts are all well-trained pre-flight to use the tools, and this can be done in real time or remotely with storage of the data if the communication is not available, as it can happen.

On space side, we can differentiate space on board ISS where the real time communication if doable because the delay in reception is short and the expected next step on another planet like Mars, where this time the delay in one way communication is 20 minutes which still allows expertise and internet communication but not in real time because waiting 40 minutes in the two ways is not acceptable.

Also, the astronauts, one trained need to increase their own autonomy to be able to go further when on time communication is delayed, which cannot be acceptable for emergencies.

To use the tools connected to the platform during teleconsultation patient should be trained. This is how we could improve the performance of the telemedicine activities, learning from what the astronauts are doing nowadays. **Figure 2** shows tools accessible from the teleconsultation platform.

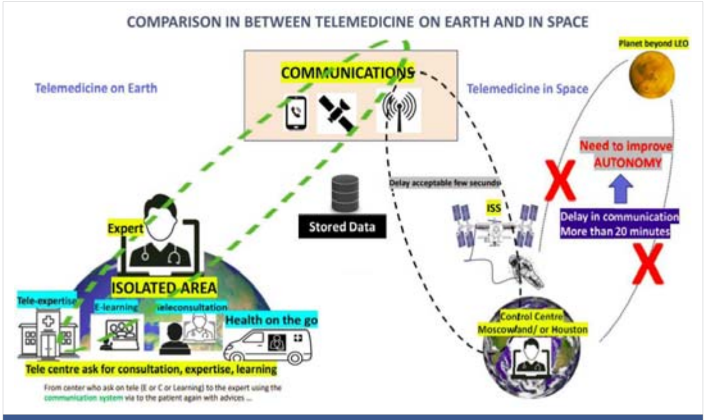

Figure 1: Comparison between the use of telemedicine in the two environments: on Earth and in Space.

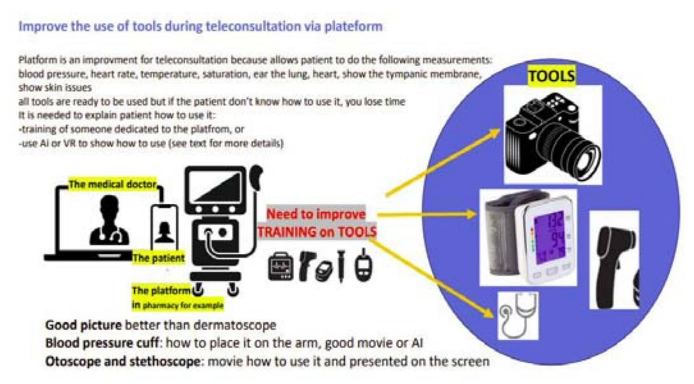

Figure 2: Tools used during teleconsultation using a platform.

Tools as shown in the picture are, for example camera to show skin issues, for example, and sample medical tools like a thermometer, otoscope, blood pressure cuff, stethoscope, and others may be used. The patient on site needs to take the picture himself, use the otoscope, data collected from it will be sent by communication set up, which may be different depending on the area, most of the time internet. It is easy to understand that a patient alone never been trained is not able without help or minimum knowledge to use it directly. Of course, the physician on the other side can help.

But as it will be detailed later in the chapter, we could use AI or VR to teach the patient, or a simple movie could easily explain to the patient how to proceed.

What do we still need to improve during our ground telemedicine?

Increase the level of trust: Patients often go to alternative medicine. Few reasons for that, among those, the time with the physician. They are very busy and have no more time to discuss a few topics; they have no time to explain what happened to the person. At the end, the patient feels not well helped and finds another way.

In that case, the telemedicine activity imposes on the physician to establish during the discussion a kind of trust with the patient; this trust should already be here in general family activity. How do you build it? Just during this short video discussion first, we really need to see each other, the voice, of course, is very important, if after your diagnosis, the patient looks unhappy, you might ask him what is wrong. The best example would be in the time of seasonal flu, if you tell the patient OK, this is just a flu, with stay at home and take medication against the fever most of the time, the patient is unhappy. Why? Because he has already been trying such and using a telemedicine platform to have another medication. This is obvious that if you are not able to make him accept what you say, either you discuss and he knows him better than you, and, in that case, you really have to accept and hear him and maybe accept his demand. If you really feel you are right, then give him a good, rational argument, and he will accept.

This kind of exchange is interesting in telemedicine, and we probably have it much more than in the general family practice.

Good example, if you don't want to use antibiotics, if the patient tells you I am using what you give me for days, you need to have a backup option.

Good recommendations on food/nutrition are very useful: This is very obvious in France, where patients want to have the answer and even better, prevent the pain from arriving. Of course, this should be the best way to do but what are the consequences of some medication we are using? Fever is not always bad to have, it is the way your body tries to trait, so we can use that he just need to wait.

The good classical recommendation in the older time, if you are sick, may be not to eat for the day, it will help your body to recover, and in one day you feel better.

Such a recommendation is probably easier to give during telemedicine: you and the patient are new to each other, so you start from the basic knowledge. New tools to increase autonomy could be used on both sides.

Increase the level of security data: Even though the level of care of the physician and, more than that, the physicians' fundamental ethical responsibilities do not change during telemedicine, the fact that a part of the data is transmitted via the internet needs to be secured.

Physicians who answer individual health queries or provide personalized health guidance electronically must be confident that the websites with which they affiliate have appropriate mechanisms in place to protect the confidentiality of individual information exchanged through the website. But they need to check it. They must have appropriate protocols to prevent unauthorized access and to protect the security and integrity of patient information [50].

A new word emerges since the wider use of the internet: cybersecurity. It refers to: "a measure for protecting computer systems, networks, and information from disruption or unauthorized access, use, disclosure, modification or destruction"

A large number of national and international standards are available to guide this process. ISO/IEC 27001 is an IT cybersecurity standard that lays the foundations for an effective information security management system, while ISO/IEC 27002 provides a set of information security controls and implementation guidelines. The management system ISO 27001 supports network communication protocols, data access control, and cryptography (i.e., password encryption), which contribute to ensuring a robust and secure communication method, inclusive of cybersecurity staff training [51,52].

Also, security laws are in place, and it is the responsibility of

https://doi.org/10.29328/journal.acee.1001076

the health care entity (hospital, physician platform), as well as the informatics team to make sure the rules are followed. For such, it will be necessary to implement robust encryption tools, password protocols, and access controls a long way towards protecting data transmission and medical device security. It will be necessary as well to have regular and thorough cybersecurity risk assessments to identify vulnerabilities. Indeed, training staff in basic cybersecurity protocols helps protect devices, medical practices, and patients.

Just as important as these specific action points, the healthcare sector as a whole needs to work hand-in-hand with policymakers and innovative companies to stay one step ahead in this rapidly changing landscape. Government regulators, for example, are increasingly requiring proof of cyber-secure systems as a condition of device use in their jurisdiction, as well as a management and monitoring plan once these systems are operational.

Nowadays, with the huge increase in data transmitted via the internet, new devices (smartphones…), due to the variety and veracity of data available, new concepts should be used to increase the security.

Although GDPR (General Data Protection Regulation) has significantly enhanced the level of personal data protection, more research is needed to facilitate some means that are still missing (like users' right to delete data, update data…). Wylde and his team proposed using the Blockchain (BC), which can provide a good and robust internet security level. It would improve cybersecurity, although it cannot eliminate cyber risks, it could significantly minimize cyber threats. Furthermore, BC eliminates single points of failure and the need for third-party intermediaries in the IT system [53].

- How can information and data processing be secured?

Generally speaking, information security is based on three pillars: availability (possibility of accessing the information), integrity (absence of modification of the information), and confidentiality (only the recipients of the information know of it). Healthcare professionals must therefore ensure that the data they process is protected against breaches of these three pillars. To do so, they must implement technical measures (e.g., a high-quality antivirus) and organizational measures (e.g., management of differentiated access to the information system). A breach of any of these three components of IT security may prevent the healthcare professional from carrying out his or her activity (if he or she can no longer access patient files, for example), or even infringe patient privacy (as is the case when personal data concerning patients is disclosed). Additional risks come from websites that offer health information but may not be as anonymous as visitors think; they may leak information to third parties through code on a website or implanted on patients' computers. Similar concerns may apply to home monitoring devices and mobile health applications to which current privacy protections may not apply.

Future of telemedicine for all (space and earth)

We see the use of IT developed in more field and even start up are growing in the telehealth not only providing tracking, monitoring of disease and delivering clinical care to patient but as well their use has shifted towards smartphone-enable AI driven personalized care, including digital therapeutics and wearable device innovation [54].

This shows how the innovation in the domain of IT can help on both sides, space and earth, in telemedicine.

If we had a reasonable wearable device, well accepted by the crew, measuring vital parameters and more complex with real-time connectivity to the ground, this could help the needs of the ISS. And for an interplanetary mission, such a device with AI capable of biofeedback without the need for a ground answer in real-time would cover some of the requests already emerging for the future.

Conclusion

To conclude on that brief review comparing the telemedicine activity on Earth and in space, we can say that the tools, the connections, the camera, and the training are very important. The training on the tools is the basic part of it.

One important information we need to take into account is astronauts during their mission on board are alone and they are using their medication … for patient on ground we need may be nowadays to think the medicine in another way, having physician on side for the very important disease and all the other minor disease treat by telemedicine of course until you see a patient requiring immediate care but using the telemedicine platform to make the patient more responsible for his health given him the best recommendation we can for example the old one coming from Hippocrates "make your food your first medicine".

Since 2018, in France, for example, these teleconsultations have been accepted and reimbursed by insurance provided via restrictive rules. Even though the first telemedicine regulations were integrated into the law of 13 August 2004 relating to the reorganization of French healthcare insurance [55].

The patient usually doesn't know the physician on the platform, it is a very nice opportunity to learn differently from him, open him the way he is more knowledgeable than you are about his own body. You are here to give him good advice or medication, or help with another prescription. In such a view, the patient probably can benefit from the orientation and discussion you had with him.

Another really important point is that even new technologies and models of care continue to emerge, the fundamental ethical responsibilities of physicians do not change.

Among the negative impacts of telemedicine is the resistance to utilizing it. This resistance comes from some patients and from some physicians, too. The first reason could be a lack of understanding of telemedicine's benefits [26].

After the COVID pandemic, there has been a rapid mobilization of digital services dedicated to healthcare work. But resistance among the clinical professional has been explained by additional burden to already unmanageable workloads, fear that could change the relation with interprofessional collaborations, erosion of their power, and a loss of autonomy over their work. The clinicians are concerned that acute cases might be missed with potentially fatal consequences [56]. Another point for the physician resistance is that he might think of losing "his power," but the coming years will probably show that we need to use it to overcome the lack of physicians.

The resistance among patients comes more from tools, people not knowledgeable in the techniques being afraid not to have the same level of care.

The solution for that resistance should come from regulations and clear broader government actions to raise public awareness and improve health and digital literacy. It is needed to have adequate preparation, planning, support, and coordination across the health system. This may include developing policies that broadly guide telemedicine design, implementation, and utilization [26].

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