Chapter

Smartphone and Surgery, Reality or Gadget?

Sassi Boughizane, Badra Bannour, Imen Bannour, Faten Hacheni, Imen Bannour, Marwa Masmoudi, Jalel Boughizane and Sabri Youssef

Abstract

Surgical care is an essential component of health care. This basic universal right is not available to everyone. Indeed, countries with low economic resources suffer from a lack of access to surgical care and the most developed countries will have to reduce the cost of health care to ensure the sustainability of provided care quality. New communication technologies have invaded the field of health and have led to the development of a new concept of mobile health. The purpose of this paper is to answer the following question: Can these new tools, and in particular the Smartphone, remedy, even partially, the lack of health care in poor countries and reduce the cost of health care in rich countries? New communication tools, led by the Smartphone, have the capacity to capture, store, retrieve and transmit data to provide instant and personalized information to individuals. This information could be a key element in health systems and can contribute to monitoring health status and improving patient safety and care quality. Mobile telephony via applications and connected objects can facilitate the pre-, intra- and post-operative management of patients. These mobile systems also facilitate the collection and transmission of data. This will allow better analysis of this data and will greatly pave the way to the introduction of artificial intelligence in medicine and surgery. The Smartphone can be used as an important tool for both, diagnosis care and surgical training. Surgeons must adapt their equipment to local resources while respecting safety standards. Covid-19 has put health systems around the world under severe strain. Decision-makers are being forced to make adjustments. The long-vaunted digital health is becoming a reality and a necessity. Healthcare authorities and strategy specialists face challenges in terms of disease prevention and therapy, as well as in terms of health economics and management.

Keywords: smartphone, surgery, mobile health, medical information

1. Introduction

Surgical care is an essential component of health care. This basic universal right is not available to everyone. Indeed, countries with low economic resources suffer from lack of access to surgical care and the most developed countries will have to reduce the cost of health care to ensure the sustainability of quality care provided.

It is estimated that two-thirds of the world's population do not have access to safe and affordable surgery and more than two billion people are unable to receive surgical care due to the lack of equipment and human resources. As a result, limited access to surgery kills nearly 17 million people each year. This is more than the number of deaths from HIV, TB and malaria combined [1, 2].

The economic inequalities on our planet are fully reflected in the field of health as 60% of surgical procedures are performed for only 15% of the world's population and only 6% of surgical procedures are performed for poor countries where one third of the world's population resides [3].

High-income countries have better indicators of quality and safety of care. However, this is associated with higher health care costs. The increase in health expenditure in developed countries is faster than the growth of the world economy. This seems to become unsustainable in the medium and long term.

New communication technologies have invaded the field of health and have been at the origin of the development of a new concept of mobile health. The purpose of this paper is to answer the following question: Can these new tools, and in particular the Smartphone, remedy, even partially, the lack of health care in poor countries and reduce the cost of health care in rich countries?

New communication tools, led only by the Smartphone, have the capacity to capture, store, retrieve and transmit data to provide instant and personalized information to individuals. This information could be a key element in health systems and can contribute to monitoring health status and improving patient safety and care quality.

Healthcare authorities and strategy specialists face challenges in terms of disease prevention and therapy, as well as in terms of health economics and management.

In addition, the Covid-19 global pandemic has suddenly put everything into question and put health systems around the world to the test. The long-vaunted digital health is becoming a reality.

2. Current state of surgery in the world

2.1 Surgical expenditure

High-income countries have excellent indicators of quality and safety of care [4], but this is associated with high health care costs in these countries.

The increase in health care expenditure in developed countries is faster than the growth of their economies. For example, in the United States of America, health expenditure has been increasing rapidly and in 2019 it accounted for 17% of gross domestic product [5].

For low-income countries, the situation is quite different. According to the Lancet Commission on Surgery, the cost of surgery and anesthesia causes "catastrophic" health care costs for 33 million people each year [6]. The problem lies mainly in the direct costs of surgical care, which are often high [7].

Given that, this burden has deleterious effects on health care systems worldwide, it has become necessary to search for solutions to reduce the cost of surgery.

2.2 Access to surgery

Despite the efforts made, at least half of the world's population lacks access to essential health services and does not enjoy the fundamental right to healthcare in practice. Striking urban–rural health inequities are still reported in many countries [8].

The Lancet Commission has established 6 key indicators for the strength of the surgical system in the world [9]:

1. Access to timely essential surgery.

2. Specialist surgical workforce density.

3. Surgical volume.

4. Perioperative mortality rate.

5. and 6. Risk of impoverishing and catastrophic expenditure on surgical management.

These indicators have revealed a perilous state of the surgical system worldwide that needs immediate improvement to achieve universal access to safe, affordable surgical and anesthesia care when needed.

It is estimated that 9 out of 10 people in low- and middle-income countries lack access to basic surgical care and that 143 million additional surgical interventions are needed each year to save lives and prevent disabilities [10].

It should also be noted that the inadequacy and uneven distribution of specialist surgical stuff has further compounded the disparity in access to care [11].

Therefore, the whole world and poor countries in particular need to develop policies to make surgical care easier to perform and learn.

2.3 Current status of minimally invasive surgery in the world

Traditionally, open surgical approaches have been the mainstay of surgical treatment, but in recent years the number of open surgeries has largely decreased in developed countries in favor of minimally invasive surgery in all surgical specialties [12].

Minimally invasive surgery has become the standard in many specialties and has overtaken traditional surgery in many cases.

Indeed, this type of surgery offers patients multiple benefits such as smaller incisions, faster recovery times, reduced adhesion rates, pain, morbidity, and postoperative length of stay, [13, 14]. It is therefore perfectly suitable for LMICs since, by reducing the length of hospital stays and speeding up recovery time, it reduces the total cost of surgery which is a major barrier to healthcare access for a significant population in these countries.

A major obstacle to assessing the adoption of this surgery worldwide is the lack of official data and publications in developing countries [2]. However, the limited published data from these countries indicate that the rates of laparoscopic surgery for gynecological indications are minimal and vary widely from hospital to hospital.

Published data from large referral hospitals in LMICs reported laparoscopic surgery rates for gynecological indications of less than 10% [15].

2.4 Obstacles to the adoption of minimally invasive surgery

The implementation and development of endoscopic surgery in LMICs is in fact confronted with multifactorial obstacles, the most important of which are insufficient investment in equipment and difficulties in accessing specific training [16]. Indeed, the lack of resources is the main obstacle. The low economic status in these countries makes it challenging to acquire and maintain endoscopic equipment, train surgeons and technicians and reinforce their capacity to perform endoscopic surgery. This explains the tendency to use endoscopy mainly as a diagnostic tool in developing countries [17].

There is a proportional relationship between a country's gross domestic product and the percentage and complexity of minimally invasive procedures performed [17].

The severe shortage of surgeons in low-income countries coupled with their heavy workload does not allow them to sub specialize; as a result, minimally invasive procedures are time-consuming and have the potential to lead to more significant complications [18].

This creates a self-inhibition that will make the learning curve much longer.

It has therefore become of paramount importance to facilitate and accelerate surgical training. The use of Smartphone seems to us to be an adequate solution [19, 20].

Surgery has traditionally been considered too expensive, complex and unprofitable. Indeed, surgery has never been included in primary health care, although surgical interventions are economically profitable in terms of saved lives and prevention of disabilities [21, 22].

The other hurdle is the socio-cultural barrier related to older surgeons' resistance to change and their reluctance to use new surgical technologies [16].

3. Concept of mobile health

According to WHO, e-health is the use of information and communication technologies (ICTs) to support health and health -related fields, including health care services, health surveillance, health literature and health education, knowledge and research [23].

In common parlance, e-health encompasses everything that is associated with the digitalization of health.

The adoption of IT tools in the field of health (e-health) has evolved throughout successive historic periods from medical records and professional messaging to telemedicine, online communities, mobile applications and connected objects, augmented reality and virtual reality, artificial intelligence and chat bots and, finally, the block chain technology [24].

Mobile health or m-health is a major component of connected health (e-health). Mobile health is defined as medical and public health practices that rely on mobile devices such as mobile phones, patient monitoring systems, personal digital assistants and other wireless devices [25].

This involves the integration of connected objects and mobile applications into the practice of medicine and the health system.

This concept has emerged from the exponential development of digital technologies in general and mobile wireless technologies in particular. Nowadays, these technologies are increasingly part of the daily life of both health professionals as well as patients. On the other hand, the world's health system is facing immense difficulties, mainly related to the increase in health expenditure and the disparity in access to care. As a result, mobile health has emerged as a promising solution to the current global health challenges.

4. Anatomy of a smartphone

A Smartphone is made up of many internal parts or components. There are differences between models and brands but the structure remains the same.

This technological jewel has several assets:

1. The wealth of its applications in number and performance

2. The increased performance of its connectivity

3. Highly sophisticated cameras

4. Sensors that turn the Smartphone into a multifunctional object

4.1 Smartphone applications

Today's Smartphone are a real revolution because of their ease of use and user-friendliness. These privileged interfaces provide applications that simplify software by making it more straightforward and accessible. The number of online health applications has grown exponentially [26].

Mobile health applications are divided into several categories:

- Remote monitoring applications.
  Remote monitoring apps help practitioners take care of patients even when they are at home [27].

- Clinical and diagnostic applications.
  Physicians can collect patient data, evaluate and share it. These apps allow practitioners to view lab results, check electronic health records or even perform digital imaging.

- Wellness apps:
  These monitor parameters such as heart rate and rhythm, diet, exercise and sleep [28].

- Clinical reference applications.
  These applications provide all the necessary information at your fingertips.

- Productivity applications.
  Productivity applications help to increase the efficiency of health care providers.

4.2 The smartphone's connectivities

4.2.1 Increasingly powerful connectivity

One of the main revolutions that the smartphone has brought to our daily lives is the ability to connect with anyone, anytime, and anywhere and with new high-speed communication standards constantly evolving, data transfer and sharing is becoming even faster. 5G, the 5th generation mobile network, promises many benefits, including much faster data transmission, Lower latency and high reliability.

4.2.2 Connected health objects

A connected object is an object that is connected to the Internet, capable of sending information in real time and interacting with its environment. A connected object is based on three essential things:

- Its ability to capture data through sensors of all types: speed, temperature, force, pressure, energy, location, power, volume, acoustics, distance, photometry, frequency, vibration, humidity, etc.

- Its capacity to provide data feedback to allow the visualization of information through specially designed dashboards.

- Its ability to inter-connect and interact to a greater or lesser extent with other objects, whether connected or not.

A connected object has two main functions:

- The collection of information from its environment, for example the user's heart rate.

- The triggering of an action based on the information collected and transmitted. For example, triggering an alarm in the event of a heart rate anomaly.

Examples of connected objects:

The weight is displayed directly on the scale and can also be displayed on the Smartphone via Bluetooth or Wi-Fi. The latter allows the saving and synchronization of measurements with a weight curve and also the transfer of data to a health professional (doctor/nutritionist).

Connected watches and bracelets placed around the wrist to record activity according to the sensors they contain (heart rate, GPS, accelerometer etc.). The recorded data is communicated to the Smartphone.

Connected mattresses, contain sleep and environmental sensors that collects and sends data to your Smartphone in order to determine your ideal sleeping temperature [29].

4.2.3 Connectivity and the internet of things

The Internet of Things is the set of objects connected to the Internet that generate data through specific sensors. What they have in common is that they are physical objects and transmit digital information as well as computations, remotely, through an application, often directed from a mobile device (phone, tablet, and computer) [24].

This allows data to be collected, sent and stored over a network without requiring human-to-human or human-to-computer interaction [30].

The application of the IoTconcept in the field of medicine and surgery has great potential. For example, the connection to various external sensors for diagnosis, monitoring and follow-up is a promising technological advance. The data collected from these different sensors constitute a valuable database that will be of great help during treatment. Communication between doctor and patient also takes on another dimension with these new modes of connectivity, making access to care easier.

Connected objects for medical purposes make it possible to monitor the patient's condition more frequently, more accurately and, therefore, better.

4.2.4 Connectivity and artificial intelligence

Artificial intelligence is a set of theories and techniques used to create machines capable of simulating human intelligence.

AI is applied to any activity that involves data collection, followed by decision making and taking action, the cycle repeating itself ad infinitum.

Use of AI in the medical field seems to be highly promising and the potential applications are endless. A medical device could, in theory, use the sum of the experiences of all medical images, of all surgeries if this data could be formatted and collected. It is through self-learning from real-life results that AI is becoming more and more powerful [24].

AI has been applied in various health fields including cancer research, cardiology, diabetes, mental health, etc.

4.3 Smartphone cameras

Smart phones are equipped with increasingly sophisticated cameras whose performance is equal to or better than that of professional cameras [31]. Some smart phones are equipped with high resolution cameras, even 4 K resolution, or three-dimensional cameras. Some professional films have been completely recorded by smart phones. Others have won awards [32].

The integration of microscopes into smart phones to visualize bio-components such as blood cells and micro-organisms has improved over time to the nanoscale level where nano particles, viruses and DNA can now be detected [33].

Smart phones may offer a viable solution for early diagnosis of skin diseases, specifically for remote screening and long-term monitoring of skin lesions [34].

4.3.1 The Smartphone's sensors

The Smartphone is equipped with a multitude of sensors:

- Some are intrinsic: these are the internal sensors.

- Others are integrated into the Smartphone: external sensors connected wirelessly or by cable.

4.3.1.1 Internal sensors of the smartphone

Smart phones embody a series of integrated sensors that allow them to interact with the outside world (movement, light, magnetic field ...): thus turning it into a real pocket laboratory.

In recent years, there has been a growing interest in the use of motion sensors embedded in smart phones such as accelerometers, gyroscopes and magnetometers, as well as location sensors such as GPS for real-time monitoring of physiological constants and activities of daily living.

4.3.1.2 External sensors

Nowadays, it is possible to attach several complementary electronic devices to the Smartphone, converting it into a multi diagnostic system depending on the nature of the attached device [35].

These technological solutions appear to be particularly cost-effective and attractive in resource-limited settings where access to diagnostics and care is not always possible.

Currently, many body organs can be monitored via smart phones.

For example, ultrasound probes can be directly connected to the Smartphone and seem to be a very interesting prospect for the future. Different probes are already available on the market for vascular, soft tissue, lung, abdominal and pelvic examination, FAST ultrasound… [36].

These handheld ultrasound probes have high diagnostic accuracy, sensitivity and specificity for basic anatomy and pathology and can be an acceptable and reproducible diagnostic tool with great potential for future applications particularly in low resource countries to increase access to ultrasound [37].

These connected objects can collect, store, process and transfer data or perform specific actions according to the information received. They carry out measurements in real time and can provide information on many parameters affecting health: weight, body temperature, pulse, blood pressure, breathing rate, heart rate, blood sugar level, sleep quality, etc. At the end of the object's connection is a computer or a Smartphone, a doctor or a call centre, a coaching centre, etc. aiming to create an alert system: any change in one of the parameters transmitted abruptly or reaching a previously set critical value prompts an intervention, special monitoring, advice or recommendations [24].

4.3.1.3 Biosensors

Biosensors are measuring instruments that integrate a biological element (enzyme, antibody, plant or animal cell, DNA fragment, lipid, etc.) and a physical transducer (electrode, optical fiber, etc.). The aim of biosensors is to detect characteristic markers of disease at an early stage in order to improve patient care. There are many potential applications. The most famous biosensor is the one used to analyze blood sugar levels in patients with diabetes [38].

The Smartphone is now a miniaturized computer system, to which several kinds of biosensors can be connected. A phone application can detect several biological agents using the data transmitted by the biosensor.

Currently, much work has focused on miniaturizing biosensors and bioelectronic devices, such as micro fabricated transducers and compact readout instruments, to achieve state-of-the-art, easy and reproducible real-time detection [33].

5. The smartphone in clinical evaluation and preoperative examination

We propose here the main applications of the Smartphone in preoperative care.

5.1 Cardiovascular analysis

Measurements of heart rate, blood pressure and even continuous monitoring have become possible [39].

One study compared finger-measured BP, using the OptiBP Smartphone application based on a pulse wave analysis algorithm, with BP measured via an arterial catheter. The difference in BP (mean ± standard deviation) between the two methods was within the norm. This may therefore become a valuable tool for detecting hypertension in various settings, such as pre-anesthetic assessment especially in low income countries [39].

A Chinese study done in 2021 proposed a new method of measuring heart rate variability using the Smartphone rear camera as a sensor. The fingertip video signals of 24 students were acquired using the rear camera of an HTC M8d Smartphone. ECG signals were recorded simultaneously as a reference. The results were comparable [40].

Some Smartphone-connected watches can perform a single-lead electrocardiogram (ECG) and detect atrial fibrillation. The clinical accuracy of the waveforms of these single-lead ECGs is still lower than a 12-lead ECG. But there is evidence, for example, that the Apple watch produces accurate ECGs in healthy adults with moderate to high agreement of baseline ECG intervals [41].

A study evaluating the efficacy of Cardio-Rhythm was conducted in 1013 patients with T2DM and hypertension: Atrial fibrillation was diagnosed in 28 patients (2.76%). The diagnostic sensitivity of CardioRhythm was 92.9% and was higher than that of a clinical score algorithm Alive Corautomated Algorithm (71.4%) [42].

5.2 Respiratory status

Smart phones can monitor and transmit arterial oxygen saturation (SpO2) data. The validity and reliability of a Smartphone oximeter has been validated by several studies [39, 43].

5.3 Measurement of hemoglobin level

- Non-invasive Hb measurement: HemaApp.

The HemaApp is an application to detect the hemoglobin level in the blood by color analysis using the HemaApp camera flash. By passing the light from the phone's camera flash through the patient's finger, HemaApp analyses the color of the patient's blood to estimate hemoglobin levels.

The FDA has approved it in the US as a non-invasive hemoglobin measurement tool [44].

- External sensors connected to the Smartphone to measure hemoglobin levels:

Automated external sensors linked to the Smartphone are able to quantitatively measure, without chemical reactions, the concentration of hemoglobin ([Hb]) in whole blood samples [45].

5.4 Measuring blood glucose

The conventional method of measuring blood glucose requires several pieces of equipment such as a glucometer, a test strip, a needle, an alcohol swab and gloves. This method of measurement is uncomfortable for the patient, especially if several measurements have to be performed every day.

To make the measurement more convenient and less invasive, researchers have developed a method based on colorimetric and electrochemical techniques to determine the glucose level using a Smartphone. This is called photo-plethysmography (PPG), a non-invasive, low-cost technique that measures the volumetric variation of blood in the arteries.

The principle of the proposed non-invasive technique is to record a short video (20 s–50 s) of the subject's fingertip using a commercial Smartphone camera. This video is then converted into images containing RGB channel information of different wavelengths. Because the wavelengths of the transmitted light (red, blue and green) are different, each penetrates the tissue differently: Red light has a longer wavelength than green or blue, and therefore penetrates deeper into the tissue. By integrating this image data (RGB channel), a PPG signal is generated from the recorded video.

Using these PPG signals acquired from the Smartphone and the corresponding glucose levels acquired with a glucose meter, linear regression models for glucose level prediction are created, allowing each PPG measurement to be assigned a blood glucose level. (Blood Glucose Level Regression for Smartphone PPG Signals Using Machine Learning Tanvir).

5.5 Hyperbilirubinemia

Other applications have been developed to detect hyperbilirubinemia based on the degree of absorption of the blue light emitted by the Smartphone flash. The image of the skin taken with this flash is compared to a color spectrum to classify it as icteric or non-icteric skin. The results are comparable to modern transcutaneous bilirubinometers [46].

5.6 Examples of connected medical devices

Several connected medical devices have been marketed in recent years such as stethoscopes, blood pressure monitors, ECGs, etc. [29].

The company EKO introduced on the market one of the first connected smart stethoscopes, capable of detecting heart murmurs with a sensitivity and specificity of 87% [47, 48].

There are many connected ECGs available on the market. Thanks to their connectivity with a Smartphone, sharing recordings is now easy between patients and doctors [49]. The principle consists in placing two fingers of each hand on the device and the result is displayed directly on the Smartphone.

Several studies have shown that these connected ECGs are capable of detecting atrial fibrillation in the ambulatory setting [50].

6. The smartphone in the operating theater

6.1 Estimation of blood loss in the operating room

Accurate assessment of blood loss is an important aspect of surgical management. Blood loss is usually assessed by visual estimation of the amount of blood in suction cartridges, surgical sponges and surgical drapes, which makes it very subjective.

An application has been recently developed to make this assessment more objective. It uses the Smartphone camera to capture images of surgical fields and then uses image analysis algorithms and cloud-based machine learning to accurately estimate the amount of hemoglobin (Hb) blood loss in real time on soaked surgical fields [51].

Another more relevant application developed by the same author allows the assessment of blood loss by estimating the hemoglobin level [52].

6.2 Location of tumor lesions

6.2.1 In neurosurgery

Operating theaters are equipped with microscopes to provide a good standard of care. However, in developing countries, microscopes are not always available. An adaptation of the Smartphone camera has been used as a valid alternative to the microscope. In a hospital in West Africa: using a simple tin can, a Smartphone shell and a rod attached to the bed, a Smartphone holder was created. This device provided surgeons with a magnification tool and a source of light in the surgical field. This simple "Smartphone-based exoscopy" allowed surgeons to obtain adequate magnification during brain surgery. This device has made it possible to overcome the lack of microscopes or surgical magnifying glasses, and can be useful in countries with limited resources [53].

6.2.2 Use of augmented reality to localize tumor lesions

Accurate localization of intracranial lesions before surgery is important, but sometimes difficult. Modern navigation systems are very useful, but expensive.

A low-cost solution for locating brain lesions and their surface projections in augmented reality has been described by a Chinese team. They used an iPhone to partially achieve this goal and assessed its accuracy and feasibility in a clinical neurosurgical setting.

This low-cost, iPhone-assisted, image-based augmented reality solution is technically feasible and useful for the localization of certain intracranial lesions, in particular superficial supratentorial intracranial lesions of medium size [54].

6.3 The smart scope

Another technological revolution should be mentioned: endoscopes Smartphone cameras, or otherwise called "Smart-Scopes".

In this case the Smartphone replaces the endoscopic camera and monitor by using its own camera and screen. The endoscope is coupled to the Smartphone camera and a removable light source completes the device. The Smartphone will be protected by a transparent sterile bag. The result is another laparoscopic surgical device called the smartscope that offers portable, cable-free, low-cost laparoscopic visualization.

Since the Smartphone used will mainly provide its camera to the surgical device: the higher the quality of the camera (4 K and 3D), the better the image of the surgical site. The size of the Smartphone is not important since the image obtained is immediately casted via Wi-Fi on a larger monitor. The image transfer is instantaneous and keeps the native resolutions.

The part that adapts the Smartphone to the endoscope can be made from an old, unusable camera head or purchased new. Different models are available on the market; some are specific to certain smart phones.

Removable camera sources are available on the market. Their disadvantage is that they have a limited life span.

The main advantage of this system is that it does not require any wiring. The image obtained on the Smartphone screen can be directly casted via Wi-Fi on a large monitor. It is a stand-alone system that completely dispenses with expensive laparoscopic columns. The surgeon holds the device and stands behind the Smartphone to watch the screen.

Real-time transmission of the image can be done through media streaming devices (such as Chromecast and Airplay). The device is plugged into the HDMI port of a TV and communicates, via Wi-Fi connection, with another Internet-connected device (computer, Smartphone, tablet, etc.), in order to display the received multimedia content on the TV [55].

The Smartphone therefore benefits from the power of the new cameras fitted to high-quality smart phones. As their cameras are constantly evolving, they allow high-definition images with true-to-life colors to be obtained. 4 k cameras are now available in many smart phones at much more affordable prices than 4 k-ultra HD laparoscopic columns.

The only limitation to this system is the limited duration of the removable light source.

The feasibility of this system is no longer in question. The smart scope has been used in various specialties: gynecology, urology, gastrology, otorhinolaryngology, etc.

In gynecology, a Greek team was able to create and test this device and proved its effectiveness in various surgical procedures. Thus it was possible to operate on ruptured ectopic pregnancies with hemoperitoneum, adnexal torsion, tubo-ovarian abscesses. This device has also made it possible to carry out diagnostic laparoscopy of ovarian cancer, enabling the extension and condition of the abdominal cavity to be assessed and biopsies of the mass to be performed. Image quality, resolution and acquisition were excellent, and the surgeons who performed the procedures reported no diagnostic problems with the new system [55].

Extrapolating the same principle, other basic surgeries such as appendectomy or cholecystectomy could be carried out without the need for a costly laparoscopic column.

In otolaryngology a Smartphone-based endoscopic device has also proven its clinical value and performance: The Smartphone system has shown an acceptable level of clarity for an ENT specialist to distinguish between healthy and diseased or damaged tissue regions via the Smartphone screen. By connecting to a wireless headset, the Smartphone-based endoscope system could even superimpose an endoscopic image on a real-world view [56].

In urology, a Smartphone coupled with a rigid endoscope can replace a cystoscope. It can be used in the emergency department for diagnostic procedures. As the system is fully self-contained and portable, it will make old, cumbersome and time-consuming procedures more efficient and cost-effective.

The 1951 USAF resolution test pattern was used to evaluate the image obtained from the smartscope. The results were found to be comparable to conventional cystoscopy for the rigid cystoscope [57].

The cost is approximately 50 to 70 times less than that of a standard high definition endoscopic camera [58]. Other devices replacing the usual laparoscopic surgical equipment have been developed and are constantly being improved. Optimization and validation of these systems is needed in terms of safety, as most of these devices are still in the experimental stage, but they have already proven to be of enormous benefit in developing countries: they are inexpensive and very easily reproducible. These devices have already been tested in basic laparoscopic surgeries: cholecystectomy, appendectomy, tubal ligation… [59].

The main advantages of the smart scope are:

- Cost: it costs 70 times less than the standard HD endoscopic camera [58].

The endoscope system with LED light source costs around $45 with the cost of a Smartphone with a good camera estimated at $1000 versus conventional video endoscopy with a standard camera and XL light source which costs $45000 [60].

Ease of use and availability:

- This system allows simple procedures: salpingectomies, adnexal detorsions, abscess drainage, tubal ligation….

- Facilitates access to endoscopic surgery, which remains limited in some regions: This device could save surgeons' time and save patients in hospitals where resources are not available. In some hospitals that have only one laparoscopic column, two surgical emergencies that require immediate interventions could not be managed at the same time due to the lack of resources. This surgical Smart-scope allows to ensure the same chances in terms of access to care.

- Facilitates the sharing of peroperative videos in real time through the internet, case presentation and discussion with colleagues.

- The ability to use the properties of the smartphone e.g. to zoom in on images.

- The possibility to access HD, 4 K and 3D quality images.

The only disadvantage of the smartscope is the limited duration of the removable light source.

7. The smartphone in postoperative care

The fields of application of the Smartphone in postoperative care are limitless, among which we can cite.

7.1 Monitoring of hemodynamic and vital constants

Several systems enable the delivery of mobile health monitoring services for outpatients and/or those outside of healthcare settings. Examples of these systems include the pulse oximeter of Masimo.com, the adhesive patch of Isansys.com, the electronic tattoo of mc10inc.com, or necklace of Tosense.com.

Several parameters can be analyzed such as: heart rate, heart rate variability, respiratory rate, skin temperature, stroke volume and cardiac output.

The information is transmitted to the Smartphone so that health professionals and/or patients can be informed quickly in case of clinical deterioration [61].

7.2 Remote monitoring of surgical wounds

Postoperatively, the Smartphone can be used as a tool for the monitoring and surveillance of postoperative infection sites. These infections can occur up to 30 days postoperatively. Monitoring can be done through sharing images of the surgical site and remote video conferencing [62, 63].

7.3 Monitoring of flap vitality

Some applications have also been developed in the field of plastic surgery to assess the vitality of grafted flaps through the communication of images postoperatively. Flap vitality assessment is done by comparison to a colorimetric scale, which reduces the time interval between the first notification of flap compromise and the start of re-exploration (4.0 vs. 1.4 hours).

8. Initial and continuing surgical education and information sharing

8.1 Access to medical information

Mobile phones facilitate access to medical information, particularly medicinal information, as they are more ergonomic and faster than consulting a paper book. The challenge for professionals is to identify validated applications that meet a real need and save time. Of the large number of applications available in the health sector, very few survive this triple filter.

Many specialists therefore stick to the applications proposed for their specialty, in addition to Vidal, which is appreciated by all.

Several learned societies and colleges of specialties offer specialized applications. This makes it possible to take advantage of reference systems and decision-making algorithms in just a few clicks.

8.2 Telemedicine, telemontoring, tele-expertise

The non-health-specific consumer platforms, Facebook (WhatsApp, Messenger and Instagram) and Google (Google Maps, YouTube and Google Play) largely dominate the mobile offer, but these applications do not allow the secure exchange of medical information.

TeamDoc has been proposed as a secure mobile application to replace WhatsApp, with features designed for healthcare professionals, which can be used in hospitals, clinics and private practices.

In the face of the coronavirus, many creative ideas and skills have led to the rapid launch of health applications [24].

A surgeon can now seek the expertise of a remote colleague at any time of the day through the transmission of images and videos. The use of social networking and instant messaging services is of real interest to developing countries because of its availability in remote and rural areas and its cost effectiveness [64].

With the new communication platforms, medical education has become more easily accessible.

The recording of an operation has become easy and reproducible with the Smartphone, thus allowing the creation of multimedia repertoires of great educational value.

Telementoring allows an experienced surgeon, located at a distance, to mentor a second operator in real time, thus boosting the dissemination of scholarly knowledge across borders and covering previously inaccessible geographical areas.

8.3 Simulation of surgical interventions by smartphone using virtual reality

Virtual Reality is being used to train and support healthcare professionals during initial and continuing training, during the simulation of surgical gestures and interventions, and during therapeutic treatments.

This directly therapeutic dimension of virtual reality is rare in the world of digital tools.

8.4 The advent of applications dedicated to learning

Several medical applications allow surgical trainees to become familiar with surgical interventions and to facilitate the learning of anatomy. Simulation is a validated method of medical learning. Simulations of certain surgical procedures have even become possible with several case scenarios [64].

8.5 Making laparoscopic Pelvi-trainers

It has become quite possible to create a laparoscopic surgery simulation box using a Smartphone. Improving skills through continuous practice is becoming an increasing priority in surgical training programs. It is an inexpensive, easily assembled, reproducible solution that is readily available as a useful tool for learning and improving laparoscopic techniques [65].

8.6 Touch surgery

The Touch Surgery mobile application is a mobile surgical training platform designed to simulate surgical procedures. As of October 2019, the Touch Surgery mobile app included surgical instructions for approximately 200 surgical procedures in 17 different specialties [66].

It is a useful tool for improving both technical skills and knowledge of the steps in the tendon repair procedure; however, its role may be limited to an additional tool as it does not improve theoretical knowledge. The TS has the potential to be implemented in an academic surgical program in low- and middle-income countries [66].

8.7 Other fields of application of the smartphone

Chat bots, or conversational agents, are used on many websites, mobile applications and consumer messengers.

An avatar greets the visitor and asks closed questions that lead the user through a tree structure. The concept originated in the medical world.

Many independent health mobile applications ask users questions about their symptoms to help them determine a pre-diagnosis or even guide them towards solutions.

9. Security of mobile health

Although mobile health represents a strong potential for innovation, it will have little future without a trusted environment. Its use requires a secure framework to guarantee the quality of care. The development of applications and connected health objects in an unregulated international framework presents several risks and raises ethical questions. These risks mainly concern:

- The reliability of technologies: malfunctioning of products and software, unreliable sensors.
- The protection of personal data: health data and confidentiality.

As a result, the establishment of a set of quality criteria for mobile health has proved necessary at the present time.

The French High Authority for Health has published a reference framework of good practices for manufacturers and assessors of connected applications or objects. The quality criteria adopted are divided into 5 areas (Haute Autorité de santé. Good practice guidelines on applications and connected objects (Mobile Health or mHealth) [66].

- Informing users: œ Description œ/Consent.
- Health content /œ Design of initial content /œ Standardization œ Generated content/œ Interpreted content.
- Technical content: œ Technical design œ/Data flow.
- Security/Reliability: œ Cybersecurity/œ Reliability/œ Confidentiality.
- Usability/use œ.

This standard was designed to ensure that an application or connected object is technically capable of delivering reliable and quality health information, protecting personal data and is easy to use.

In the US, the FDA has differentiated between medical and wellness applications, as well as between diagnostic and monitoring applications. It has applied regulatory oversight to the various internal or external sensors of the Smartphone as well as applications used to diagnose or monitor the health status of patients to ensure their safety [67]. To this effect, these different devices must provide evidence and undergo clinical trials that prove their reliability and safety [68]. Several mobile applications have received FDA approval. Examples include the KardiaMobile (AliveCor, Inc.) which provides electrocardiograms, the "Mobile MIM" diagnostic radiology application, the "BlueStar" for the management of type 2 diabetes... [69].

10. Conclusion

- Mobile telephony has profoundly transformed our lifestyles. The health sector has seized on these new technologies both on the side of health professionals, and on that of users.

- Mobile telephony via applications and connected objects make it possible to facilitate the pre-, per- and post-operative care of patients. This will allow better access to surgical care in developing countries and reduce healthcare costs in developed countries.

- These mobile systems will also facilitate data collection and transmission. This will allow better analysis of this data and will greatly pave the way for the introduction of artificial intelligence in medicine and surgery.

- The Smartphone can be used as an important tool for both diagnosis, care and surgical training. It can replace a whole column of operative endoscopy.

- Surgeons need to adapt their equipment according to local resources while respecting safety standards.

- Surgeons, policy makers and manufacturers need to work together to make more efforts in innovation to facilitate access to surgery in poor countries and reduce health care spending in rich countries.

- Covid-19 has put health systems around the world under severe strain. Policymakers are being forced to make adjustments. The long-vaunted digital health is becoming a reality and a necessity.

Author details

Sassi Boughizane[1,2]*, Badra Bannour[1,2], Imen Bannour[1,2], Faten Hacheni[1,2], Imen Bannour[3], Marwa Masmoudi[1], Jalel Boughizane[4] and Sabri Youssef[5]

1 Department of Gynecology and Obstetrics, University Hospital Farhat Hached, Sousse, Tunisia

2 Faculty of Medicine Ibn Al Jazzar, University of Sousse, Sousse, Tunisia

3 Department of Anesthesiology-Intensive Care, University Hospital Farhat Hached, Sousse, Tunisia

4 The Higher Institute of Technological Studies in Sousse, University of Sousse, Tunisia

5 Department of Digestive Surgery, University Hospital Farhat Hached, Sousse, Tunisia

*Address all correspondence to: sassi.boughizane@laposte.net

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