



5G Technology is the Future of Healthcare: Opening Up a New Horizon for Digital Transformation in Healthcare Landscape

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Abstract

There is a new cause for concern regarding healthcare's skyrocketing costs in the recent times. To overcome these obstacles, 4G and various communication standards are applied in health-care for smart health-care services and applications. However, cutting-edge technologies are being developed, like I O T (Internet of things), Big Data, Artificial intelligence (AI) and through the utilization of 5G wireless transmission technology, we can enhance the patient care and improvise healthcare services whilst decreasing the overall healthcare delivery cost. There is a gradual but clear transformation taking place in healthcare as a result of these new technologies. Future healthcare applications are highly dynamic and time-sensitive, making it challenging for current communication systems to meet their requirements. Consequently, 5G networks are conceived and built to meet the varied communication requirements of healthcare applications. In this review, we look at an overview of 5G wireless transmission technology applications in healthcare which opens up a new horizon for digital healthcare transformation.

Keywords: 5G technology; Healthcare; Digital transformation, Wireless technology; Artificial intelligence.

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1. Introduction

5G technology, being the fifth generation of wireless technology (5G), is set to be one of the fastest and most efficient ways to connect to the internet.^[1] 5G technology will provide faster speeds, lower latency, and more capacity than previous generations of wireless technology.^[1] 5G technology was rolled out in 2020 and was made available in select markets. 5G has exceedingly low latency (less than one millisecond (ms) of delay versus approximately 70 ms on the

4G network) and faster, high bandwidth (approximately 100-fold as compared to 10 megabits per second on 4G) (Table 1).^[2,3] The integration of 5G into healthcare has the prospect to solve numerous healthcare inefficiencies. For example, 5G can be used to connect patients in rural areas to specialists in urban centres via telemedicine. This would provide faster much-needed care to underserved populations while also decreasing the strain on overburdened urban hospitals. In addition, 5G can be used to connect medical devices wirelessly in order to create a "smart hospital" where all devices are connected and can share data in real time. This would allow for better coordination of care, as well as early detection of any health related problem (Fig. 1).

2. Artificial intelligence and 5G

5G can be used to support the increasing use of artificial intelligence (AI) in healthcare. AI has the potential to revolutionize healthcare by providing early diagnosis of diseases, personalized treatment plans, and predictive analytics. However, AI requires large amounts of data to be processed quickly, which is something that 5G can enable. 5G's data transmission rate, latency, coverage, capacity, and networking utilisation are vital to healthcare. 5G mainly helps in high-speed transmission of data and super-low latency,

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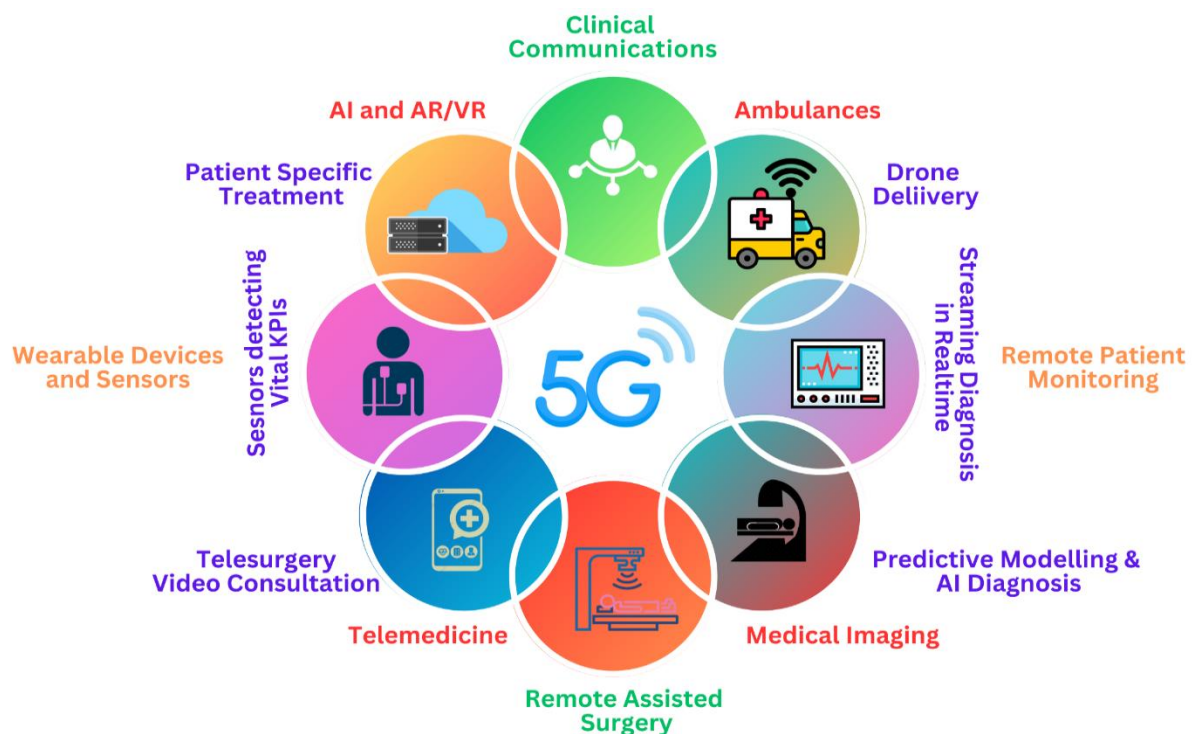


Fig. 1 Applications of artificial intelligence and 5g networks in healthcare.

connection and capacity, large bandwidth and endurance. Screening, diagnosing, and monitoring diseases can be drastically improved and made better by integrating these technologies. Furthermore, it helps in profiling of disease development and the refining and/or personalization of treatments.^[2,3] Therefore, the extent of this study is confined to a review of existing literature on healthcare uses of 5G, followed by a discussion of future implementation with regard to infrastructure and biological principals.

3. M2M connectivity and big data analysis

It is anticipated that M2M connectivity and the Internet of Things would form the backbone of smart healthcare in 5G networks.^[3,4] Analyzing large amounts of data is the priority in a smart healthcare network. Millions of devices will make up the future smart healthcare network, producing a mountain of data that will need to be analysed.^[4,5] The information in these files is highly sensitive (*i.e.*, Data of Patient), thus providing details on the patient's immediate surroundings (*i.e.*, Heartbeat rate, ECG, etc.). Therefore, data analysis requires the use of intelligent methods and algorithms. For instance, machine

learning (ML) methods must be used effectively to analyse data collected from network nodes. Due to the interoperability of several Internet of things (IoT) devices, smart healthcare networks provide unique security challenges. Because of finite battery life and processing power, it is difficult to execute complicated security algorithms and protocols on IoT devices.^[5,6] In future, intelligent health-care network might include millions of different devices. The idea behind this network can only be realised to its full potential if connectivity is offered to each and every device.^[6,7] After performing a sensing function, these devices are able to provide information. In this network, IoT devices are able to make use of any existing communication technology, including cellular networks (such as 5G and LTE), Bluetooth, and Wi-Fi, among others.

4. Use of telesurgery

With the rapid advancements in 5G network communication technologies and surgical robotic instruments, telesurgery has progressed rapidly since the Lindbergh procedure.^[7,8] The telesurgery platform has the potential to alleviate health care disparities by facilitating access to high-quality medical care for the underserved communities.^[8,9] The need for telesurgery has increased dramatically, especially on account of the COVID-19 pandemic. To enable telesurgery, the real-time acquisition of high-quality surgical images is essential for the remote surgeon to monitor the surgical progress and enhance decision making. Although recent advances in computer vision and ML has shown great success in analysing images, there are many challenges in processing surgical images. Firstly, surgical images are often low-quality and suffer from

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Table 1. Comparison of 4G and 5G wireless technology and its benefits.

| Points of distinction | 4G | 5G | 5G benefits for mHealth |
|-------------------------|--|--|--|
| Speed | Varying Speed between 300 Mbps and 1 Gigabit per second. | 5G has the potential to be significantly faster than 4G, with speeds of up to 10 Gbps | 5G networks' faster speeds and lower latency will help doctors swiftly access patient data. This will help them make better decisions faster, improving patient outcomes. |
| Latency | Higher latency <50 m s. | lower latency than 4G <1ms. | 5G's decreased latency will allow surgeons to do difficult operations remotely, minimising patient infection risk. |
| Reliability | Less reliable than 5G. | 5G will have better reliability than 4G due to its improved error correction and better connection quality. | Providers can get high-quality X-rays and MRIs. This improves medical diagnosis and therapy. |
| Connectivity | Less connectivity compared to 5G. | 5G could connect 1 million devices per square kilometre, compared to 4G's 10,000. | 5G will improve healthcare provider-patient and provider-provider communication. This will speed up patient care. |
| Security | Less secure than 5G. | 5G will be more secure than 4G, with built-in encryption and authentication capabilities to protect data from unauthorized access. | 5G technology offers improved security and stronger authentication techniques, reducing data breaches and protecting patient data. |
| Network Flexibility | Less flexible compare to 5G. | 5G's network design will be more flexible than 4G's, allowing for topology modifications, simple scalability, and more efficient resource use. | 5G networks will enable remote patient monitoring and treatment. This could cut hospital visits and simplify medical advice. |
| Healthcare Applications | Less applications when compared to 5G. | 5G will enable new healthcare applications such as remote monitoring, telemedicine, connected medical devices, and patient data analytics. | 5G will provide individualised treatment and more efficient medical services to patients. This reduces patients' wait time and stress. It can also improve care through remote patient monitoring and telemedicine. Patients can get medical advice and treatment anytime, anywhere. |

severe artifacts, making it difficult to extract useful visual features. Secondly, surgical images contain a lot of redundant information, which makes it challenging to compress them with limited bandwidth. Third, surgical images are often generated at a high frame rate, which makes it difficult to analyse them in real-time. In this paper, we aim to tackle the above challenges by exploiting the deep learning (DL) technology to automatically learn good visual features from surgical images and compress them efficiently to enable real-time telesurgery.

5. Medical imaging and 5G

Manual segmentation of exceedingly high quantity of image accumulation demands a considerable amount of time, therefore, evaluating and diagnosing them becomes difficult, and manual segmentation may not match the demand for analysing large image datasets.^[9,10] The challenge is addressed utilising automatic methods for sectioning medical images

(SMI) to obtain any viewing angle via multiplanar reconstruction (MPR) by employing multitude of technologies, such as region-based methods, clustering methods, threshold algorithms, machine learning, and deep learning.^[10,11] But every MPR interaction needs rebuilding the raw data, hundreds of megabytes of SMI data must be transferred. This makes it harder to send data over the Internet without creating a bottleneck, and increases the threat of data leakage.^[11,12] This instance shows how 5G communications with Software-Defined Networks (SDN) and "network slicing" can be used to improve Intranet and Internet security and capabilities in a more flexible, efficient and cost-effective way. Transmission of high-quality images for simple imaging, such as echocardiogram or dermatologic images can be achieved using either budgeted transmission equipment or photos/videos from freely obtainable apps. Similarly, a recent review reveals that remote or video-otoscopy images can offer sufficient information acceptable for diagnosis in many

situations, leading to high levels of user satisfaction.^[12,13] This is also true with otolaryngologic examinations.

High-quality images are crucial for pathological diagnosis. Because only one person at a time can study a cytological glass slide, the traditional examination process might be lengthy. Recent developments in telepathology have expanded its utility beyond static images to include the live, telecommunications-based delivery of dynamic content like microscopic slide images.

6. Smart cells, ultra-dense networks and heterogeneous networks

Because of higher frequency re-utilization that will result from the utilisation of small cells, the system's traffic capacity will be increased. One other pattern that is emerging for 5G wireless network is utilisation of tiny cells within the context of an ultra-dense network. Additionally, the utilisation of small cells increases the SNR while decreasing the transmission power. This will result in a decrease in the communication power, a maximisation of the link capacity, and an increase in the amount of energy saved. Another emerging idea for 5G is the use of a heterogeneous network consisting of small cells, macrocells, picocells, and femtocells. In this scenario, the control plane is supported by the macrocell, which enables it to provide mobility and connectivity. On the other hand, the data plane is supported by the picocell, the femtocell, and the microcell, which demonstrates this point.^[13-16] Nevertheless, it is absolutely necessary to keep in mind that WRAN environments are not the appropriate place for small cells. For the WRAN situation, super microcells are a viable option to examine. Millimeter wave communication is likewise inappropriate for this case because of its complexity. As a result, the 5G network will take into consideration the possibility of combining millimetre wave communications and communications at low frequencies. Another emerging feature of the next-generation 5G network is direct communication between users.^[16,17] There are actually two ways that you can use that strategy. The first involves a terminal working with others to boost the capabilities of the connections between the base station and other terminals. The other way being terminal-to-terminal communication, in which no base station is involved. Channel dependability, system throughput, operating price contraction and energy efficiency can all benefit from devices talking to each other. Since several D2D links can use the same bandwidth at the same time, thanks to D2D's direct communication, the cell's capacity for traffic can be increased. Comparably, direct communication can boost SNR (in comparison to communicating via a base station), less power is transmitted, which helps conserve resources or maximise connection capacity. D2D direct communication finally decreases radio link latency.^[17,18]

7. Emergency medicine

Instead of coming immediately to the emergency department

(ED) in person, virtual triage using telemedicine might be widely implemented in the ED, which is a good example of this type of widespread introduction. Patients gain convenience in space and time because they are not required to attend the clinic physically whilst being managed with medicines that are supplied remotely. Once this is achieved, they can more effectively make an appointment flexibly, for them to be seen directly by the specialists, and avoid spending a significant amount of time sitting in the emergency room. In addition, the development of chatbots has made it possible to conduct counselling sessions with the vast majority of patients flawlessly through the use of video consultation. With virtual presence, savings derived from the efficient usage of time and place, the wearing of protective gear, all work to the advantage of the healthcare providers. Those members of the healthcare workforce who have the option to work from home can make a significant contribution to the effective utilisation of manpower at a situation when sustainability has to be taken into consideration. Additional use could be communication between two different hospitals (example, remote hospital with limited resource and a tertiary care center) in emergent situation where immediate data transfer can be lifesaving. As the number of patients who attend the emergency department physically decreases, it lowers the danger of COVID-19 for the entire workforce. This also helps prevent the highly unpleasant scenario in which the virus is passed from clinicians to patients or vice-versa.^[18,19] The effectiveness and safety of automated counselling and remote triage needs to be evaluated, and until that can be done, physicians need to oversee each session just as they did before the pandemic.

Virtual triage has been successful in many areas of healthcare, not just for emergency departments. For example, it is used by primary care physicians for follow-up visits, and in mental health, virtual triage is used to assess the risk of suicide and provide referrals to the appropriate professionals. It can also be used to monitor chronic conditions and provide advice on medications and lifestyle changes. The use of remote triage in hospitals has been found to be helpful in preventing overcrowding in emergency departments, improving access to care and reducing wait times. The widespread use of virtual triage has several advantages. It can reduce the amount of time that patients must wait to be seen, decrease the risk of infection, save time and money. Overall, this allows patients to access medical advice and care without having to leave the comfort of their own homes. Virtual triage also makes it easier for physicians to provide personalized care to their patients, as they can assess their symptoms remotely and provide appropriate treatment quickly. In addition, virtual triage can be used to identify patients who need to be seen in person, and to connect them with the appropriate healthcare provider. Finally, virtual triage can be an invaluable tool in the contest of battling COVID-19 pandemic.

8. Obstetrics

Obstetrics is a branch of medicine and surgery focused with

female pregnancy, childbirth, and postpartum phase. It involves providing antenatal care to monitor the progress of the pregnancy, advice and preparation for labour, delivery, and postnatal care. Obstetricians provide care and support to the mother and baby throughout the entire pregnancy and delivery process, as well as performing necessary medical procedures. So far, when there is an emergency, people use their smartphones to take videos that are sent in actual time to the specialist at a tertiary hospital, who can then evaluate the condition.^[19,20] A cardiotocogram can be used in an emergency to get an idea of the health of a foetus in the uterus in real time (CTG). But the use of it is limited to health care center, and there is scarcity of record of people trying to send CTG data from domestic or an ambulance base to a health care facility over a mobile network. Diverse problems could be encountered, thereby, mere single case that worked was published.^[20,21] Further study and feasibility has to be assessed regarding CTG as this is a time sensitive test. By implementation of 5G, according to a recent paper, where the authors simulated the feasibility to send both CTG and real-time ultrasound videos of the foetus at the same time with great results. So, with the exception of CTG, the ultrasound images were high-quality videos of the patients that were sent without any problem.^[38] So, monitoring a foetus from home with 5G system can be a very functional application that might change the way obstetric care is done in the future.

9. Surgery

A surgeon's job is similar to that of a general doctor, but what makes them different is the skill of performing surgery, time spent assessing the indication of surgery, doing surgery and following up on their patients post operatively. They possess similar academic and administrative requirements as other doctors. This includes the basics of taking a patient's history, doing a physical exam, doing lab or imaging studies, caring for patients in and out of the hospital, sending them home, and following them.

In response to the COVID-19 pandemic, more teleconsultations, teleconferences, etc. are being used, and it is expected that this will continue after the pandemic is over. But, like all specialties in health care, surgery has its own requirements and opportunities. The following surgical areas focus on these:

1. Getting ready for surgery (pre-operative period)
2. The procedure during surgery, (peri-operative period) and
3. Care after surgery, (post-operative period) both in the hospital and at home.

9.1 Medical telesurgery

The goal of telesurgery, also called "remote surgery," is to get around the problem of distance when it comes to giving high-quality medical care and performing the most complicated surgeries. Through remote surgery, diagnostics and telemedicine, high-quality medical knowledge will be moved from large hospitals to smaller ones that aren't as close together.

This will save a lot of money, and make health care services more efficient. Telesurgery, in which a surgeon controls parts of a procedure from the principal location to a distant location, is one of the most challenging aspect of the remote healthcare system. If the technology can be proven to work for this application, it can be assumed to work for the less demanding remote healthcare applications as well.^[21,22] The technology behind telesurgery is complex and requires the integration of several different elements, including robotics, communications, imaging, and computer visualization. For robotic surgery, the robots used in telesurgery are usually articulated arms, with a surgeon controlling the robot from a remote location, called "Console". The robot is equipped with tools and cameras, so that the surgeon can see what they're doing, and a computer interface is used to control the robotic arms and tools. Communications are also important, as they allow the surgeon to communicate with the patient and medical staff at the remote location. Imaging technology facilitates the surgeon with the 3D vision of the patient's body, and computer visualization is used to provide a graphical representation of the surgical procedure. The recent study from China assessed the potential of telesurgery, where a distant surgeon controlled surgical robot in a tertiary hospital, was used to remotely conduct robot-assisted laparoscopic radical nephrectomy (RN) in 29 patients. The cumulative round-trip distance was >14 700 km and the furthest surgical distance was approximately 1775 km. None of the patients had to be converted to open surgical procedures and there was no perioperative complication.^[22] Telesurgery has the potential to revolutionize the way healthcare is delivered, allowing for more environment-friendly, efficient and cost-effective care. It can reduce the need for travel and provide access to specialized surgeons who may not be available in the patient's local area. It also has the potential to reduce the risk of infection and other complications associated with surgery. As the technology continues to develop, we may see even more applications and improvements in the quality of healthcare that can be provided through telesurgery.

Even though telesurgery seems to have a bright future, there are still some problems that need to be fixed. Here are some ideas for studies to look into:

1. Both the robotic console for the surgeon and the cart for the patient need to be smaller or more portable. For example, as feasible as carrying a laptop computer for the console and small enough patient cart to fit in a rescue transport (En-route "damage-control" surgery).
2. Robotic platforms for surgery can be integrated with AI that can potentially alert the surgeon of vicious situation while performing surgery (predicting error and avoiding hazards).
3. Error depiction between surgeon and the device should be outlined.
4. Communication companies needs to step up making sure that telesurgery gets enough bandwidth and a high priority.
5. Since network security is still one of telesurgery's biggest problems, a safeguard system for has to be outlined and put in

place (anti-hacking).

6. Further assessment, improvising and access of application of deterministic networking for reducing network delay would facilitate conduction and widespread acceptance of telesurgery.

9.2 Spine surgery via telerobot

Robotic spine surgery is well received and safe way to do surgery for a long time. A contemporary meta-analysis revealed that robotic pedicle screw placement was more accurate than placing screws by hand.^[23] In a recent study, six medical centres from six distinct cities in China worked together to do 5G telerobotic spinal surgeries on twelve patients. Using this telerobotic surgical platform, 62 pedicle screws were put efficiently.^[24] The procedure took 142.5 ± 46.7 minutes, the average guidewire introducing time being 41.3 ± 9.8 minutes with no complications. Derived conclusion was that 5G-based telerobotic surgery for spine is accurate, secure, and reliable. In the future, there is a lot of potential and value in using the 5G system in the clinical sector. The authors also looked into "one-to-many" remote surgery, which is a new trend. Beneath this method of remote surgery, single specialist surgeon can dispense expert care to multiple remote hospital at the same time, which was not possible before because of the limited bandwidth of the network. During this study, a "one-to-three" telerobotic surgery was done efficiently. With the higher potential of 5G network, multicentre remote surgery at one point in time seems feasible.^[24]

10. Medical education

The trend of training in the surgical field, has transformed from "see one, do one, teach one" with a mentor in the surgical theatre to "proficiency-based progression" (PBP) training.^[25] The evaluation in training can be achieved by judging the performance of the trainee objectively in simulation center. This can also be used to compare the efficiency between a novice and an experienced surgeon utilizing Machine learning algorithms which incorporates motion analytics, energy and strength usage, overall, augmenting the quality of the training.^[26] AI software, computational analytics on the huge amounts of data collected by simulators, and immediate, formative feedback are all ways that AI is used to improve assessment. During the initial period of rampant COVID-19 spread in Wuhan, China, upto 800,000 individuals utilized the COVID-19 training database.

In the near future, after the pandemic, it is predicted that, the focus would be shifted onto a new "hybrid model" of medical teaching, in which several benefits of just-in-time learning and remote learning will be added to traditional models.

11. Healthcare research

The latest 5G data environment makes clinical research much more productive. Fundamentally, the technologies make it much easier for people from different institutions to work together on studies. Second, these technologies make it easier

for people to access massive data (BD), repositories, AI, and software for computational analysis. The heaps of machineries that are linked to the IoT often send data to it on their own. The Research of basic sciences, chiefly at the cellular, molecular, genetic, and "-omics" level, produces huge quantity of raw data that were excessively big to share between research centers, which also could not be processed by Artificial intelligence, computational analytics, and supercomputers in the past. Scientists can now work together in near real-time to find sufficient patients to conduct huge clinical trials to validate. This is possible because 5G communications have enough bandwidth.

12. 5G and COVID-19 pandemic

The coronavirus pandemic has had an extensive effect on our lifestyle. As the world struggles to suppress the spread of the virus, several countries are turning to technology to help them manage the situation. In particular, 5G technology has been touted as a potential solution for managing the pandemic. In Wuhan, China's healthcare infrastructure was quickly overruled during the 2009 COVID-19 outbreak. Emergency plans, including the latest in 5G wireless technology, were rapidly put in place.^[26,27] Three 'shelter' (fangcang) hospitals with 4,000 beds were set up in empty stadiums and auditoriums in the first 29 hours, complete with intranets inside the hospitals and internet linking medical centres broadly and locally, particularly giving access to the 5G wireless networks in all of the city's healthcare centres.^[24] Saving time by avoiding setting up of cables all over the hospitals, the intranet linked all of the smart devices such as imaging scans, laboratory works, electronic medical data, housekeeping, administrative, and mobile phone services instantly.^[27] Cabin hospitals, which are simply normal "shipping containers" which were configured as independent departments of the health centre for beds and services, were used to build an extra 13,000 beds during the course of the following week. Each division was given its own VPN using a software approach named "network slicing," which merely involved linking several containers (cabins) together and introducing 5G wireless networking. Thanks to the massive 5G bandwidth, the city now has 17,000 more beds that can instantly connect (with almost no latency) to regular telephones, teleconsultations with medical experts across the country and tele referrals for critically ill patients. Furthermore, AI has been applied in computer vision and infrared-based temperature measurement and intelligent medical imaging diagnosis, while AI and BD have been utilised in epidemic scenario analysis; tagging; contact tracing; people movement monitoring; just-in-time shipping, stock management, asset monitoring, and resource distribution are all examples. In a nutshell, having access to massive bandwidth allowed for real-time access and "visibility" to every parts of medical services.

13. Pitfalls of use of 5g in healthcare

1. Security Concerns: 5G technology is highly vulnerable to hacking and cyber-attacks due to its increased bandwidth and

faster speeds. As new networks are rolled out, it is important to ensure that security measures are in place to protect user data.

2. Environmental Impact: As 5G technology is implemented, more antennas and transmitters will be installed to provide coverage. This could potentially have an impact on the environment, as these antennas and transmitters could cause air and noise pollution.

3. Cost: 5G technology is likely to be more expensive than current networks, as the hardware and infrastructure required is much more advanced. This could mean that some people may not be able to access 5G services.

4. Interference: 5G technology is likely to be more susceptible to interference from other signals, such as Wi-Fi, Bluetooth, and mobile phones. This could potentially lead to slower speeds or dropped connections.

5. Capacity: As 5G technology still commencing, it is not yet known how much bandwidth it can support. This could mean that the networks could become overloaded, leading to slower speeds for users.

14. Conclusion

More and more evidence shows that 5G will give healthcare new options and enormous possibilities to embark upon in future. In this review, we didn't look at all of the ways 5G will change the way healthcare systems work. Instead, we chose a few examples to show how virtual reality (VR), telemedicine, and self-determination medicine will be affected by 5G. Even though there are some problems, like data privacy and security risks, there is a plan to regulate how healthcare data should be used.

5G has started to show great benefits in improving hospital intelligence services by allowing automatic patient monitoring, precise remote surgical operations, better use of quality medical resources, and efficiency. This generation of innovations has cultivated a good environment for telemedicine to grow and thrive, as shown by rapid retaliation to the COVID-19 pandemic. Thus making people more aware of how important these digital technologies are. Telemedicine has been shown to be helpful, during and after the pandemic. Adaptation of clinicians to the ever-changing models of health care delivery is of utmost importance. And working with larger teams that includes experts in technology and data scientists provides high-quality, long-term healthcare services for everyone. The best new things about 5G are software-defined networks (SDN) and "slicing" of bandwidth, which is especially useful for networking in hospitals. But there are some problems and challenges with technology that need to be solved. For example, new communication capabilities don't always match up with human limitations (the solution is to pay attention to human interface technologies), and there are also behavioural, political, equity, financial, accessibility, and availability problems that aren't caused by technology. Lastly, haptics and virtual reality are two common technologies that aren't ready yet, without having major breakthroughs in future.

The 5G era is coming, whether we are ready to use these new technologies or not. Even though maximum deployment of 5G networks would take 5-10 years, multiple health care and research institutes are making plans on adopting it. These plans include figuring out 5G's clinical data centre architecture and how to buy medical equipment. The exciting aspect of 5G is that, this is just the dawn of a substantial uprising in digital healthcare that has endless room for growth, and seems like the future of digital healthcare revolution.

Conflict of Interest

There is no conflict of interest.

Supporting Information

Not applicable.

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