PERSPECTIVE

5G and intelligence medicine—how the next generation of wireless technology will reconstruct healthcare?

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Abstract

Despite intensive efforts, there are still enormous challenges in provision of healthcare services to the increasing aging population. Recent observations have raised concerns regarding the soaring costs of healthcare, the imbalance of medical resources, inefficient healthcare system administration, and inconvenient medical experiences. However, cutting-edge technologies are being developed to meet these challenges, including, but not limited to, Internet of Things (IoT), big data, artificial intelligence, and 5G wireless transmission technology to improve the patient experience and healthcare service quality, while cutting the total cost attributable to healthcare. This is not an unrealistic fantasy, as these emerging technologies are beginning to impact and reconstruct healthcare in subtle ways. Although the technologies mentioned above are integrated, in this review we take a brief look at cases focusing on the application of 5G wireless transmission technology in healthcare. We also highlight the potential pitfalls to availability of 5G technologies.

Key words: healthcare; 5G; the Internet of Things; big data; artificial intelligence

Introduction

The term "5G" refers to the fifth generation of wireless transmission technology, expected to have a significant influence in many aspects of contemporary society, including healthcare. The important characteristics of 5G technology include data transfer rate, latency, coverage, power, and network energy usage, with the following unique features of most value to healthcare: (i) high-speed data transfer rate; (ii) super-low latency (delay in the data transmission-response system); (iii) connectivity and capacity; and (iv) high bandwidth and durability per unit area[1] (Fig. 1).

A breakthrough in 5G technology is transmission speed, with 5G offering up to 10 Gbps data transfer rate, that is a 10-fold to 100-fold improvement over 4G and 4G Long-term Evolution (LTE). Beyond speed improvement, another distinctive feature of 5G is low latency; the latency is <1 ms in the 5G era, almost equivalent to zero data response time in the real world. Additionally, 5G is expected to massively increase the Internet of Things (IoT) services. Based on 5G super bandwidth per unit area, connectivity, coverage (up to 100%), and capacity to connect devices per unit will lead to an ecosystem in which an "intelligence network" can serve real-time
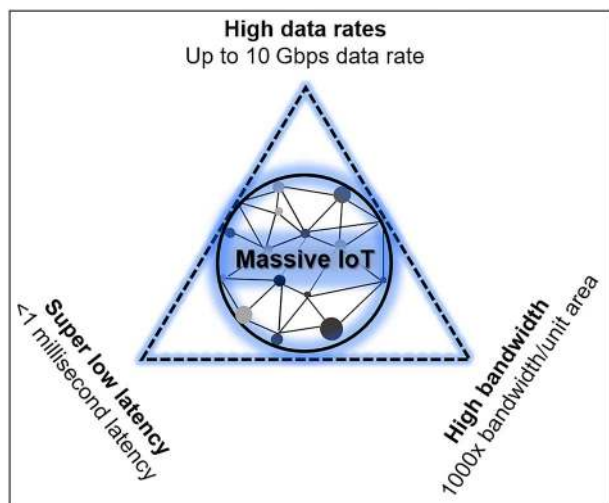
Figure 1. Basic features of 5G technology. IoT, Internet of Things.

interactivity for massive medical equipment and patients' wearable devices, with cloud computing-based trade-offs between speed, latency, coverage, availability, and low power IoT service.

For the purpose of more precisely deriving the potential value of 5G, before illustrating the specific applications of 5G in healthcare, we will briefly review the deficiencies of the current healthcare system. The system: (i) can make it inconvenient for patients to seek healthcare service; (ii) offers only a non-individualized diagnosis and treatment model; (iii) provides an imbalance in medical resources; and (iv) is not a holistic data-driven healthcare practice model. In addition, transportation can be inconvenient, the registration system faced by patients in hospitals is cumbersome, and the medical system is hierarchical. More importantly, in the current healthcare service system, a unified diagnosis and treatment plan, or so-called "one-size-fits-all" plan, is applied to any population or a group of individuals, while advocating for standardized guidelines and treatment procedures. Another common phenomenon in many developing countries and regions is overcrowding in hospitals, resulting in overloaded medical staff, because the imbalance of health resources, including medical equipment and well-trained practitioners, causes large numbers of patients to come from rural areas to urban areas seeking a high-quality healthcare service. Medical staff, in the provision of healthcare services, rely heavily on their own experience rather than this being holistically data-driven. Taken together, these constitute the major deficiencies of the current healthcare system.[2]

The potential benefit of 5G to healthcare could be significant, and it is hoped that 5G and concomitant emerging technologies can overcome some of the current challenges to healthcare and reconstruct the system. As discussed above, 5G is not a single technology or standard, but rather a combination of different technologies. Technically, 5G has at least four unique technological features with the potential to significantly impact on

healthcare. Notably, the effects of these features would not contribute equally, and it would be misleading to advocate one major advantage of 5G.

5G and its application in healthcare at a glance

It is worth pondering what 5G means for healthcare. Although for most people 5G simply means faster internet, the impacts of 5G on healthcare are likely to be multiple. In addition to faster internet, healthcare would benefit greatly from reliable internet connectivity for massive objects and medical devices, with greater bandwidth and super coverage and availability than provided by 4G LTE. The areas of virtual reality (VR) and augmented reality (AR) are most likely to directly benefit from 5G, with potential contributions to intelligence medicine when 5G technology matures. Promotion of the integration of VR and AR is critical for comprehensive rehabilitation training, as well as concise extremity rehabilitation and telemedicine, because of the technical characteristics (Fig. 2).

Closely related to application of VR and AR in healthcare is extremity rehabilitation exercise, including robotic support for the fine motor skills of the limbs, gravity compensation, and individually tailored video training programs. The application of VR in healthcare is not a new technology emerging in the 5G era, the medically applicable technology can be traced back at least 20 years.[3] However, this technology has not been fully developed, because an important constraint is latency, that is the response time between sending a data request to a terminal device and receiving the data. Compared with 4G LTE wireless communication technology, technically, 5G can offer a 10-fold decrease in latency, namely from the current 20 ms at 4G LTE to as low as 1 ms. This benefit is extremely important for VR technology and telemedicine.[4] In the 5G era, with its innate high bandwidth and low latency advantage, VR is expected to help streamline the entire hospital, especially in telemedicine, teleconsultation, and even remote surgery. Vital signals could be streamed to medical equipment or screen monitors in the hospital with almost zero latency (<1 ms radio latency with 10^{-9} error rate) during intuitive surgical training or even in remote surgery. The current LTE band spectrum allocations for 4G cannot meet these demands. Also, 5G is powerful enough to support thousands of medical devices simultaneously, from sensors to mobiles, medical equipment, and video cameras. Supplemented by a 4 k or even 8 k ultra-high-definition television, or monitor system, this could offer sharper, clearer streaming video with more detail content resolved information beyond the retina.

Another area to benefit would be telemedicine as 5G would expand the scope of telemedicine, and this could happen quickly. People tend to link big data and artificial intelligence with personalized medicine, also known as
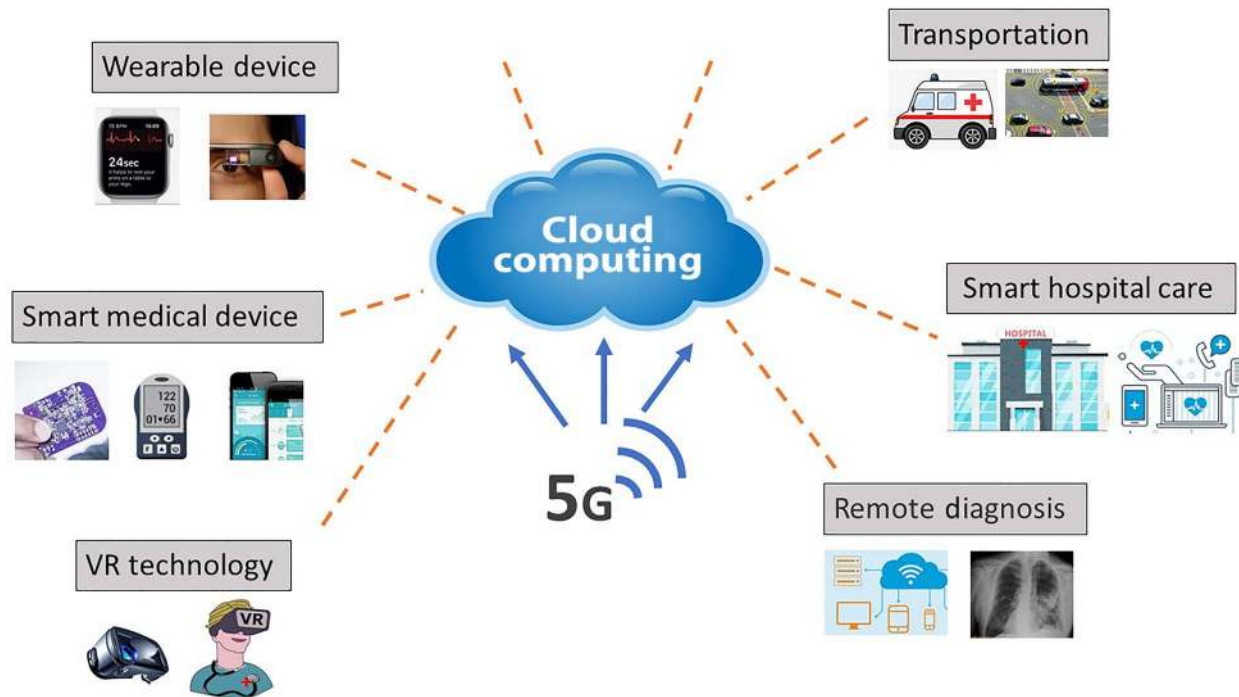
Figure 2. Schematic drawing illustrating applications of 5G technology in healthcare. VR, virtual reality.

individualized medicine or precision medicine. However, it is clear that without the technical support offered by 5G, precision medicine is a puzzle that cannot be solved. The primary limiting factor has long been attributed to bandwidth and data transmission speed. In the era of 4G, even 4G LTE-advanced, within a limited bandwidth, can only offer around 50 Mbps and theoretical limits of 300 Mbps download speeds in the real world, not to mention the need to stabilize high-speed streaming video and image data and efficient super-low latency interventions. Data-transfer speed is not the only issue that has impeded implementation of telemedicine with 4G LTE. The key point is bandwidth and lower latency. This means that massive medical devices can connect to the central cloud computing platform, server or inter-device connectivity at the time without network congestion. This supports truly immersive VR, no delay response, and AR applications, which can create an interactive experience in telemedicine. This kind of telemedicine, together with a 4 k/8 k monitor, and 360° VR could offer a "live" experience not only for physicians in terms of immediate diagnosis and decisions regarding treatment strategy, but also for medical staff in terms of more effective operation and powerful training tools.[5] Beyond enabling high-speed data transmission, 5G has revolutionized delivery of low latency stream video, 3D high-resolution medical imaging, and mission-critical interventions.

Self-determination medicine: a new healthcare model that could be delivered by 5G

As mentioned, 5G is not a single technology, rather it is a combination of cutting-edge technologies, including big

data, cloud computing, and artificial intelligence. In the 5G era, with the improved ability of computers to process massive amounts of information, self-determination medicine will come into being. Rather than the dominant doctor-centered contemporary diagnosis and treatment model, the self-determination medical model will significantly enhance the patient's autonomy by giving the patient subject participation throughout the entire treatment system. Notably, different from personal or individualized medicine, in self-determination medicine based on the algorithm and high-speed interactive information, the diagnosis and treatment plan will be timely, dynamic, and interactive allowing for individual status feedback with regards to lifestyle elements, behavioral factors, and treatment effect, to help patients to become more autonomous from clinical services.[6] During this process, patients can build/grow an individual health ecosystem based on a secured communication and interactive social network. In this instance, ultra-reliable and low latency 5G networks will have a critical role.[7]

Potential pitfalls of 5G technology applications in healthcare

The most obvious pitfall is the emphasis on increased speed of data transfer. There are great expectations of improvements in transmission speed, and it is not surprising that most people believe the basic characteristic of 5G is high-speed data transfer. Indeed, as the next-generation wireless communication technology, 5G is expected to increase the data transmission speed by up to 100 times when compared to the existing 4G LTE

network, making 5G competitive with today's fastest wired broadband networks. This is a big deal! However, the revolutionary changes offered by 5G include its high bandwidth and low latency. There are often breakdowns in service because of the limitations of current bandwidth and latency, particularly when many users in the same area are trying to access online mobile services at the same time. More devices on the network will create more need for connections, which is something that 4G cannot support.[8]

Another pitfall is the split of 5G and other emerging technologies. As mentioned, 5G is not a single technology, 5G is the underpinning of the IoT, plus other emerging technologies such as big data, cloud computing, and artificial intelligence, which can be combined with 5G organically. This pattern can be used in the healthcare industry. Currently, the cloud-native architecture is the foundation of 5G technology and adding other related technologies to exaggerate the role of 5G in healthcare is somewhat misleading.

Conclusions

Growing evidence reveals that 5G will open up possibilities for healthcare, and the impacts of 5G on healthcare would be multiple and far-reaching.[9] In this review, we have not exhausted the effect of 5G on healthcare systems, rather, we selected a small number of representative cases of how 5G will restructure the healthcare system in the fields of VR, telemedicine, and self-determination medicine. Despite the limitations and challenges, such as data confidentiality, security risks, as well as lacking entire network deployment and support, and the standing proposal for the regulation of healthcare data use, 5G has begun to show great advantages in improving hospital intelligence services, allowing automatic patient monitoring, performance of precise remote surgical operations, promotion of the the rational allocation of quality medical resources, and efficient management of massive wearable devices and monitoring devices carried by patients.

No matter whether we are ready to embrace these emerging technologies or not, the 5G era is coming. China has begun to play a leading role in some areas of smart medical care, with several top hospitals, including the West China Hospital of Sichuan University, taking the lead in deploying and applying 5G in their clinical practice and smart medical strategy.[10] Although the full deployment of 5G networks is likely to take 5-10 years, more and more medical research institutes and hospitals are laying out their strategies on healthcare, including determining 5G's clinical data center architecture, medical equipment procurement strategy, and close

cooperation to telecom operators. These are notable trends, particularly in the area of healthcare driving the 5G era transition. Smart healthcare appears to be growing quickly, and 5G will reconstruct the healthcare system by intelligently improving the quality of medical service, balancing the distribution of medical resources between urban and rural areas, and reducing the burden of healthcare costs. We are cautiously optimistic about these changes, although we still have a long way to go to ultimately achieve the goal of smart healthcare.

Conflict of interest statement

None declared.

Acknowledgements

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