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The Metaverse in Urology: Ready for Prime Time. The ESUT, ERUS, EULIS, and ESU Perspective

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In the past two decades we have faced a groundbreaking technological revolution thanks to the spread of multiple new technologies and tools that offer a previously unseen range of opportunities. Health care systems have been heavily impacted by digital transformation, further pushed by COVID-19 pandemic restrictions and social distancing that inevitably led to an increase in digital literacy for both patients and physicians thanks to wider adoption of digital infrastructure and a new awareness of the potential of these relatively new technologies. The new opportunities in health care systems result from the application of various digital innovations, such as telemedicine, 5G wireless networks, and artificial intelligence (AI) with machine learning and deep learning.

A significant increase in the diffusion of telehealth has been achieved in recent years, including urology [1]. Patients can be evaluated remotely not only during the decision-making process but also during follow-up after an intervention. Specifically developed platforms allow collection of clinical data and visualization and sharing of medical images to create an accurate digital medical chart for every patient (eg, Maia Connected Care). Furthermore, with new devices (eg, Tytocare) it is possible to record patients' vital signs, such as heart or pulmonary sounds and blood pressure, remotely, opening the door to a new form of monitored discharge that can potentially reduce hospital stays without affecting patient safety.

Broader use of internet infrastructure in medicine has been possible thanks to the introduction of 5G wireless networks, characterized by low latency and higher data transmission speeds in comparison to previous network generations [2]. A few centers have started to explore potential applications. The ability to manage a huge amount of data allows storage of more complex information for consultation, such as full three-dimensional (3D) images. Furthermore, surgical interventions can be rehearsed with a virtual simulator requiring real-time access to a vast amount of data.

In term of intraoperative applications, some experiences with real-time transmission of biopsy images have been reported. "Real time" telepathology can be performed in the same hospital and anywhere else, allowing expert consultation for complex or undefined cases [3]. Remote surgery (or telesurgery) represents the maximum utilization of 5G connection technology, in which the aim is to overcome the issue of physical distance, allowing experienced surgeons to perform high-quality procedures for complex cases virtually anywhere in the world. Some pioneering experiences have been reported from 2018, and Li et al. [4] recently presented their experience with 29 radical robotic nephrectomies performed remotely, merging the potential of robotics and 5G connectivity.

Another exciting field exploiting 5G capability is the continuous evolution of the performance of head-mounted display systems in terms of hardware and software. A pioneering study used 3D virtual models of patients' organs stored on a cloud platform (ICON3D; Medics3D) for real-time surgical navigation in a mixed reality setting during
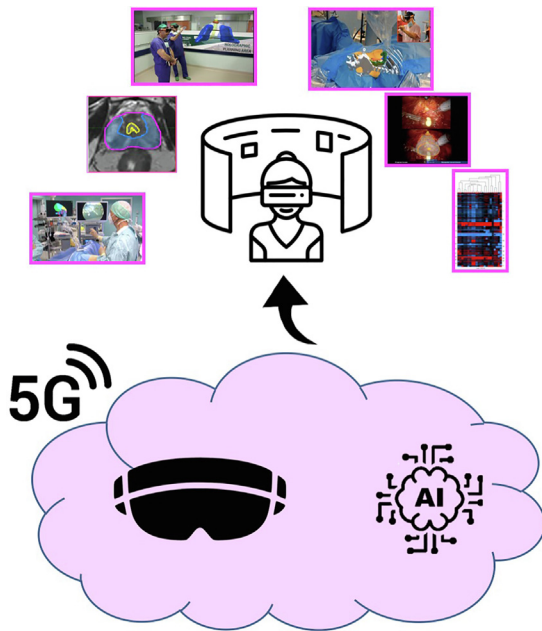
Fig. 1 – Integration of extended reality and artificial intelligence (AI) in a 5G environment brings physicians into the metaverse, where three-dimensional models, holograms, augmented reality images, radiomics, and genomics can improve health care, thanks to information sharing boosted by these new technologies.

percutaneous kidney puncture [5]. The availability of high-definition 3D models [6] can facilitate further improvements in the precision of surgical procedures thanks to augmented reality (AR) real-time navigation, especially in robotics [7].

A further step is the introduction of AI for more sophisticated hybrid interactions between digital and natural environments, achieving so-called "extended reality" [8]. AI is trained to "learn" from a given example to replicate the same characteristics in unseen settings. This concept can be applied to any input; big data, radiology with radiomics, and pathology are the major fields in which developments are ongoing. However, AI is limited by the quality and quantity of data provided for the training phase, which represents the greatest challenge to further development and implementation. Focusing on surgery, can we expect autonomous AI-driven surgical robots in the next few years? Automated surgery could be possible in the distant future, but, as reported by Heller et al. [9], AI is currently able to execute small automated surgical steps in urological procedures. "Man + machine" cooperation would be desirable to, at least in part, relieve burdens on health care systems, reduce burnout, enhance patient satisfaction, and improve the way in which we exert "human" intelligence to improve patients' lives [10].

As highlighted above, all these technologies are strictly correlated and deeply integrated and present a synergistic effect, allowing each technology to maximize its potential. Therefore, the concept of the internet of medical things (IoMT), defined as the translation of real objects on the internet, allowing perception, transmission, and intelligent processing in multiple settings, seems to perfectly fit this scenario [11] and opens the door to a metaverse in urology. Access to the IoMT, thanks to virtual reality (VR) and AR glasses, will allow everyone to use avatars for interaction in the digital world [11]. The technologies required (5G, VR/AR, AI) are mature for establishing a metaverse in urology.

Virtual and real environments can be merged to improve the quality of our care (Fig. 1):

(1) A 5G network can store and share a vast amount of data and patient information, even computationally heavy items such as 3D models and streaming video.
(2) AI can allow extraction of more information from patient data, including history, medical images with radiomics, and genomic analyses.

Fig. 2 – With the advent of the metaverse, multidisciplinary team discussion can be conducted in a virtual environment using physician avatars and consultation regarding a patient's digital images.

(3) Extended reality permits navigation in a virtual environment, allowing physicians to explore and directly interact with all of a patient's digital data.

Therefore, even though the metaverse is virtual, the impact will be real.

We can hypothesize a multidisciplinary team discussion (MTD) planned in a virtual environment with digital avatars in which all the experts needed for a specific disease are brought together in a virtual room to improve the quality of patient care. The virtual elements will be real, helping to overcome the distance barriers in more remote areas of the world. The 3D models of a patient's anatomy and disease can be explored, navigated, and discussed by clinicians (radiologists, urologists, oncologists) and engineers, as in a video game, thanks to immersive VR head-mounted display systems (Fig. 2) delivering unprecedented levels of detail and interaction. Moreover, other functions could be available in the metaverse and shown on AR glasses, such as treatment possibilities, disease management, and quality control parameters. In the metaverse, surgeons will be able to practice virtually as many times as needed before laying hands on a real patient. Furthermore, in the near future, cloud experts could guide an alien robot to perform surgical procedures on a patient during robotic surgery.

In conclusion, human-computer MTD is the first clear demonstration of the potential of the metaverse in medicine and urology, in which the aim is to create an immersive environment that integrates virtual and real worlds. In the future, further technological developments may have potential applications for surgical training, mentoring, and navigation, and the additional value of such possibilities in clinical practice should be investigated.

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