**Telesurgery with Cognitive 3D model guidance during robot-assisted partial nephrectomy:**

**first experience across Europe**

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**ABSTRACT**

**Background**

Telesurgery has found application in the modern era using 3D technology to improve surgical performance and organ preservation outcomes. Virtual congresses were created during the Covid-19 pandemic, giving to the participants the possibility to interact through digital platforms for professional development. The aim of this study was to describe the feasibility of using remotely guided telesurgery while applying 3D-technology to aid the surgeon with intraoperative navigation as well as preoperative planning.

**Case Description**

Initially, 3D models were created using CT-scan imaging and uploaded to remote servers. The lesion was rendered semi-automatically and then ''segmentation'' was performed by a dedicated software. The generated three-dimensional reconstruction was refined by a biomedical engineer under the supervision of the urologist to obtain a detailed 3D model of the organ and surrounding structures. Intraoperatively, the 3D virtual model was displayed and consulted during the intervention by the first surgeon in a cognitive (on-demand) manner aimed to maximize the benefits of real-time navigation. During the Techno Urology Meeting (TUM) of 2021 we offered this technology to two surgeons based in Belgium (O.L.V. - Clinic, Aalst) and Spain (Fundacio’ Puigvert, Barccelona, Spain) using real-time connection provided by Zoom through the Tile-Pro software while an expert surgeon from Italy (IRCCS Candiolo Cancer Institute, Candiolo – Turin - Italy) aided with intraoperative navigation. The patients were aged 49 and 58-years-old, respectively, while tumor maximum diameters were 60 and 30mm (PADUA Score 10 and 7; R.E.N.A.L score 8 and 6) for the first case, and 46 mm for the second case (PADUA score 8; R.E.N.A.L. score 7). No major complications occurred in either cases nor blood transfusion was necessary intra or postoperatively.

**Discussion**

Due to the COVID-19 pandemic containment measures, most countries restricted gatherings which included in- person meetings and congresses. In these cases, telementoring provided the possibility to operate with the assistance of an expert surgeon who was not present in the operating room but could virtually supervise and help during critical steps.

**Key words:** telesurgey; 3D models; robotics; kidney cancer

**1. Background**

The concept of "precision surgery" is intrinsic to the management of genitourinary tumors today [1]. Detailed understanding of the surgical anatomy is the key point for tailored treatment planning especially for renal surgery and preservation of renal function, which covers a key role today [2-4].

In this context, 3D reconstruction of standard two-dimensional cross-sectional imaging has been increasingly popular as it allows a better representation and understanding of the surgical anatomy resulting in a tailor-made surgery for each individual patient [5].

This technology is perceived as a useful tool in patient counseling, surgical planning, and training, as it avoids the "building-in-mind" process of two-dimensional cross-sectional imaging, allowing a better understanding of the anatomy, vasculature, and location of organs.

Importantly, correct interpretation of information obtained from standard preoperative 2D images (contrast-enhanced CT or MRI) requires extensive anatomical knowledge and clinical experience. In addition, mental transformation from 2D to 3D is not a simple process. Therefore, following these principles and trying to overcome these problems, 3D technology finds its role, gradually becoming an important tool in daily clinical practice [6].

In the past, automatic rendering of 2D images resulted in low-quality 3D reconstructions, which were of little use for accurate preoperative planning or intraoperative navigation. Today, thanks to technological innovations, development of dedicated software, and collaboration between bioengineers, radiologists, and urologists, it is possible to obtain high-definition 3D models.

Virtual 3D models have several fields of application: preoperative patient counseling (such as 3D printed models), surgical training and simulations, preoperative surgical planning, and intraoperative surgical navigation [7, 8].

Such technology, however, is currently available only in few specialized centers, and their fruition is not common. Several studies have shown how such technology could play an essential role in preoperative planning in all settings to pursue the path of precision surgery [9-12].

In an era of technological boom and concomitant confinement due to the COVID-19 pandemic, platforms and software which allow patients’ remote management have been developed: telemedicine is one example that has invaded the urological setting as well [13,14]. Telesurgery, which in the past had been explored for laparoscopic techniques [15] has found application in the modern era using 3D technology to improve surgical performance and to ensure organ preservation even in difficult neoplasms [16].

The Covid-19 pandemic bent all scientific circles, making not only patient management (diagnosis, treatment, follow-up) difficult, but also the scientific reports being developed through congresses. Therefore, virtual congresses where participants could interact through digital platforms for professional development were also created in this area [17]. The aim of this study was to describe the feasibility of using remotely guided telesurgery by also applying 3D-technology to aid the surgeon in intraoperative navigation as well as preoperative planning.

**2. Case description**

**2.1 3D models creation**

To realize this project, we started with the creation of the 3D model following a rigorous approach [9].

First step is the sharing of the images on dedicated and authorized cloud platforms (www.mymedics3d.com). On such platforms it is in fact possible to upload CT-scan DICOM images, making them accessible from anywhere in the world. Using DICOM image visualization software, it is necessary to analyze the object, select the most useful images (e.g., arterial, or late phase images of a CT scan), modify and adjust specific parameters (e.g., image contrast and brightness) according to the needs of the project. This phase is referred to as the "preprocessing phase." Next, a rendering of the volume is created and then ''segmentation'' is performed, which is a process being performed semi-automatically by a dedicated software. At the end of the process, the generated three-dimensional reconstruction is usually refined by a biomedical engineer under the supervision of the urologist. The goal is to obtain a 3D model, a detailed reproduction of the organ and surrounding structures. This is made possible by so-called thresholding, which is based on selecting a specific range of a defined parameter (e.g., grayscale). The final steps in the process are the creation of a transcription code for visualizing the reconstruction in an interactive 3D-PDF format to improve understanding of the relationships between the tumor and surrounding structures, and the conversion of each part into stereolithographic (STL) format.

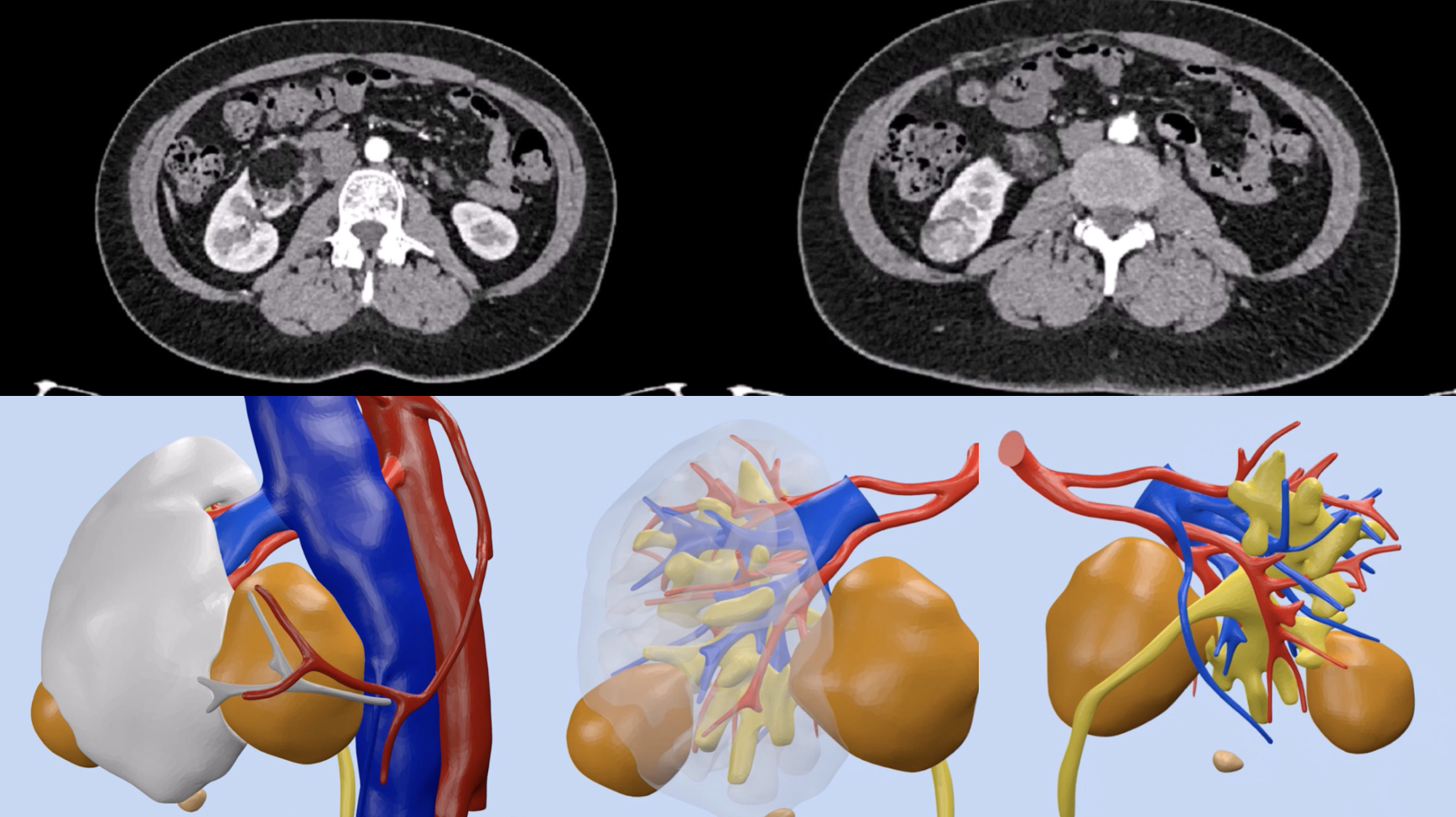
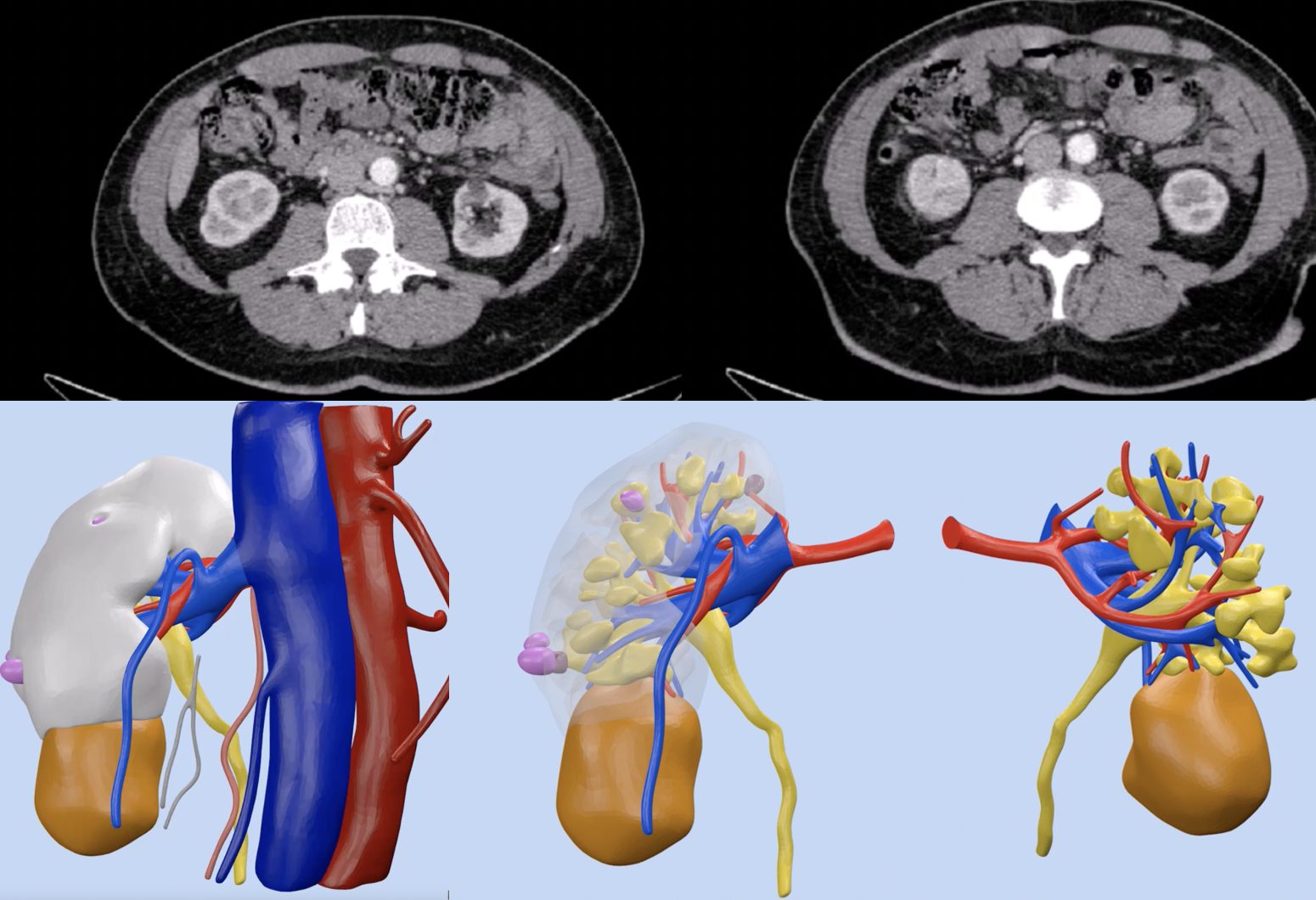
Then, thanks to the same cloud platform, virtual reconstructions can be downloaded and displayed on an electronic device for use in preoperative planning (Figure 1 and 2).

Figure 1. CT-scan and 3D reconstruction of case 1

Figure 2. CT-scan and 3D reconstruction of case 2

**2.2 Intraoperative navigation**

Intraoperatively, the 3D virtual models can be displayed and consulted during the intervention by the first surgeon, in a cognitive (on-demand) manner, aimed to maximize the benefits of real-time navigation.

During the 2021 edition of Techno Urology Meeting (TUM), taking advantage of the changeover to the virtual format of the Congress, we offered this technology to surgeons invited to operate even during procedures performed remotely.

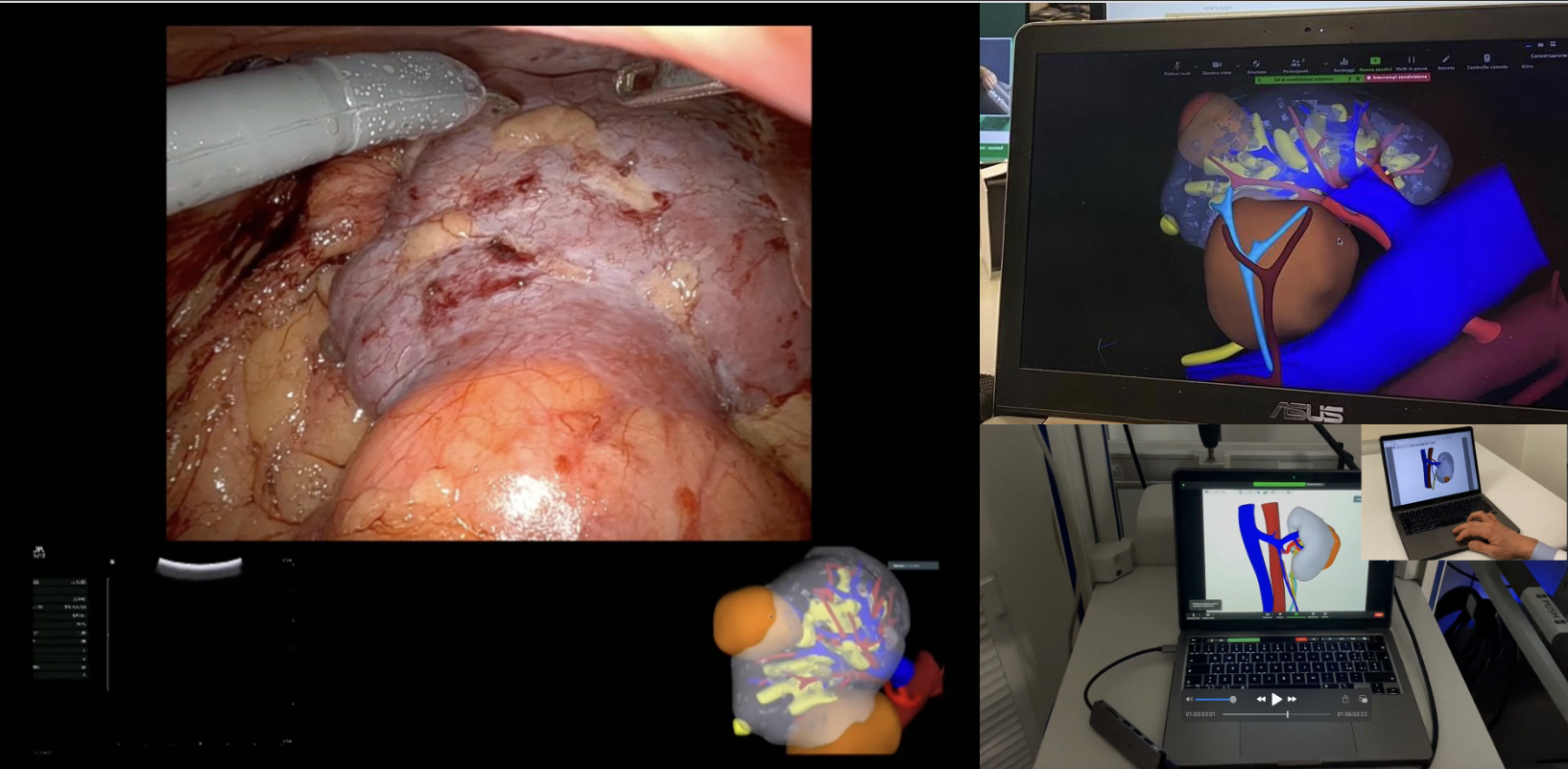
Thanks to a real-time connection provided by Zoom (<https://zoom.us>), an expert 3D-model navigator was able to interact with the surgeon, modifying the virtual images displayed directly inside the robotic console, thanks to the Tile-pro software.

For the first time, two cognitive 3D robot-assisted partial nephrectomy operations were performed, guided live by one urologist expert in intraoperative navigation (D.A.) who assisted the surgeons (A.M. and A.B.) in the most difficult phases of the operation (Figure 3).

Figure 3. Intraoperative navigation with 3D models cognitive assistance.

In particular, the intraoperative navigation expert performed his activities from Italy (IRCCS Candiolo Cancer Institute, Candiolo – Turin - Italy) while the surgeons performed surgery in Belgium (O.L.V.-Clinic in Aalst, Belgium) and in Spain (Fundació Puigvert, Barcelona. Spain).

**2.3 Clinical Cases**

The first case was a 49-year-old female patient. Her past medical history included arterial hypertension, dyslipidemia, and a prior appendectomy. Incidental ultrasound found two right-sided renal masses at the lower pole measuring 60 and 30 mm at CT scan study (PADUA Score 10 and 7, R.E.N.A.L score 8 and 6). The patient was admitted to the Department of Urology O.L.V Hospital in Aalst, Belgium.

The second case was a 58-year-old male patient. His previous medical history included arterial hypertension, history of peptic ulcer, removal of a dorsal cutaneous squamous carcinoma and a rhinoseptoplasty. An incidental ultrasound finding of right-sided renal mass was confirmed by CT-scan and a 46 mm solid right renal mass located at the inferior pole was evaluated (PADUA score 8, R.E.N.A.L. score 7). The patient was admitted in the Department of Uro-Oncology at the Fundació Puigvert, Barcelona.

For both patients, consent was obtained for surgery, including the use of a telesurgery platform to remotely involve another consultant surgeon during the procedure. The connection between the sites was easy to establish and was maintained during all the procedures without the occurrence of technical issues.

The size of the tumors were respectively 60 mm and 33 mm in the first case and 46 mm in the second case. The operative time was respectively 98 min and 82 min. Blood loss was 120 cc in the first patient and 130 cc in second one. No blood transfusion was necessary intra or postoperatively in both cases. The value of hemoglobin at admission was 12,8 g/dl and the value of hemoglobin at the discharge was 12,4 g/dl in the first patient and 13.3 g/dl and 13.2 g/dl in second one, respectively. The duration of hospital stay was 4 and 5 days, respectively; the bladder catheter was removed on the 2nd postoperative day for the same patients. The characteristics of patients undergoing surgery are summarized and divided by case (case 1 patient of Fundació Puigvert and case 2 patient of OLV Hospital) in table 1.

**3. Conclusions**

Robot-assisted Partial Nephrectomy (RAPN) outcomes are strictly related to surgeon’s experience and a good method of increasing the learning curve is having the opportunity to connect more experienced surgeons [7]. Traditionally telesurgery and telementoring were used as a means to share expert surgeons’ knowledge to help guide less experienced colleagues during the learning curve of complex procedures [14,15]. Furthermore, due to the COVID-19 pandemic containment measures, most countries restricted gatherings which included in- person meetings and congresses [16]; and these limitations allowed to increase the number of broadcasted live surgeries during the meeting, transmitted by the own hospital of the invited surgeon.

In our series we mixed these two technology-driven surgeries (telementoring and broadcasted surgery) introducing the possibility to have a 3D tele-assistance during a broadcasted RAPN.

In fact, we furtherly implemented these technologies alongside the use of 3D cognitive guided surgery to connect a skilled robotic surgeon from one institution with a distant experienced user of 3D navigation systems to complete a 3D cognitive RAPN.

As suggested by a recent study published by Porpiglia et al. [17], the use of 3D Virtual Models as an evaluation tool for intraoperative surgical navigation gives the surgeon a more accurate understanding of the renal mass nephrometry details and surgical complexity, which in turn helps predict intra and postoperative complications.

In our preliminary experience, telementoring provided the possibility to have at surgeon disposal a 3D model of the patient’s kidney and tumour anatomy, and some specific phase of the intervention, such as the pedicle management and the suturing or the parenchyma, were driven by the assistance of an expert 3D model user/navigator.

The use of this technology confirmed the advantages related to 3D-guided surgery, as highlighted in our previous works [9, 18-20]. In particular, the surgeon was able to study the case preoperatively after sharing the model. The relationship between the tumoral lesion and the vascular and urinary system were analyzed and later confirmed intraoperatively by the possibility to visualize the model inside the robotic console by using the tile-pro software.

Surely this technology must face some issues, which need to be addressed: first of all, a stable and high-performance internet connection (e.g., 5G) is needed to allow the dataflow between the two parties involved. Secondly, the connection must be protected and, maybe, crypted, to protect patients’ personal data from informatic attacks. Lastly, the urologist maneuvering the model, although he/she may be self-taught, would benefit from a dedicated training, which could be fulfilled using the same concept of tele-mentoring proposed for live surgery.

In conclusion, our experience suggests that telementoring with 3D models cognitive assistance can be easily performed, supporting the surgeon during the crucial steps of complex procedures such as RAPN.

In the actual technology-driven era, facing the pandemic and environmental issues, the implementation of telesurgery will allow to reduce the physical barriers and distance avoiding the need of physical travels.

**Authors' Contributions**

Sica M.: Study concepts, Study design, Formal anal- ysis and interpretation, Manuscript preparation, Manuscript editing.

Meziere J.: Study concepts, Study design, Formal anal- ysis and interpretation, Manuscript preparation, Manuscript editing.

Verri P.: Data acquisition, Data Formal analysis.

Daniele Amparore: Study design, Manuscript review.

Piramide F.: Data acquisition, Data Formal analysis, and interpretation.

Volpi G.: Data acquisition, Data Formal analysis.

De Cillis S.: Data Formal analysis and interpretation.

Breda A.: Study design, Manuscript review.

Mottrie A.: Study design, Manuscript review.

Porpiglia F.: Study concepts, Study design, Manuscript editing, Manuscript review.

Checcucci E.: Study concepts, Study design, Manuscript editing, Manuscript review.

**Availability of Data. and Materials**

Not applicable

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None

**Conflicts of Interest**

All authors declared that there are no conflicts of interest

**Ethical Approval and Informed consent**

Informed consent for publication was obtained from all patients

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