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First live case of augmented reality robot-assisted radical prostatectomy from 3D magnetic resonance imaging reconstruction integrated with PRECE model (Predicting Extracapsular extension of prostate cancer)

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ABSTRACT

Objectives: To report the feasibility of a console integrated augmented reality model during robotic assisted radical prostatectomy (AR-RARP) developed from combining the results of prostate multiparametric magnetic-resonance-imaging (mpMRI) and a statistical tool for the prediction of the extent of extracapsular extension (ECE) of prostate cancer (based on clinical and biopsy pathological variables). The first live case was presented during the European Section of Uro-Technology (ESUT) Congress on May 2018.

Materials and methods: We describe the case of a man (59-years) with PSA 4.6 ng/ml and GS3+3 involving up to 30% of the samples. The Predicting Extracapsular Extension of PCa (PRECE) tool – a side specific model anticipating the risk of ECE at different distances from the capsule- predicted a 1.8% and 2.1% ECE risk at 1 mm-distance from the prostatic capsule in the left and right lobes, respectively. These outputs were combined with the mpMRI images to develop a 3D-virtual model integrated in the DaVinci console (High Fidelity and Precision 3D Reconstructions HA3D program).

Results: The location and the extent of the mpMRI detected lesions were superimposed on the prostate in a real time fashion allowing both the detection and the continuous control of the adequate plane of dissection. Pathological examination revealed a pT2c with negative surgical margins; functional outcomes were satisfactory at 2-months follow-up.

Conclusion: AR-RARP based on mpMRI plus PRECE is a promising tool that may result in a more precise intra-operative navigation rather than other models based only on imaging, and ensuring the ideal of the precision surgery.

Introduction

The knowledge of local staging is of paramount importance to tailor the amount of nerve sparing and to improve the tradeoff between functional and oncological outcomes of radical prostatectomy. Several nomograms have been developed to predict extracapsular extension (ECE) of prostate cancer (PCa) [1–3], based on pre-operative clinical and pathological variables. However, most of them are not side-specific and only few tools were externally validated.

Furthermore, the prediction of the amount ECE is essential to detect the correct plane of dissection. “Predicting Extracapsular extension of Prostate cancer” (PRECE) tool [4] is a novel side specific statistical model developed from the analysis of roughly 12,000 prostatic lobes to address this issue; it predicts the extent of the tumor out of the prostate (radial distance, mm) and provides a decision rule, advising the surgeon about the risk of ECE at different distances from the prostatic capsule (1– 2–3–4 mm).

Beyond the importance of a pre-operative surgical planning, the intra-operative assessment of tumor location and eventual ECE through augmented reality (AR) was used to detect and continuously track the correct plane of dissection [5].

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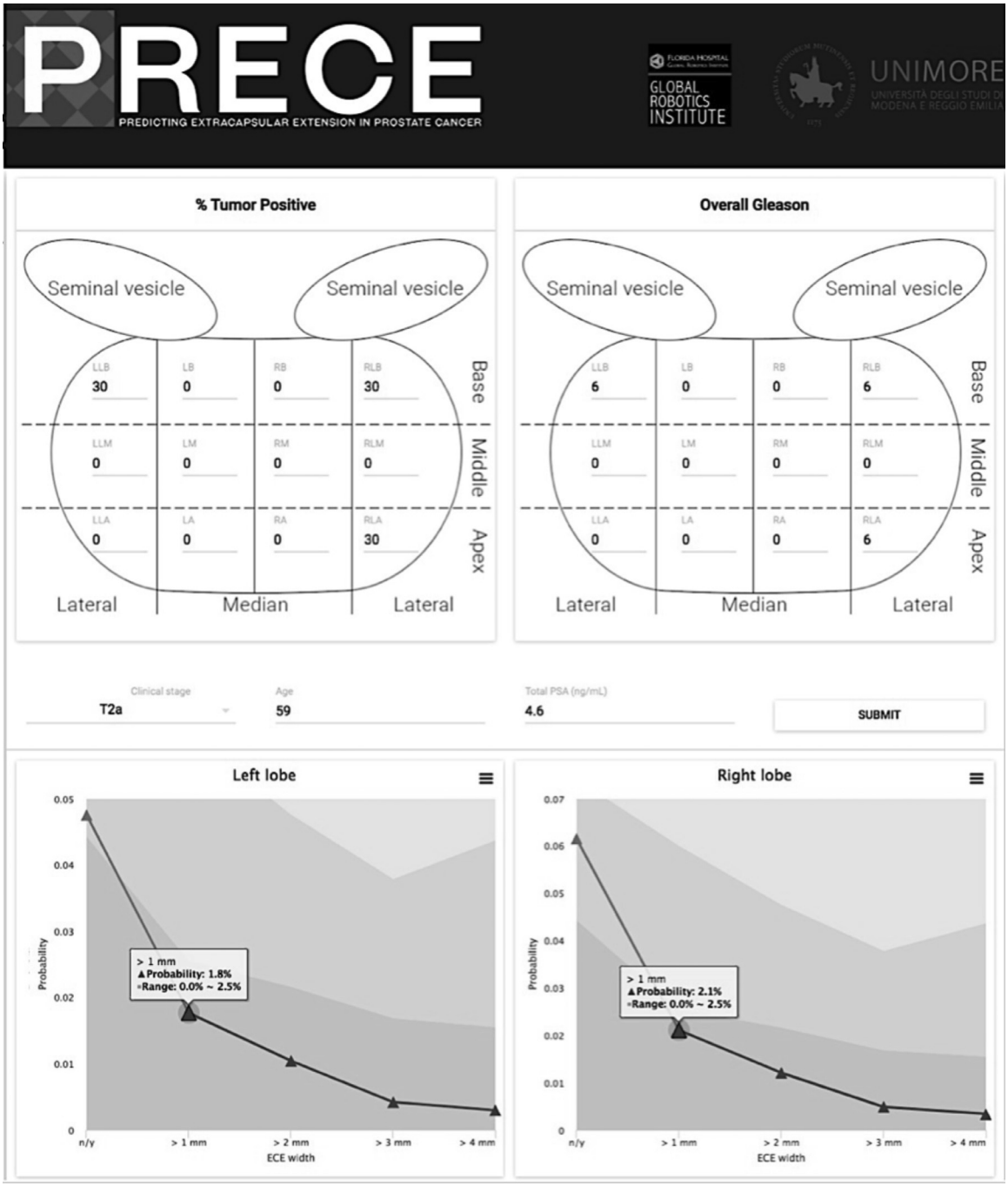

Fig. 1. PRECE tool for individual and side specific risk assessment of ECE.

AR improves visualization for surgical navigation and may help to achieve the ideal precision surgery. AR robot assisted radical prostatectomy (AR-RARP) consists of the integration of three dimensional (3D) multiparametric magnetic resonance imaging (mpMRI) in the robotic console [5]; Porpiglia et al. [5] reported the feasibility and effectiveness of this procedure on a preliminary series of 30 patients.

To further improve the precision of surgical dissection with concern to ECE, we integrated the outcomes of the PRECE tool (mm and side of predicted ECE) with the 3D mpMRI reconstruction and robotic superimposition. The first live case was performed and presented at the European Section of Uro-Technology (ESUT) Congress on May 2018.

Materials and methods

A 59-years-old Italian male (International Index of Erectile Function = 23) presented with an increase in PSA (4.6 ng\ml) and was suspected for having a clinical T2 PCa. Transperineal prostate biopsy confirmed a prostatic adenocarcinoma, Gleason score 6 (3 + 3) in 2 cores out of 6 on the right, and one out of 6 on the left, involving from 10 to 30% of the samples. The mp-MRI (Philips Ingenia 1.5 Tesla, 32 channel MRI system) documented a 66 ml prostate with two lesions in the right apical zone (PI-RADS 4 and PI-RADS 3 measuring 7 × 9 mm and 5 mm, respectively), while, the median left apical zone showed a PI-RADS 3–4 lesion of 7 mm. RARP was subsequently scheduled and accurately planned. The Memorial Sloan – Kettering Nomogram showed a risk of lymph node in-

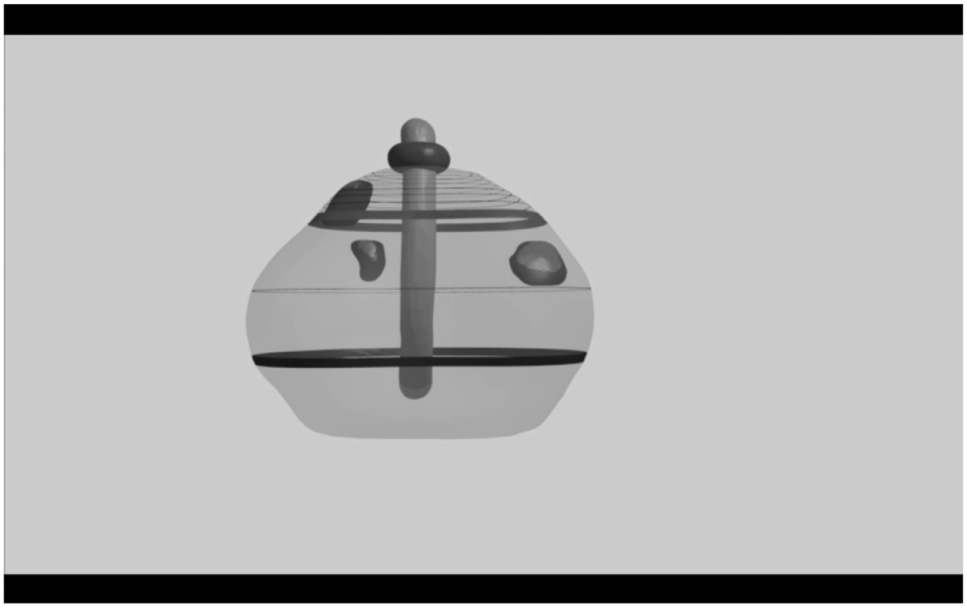

Fig. 2. 3D-PDF model combining information about the precise size and location of prostate nodules.

volvement of 1%; PRECE (prece.it) predicted a 1.8% and 2.1% ECE risk at a distance of 1 mm from the prostatic capsules on the left and right lobes, respectively (Fig. 1).

Output from PRECE tool and those of the mpMRI were provided to the engineers of Medics SRL. A 3D-PDF model combining the information about the precise size and location of the prostatic nodules from the mpMRI with the outcomes of the PRECE nomogram was developed using the "High Fidelity and Precision 3D Reconstructions (HA3D)" program (Fig. 2).

The three-dimensional model was carefully analyzed by the surgeon (GB) and the bioengineers, to confirm the accuracy of the model with regards to the clinical and radiological preoperative patient's data.

Live RARP was performed with a standard six-port transperitoneal technique, with the "da Vinci Si" system, using the technique described by Mattei et al. [6].

After the bladder neck dissection and before performing the dissection of the right neurovascular bundle, the HA3D reconstruction was integrated inside the console using the Tile-Pro (Fig. 3). A dedicated bioengineer was responsible for navigating the superimposed model. The 3D-PDF model was superimposed on the prostate using urethral catheter as the landmark.

Results

The superimposition of the 3D virtual model allowed the visualization of both the site and the extent of the mpMRI-detected lesions; the ideal plane of dissection was easily identified with live assessment and control. Overall operative and console times were 181 and 145 min, respectively. Post-operative course was uneventful and the patient was discharged 3 days after surgery. Pathological analysis was consistent with mpMRI findings and documented a prostatic adenocarcinoma, Gleason Score 6, WHO 2016 grade group 1, pT2c with negative surgical margins. Continence – defined as no-pad usage – was achieved after 30 days, and erectile function was completely recovered after 60 days. Post RARP PSA was < 0, 01 ng/ml.

Discussion

Surgical tailoring in the field of PCa is a topic of outmost importance, and technical advances have to measure up with the current need for a precision surgery [7,8]. Precision surgery relies on technology, biomedical engineering and digital imaging; it aims to combine the radical excision of the tumor – or the organ of interest – while preserving adjacent structures and ensuring minimal surgical trauma [9].

The AR from standard imaging has been developed at first to allow a precise surgical pre-planning with a 3D imaging overview [10], but then evolved toward the concept of a precise intra-operative navigation with 3D virtual model superimposed in the surgical field [5,11].

When dealing with radical prostatectomy, AR aims to detect the tricky sites and steps of the procedure and to guide the surgeon toward the best plane of dissection in a real-time fashion. Porpiglia et al. [5] – while describing the feasibility of AR-RARP – analyzed the concordance between the integrated virtual model and pathological findings, concluding an adequate overlap of 3D mpMRI and the prostate contour. Moreover, final pathology confirmed lesion location in all patients with intraprostatic MRI detected lesion. Furthermore, the same Author verified the reproducibility of the technique applied by different surgeons in a live-surgical event, pointing out that the main steps of RARP were improved by the AR (bladder neck and apex dissection, NS technique) [11]. Despite the promising efficacy, it should be remarked that the virtual model from Porpiglia was built on images from mpMRI, whose sensitivity for local staging is variable among series and still as low as 0.57 from the meta-analysis of DeRojii et al. [12]. Likewise, the incremental value of mpMRI added to traditional nomograms is still debatable as well [13,14].

To address this concern and to provide a more accurate depiction of ECE, we integrated the mpMRI 3D reconstruction with the outcomes of the PRECE tool. This model aims to define the presence, the location and the amount of PCa outside the prostatic capsule and, as for other statistical tools, it is developed from several covariates [4] (age, total PSA, clinical stage, zonal specific percentage of cancer and Gleason score). Whereas previous 3D models are built merely from imaging and do not take into account clinical and pathological details, the integration of PRECE may improve the accuracy of 3D models as it consider both mpMRI findings and patient's and cancer's characteristics. More complex cases – like intermediate risk PCa or patients at risk of extracapsular extension from mpMRI – would have been more representative of the importance of these technique.

To our knowledge, this is the first live case of intra-operative surgical navigation based on the integration of a nomogram into an image-derived model. Such a report represents a feasibility case and despite the promising perspectives, further cases are required to confirm the advantages of such an image-guided surgery to improve dissection, functional and oncological outcomes, and overall surgical precision.

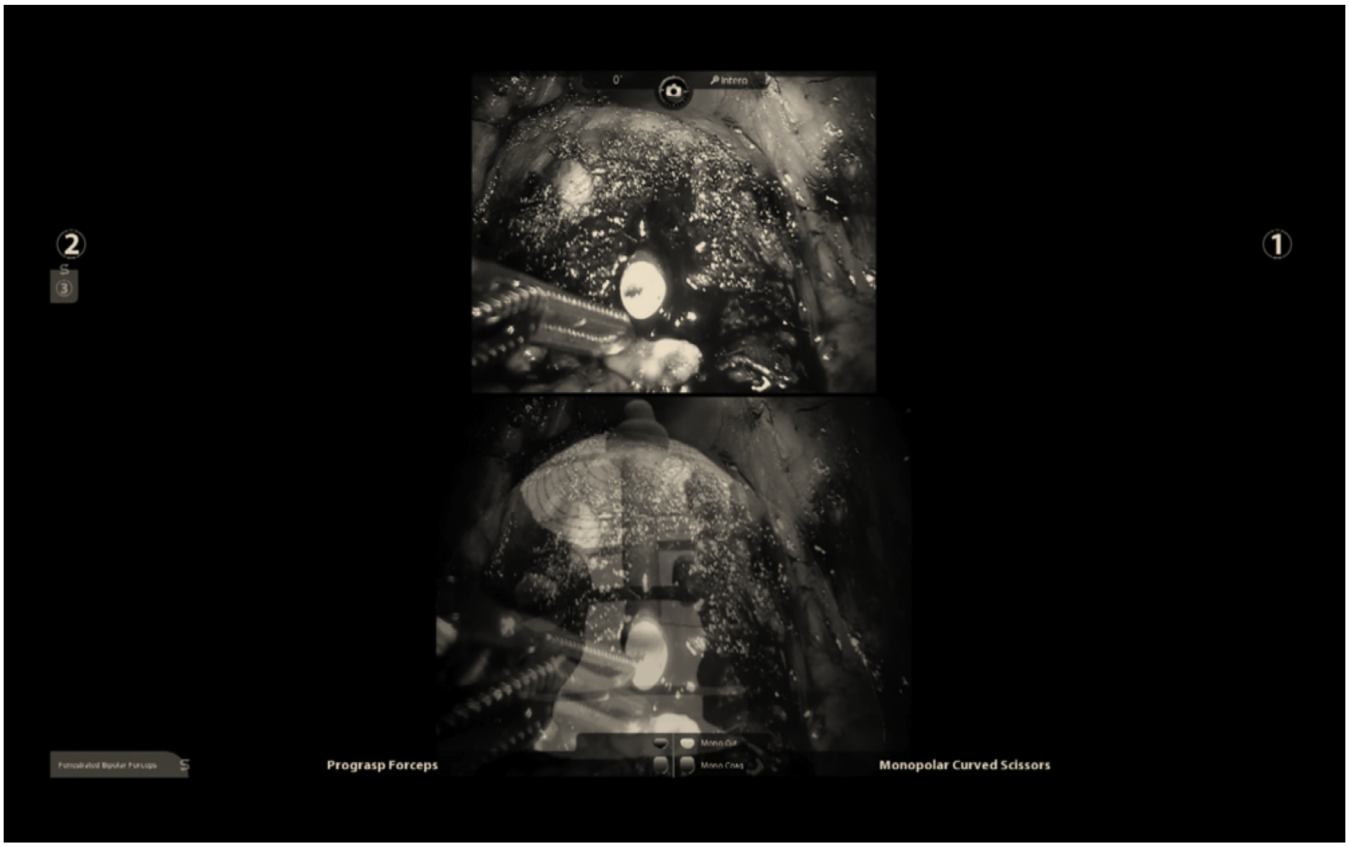

Fig. 3. HA3D reconstruction was integrated inside the console using the Tile-Pro.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.urolvj.2019.100002.

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