Robotic Transrectal Ultrasonography During Robot-Assisted Radical Prostatectomy

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1. Case report

Robot-assisted prostatectomy (RAP) has become an accepted and popular approach to radical prostatectomy (RP). Nonetheless, certain aspects of the procedure remain challenging. In addition to the inherent learning curve associated with robotic surgery [1], the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) lacks haptic feedback. As such, certain critical steps of the procedure, including posterior bladder neck transection, neurovascular bundle (NVB) preservation, and apical dissection, are performed solely with visual cues. Furthermore, cancer abutting the prostate capsule or focally extending into periprostatic tissue increases the risk of positive surgical margins (PSMs).

Transrectal ultrasound (TRUS) is widely used for diagnostic and therapeutic purposes for prostate cancer (PCA). Previously, we described the use of real-time TRUS...
evaluation during laparoscopic RP (LRP) to facilitate the identification of dissection planes and decrease PSMs while prospectively identifying and preserving the NVB and thus potency [2,3]. Real-time TRUS evaluation can also identify hypoechoic lesions (HELs) corresponding to biopsy-proven cancer and suggest evidence of extracapsular disease—all of which may contribute to a significant decrease in the incidence of PSMs during LRP [4].

Unlike open prostatectomy or LRP, positioning and manually manipulating a TRUS probe during robot-assisted RP (RARP) is more difficult from a practical standpoint because of the docked position of the robotic system. We describe a novel adaptation of the ViKY System (EndoControl Medical, Grenoble, France) to robotically manipulate a TRUS probe during RARP.

With institutional review board approval, 10 patients with clinically organ-confined (<cT2N0) PCa undergoing RARP underwent robot-manipulated TRUS (robotic TRUS) evaluation. Preoperative (baseline) and intraoperative real-time TRUS evaluation was performed using a Type 2102 Hawk ultrasound machine (B-K Medical, Copenhagen, Denmark) and a Type 8818 biplane TRUS probe (B-K Medical).

The ViKY System with a custom-made TRUS holder was used (Fig. 1). A foot pedal controller either at the bedside by a dedicated ultrasonographer (Fig. 1C) or at the surgeon console by the robotic surgeon (Fig. 1D) moved the biplane TRUS probe along three directions (Figs. 2–4).

When the RARP procedure began, real-time biplane TRUS allowed spatial localization of relevant anatomy in relation to the area of surgical dissection (Fig. 5). For example, the da Vinci scissors tip was tracked as a focal, moving hyperechoic object. Characteristics of the NVBs, including color Doppler flow and distance from the lateral edge of prostate and/or HELs, were recorded.

1.1. Clinical outcomes

Demographic and preoperative data of the 10 patients are listed in Table 1. Median setup time of the ViKY device was 7 min. (range: 4–12; Table 2). Full TRUS evaluation was successfully completed in all 10 patients (median lobe identified in two patients [20%] and posterior protrusion of the prostate apex in three patients [30%]). Such details were relayed in real time to the console surgeon.
**Fig. 2** – Biplane transrectal ultrasound (TRUS) images of a prostate when the TRUS probe is robotically manipulated into and out of the rectum, permitting axial (top) and longitudinal (bottom) views of the prostate from the (A) seminal vesicles (SV), (B) base, (C) mid, to (D) apex.

**Fig. 3** – Biplane transrectal ultrasound (TRUS) images of a prostate when the TRUS probe is robotically manipulated rotationally around the probe axis, showing axial (top) and longitudinal views (bottom) of the prostate from left lobe (left) to right lobe (right). HEL = hypoechoic lesions; NVB = neurovascular bundle; SV = seminal vesicles.
No intraoperative complications resulted from robotic TRUS or during RARP. In no case did the surgeon experience technical difficulty in performing RARP because of the presence of the TRUS probe in the rectum. Surgical margins were negative in 9 of 10 cases (90%). At a median of 9-wk follow-up (range: 7–13), 3 of 7 men (43%) who were potent preoperatively had erections sufficient for intercourse, and 8 of 10 patients (80%) were continent (0–1 pads daily).

1.2. Intraoperative assessment of technique

Real-time robotic TRUS identification of biopsy-proven cancerous HELs abutting the prostate capsule in 5 of 10 cases (50%) alerted the surgeon to guard against iatrogenic capsulotomy and PSMs at that specific location. In one case with Gleason 6 cancer at bilateral prostate bases, robotic TRUS identified significant-sized HELs abutting the capsule (Fig. 6). The surgeon was alerted to excise wider margins of periprostatic fat at those locations yet achieve bilateral nerve preservation. Final pathology

![Fig. 4 – Axial (top) and longitudinal (bottom) transrectal ultrasound (TRUS) images of a prostate when the TRUS probe is robotically angulated away from prostate (left) or toward prostate (right). Note that angulating toward the prostate places more pressure against the rectal wall and prostate.](image)

**Table 1 – Demographic and preoperative data**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>10</td>
</tr>
<tr>
<td>Age, yr (range)</td>
<td>66 (54–88)</td>
</tr>
<tr>
<td>Preoperative PSA, ng/ml (range)</td>
<td>5.3 (1.3–17.9)</td>
</tr>
<tr>
<td>Preoperative Gleason score (index lesion), no. (5):</td>
<td></td>
</tr>
<tr>
<td>3 + 3 = 6</td>
<td>6 (60)</td>
</tr>
<tr>
<td>3 + 4 = 7</td>
<td>1 (10)</td>
</tr>
<tr>
<td>4 + 3 = 7</td>
<td>2 (20)</td>
</tr>
<tr>
<td>4 + 5 = 9</td>
<td>1 (10)</td>
</tr>
<tr>
<td>Clinical stage, no. (%):</td>
<td></td>
</tr>
<tr>
<td>T1c</td>
<td>6 (60)</td>
</tr>
<tr>
<td>T2a</td>
<td>3 (30)</td>
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<tr>
<td>T2b</td>
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<tr>
<td>SHIM score (range)</td>
<td>23 (0–25)</td>
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<tr>
<td>IPSS value (range)</td>
<td>8 (0–17)</td>
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<tr>
<td>Nerve-sparing plan, no. (%):</td>
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<tr>
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<td>2 (20)</td>
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<tr>
<td>No nerve sparing</td>
<td>1 (10)</td>
</tr>
<tr>
<td>Preoperative TRUS with HEL with biopsy-proven cancer</td>
<td>5 of 10 (50%)</td>
</tr>
</tbody>
</table>

PSA = prostate-specific antigen; SHIM = Sexual Health Inventory for Men; IPSS = International Prostate Symptom Score; TRUS = transrectal ultrasound; HEL = hypoechoic lesion.
Fig. 5 – Real-time robotic transrectal ultrasound (TRUS) of prostate and periprostatic anatomy. Real-time TRUS monitoring (longitudinal TRUS views) of bladder neck dissection at the (A) anterior bladder neck and (B) posterior bladder neck for visualizing the bladder neck anatomy (vas deferens and seminal vesicles behind the posterior bladder neck) and facilitating the dissection of the bladder neck. (C) Robotic TRUS also identifies the pulsatile arterial flow of the neurovascular bundle (NVB). (D) Intraoperative TRUS can visualize the biopsy-proven hypoechoic lesion on the posterior-lateral margin of the prostate, adjacent to the NVB. Size and distance of the NVB to the cancer is confirmed by Doppler. SV = seminal vesicle; NVB = neurovascular bundle; HEL = hypoechoic lesion.

Fig. 6 – Case 1: A 76-yr-old man with a prostate-specific antigen of 4.6 and normal digital rectal examination. Prostate biopsy revealed bilateral Gleason 3 + 3 = 6 prostatic adenocarcinoma. (A) Robotic transrectal ultrasound showed extensive hypoechoic lesions (R HEL, L HEL) of the bilateral prostatic bases, with Doppler showing increased blood flow to the L HEL. A catheter in the urethra is also shown, with shadowing artifact. (B) Final pathology demonstrated significant bilateral prostate adenocarcinoma abutting the prostate capsule but negative surgical margins.
confirmed organ-confined extensive bilateral adenocarcinoma with negative surgical margins (Fig. 6B). In another patient, intraoperative robotic TRUS closely guided the surgeon’s robotic manipulation of the TRUS probe using a foot pedal within the console space involved a learning curve and was challenging, given the concurrent responsibility of performing the RARP. Nonetheless, it was feasible with time and experience.

2. Discussion

This initial series demonstrates the feasibility and safety of robotically manipulated TRUS during RARP. Potential advantages of real-time biplanar TRUS include (1) enhanced three-dimensional anatomic understanding during RARP; (2) improved quality of robotic dissection, especially for the novice surgeon, at critical steps of the operation; and (3) decreased incidence of PSMs, particularly at areas of ultrasound-visible disease, while still preserving the NVB.

It appears to us that, during minimally invasive prostatectomy, we should take technical advantage of the immediate proximity of the rectum to the prostate. Inserting a TRUS probe would allow the rectum to be used as an objective “window” for real-time guidance for the delicate steps of a RP. Such image-based guidance could provide visual cues about tissue characteristics that are otherwise opaque to the surgeon. Prospective intraoperative identification of HELs, especially those already proven to be cancerous on preoperative biopsy, could minimize PSMs at those high-risk locations. One application of real-time TRUS that dramatically enhances operative efficiency and safety is during salvage RARP, wherein the prostate–rectal surgical plane is often fused, and the cancer is often advanced.

Intraoperative robotic TRUS can indeed mirror any findings of manual TRUS as long as the prostate has not yet been significantly manipulated during surgery. Reproducible findings of manual TRUS included location and extent of biopsy-proven cancer lesion, case-specific apical protrusion or median lobes, and characteristics of the NVBs (Table 2). Compared with free-hand manipulation of the TRUS probe, however, limitations of robotic control include the lack of fine manipulation with appropriate pressure to the rectal wall to preserve a high-quality ultrasound image. Movement of the current ViKY system is currently limited to one direction at one time (i.e., in/out, rotational, or up/down), making real-time tracking of dissection challenging. Manipulation of the robotic TRUS system also requires the special attention of an operator (direct or indirect) experienced with TRUS evaluation of the prostate and periprostatic anatomy. Consequently, the benefit of TRUS evaluation during RARP is operator dependent.

We believe that TRUS is an underutilized tool that can significantly improve clinical outcomes in various surgical interventions involving the prostate [5]. In its further development and use, TRUS may serve not only as a real-time image-navigation tool during RARP but also as an excellent image-registration tool for subsequent projection of corresponding preoperative imaging onto the intraoperative surgical field (i.e., augmented reality demonstrating location of the most significant cancer burden).

In the coming years, surgical navigation (image-based guidance for surgery) will increasingly rely on augmented reality, and significant work in this field has already occurred [6–8]. Because the prostate is a mobile organ and deforms with surgical manipulation, precise real-time registration is necessary to superimpose detailed preoperative imaging such as magnetic resonance imaging onto the live operative field; to that end, real-time tracking technology such as a “body-GPS” system with real-time ultrasound imaging is being developed [9]. Future integration of augmented reality with enhanced robotic TRUS maneuverability may allow real-time guidance delivered
directly to the surgeon’s control in a format that is more easily navigated.

We have demonstrated the feasibility of robotically manipulated real-time TRUS guidance during RARP. Real-time biplane TRUS evaluation guides dissection around potential trouble spots and difficult-to-visualize steps. Further experience and refinement of this technique, including the integration of image-based surgical navigation and augmented reality, may further enhance its utility and clinical outcomes.

Conflicts of interest: The authors have nothing to disclose.

Fig. 7 – Case 2: A 69-yr-old man with a firm hard nodule on his right prostatic lobe and a prostate-specific antigen of 8.4 ng/ml. Prostate biopsy revealed bilateral Gleason score 4 + 5 = 9 prostatic adenocarcinoma. Staging computed tomography scans and bone scan did not reveal nodal or metastatic disease. (A) Intraoperative robotic transrectal ultrasound was highly suggestive of extracapsular extension: A hypoechoic lesion corresponding to biopsy-proven cancer had a wide contact length with a capsule and irregular margin. Final pathology revealed that bladder neck and radial surgical margins were negative in spite of (B) extracapsular extension (adjacent to the posterolateral biopsy-proven cancer area) and (C) seminal vesicle involvement. The apical and seminal vesicle margins were positive, as were pelvic lymph nodes.
EU-ACME question

Please visit www.eu-acme.org/europeanurology to answer the following EU-ACME question online (the EU-ACME credits will be attributed automatically).

Question:

How do intraoperative image guidance of the intraprostatic location and risk classification of the biopsy-proven cancer during prostatectomy contribute to surgical outcomes?

A. Facilitate intentional wide dissection adjacent to the high-risk cancer, with suspicious extracapsular extension to achieve negative surgical margins
B. Help decision making of nerve-sparing site or side
C. Help to determine the distance between the prostate posterior-lateral margin and dissection plane of the lateral pedicle
D. All of above

References


