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ORIGINAL PAPER

The role of intraoperative ultrasound in small renal mass robotic enucleation

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Summary

Introduction: As a result of the growing evidence on tumor radical resection in literature, simple enucleation has become one of the best techniques associated to robotic surgery in the treatment of renal neoplasia, as it guarantees minimal invasiveness and the maximum sparing of renal tissue, facilitating the use of reduced or zero ischemia techniques during resection. The use of a robotic ultrasound probe represents a useful tool to detect and define tumor location, especially in poorly exophytic small renal mass.
Materials and methods: A total of 22 robotic enucleations were performed on < 3 cm renal neoplasias (PADUA score 18 Pz 6/7 e 4 Pz 8) using a 12-5 MHz robotic ultrasound probe (BK Drop-In 8826).
Results: Once kidney had been isolated from the adipose capsule at the site of the neoplasia (2), the exact position of the lesion could be easily identified in all cases (22/22), even for mostly endophytic lesions, thanks to the insertion of the ultrasound probe through the assistant port. Images were produced and visualized by the surgeon using the TilePro feature of the DaVinci surgical system for producing a picture-in-picture image on the console screen. The margins of resection were then marked with cautery, thus allowing for speedy anatomical dissection. This reduced the time of ischemia to 8 min (6-13) and facilitated the enucleation technique when performed without clamping the renal peduncle (6/22). No complications due to the use of the ultrasound probe were observed.
Conclusions: The use of an intraoperative robotic ultrasound probe has allowed for easier identification of small, mostly endophytic neoplasias, better anatomical approach, shorter ischemic time, reduced risk of pseudocapsule rupture during dissection, and easier enucleation in cases performed without clamping. It is noteworthy that the use of intraoperative ultrasound probe allows mental reconstruction of the tumor through an accurate 3D vision of the hidden field during surgical dissection.

KEY WORDS: *Robotic ultrasound probe; Renal tumor; Simple enucleation; Psychomotor skills.*

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INTRODUCTION

The widespread use of little invasive imaging tools such as ultrasound has lead to a growing number of diagnosed small renal masses treatable with nephron sparing surgery (NSS) in the past decades.
On the basis of literature evidence, simple enucleation (SE) is one of the partial nephrectomy techniques that mostly combines functional sparing with radical tumor resection (1-3).
In addition, NSS has been encouraged by the recently introduced robotic technique for the conservative treatment of renal neoplasias, assuring minimal invasiveness through the sparing of renal tissue and enabling the use of reduced or zero ischemia techniques during surgery.
In the present paper we report our experience of the use of intraoperative ultrasound imaging in SE, showing how, besides providing more accurate anatomic detection of neoplasias, it may improve the surgeon's spatial proprioception, thus facilitating SE performance.

MATERIALS AND METHODS

Since April 2013 we have performed in our Unit a total of 22 robotic enucleations on < 3 cm renal tumor (PADUA score 18 Pz 6/7 e 4 Pz 8) through a 12-5 MHz robotic probe (BK Drop-In 8826) (Figure 1).
We used the DaVinci Xi system in the three-armed configuration, connected to a 5-mm port utilized for suction and retraction of the bowel, and a 12-mm assistant port for inserting the drop-in ultrasound probe and for applying the vascular bulldog clamps and the Hem-o-lok clips.
A ProART robotic trasducer 8826 (BK Medical) was used for the intraoperative ultrasonography. The TilePro was selected to observe the images on the robotic console, which allowed simultaneous vision of both the operative field and the ultrasound images (4).
The probe was managed by the proGrasp forceps; image quality was optimal also thanks to the large field of view. Tumor excision was performed with scissors and the ProGrasp forceps (Intuitive Surgical). No patient had positive surgical margins detected at the pathologic examination. After excision, the renal cortex was closed using the sliding clip renorrhaphy technique (5).

RESULTS

Once kidney had been isolated from the adipose capsule at the site of the neoplasia (2), the exact position of the lesion could be easily identified in all cases (22/22), even for mostly endophytic lesions.

No conflict of interest declared.

The margins of resection were marked with cautery allowing for speedy anatomical dissection, reducing either time of ischemia to 8 min (6-13) or facilitating enucleation when performed without clamping the renal peduncle (6/22). No complications due to the use of the ultrasound probe were observed.

Discussion

A comparison of the different types of intraoperative ultrasound probe has shown that handling issues of laparoscopic probes impede an accurate spatial evaluation of the tumor, while robotic drop-in probes combined with ProGrasp forceps enable fast and efficacious ultrasound exploration on 3D planes (6). In addition, while assistant-controlled laparoscopic probes limit the autonomy of the surgeon, only robotic drop-in probes can be handled directly by the surgeon at the console.
Picture-in-picture vision technology (*TilePro*) on the DaVinci robotic system enables routine simultaneous live vision of both operation field and ultrasound images (Figure 2), while the attached surgeon-controlled drop-in ultrasound probe improves the operator's sensation of the tool.
A possible limitation might be that the methodology is highly operator-dependent: adequate ultrasound imaging training should therefore be included in the operator's preparation. The presence of a radiologist in the initial phases of the training might accelerate the learning curve itself.
In a recently published study (7) 87% of interviewees highlighted the potential usefulness of augmented reality, especially during RAPN for detecting the neoplasia, and during mass resection. As yet, however, such technology has not been insufficiently mastered to be transferred to clinical practice (8).
It has also been suggested to display overlapped 3D images using the open source processing software (*OsiriX*) on the surgeon's console screen through TilePro display for identifying the tumor and vascularization sites, and performing a selective arterial clamping. The combination of this technique with the use of an ultrasound probe will allow for an accurate drawing of the neoplasia profile (9).
Augmented reality techniques, however, are still far from being perfect (10): since augmented reality cannot be used in fine anatomy until adequate technique development and mastering has been accomplished, it is all the more crucial to optimize the use of a modality which is safe and reproducible, such as intraoperative ultrasound, possibly implemented by the contrast enhanced ultrasound (CEUS).
In our experience, both the easily-handled ultrasound probe and the freedom of movement of the robotic tool have enabled the correct vision of the morphology especially in the deep planes, indicating the best tumor dissection way, reducing time, risk of pseudocapsule rupture during dissection, and ultimately surgical invasiveness (11).
A possible limitation of the methodology might be the application of the ultrasound probe to the renal parenchyma after it has been removed from the adipose capsule, especially in case of high renal sclerolipomatosis.
Despite the easier handling of the ultrasound probe and the more focused dissection of the sclerolipomatosic capsule thanks to the CT scan images, a higher chance of bleeding and a longer operating time indisputably represent major weaknesses. Future use of CEUS will partly overcome these issues.
Efficacy of CEUS has been demonstrated by several studies: ultrasound scan can be performed without adipose capsule removal, limiting the dissection of the capsule to the precise site of the neoplasia (12).
Evaluation of renal vascularization by means of CEUS has also been described. This methodology assists zero-ischemia partial nephrectomy techniques providing several more advantages than the fire-Fly technology, including non defatted kidney, good control of medullary blood flow, no toxicity (potential risk of allergic reactions to sodium iodide).
RAPN was performed with selective clamping and evidence of a nonperfused segment of kidney (occlusion angiography) using intraoperative CEUS (13-14).
Evidence has been reported on the higher safety of selective ischemia than total ischemia (15). To optimize this technique, the use of a robotic ultrasound probe represents a useful tool to detect and define tumors, especially in poorly exophytic small renal mass, which is usually difficult to identify, and to better assess vascularization.
It is noteworthy that the use and the easy handling of the ultrasound probe result in a more accurate identification of the neoplasia site, and in the improvement of psychomotor skills, in particular visuospatial skills, enabling a 3D mental image of the tumor with defined profiles, depth and relationship with other structures (16).

Figure 1. *Ultrasound robotic probe.*

Figure 2. *Picture-in-picture vision technology (TilePro).*

The ability to build a mental image of the neoplasia improves both accuracy and awareness of the surgeon's gesture, consequently optimizing execution time, reducing warm ischemia time (WIT), and facilitating SE, partly compensating the lack of force feedback, which is still a major limitation in robotic technology.

Conclusions

The use of a robotic ultrasound probe has allowed easier identification of small, mostly endophytic neoplasias, better anatomical approach, shorter ischemic time, reduced risk of pseudocapsule rupture during dissection and easier enucleation in cases performed without clamping.

Reduced WIT and intraoperative ultrasound allowed accurate excision with sparing of normal parenchyma in an NSS perspective.

Ultrasound methodology using contrast medium will be the natural evolution of intraoperative ultrasound in mininvasive robotic surgery.

The major oncological and function sparing results are obtained through the combination of the benefits derived from all available imaging techniques: drop-in ultrasound probe for identifying and mentally reconstructing the neoformation, CEUS for reducing time and avoiding bleeding in case of sclerolipomatosis, fire-Fly for an intuitive evaluation of the exact ischemia area, and virtual reality in the near future.

Interestingly, such ultimate technologies have not succeeded in superseding the human being: rather, in this way greater importance is conveyed to the surgeon himself who employs such techniques for a more comprehensive 3D mental vision which includes also depth.

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