The Uro Dyna-CT Enables Three-dimensional Planned Laser-guided Complex Punctures

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**Abstract**

**Background:** Ultrasound and fluoroscopy are the standard imaging techniques used to perform punctures in urology. Cross-sectional and three-dimensional (3D) imaging may enable safer procedures, especially in complex cases.

**Objectives:** To assess the feasibility of 3D planned laser-guided punctures in urology performed with the Uro Dyna-CT (Siemens Healthcare Solutions, Erlangen, Germany).

**Design, setting, and participants:** A total of 27 punctures using the laser-guided system syngo iGuide (Artis Zee Ceiling; Siemens Healthcare Solutions, Erlangen, Germany) for the Uro Dyna-CT have been performed to date. Patients with complex puncture indications due to unclear ultrasound findings or a suspicion of surrounding bowel were included.

**Surgical procedure:** Image acquisition was performed using a customized 8s syngo iGuide protocol of the Uro Dyna-CT. The puncture tract was planned after 3D and cross-sectional image reconstruction. The puncture was performed supported by the laser-guiding system.

**Outcome measurements and statistical analysis:** The primary end point of our assessment was accuracy and applicability of the system in a clinical setting. Secondary end points were planning time, puncture time, and radiation exposure of the patient.

**Results and limitations:** Overall, 24 of 27 punctures were successful. No severe complications occurred. Median radiation dose of the Uro Dyna-CT scan was 6113.1 microgray per sq meter (μGy m²; range: 1081.6–7957.2 μGy m²). The small patient cohort is the major limitation of our study.

**Conclusions:** We believe the Uro Dyna-CT–based puncture technique is an excellent additional instrument that allows the urologist to handle complex punctures. Image acquisition leads to higher radiation doses than standard fluoroscopy but does not exceed the radiation exposure of alternative procedures such as computed tomography (CT)–guided punctures with multidetector CT, which is used mainly for complex cases.

**Patient summary:** We report our experience with a three-dimensional planning and laser-guiding tool to perform complex punctures for urologic indications. The technique is feasible in the endourologic intervention suite.

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1. Introduction

The standard techniques for gaining access to the renal pelvis for percutaneous stone treatment are usually based on ultrasound and fluoroscopy. The exact technique depends on the imaging modalities that are available in different countries and medical centers. Both techniques have some drawbacks, especially in complex cases. Although ultrasound is a perfect real-time imaging tool, image resolution and contrast are limited even in modern systems. Fluoroscopy provides a detailed depiction of the renal calyceal system using a contrast agent, but it does not offer the possibility of soft tissue imaging. Consequently, the risk of organ injury during the puncture or bleeding might be increased [1].

To overcome these problems, new techniques based on three-dimensional (3D) imaging have been developed. The Uro Dyna-CT (Siemens Healthcare Solutions, Erlangen, Germany) installed in the endourologic operating suite provides not only standard x-ray and fluoroscopy but also interventional 3D imaging and cross-sectional image reconstructions [2]. It also offers a 3D planning and laser-guiding puncture tool called the syngo iGuide [3]. We have evaluated this new tool in terms of accuracy and applicability for urologists in cases of complex punctures. The aim of our study was to describe this innovative technique for complex punctures in the field of urology.

2. Methods and patients

2.1. Study design

After having evaluated the accuracy and feasibility of the Uro Dyna-CT–guided puncture technique successfully in an ex vivo model [3], we prospectively documented consecutive patients who underwent Uro Dyna-CT–guided punctures in our department between December 2012 and March 2015. The study was approved by the local ethics committee (2011-21Str.-MA). Our Supplementary Video shows the development and evaluation of the technique with the ex vivo model and one 3D step-by-step planned laser-guided puncture of a lower renal calyx before percutaneous lithotomy. All punctures were performed by a single surgeon (M.R.). An indication for a Uro Dyna-CT–guided puncture was an unsuccessful puncture with our standard technique (ultrasound and fluoroscopy combined) or complex situations such as suspicion of organs or vessels in the way of the puncture (eg, bowel) and/or difficult anatomy. Patients who were underage, pregnant, or disabled were not eligible for the technique. We documented puncture success, puncture time, planning time, fluoroscopy time during the puncture, and radiation exposure of the complete procedure.

2.2. Procedure technique

2.2.1. Image acquisition and puncture planning

For image acquisition, an Artis Zee Ceiling (Siemens Healthcare Solutions, Erlangen, Germany) with a modified imaging protocol was used. The system and its technical features were described previously [2]. The imaging protocol acquires 396 frames during its 8-s isocentric 240° C-arm rotation. The time for image acquisition and for 3D rendering is <2 min. Planning of the puncture and image windowing were performed at the dedicated 3D workstation of the system using the syngo MMWP VE 40A 3D reconstruction software (Leonardo; Siemens Healthcare Solutions, Erlangen, Germany).

The most suitable puncture tract to avoid interference with surrounding organs was planned using cross-sectional images and could be checked in the 3D reconstruction for the ideal direction to reach the target, especially for entering a renal calyx. The planning software shows the exact length of the planned puncture tract. It also provides an analysis of the ideal C-arm positions to depict the required planes for the puncture.

2.2.2. Puncture step by step

To start the laser-guided puncture, the table was adjusted, and the C-arm was placed in the bull’s eye position to indicate the puncture site and direction with a laser cross (Fig. 1). The needle was inserted, keeping the laser cross permanently in an inline position to the needle. The correct placement of the needle can be checked by fluoroscopy. The placement of the needle can be corrected as required by matching it with the indicated road map on the fluoroscopy screen in the bull’s eye oblique and lateral view until the target is reached. This road map is provided by the system in any position of the C-arm that might be necessary during the puncture because the Dyna-CT system knows the exact position of the table in relation to the C-arm at any time.

When puncturing a renal calyx, fluid excretion through the needle indicated puncture success. This was additionally checked by antegrade pyelography. The puncture of the right kidney (shown in the Supplementary Video) to provide access to the dorsal calyx of the lower pole was performed with our standard 20-cm 19F needle.

When puncturing solid structures as for tumor biopsy, the correct position of the needle can be verified by a customized low-dose Dyna-CT imaging protocol with the possibility of modifying the puncture direction by image overlay with the initial planning data.

3. Results

We performed 27 punctures in 26 patients. A total of 24 of 27 punctures (89%) were successful. Ten suprapubic catheters were placed in nine patients with low bladder capacity or suspected bowel in the puncture tract during the ultrasound examination. One tumor in the minor pelvis was biopsied, and one small lymphocele in the minor pelvis was drained. Two percutaneous nephrostomies were placed, and 10 punctures of the renal calyceal system before percutaneous stone treatment were performed (Fig. 2).

Three kidney tumor biopsies were performed (Fig. 3).

The time for image acquisition (8 s) and 3D rendering of the images was <2 min. Median planning time at the workstation was 5 min (range: 3–15).

Fig. 1 – Laser guidance indicating the puncture site and direction.
Median puncture time of the successful punctures starting with insertion of the needle was 30 s (range: 30–420). Median fluoroscopy time during and after the puncture to check the needle position in different angles by the indicated road map on the fluoroscopy screen was 0.7 min (range: 0.1–4.4). Radiation dose caused by the procedure led to a mean dose area product of 96.9 micrograys meter squared (\( \mu \text{Gy} \cdot \text{m}^2 \); range: 13.4–840.8 \( \mu \text{Gy} \cdot \text{m}^2 \)) by fluoroscopy during the procedure and 6131.1 \( \mu \text{Gy} \cdot \text{m}^2 \) (range: 1081.6–7957.2 \( \mu \text{Gy} \cdot \text{m}^2 \)) by the Dyna-CT scan for puncture planning. Table 1 lists detailed data about the different indications.

Overall, 22 of 25 punctures (88%) were successful with the first attempt; two attempts were necessary in two punctures and a third attempt in one puncture. The punctures that required further attempts were punctures of the renal calyceal system in two cases and a suprapubic catheter in one case where the dislocation of the guidewire necessitated a second puncture of a low-capacity bladder (50 ml). Two puncture attempts before percutaneous lithotomy were aborted due to limited vision after contrast agent extravasation, and the third unsuccessful puncture was switched to an ultrasound-guided puncture due to the extended motility of the kidney even during breath-holding maneuvers by the anesthesiologist. No further complications occurred during or after the procedures.

4. Discussion

Most of the punctures performed by urologists can be accomplished safely and quickly by ultrasound alone or in combination with fluoroscopy [4–6]. Ultrasound provides inexpensive, fast, and real-time imaging, but problems include availability in the endourologic suite in some countries, the need for extensive training, and relatively low spatial contrast depending on the abilities of the available system. Common ultrasound machines enable only two-dimensional (2D) imaging. Fluoroscopy systems, either C-arm based or stationary units, are available almost everywhere worldwide to support the performance of endourologic procedures. The main disadvantage of the technique is the lack of soft tissue imaging, the use of ionizing radiation, and only a 2D depiction of the structures of interest. However, in cases of difficult anatomy, unclear ultrasound findings or unsuccessful fluoroscopy-guided attempts, computed tomography (CT)–guided punctures with rather high radiation exposure and a long procedure may be necessary [7].

To overcome the drawbacks of ultrasound and fluoroscopy-guided punctures, recent technical developments

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### Table 1 – Details of procedures for different puncture indications

<table>
<thead>
<tr>
<th>Procedure</th>
<th>n</th>
<th>Success</th>
<th>Planning time, min, median (range)</th>
<th>Puncture time, s, median (range)</th>
<th>Dose area product, Uro Dyna-CT, ( \mu \text{Gy} \cdot \text{m}^2 ), mean (SD)</th>
<th>Fluoroscopy time, min, median (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percutaneous kidney access</td>
<td>12</td>
<td>9/12</td>
<td>6.5 (4–15)</td>
<td>60 (30–90)</td>
<td>5850 (±1679.36)</td>
<td>1.75 (0.1–4.4)</td>
</tr>
<tr>
<td>Tumor biopsy</td>
<td>4</td>
<td>4/4</td>
<td>6 (5–6)</td>
<td>30 (30–420)</td>
<td>5294.9 (±1658.25)</td>
<td>0.45 (0.2–0.9)</td>
</tr>
<tr>
<td>Suprapubic bladder catheter</td>
<td>10</td>
<td>10/10</td>
<td>5 (3–5)</td>
<td>30 (30–90)</td>
<td>5879.18 (±2266.49)</td>
<td>0.2 (0.1–2.9)</td>
</tr>
<tr>
<td>Lymphocele minor pelvis</td>
<td>1</td>
<td>1/1</td>
<td>8</td>
<td>30</td>
<td>5956.8</td>
<td>0.5</td>
</tr>
</tbody>
</table>

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**Fig. 2** – Three-dimensional planning of the lower calyx puncture before percutaneous lithotomy.

**Fig. 3** – Planned puncture tract for renal tumor biopsy.
enable 3D-guided punctures in the urologist’s hand [8,9]. Techniques based on needle position tracking or optical control of the needle have been described [10,11]. Direct optical control of the puncture may avoid organ injury by visualization of the tissue and allow for control of the ideal needle position before tract dilation for percutaneous lithotomy [10]. However, the technique still relies mainly on ultrasound and fluoroscopy planning of the puncture. Using the technique for gaining access to the renal calyceal system before stone treatment might reduce complications, but identifying passing structures while performing tumor biopsy, for example, seems questionable. Electromagnetic tracking allows for fast and exact punctures of the renal calyceal system with a steep learning curve too [11,12]. However, the technique does not provide any information about the structures that need to be passed during the puncture and therefore does not directly decrease the risk of injuring adjacent organs apart from the information again provided by ultrasound and/or fluoroscopy. Furthermore, the technique depends on the placement of the electromagnetic tracking sensor into the desired puncture site, which makes the technique non-applicable for urologic punctures other than the bladder or the renal calyceal system. However, Rodrigues et al described a 100% success rate in their ex vivo study that offers promising results for further clinical development of the technique in the future [12].

The iPAD-assisted puncture technique described by Rassweiler et al faces all these problems apart from real-time imaging [8]. It provides a high-resolution 3D reconstruction by segmenting the areas of interest of the previously performed CT scan with marker-based tracking during the procedure. The ideal puncture tract is visualized during the puncture and helps the surgeon avoid organ injury while accessing the puncture goal, which is not necessarily the renal calyx or the bladder but might also be a solid structure such as a tumor. The technique might be available with relatively low costs compared with our system. However, it is a two-stage procedure depending on exact patient positioning during image acquisition in the CT scanner and the procedure. Segmenting of the acquired images using the dedicated software needs to be performed and thus is somewhat time consuming.

The main goal of new technical developments of puncture techniques is high accuracy with further image information compared with the standard techniques of ultrasound and fluoroscopy. The 3D planned laser-guided punctures with the Uro Dyna-CT can be performed quickly and safely in our experience. Especially targets with no or only little movement due to respiration can be punctured successfully with high accuracy. Structures with extensive movement might profit from additional live image acquisition as with ultrasound or the additional use of electromagnetic tracking of previously placed sensors inside the kidney, for example. Both techniques could be easily combined with the described Uro Dyna-CT puncture technique. The technique is applicable not only for the urinary tract but for any target that can be depicted by the Dyna-CT scan with excellent image quality such as lymph nodes, metastases, tumors, or an abscess. This enables the diagnostic use of the system for gaining histology or therapeutic use for drainage or focal therapy. Image quality of these scans, especially for soft tissue imaging, correlates with radiation dose exposure of the patient. The radiation dose is naturally higher than with standard fluoroscopy. However, compared with complex punctures with standard multidetector computed tomography (MDCT), the radiation dose even might be lower in cone-beam CT-guided procedures as with the Uro Dyna-CT [13–15].

Handling of the system and the guiding software requires specific training as other puncture techniques do; therefore, our first description of the technique evaluated a biologic training model for percutaneous lithotomy. These ex vivo experiments are shown in the first part of the Supplementary Video. After being trained with the system and having expanded our skills by training with this biologic model, we found the puncture technique suitable for complex urologic punctures; therefore we established it in a clinical setting. However, the learning curve seems to be steep, although this was not evaluated in our recent study. Apart from the technical aspects of the image acquisition and competent use of the planning software, training of the team (nurse, anesthesiologist) is essential for the successful use of this puncture technique. One limitation of the technique might be the relatively high costs due to the system that needs to be installed in the endourologic operating room. It can easily double the price of a standard endourologic suite with a stationary fluoroscopy system. No further costs arise by the performed scans once the system has been installed.

However, the system is fully applicable for any endourologic intervention with high image quality and low radiation dose for the standard fluoroscopy procedures [16]. With the increasing number of hybrid operating rooms with integrated cone-beam imaging systems, the technique might become widely available in such medical centers. In these centers the presented technique might be used for selected patients with an increased risk of rare but severe complications such as bowel perforation. For routine procedures the available standard techniques of ultrasound and fluoroscopy should be used. Dyna-CT scans of the patient are possible in the supine position, which might also enable the application of our puncture technique for supine percutaneous lithotomy in complex cases.

Limitations of our study are the small number of patients and the inhomogeneous indications for the presented technique. However, in our opinion the technique is an additional option for complex cases in the urologist’s hands and thus should only be used in indications that mean increased risks for the patient if performed with standard techniques such as ultrasound and fluoroscopy. Even with the presented technique, punctures still might be unsuccessful, especially of the renal calyceal system. Because a puncture of a small moving target represents the most challenging situation for a surgeon with any imaging and guiding system, our results well illustrate the great potential of the presented technique. Our inhomogeneous patient selection shows the wide applicability of the
technique without limitations to specific indications as with other options.

5. Conclusions

We believe the Uro Dyna-CT–based puncture technique is an excellent additional instrument that allows the urologist to handle complex punctures. The image acquisition uses higher radiation doses than the standard fluoroscopy technique. However, it is in an acceptable range compared with alternative procedures such as CT-guided punctures with an MDCT that is mainly used for complex cases.

Author contributions: Manuel Ritter had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Ritter, Michel.

Acquisition of data: Ritter, Rassweiler.

Analysis and interpretation of data: Ritter, Rassweiler.

Drafting of the manuscript: Ritter, Michel.

Critical revision of the manuscript for important intellectual content: Michel.

Statistical analysis: Ritter, Rassweiler.

Obtaining funding: None.

Administrative, technical, or material support: None.

Supervision: Michel.

Other (specify): Editing of the Supplementary Video: Ritter, Rassweiler.

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Appendix A. Supplementary data

The Surgery in Motion video accompanying this article can be found in the online version at http://dx.doi.org/10.1016/j.eururo.2015.07.005 and via www.europeanurology.com.

References


