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Short Report

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Brief Communications


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Abstract

Detailed knowledge of the anatomical relationships between renal tumors, vascular structures, and the urinary tract is required to perform robot-assisted partial nephrectomies (RAPN) successfully. Recent improvements in imaging modalities include computed tomography and magnetic resonance imaging. In addition, three-dimensional (3D) workstation systems for intraoperative navigation have also been developed.

This report introduces a novel 3D workstation system for intraoperative navigation while performing RAPN called “Atrena”. Atrena is equipped with multiple methods for the stereoscopic viewing of 3D images. Furthermore, Atrena operates on a tablet. Therefore, using Atrena in RAPN enables the rotation and enlargement of stereoscopic 3D images through manipulations on the tablet's screen. Atrena was successfully used for intraoperative navigation in initial 15 cases of RAPN with high trifecta achievement ratios.

We believe that this novel 3D workstation system, “Atrena”, is beneficial
in performing RAPN and enhances its success. We also believe Atrena may be useful as an educational tool for medical staff.

**Keywords:** RAPN, 3D Workstation System, Intraoperative Navigation, Tablet Screen

The surgical treatment options for small renal tumors have shifted from open nephrectomies to laparoscopic nephrectomies. Laparoscopic nephrectomies are less invasive than open nephrectomies. Even so, partial nephrectomies (PNs) are recommended as the standard treatment for small renal tumors. According to recent guidelines, this recommendation is based on the fact that PNs offer similar oncological outcomes as radical nephrectomies. However, PNs are the superior treatment option for renal function preservation [1]. There has been a steady increase in robot-assisted surgeries; hence, the number of robot-assisted PN (RAPN) procedures for small renal tumors has markedly increased. Rapid advances in computed tomography (CT) image reconstruction methods and image processing workstation technologies,
combined with the widespread use of RAPN, have significantly improved surgical navigation.

The da Vinci Surgical System (da Vinci) features a high-resolution three-dimensional (3D) field of view, multidegree-of-freedom forceps, and good operability with an antishake function. Its usefulness in RAPN for treating small renal tumors is widely recognized. Recently, the indications for RAPN have expanded to include highly complex tumors, such as hilar tumors, completely endophytic renal tumors, and T1b tumors.

When performing RAPN, preoperative understanding of tumor locations, vascular structures, and their relationship with the urinary tract is directly related to the success of the surgery. Therefore, the achievement of trifecta has been proposed as a comprehensive surgical outcome assessment for RAPN, which examines the following goals: (1) a negative surgical margin, (2) warm ischemia time (WIT) <25 min, and (3) no complications [2-4]. We previously reported that the achievement rate of trifecta for highly complex tumors was significantly lower than that for other renal tumors [5]. Therefore, safer surgical procedures with appropriate intraoperative navigation are required for RAPN, especially
for highly complex tumors.

Preoperative diagnostic imaging and image construction are important factors that should be considered for proper navigation during RAPN surgery. Advances in imaging modalities, particularly ultrasound, CT, and magnetic resonance imaging, have revolutionized diagnostics. Dynamic contrast-enhanced CT of the kidney accurately confirms the anatomical relationship between the tumors, surrounding vascular structures, and the urinary tract through intravascular contrast enhancement of the arterial, venous, and excretion phases. We have previously reported a novel navigation system using an ultrahigh-resolution CT scanner that provides a shorter WIT and lower estimated blood loss (EBL) than area-detector CT. We concluded that this novel navigation system could be useful in patients undergoing RAPN [6]. Before RAPN surgery, 3D constructions of the renal tumor, vascular structures, and the urinary tract were performed using various image processing software based on these CT imaging data. As an intraoperative navigation system, da Vinci projects these 3D images and intraoperative echo images onto the console using TilePro software.
The 3D image displayed on the monitor by the Picture Archiving and Communication System is a two-dimensional (2D) representation of the 3D image. Consequently, this 2D representation fails to provide a sense of depth in tissues, such as blood vessels. Therefore, it is undoubtedly difficult to visualize the precise anatomical location where the blood vessels overlap on the monitor's front and back. However, it becomes easier to visualize these anatomical relationships by displaying images stereoscopically using left-right parallax images.

The da Vinci system has two input terminals on the vision cart. The input terminals include the upper and lower terminals on the left and right sides, respectively. The entered information is displayed on the left and right sides of the TilePro. By inputting images with parallax to each of the two terminals, the images are displayed as instereoscopic 3D instead of non-stereoscopic 3D images. After inserting the image for the left eye into the left terminal (upper) and the image for the right eye into the right terminal (lower), a stereoscopic image was obtained by tapping the 3D button in TilePro.

In this study, we introduced a novel 3D workstation system called
“Atrena” (AMIN, Tokyo, Japan) for intraoperative navigation during RAPN. This Atrena software is used for intraoperative 3D image navigation. It is commercially available on tablet personalized computer (PC) after its installation. Surgeons can rotate, zoom, and move 3D images in real time during RAPN. Moreover, vascular vessels, organs, and bones may be visualized as translucent or opaque structures. Thus, Atrena enables the precise identification of blood vessels located deep within the organs. Atrena is equipped with multiple methods for the stereoscopic viewing of 3D images. Images with stereoscopic information (such as side-by-side) or two images with parallax are provided and displayed on the tablet PC. By connecting two images with parallax to the input terminal of da Vinci, 3D images can be stereoscopically displayed on TilePro. Stereoscopic 3D images displayed on TilePro can be rotated and enlarged by manipulating the tablet’s screen. Surgeons can view organs as translucent or opaque structures through an onscreen selection with either a finger or mouse (Figure 1). 3D segmentation volume data were created using a workstation (Ziostation2; version 2.1.x, Qi Imaging, Redwood City, CA, USA). Atrena does not have a segmentation-creation functionality.
Instead, it was designed to import 3D volume data segmented at the workstation, then reconstruct and display the data in real time when the displayed image is moved (the image is rotated or enlarged).

We used Atrena for intraoperative navigation during 15 cases of RAPN performed between December, 2021 and October, 2022. Patient characteristics, including age, gender, body mass index, tumor size, surgical approach, RENAL score [7], and the presence of hilar or cystic tumors, are shown in Supplemental Table 1. Perioperative factors, including operation time, console time, WIT, EBL, transfusion, negative surgical margin, Clavien-Dindo classification $\geq 3$ [8], and trifecta achievement, are also shown in Supplemental Table 1. Based on the high trifecta achievement rate, we successfully performed RAPN using Atrena for intraoperative navigation. Consequently, we believe that Atrena can support RAPN by providing accurate 3D images that display the anatomical relationships between the renal tumors, vascular structures, and the urinary tract. As previously described, the difficulty level in RAPN increases with the increasing complexity of the renal tumors. Therefore, an improved understanding of the anatomical relationship between the
renal tumors, vascular structures, and urinary tract is necessary to perform RAPN. Therefore, stereoscopic 3D images produced in Atrena and the rotation or enlargement of them through manipulations on the tablet's screen can help operators perform RAPN successfully. Among the highly complex renal tumors, we believe that Atrena is more useful when treating completely endophytic renal tumors since it enables stereoscopic viewing of 3D images.

In conclusion, the novel 3D workstation system, “Atrena”, is beneficial in performing RAPN with greater success rates. Furthermore, Atrena is useful for surgeons and their assistants as it elucidates the anatomical relationship between renal tumors, vascular structures, and the urinary tract. In addition, we believe the high-quality stereoscopic viewing of 3D images produced by Atrena may also be useful as an educational tool for medical staff.

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Competing Interests
The authors have no relevant financial or non-financial interests to disclose.

Author Contributions
All authors contributed to the conception and design of the study. Material preparation, data collection, and analysis were performed by KT, MK, ST, MN, AK, and RS, respectively. The first draft of the manuscript was prepared by KT and MK. All authors contributed to the revision of previous versions of the manuscript. The final manuscript has been read and approved by all the authors.

Ethics approval
This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by Fujita Health University Ethics Review Committee (HM22-176).

**Consent to participate**

The retrospective design of this study resulted in a waiver of the need to obtain informed consent from the included patients.

**Figure & Table legends**

Figure 1: Intraoperative Navigation System Using Atrena

Supplemental Table 1: Patients’ Clinical Characteristics and Surgical Outcomes

**References**


Figures

Figure 1

Intraoperative Navigation System Using Atrena

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementalTable1.pdf