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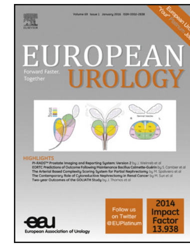

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Surgery in Motion

Robotic Laparoendoscopic Single-site Retroperitoneal Renal Surgery: Initial Investigation of a Purpose-built Single-port Surgical System

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Abstract

Background: Robotic single-site retroperitoneal renal surgery has the potential to minimize the morbidity of standard transperitoneal and multiport approaches. Traditionally, technological limitations of non–purpose-built robotic platforms have hindered the application of this approach.
Objective: To assess the feasibility of retroperitoneal renal surgery using a new purpose-built robotic single-port surgical system.
Design, setting, and participants: This was a preclinical study using three male cadavers to assess the feasibility of the da Vinci SP1098 surgical system for robotic laparoendoscopic single-site (R-LESS) retroperitoneal renal surgery.
Surgical procedure: We used the SP1098 to perform retroperitoneal R-LESS radical nephrectomy ($n = 1$) and bilateral partial nephrectomy ($n = 4$) on the anterior and posterior surfaces of the kidney. Improvements unique to this system include enhanced optics and intelligent instrument arm control. Access was obtained 2 cm anterior and inferior to the tip of the 12th rib using a novel 2.5-cm robotic single-port system that accommodates three double-jointed articulating robotic instruments, an articulating camera, and an assistant port.
Measurements: The primary outcome was the technical feasibility of the procedures, as measured by the need for conversion to standard techniques, intraoperative complications, and operative times.
Results and limitations: All cases were completed without the need for conversion. There were no intraoperative complications. The operative time was 100 min for radical nephrectomy, and the mean operative time was 91.8 ± 18.5 min for partial nephrectomy. Limitations include the preclinical model, the small sample size, and the lack of a control group.
Conclusions: Single-site retroperitoneal renal surgery is feasible using the latest-generation SP1098 robotic platform. While the potential of the SP1098 appears promising, further study is needed for clinical evaluation of this investigational technology.
Patient summary: In an experimental model, we used a new robotic system to successfully perform major surgery on the kidney through a single small incision without entering the abdomen.

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1. Introduction

Laparoendoscopic single-site (LESS) renal surgery, including radical nephrectomy (RN) and partial nephrectomy (PN), offers several advantages over the standard multiport approach, namely improved cosmesis, less postoperative pain, and faster recovery [1]. Unfortunately, conventional LESS is fraught with technical challenges, including in-line vision, reverse handedness, loss of triangulation, and instrument clashing, which have limited its dissemination [2,3]. The application of the standard robotic platform to LESS (R-LESS) addressed some but not all of these limitations [4]. The largest contemporary study comparing R-LESS PN to multiport robotic PN reported inferior trifecta outcomes for R-LESS, demonstrating the limitations of a non–purpose-built robotic platform for R-LESS [5]. Two prior generations of task-specific, single-site robotic platforms have been developed to address these challenges. The second-generation single-site robotic system successfully overcame the instrument clashing and space constraints of prior systems through the use of three articulating endoscopic instruments and an articulating endoscopic camera introduced via a single robotic port. Despite the improvements offered by this system, maneuverability within the working space was still restricted owing to the fixed position of the robotic arms at their entrance to the body [6].

Standard robotic and R-LESS renal surgery is commonly performed via a transperitoneal approach because of the large working space and familiar landmarks of the peritoneal cavity. A retroperitoneal approach has been advocated for minimally invasive PN to avoid bowel mobilization and expedite recovery; however, technical constraints have hindered adoption and limited application to polar or posterolateral tumors [7,8].

We sought to evaluate the latest purpose-built single-site robotic surgical platform, designed specifically for extraperitoneal R-LESS surgery, in performing retroperitoneal RN and PN in a cadaveric model.

2. Materials and methods

2.1. Objective and outcome measures

The primary objective of this experimental study was to determine the feasibility of RN and PN using the new single-site robotic platform, as measured by the rate of conversion to alternative approaches, operative times, and occurrence of intraoperative complications. An intraoperative complication was defined as any accidental puncture or laceration to an organ, hollow viscus, or vessel. For PN, since the kidneys did not contain tumors, the maximum diameter of the resected parenchyma was measured and recorded as the excision size.

2.2. Third-generation da Vinci SP surgical system

The new da Vinci SP surgical system (model SP1098; Intuitive Surgical, Sunnyvale, CA, USA) represents an evolution of the second-generation robotic system (SP999) with upgraded technology designed specifically for extraperitoneal single-site surgery (Fig. 1) [6]. The improvements include enhanced high-definition three-dimensional optics and intelligent instrument arm control. Similar to the SP999, the SP1098 consists of three main components: a surgeon console, a patient side cart, and a vision cart. The designs of the articulating endoscopic camera and three double-jointed articulating endoscopic instruments, which enter the patient through a multichannel robotic port, are unchanged. As before, four robotic manipulators, or instrument drives, that control the camera and instruments are mounted on an instrument arm that is attached to the patient side cart (Fig. 2). The surgeon console is identical to the second-generation robotic system (SP999) with a foot pedal that allows control of the instrument arm. Unique to this robotic system is the ability to clutch and pivot the instrument arm about its remote center without moving each individual instrument. In effect, an instrument can be stationed at one location in the surgical field (eg, for retraction) while the instrument arm is clutched and reoriented to a separate site, where the remaining instruments can be deployed without disturbing the stationary instrument. This improvement overcomes the constraint of multiple instruments entering the body through a fixed point, effectively expanding the workspace and improving maneuverability. The new vision cart is similar to the previous generation with upgraded resolution to accommodate the improved camera optics.

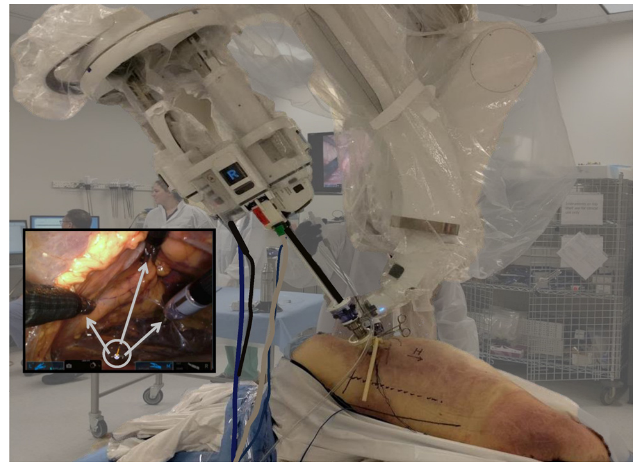

Fig. 1 – The da Vinci SP1098 surgical system (Intuitive Surgical, Sunnyvale, CA, USA). The inset is an intraoperative view showing the instrument compass (circle), which demonstrates the location of the robotic instruments (arrows) within the surgical field. The instrument icon turns orange when the instrument is near the limit of reach, and red when the instrument has reached its limit.

2.3. Surgical technique

The cadavers were placed in a full (90°) flank position and secured to the operating table. A 2.5-cm transverse skin incision was made 2 cm anterior and inferior to the tip of the 12th rib, and dissection was carried down through the subcutaneous tissues. The flank musculature was identified and split, exposing the thoracolumbar fascia. The fascia was incised and the retroperitoneum was entered. A novel 25-mm multichannel robotic port was inserted into the retroperitoneal opening, and the retroperitoneal space was developed. This proprietary port accommodates an oval articulating camera (12 mm $\times$ 10 mm), three 6-mm double-jointed articulating instruments, and a 8-mm accessory port for the introduction of sutures and suctioning. The robot was docked.

The surgical steps were performed according to our previously described technique (Fig. 3) [9,10]. For PN, the retroperitoneal space was fully developed; the hilum was identified and prepared for clamping; the kidney surface was exposed; the line of excision was marked with cautery; the hilum was clamped; and renal excision and reconstruction