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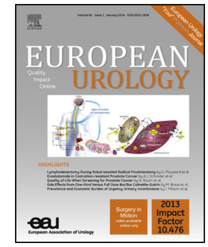

Surgery in Motion

Near-infrared Fluorescence Imaging: Emerging Applications in Robotic Upper Urinary Tract Surgery

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Please visit www.europeanurology.com and www.urosource.com to view the accompanying video.

Abstract

Background: Near-infrared fluorescence (NIRF) imaging is a technology with emerging applications in urologic surgery.
Objective: To describe surgical techniques and provide clinical outcomes for robotic partial nephrectomy (RPN) with selective clamping and robotic upper urinary tract reconstruction featuring novel applications of NIRF imaging.
Design, setting, and participants: Data from 90 patients who underwent successful RPN with selective clamping or upper urinary tract reconstruction utilizing NIRF imaging between April 2011 and October 2012 were reviewed.
Surgical procedure: We performed RPN utilizing NIRF imaging to aid with selective clamping and upper tract reconstruction with NIRF imaging, the details of which are outlined in this paper and the accompanying video.
Outcome measurements and statistical analysis: Patient characteristics, perioperative outcomes, and complications were analyzed.
Results and limitations: Of the 48 RPN patients for whom selective clamping was attempted successfully, median estimated blood loss was 200.0 ml, warm ischemia time was 17.0 min, and median change in estimated glomerular filtration rate was −6.3%. There was a 12.5% complication rate, and all complications were Clavien grade 1–3 (14.3%). The upper urinary tract reconstruction utilizing NIRF imaging was performed in 42 patients and included pyelopasty ($n = 20$), ureteral reimplant ($n = 13$), ureterolysis ($n = 7$), and ureteroureterostomy ($n = 2$). Radiographic and symptomatic improvement was observed in 100% of the pyeloplasty, ureteral reimplant, and ureteroureterostomy patients and 71.4% of ureterolysis patients, for an overall success rate of 95.2%. This study is limited by the small sample size, the short follow-up period, and the lack of a comparative cohort.
Conclusions: Our technique of RPN with selective arterial clamping and robotic upper urinary tract reconstruction utilizing NIRF imaging is presented. This technology provides real-time intraoperative angiogram to confirm selective ischemia and may be an adjunct technology to confirm well-perfused tissue within a reconstruction anastomosis. Further investigation is needed to evaluate long-term outcomes of NIRF imaging in robotic upper urinary tract surgery and to delineate its indications.

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1. Introduction

Since its introduction into the field of urologic surgery, the use of robotics has been integrated into a growing number of procedures [1,2]. Along with more widespread adoption of this surgical platform have come recent developments in functional intraoperative imaging that stand to further enhance its utility [3]. One such innovation is the use of fluorescent contrast agents, which emit light in the near-infrared wavelength after activation by a light-emitting diode. Light in this wavelength (700–850 nm) is not visible to the naked eye and must be captured by a specialized charge-coupled device camera to be visualized. To date, the most widely studied fluorescent tracer is indocyanine green (ICG), which can be used as part of a near-infrared fluorescence (NIRF) imaging system to allow the surgeon to toggle between standard white light and fluorescence-enhanced views in real time within the preexisting robotic console display [3].

Although NIRF imaging applications within urology are still in their infancy, they are being tested as an adjunct technology in a variety of procedures. In robotic partial nephrectomy (RPN), for example, NIRF imaging has been used in an attempt to distinguish benign from malignant tissue, with varying success, as well as for identification of the intrarenal vasculature [4–6]. In addition, NIRF imaging may potentially be useful in confirming tissue perfusion in upper tract reconstruction, similar to its use in other surgical fields [7–10]. The objective of the present study is to provide a detailed description of our surgical technique using NIRF imaging to facilitate selective arterial clamping during RPN along with a description of our novel use of NIRF imaging in upper urinary tract robotic reconstruction to aid in identifying well-perfused and devascularized tissue. We focus on functional renal outcomes in our partial nephrectomy cohort and on radiographic and symptomatic improvement in our reconstruction cohort. Furthermore, we describe technical challenges and recommendations to optimize NIRF imaging in robotic upper urinary tract surgery.

2. Patients and methods

2.1. Study population

Medical data of consecutive patients undergoing robotic upper tract procedures utilizing NIRF imaging between April 2011 and October 2012 at two referral centers were retrieved from a prospectively maintained, institutional review board (IRB)-approved database. Database variables include preoperative imaging, clinical stage, RENAL nephrometry score, laterality, procedure planned, procedure performed, surgical approach, success or failure of selective arterial clamping, hilar microdissection time, ICG dose, complications, and management, in addition to standard pre- and postoperative laboratory analyses and renal function. Procedures included in this study are RPN and robotic upper tract reconstruction (consisting of pyeloplasty, ureteral reimplant, ureterolysis, and ureteroureterostomy). In total, there were 74 instances of RPN for which NIRF imaging was attempted; NIRF was used in 42 upper urinary tract reconstructive procedures (20 robotic pyeloplasties, 13 ureteral reimplants, 7 ureterolyses, and 2 ureteroureterostomies).

This study received IRB approval, and informed consent was obtained prior to surgery. Comprehensive demographic, intraoperative, and outcomes-related data were entered into the aforementioned database.

2.2. Surgical technique

A detailed illustration of the surgical technique for ICG-guided NIRF imaging for upper tract robotic surgery used at our institution can be found in the accompanying video material.

2.2.1. Preoperative planning

All patients have preoperative abdominal computed tomography or magnetic resonance imaging, and a RENAL nephrometry score is calculated for partial nephrectomy candidates. A comprehensive staging assessment is also completed in addition to standard preoperative blood work. Absolute and elective indications for RPN have been applied and based on a variety of factors, including tumor factors (size, location, nephrometry score, and multifocality), and patient factors (sex, comorbidities, body mass index, previous surgical procedures, presence of renal insufficiency or anatomic anomalies, and personal preferences). Inclusion criteria included any patient with a renal mass that was amenable to partial nephrectomy or any patient requiring upper tract urinary reconstruction. Exclusion criteria included an iodine allergy or elevated liver functions tests, which are contraindications for ICG administration. Surgical candidates for upper tract reconstruction also undergo relevant renal functional studies and generally have any indwelling stents removed 3–7 d prior to surgery. Anticoagulants are discontinued for 7 d prior to surgery when feasible, and a mechanical bowel preparation is done the day before the operation.

2.2.2. Robotic partial nephrectomy with selective arterial clamping using near-infrared fluorescence imaging

Our technique of a four-arm transperitoneal and retroperitoneal RPN with or without selective arterial clamping has been described previously [11–13]. All steps of exposure, preparing tumor for excision, and preparing the hilum for clamping are similar to a full main renal artery clamp technique. However, prior to applying any clamps, a flexible drop-in robotic Doppler probe (Vascular Technology Inc., Nashua, NH, USA) is introduced to identify the arterial branches. Hilar microdissection is performed in a medial-to-lateral direction to identify the specific arterial branch or branches supplying the tumor and its local target area. Hilar fat is removed to improve access as the renal vein and artery branches enter the kidney. If required, small venous branches can be sacrificed to improve exposure. If the tumor is completely anterior or posterior to Brodel's line, we typically only dissect out the anterior and posterior branches. Before clamping, mannitol 12.5 g is given intravenously to aid in renal protection. Robotic mini-bulldog clamps (Scanlan International, St. Paul, MN, USA) are then applied to the secondary-, tertiary-, or quaternary-level arterial branches at the discretion of the console surgeon using the robotic ProGrasp in an attempt to induce local ischemia in the tumor and the immediately surrounding renal segment. ICG is administered at a dose of 5–10 mg intravenously (IC-Green; Akorn, Lake Forest, IL, USA). Well-perfused renal parenchyma appears fluorescent green under NIRF imaging. Ischemic tissue and tumor do not fluoresce under NIRF imaging (Fig. 1), verifying that the correct arterial branch has been controlled. If peritumoral arterial flow continues despite selective arterial clamping, either additional arterial branches may be sought and selectively clamped or complete arterial clamping may be utilized (Fig. 2). In tumors that appear to have multiple arterial branches, we often dissect and selectively clamp each individual higher-order artery, administer ICG, and sequentially unclamp each artery under NIRF imaging. This technique allows us to perform a renal arteriogram, which, under NIRF imaging, defines the specific higher-order artery or arteries supplying the tumor. When the tumor and