Technique of Robotic Partial Nephrectomy: How to Minimize Warm Ischemia

Li-Ming Su, MD
David A. Cofrin Professor of Urology, Associate Chairman of Clinical Affairs, Chief, Division of Robotic and Minimally Invasive Urologic Surgery, University of Florida College of Medicine; Gainesville, Florida

Objectives:
- Discuss the indications, operative set up and surgical technique of robotic partial nephrectomy
- Interpret the published literature regarding methods to reduce warm ischemia during partial nephrectomy
- Describe surgical techniques to reduce warm ischemia during robotic partial nephrectomy
- Describe new technologies that may aid in assessing and reducing warm ischemia
Robot-Assisted Partial Nephrectomy: How to Minimize Warm Ischemia

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Department of Urology
University of Florida College of Medicine
Outline

- Indication
- Surgical Technique
- Techniques to Minimize Warm Ischemia
- New Technologies
Indications (Past)

The Ideal Exophytic Tumor

- Small tumor (i.e. cT1a)
- Mostly exophytic
- Single artery and vein
- Anterior location
- Far from sinus, hilar vessels, collecting system
- Normal renal function
Indications (Expanded)

More Challenging Tumors

- Multiple vessels
- Large tumor size (cT1b, ?cT2a)
- Endophytic, multiple
- Tumor location
  - Upper pole
  - Posterior
  - Hilar
- Adjacent to sinus, hilar vessels, collecting system
- ?Solitary kidney
Contraindications

- Contraindication to laparoscopy
- Bleeding diatheses
- ?Solitary kidney
- ?Renal insufficiency
Trocar Configuration

4th robotic arm
12 mm (Assistant)
5 mm (Liver retractor)

(Courtesy of Intuitive Surgical, Inc., Sunnyvale, CA)
Identifying Renal Hilum

- Step 1: Reflect colon, spleen/liver
- Step 2: Identify gonadal vein and ureter and trace to hilum
- Step 3: Skeletonize renal artery and vein using scissors or hook
- Step 4 (optional): Place vessel loop around artery
Expose and Identify Renal Mass

- Step 1: Defat kidney widely around mass
- Step 2: Rotate/prop kidney so that mass is in optimal position for excision
- Step 3: Ultrasound mass to identify safe margin and score parenchyma
- Step 4 (optional): Administer iv indigo carmine if collecting system entry is expected
Last Minute Checklist

• Prior to clamping renal vessels consider…..
   Storing needed sutures within the abdomen.
   Testing that both robotic needle drivers are not expired!
   Ensuring that CO₂ tank is full.
   Having endo GIA stapler in the room.
   Having a “Plan B”
    ➢ Open laparotomy tray in the room (just in case).
   Having the full attention of your team.
   Rehearsing steps with your team.
    ➢ Lap bulldog clamp application and removal
    ➢ Suture cutting, passage and removal
Excise Renal Mass

- Step 1: Apply bulldog clamp(s) on renal artery +/- vein and start timer
- Step 2: Incise periphery of scored margin circumferentially
- Step 3: Deepen resection of mass with spot cautery as needed
- Step 4: Look for deep landmarks (e.g. collecting system, sinus fat) and observe tissue margins
- Step 5 (rare): Biopsy deep margin of resection bed for frozen section
Hemostasis and Renorrhaphy

4 Steps to Achieving Hemostasis

- **Step 1**: Cauterize cortical edge
- **Step 2**: Oversew deep margin and collecting system with running 3-0 polyglactin with LapraTy clip
- **Step 3**: Reapproximate parenchymal edges with 0 polyglactin interrupted sutures with Hemolok sliding clip technique
- **Step 4** (optional): Apply hemostatic agent and surgicell along edge of renorrhaphy
Restoration of Renal Perfusion

- **Step 1**: Remove bulldog clamps
- **Step 2**: Observe for bleeding along renorraphy under low insufflation pressure
- **Step 3**: Tighten renorraphy sutures and add additional sutures only if necessary
- **Step 4**: Observe renal artery for pulsations and filling of renal vein
- **Step 5**: Assess turgor and color of renal parenchyma
- **Step 6**: Place drain
Historical “Safe” WIT

• Canine studies

• Various intervals of warm renal ischemia applied

• Methods: serum and urine gamma-glutamyl transpeptidase

• Outcomes: change in GFR, histology

• Up to 30 minutes ischemia can be tolerated with eventual “full” recovery of renal function

Lap vs. Open PN

Comparison of 1,800 Laparoscopic and Open Partial Nephrectomies for Single Renal Tumors

Inderbir S. Gill, Louis R. Kavoussi, Brian R. Lane, Michael L. Blute, Denise Babineau, J. Roberto Colombo, Jr., Igor Frank, Sompol Permpongkosol, Christopher J. Weight, Jihad H. Kaouk, Michael W. Kattan and Andrew C. Novick*

From the Glickman Urological Institute (ISG, BRL, JRC, CJW, ACN) and Department of Quantitative Health Sciences (DB, MWK), Cleveland Clinic, Cleveland, Ohio, and Departments of Urology, The Johns Hopkins Hospital (LRK, SP), Baltimore, Maryland, and Mayo Clinic (MLB, IG), Rochester, Minnesota

• 771 lap vs. 1028 open PN performed under warm ischemia

<table>
<thead>
<tr>
<th></th>
<th>Lap PN</th>
<th>Open PN</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR Time (min)</td>
<td>201</td>
<td>266</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>EBL (mL)</td>
<td>300</td>
<td>376</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>LOS (days)</td>
<td>3.3</td>
<td>5.8</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Tumor Size (cm)</td>
<td>2.7</td>
<td>3.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Central tumors</td>
<td>34%</td>
<td>53%</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>WIT (min)</td>
<td>30.7</td>
<td>20.1</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Minimizing WIT

Every Minute Counts When the Renal Hilum Is Clamped During Partial Nephrectomy

R. Houston Thompson a,*,1, Brian R. Lane b,1, Christine M. Lohse a, Bradley C. Leibovich a, Amr Fergany b, Igor Frank a, Inderbir S. Gill c, Michael L. Blute a, Steven C. Campbell b

a Mayo Medical School and Mayo Clinic, Rochester, MN, USA
b Glickman Urological Institute; Cleveland Clinic Foundation, Cleveland, OH, USA
c Keck School of Medicine, University of Southern California, Los Angeles, CA, USA

- 362 patients with solitary kidney
- Hilar clamping with warm ischemia
- Longer WIT (1-min increase) associated with ↑ risk:
  - ARF
  - postop GFR<15
  - new onset stage IV CKD
- WIT best kept < 25 minutes

• Multivariate analysis
  – Postop GFR: volume preservation >> WIT
• However **WIT is still important modifiable RF**
  – Association with postop renal atrophy
  – 20-25 minutes is a reasonable goal

Early Hilar Unclamping

Conventional Unclamping

Early Unclamping

vs.
### Early Hilar Unclamping

**Halving Ischemia Time During Laparoscopic Partial Nephrectomy**

Mike M. Nguyen and Inderbir S. Gill*

*From the Section of Laparoscopic and Robotic Surgery, Glickman Urological Institute, Cleveland Clinic, Cleveland, Ohio

<table>
<thead>
<tr>
<th></th>
<th>Traditional Unclamping</th>
<th>Early Unclamping</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR Time (hrs)</td>
<td>4.1</td>
<td>3.7</td>
<td>0.15</td>
</tr>
<tr>
<td>EBL (mL)</td>
<td>230</td>
<td>301</td>
<td>0.62</td>
</tr>
<tr>
<td>Postop bleeding</td>
<td>4%</td>
<td>2%</td>
<td>1.0</td>
</tr>
<tr>
<td>Tumor Size (cm)</td>
<td>2.8</td>
<td>3.3</td>
<td>0.06</td>
</tr>
<tr>
<td>WIT (min)</td>
<td>31</td>
<td>14</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>$\Delta$eGFR (mL/min)</td>
<td>-17.6</td>
<td>-11</td>
<td>0.03</td>
</tr>
</tbody>
</table>
## Artery vs. Artery and Vein

### Artery-Only Occlusion May Provide Superior Renal Preservation During Laparoscopic Partial Nephrectomy

Edward M. Gong, Kevin C. Zorn, Marcelo A. Orvieto, Alvaro Lucioni, Lambda P. Msezane, and Arieh L. Shalhav

<table>
<thead>
<tr>
<th></th>
<th>Artery Only</th>
<th>Artery and Vein</th>
<th>p-value</th>
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</thead>
<tbody>
<tr>
<td>Preop Cr (mg/dL)</td>
<td>1.03</td>
<td>1.17</td>
<td>NS</td>
</tr>
<tr>
<td>Tumor size (cm)</td>
<td>2.4</td>
<td>2.9</td>
<td>NS</td>
</tr>
<tr>
<td>WIT (min)</td>
<td>32</td>
<td>33</td>
<td>NS</td>
</tr>
<tr>
<td>$\Delta eGFR$ (mL/min)</td>
<td>-10.6</td>
<td>-16.1</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Gong EM et al. Urol 72: 834, 2008 (78 patients)
Superselective Clamping

Zero Ischemia Anatomical Partial Nephrectomy: A Novel Approach

Inderbir S. Gill,*,† Mukul B. Patil, Andre Luis de Castro Abreu, Casey Ng, Jie Cai, Andre Berger, Manuel S. Eisenberg, Masahiko Nakamoto, Osamu Ukimura, Alvin C. Goh, Duraiyah Thangathurai, Monish Aron and Mihir M. Desai†

From the Center for Advanced Robotic & Laparoscopic Surgery, USC Institute of Urology, Keck School of Medicine, University of Southern California, Los Angeles, California

“Zero Ischemia” PN

- 58 patients, WIT 0 min, all negative margins
- Tumor size 3.2 cm (0.9-13)
- **OR time 4.4 hours (1-8)**
- EBL 206 mL (25-1000)
- LOS 3.9 days (2-19)
- **Complication rate 22.8%:**
  - Urine leak (3), Renal bleed (0)
- **Transfusion rate 21%**

<table>
<thead>
<tr>
<th>Preop</th>
<th>D/C</th>
<th>4 mo</th>
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<tbody>
<tr>
<td>SCr (mg/dL)</td>
<td>1.0</td>
<td>1.1</td>
</tr>
<tr>
<td>eGFR</td>
<td>79.6</td>
<td>72.9</td>
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</table>

Exophytic Cortical Lesions
Endophytic Lesions
Approximating Sinus
Hilar Tumor: Stepwise Vascular Control
## UF RAPN Series

### Mean

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>N</td>
<td>250</td>
</tr>
<tr>
<td>Age</td>
<td>56.6 years</td>
</tr>
<tr>
<td>Tumor size</td>
<td>2.7 cm (0.7-8.0)</td>
</tr>
<tr>
<td>OR time</td>
<td>220 min</td>
</tr>
<tr>
<td>EBL</td>
<td>93 mL</td>
</tr>
<tr>
<td>WIT</td>
<td>21 min (11-48)</td>
</tr>
<tr>
<td>LOS</td>
<td>2.7 days</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pathology</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>pT1a</td>
<td>89%</td>
</tr>
<tr>
<td>pT1b</td>
<td>8%</td>
</tr>
<tr>
<td>pT3a</td>
<td>3%</td>
</tr>
</tbody>
</table>

### Histology

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malignant</td>
<td>84%</td>
</tr>
<tr>
<td>Clear cell</td>
<td>60%</td>
</tr>
<tr>
<td>Papillary</td>
<td>19%</td>
</tr>
<tr>
<td>Chromophobe</td>
<td>4%</td>
</tr>
<tr>
<td>Other</td>
<td>1%</td>
</tr>
<tr>
<td>Benign</td>
<td>16%</td>
</tr>
<tr>
<td>Oncocytoma</td>
<td>7%</td>
</tr>
<tr>
<td>AML</td>
<td>5%</td>
</tr>
<tr>
<td>Atypical cyst</td>
<td>2%</td>
</tr>
<tr>
<td>Other</td>
<td>2%</td>
</tr>
</tbody>
</table>
# RAPN Outcomes

## Multi-Institutional Analysis of Robotic Partial Nephrectomy for Hilar Versus Nonhilar Lesions in 446 Consecutive Cases

*Lori M. Dulabon*<sup>a</sup>, *Jihad H. Kaouk*<sup>b</sup>, *Georges-Pascal Haber*<sup>b</sup>, *Douglas S. Berkman*<sup>a</sup>, *Craig G. Rogers*<sup>c</sup>, *Firas Petros*<sup>c</sup>, *Sam B. Bhayani*<sup>d</sup>, *Michael D. Stifelman*<sup>a,·</sup>

<table>
<thead>
<tr>
<th></th>
<th>Lap PN</th>
<th>Open PN</th>
<th>RAPN Nonhilar</th>
<th>RAPN Hilar</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR Time (min)</td>
<td>201</td>
<td>266</td>
<td>187</td>
<td>194</td>
</tr>
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<td>EBL (mL)</td>
<td>300</td>
<td>376</td>
<td>208</td>
<td>262</td>
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<td>3.3</td>
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<tr>
<td>WIT (min)</td>
<td>30.7</td>
<td>20.1</td>
<td><strong>19.6</strong></td>
<td><strong>26.3</strong></td>
</tr>
</tbody>
</table>

*Dulabon LM et al. Eur Urol 59: 325, 2011*
Results

OR Time: 3.5 hours  
EBL: 75 mL  
WIT: 0 min  
LOS: 2 days  
Postop Cr: 1.0 mg/dL (0.8 preop)  
eGFR: 80 at 6 months (89 preop)

Path: 6 cm, grade II clear cell RCCa  
Margins: negative  
Margin distance: 5 mm
• 20 patients, 4 institutions

• Median tumor size 2.2 cm (1.1 – 7.2) mostly polar

• Successful in 17/20 (85%)
  – 3 failures due to incomplete distal parenchymal compression
  – converted to standard bulldog RA clamping

• Mean OR time 190 min (129 – 309)

• Mean parenchymal clamp time 26 min (19 – 52)

Selective Renal Parenchymal Clamping in Robot-Assisted Laparoscopic Partial Nephrectomy: A Multi-Institutional Experience

Davis P. Viprakasit, M.D.,1 Ithaar Derweesh, M.D.,2 Carson Wong, M.D.,3 Li-Ming Su, M.D.,4 Sean P. Stroup, M.D.,2 Wassim Bazzi, M.D.,2 Kurt H. Strom, M.D.,5 and S. Duke Herrell, M.D.1

- **Median serum creatinine (mg/dl)**
  - Preoperative (range) 0.83 (0.5 – 1.69)
  - Immediate postoperative (range) 0.81 (0.6 – 1.70)
  - At last follow-up (range) 0.81 (0.6 – 1.83)

- **Median estimated GFR (ml/min/1.73m²)**
  - Preoperative (range) 86 (39 – 118)
  - Immediate postoperative (range) 78 (40 – 124), p = 0.33
  - At last follow-up (range) 78 (36 – 126), p = 0.54

- **Mean follow-up (months)** 6.1 (1.2 – 11.9)
RAPN in Solitary Kidney

6 CM UPPER POLE RENAL MASS IN SOLITARY KIDNEY

Courtesy of B. Lee, M.D.
Retrograde Cooling Technique

Courtesy of B. Lee, M.D.
Results: *Ex-vivo* Porcine Study

Specimen Temperature vs. Time

- **Specimen 1**
- **Specimen 2**
- **Specimen 3**
- **Target Temperature Range (15 - 20°C)**

*Courtesy of B. Lee, M.D.*
Borofsky MS et al. BJUI Dec [Epub ahead of print]
Hyperspectral Imaging and Renal Ischemia

- HSI camera measures various wavelengths of reflected light
- Measures % tissue oxyhemoglobin ($%\text{HbO}_2$)
- Provides real time tissue oxygen map

Biomarkers of Acute Kidney Injury

• Opportunity to study acute kidney injury during partial nephrectomy
• Design “cocktail” to minimize ischemia-induced injury

Dvarajan P Nephrol 15: 419, 2010
Conclusions

Robotic Partial Nephrectomy

- Robotics has had an expanding role in the treatment of the small renal mass
- Partial nephrectomies in solitary kidneys under warm ischemia have given us important insights into cutoffs of WIT
- Modifications in surgical technique can help reduce WIT as an important modifiable risk factor of postoperative renal function
- Future technologies may help improve our understanding of risk and prevention of ischemic injury to the kidney