Kidney Clamp

for Laparoscopic Partial Nephrectomy

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Abstract

As a result of new imaging methods over the past few decades, there has been an increase in carcinoma detection in the kidneys resulting in an overall increase in nephrectomy surgeries. Recently, surgeons are performing more partial nephrectomy surgeries versus radical nephrectomy surgeries in order to spare viable and functioning tissue. In addition, these surgeons are switching over from open surgeries to laparoscopic surgeries in order to decrease post-operative complications. However, current methods of blood flow occlusion for laparoscopic partial nephrectomy (LPN) create global ischemia in the kidney that may lead to long term loss of renal function. Our client, an LPN surgeon, would like us to develop a device that can occlude blood flow in the kidney at the site of the partial nephrectomy, in efforts to simplify the procedure and prevent tissue damage. The device will clamp across the kidney in order to occlude renal blood flow to the tumor reducing the chance of global ischemia in the kidney, therefore, resulting in less complications.

Motivation

- Renal cancer is the 7th leading malignant condition for men , 12th leading among women in U.S[1].
- Nephrectomy is initial treatment for majority of patients
- 1/3 of patients who undergo kidney resection will have a recurrence.
- Clamping times of as little as 30 minutes have been shown to cause 10% loss in kidney function post-surgery[2].
- **Market Need**: a method to increase the effectiveness & safety of surgical treatment.

Background

The Kidney:

- Filters around 20% of body's blood per minute.
- Blood flow rate essential to maintain homeostatic functions (i.e. remove wastes).

Laparoscopic Partial Nephrectomy:

- Removal of only diseased tissue from kidney.
- Clamping needed to control blood loss and keep operating view clear.

Current Method

Occludes blood supply to entire kidney causing cell death (global ischemia) by clamping at the source of blood flow. Can cause loss of kidney function if ischemic for greater than 30 minutes.

Proposed Method

Selectively occludes blood flow to the portion of the kidney being removed (regional ischemia) by clamping around the functional part of the kidney, or parenchyma.

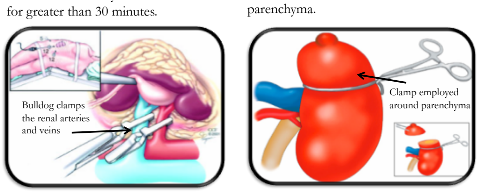

Figure 1a (left) shows the current method of tumor removal with clamps applied at the blood source. Figure 1b(right) shows the proposed method, which employs a clamp around the kidney tissue[1].

Our client Doctor E. Jason Abel at the University of Wisconsin – Madison hospital specializes in localized advanced kidney cancer. His philosophy to "provide maximal quality of life to patients by using minimally invasive approaches to cancer therapy," has prompted the idea for a new, laparoscopic tool to aid in partial kidney removal.

Design Specifications

- Must be able to fit through a 12 mm by 15 mm trocar
- Flexible shaft
- Provide enough strength to occlude renal blood flow
  - Without causing harm to kidney
  - Adjustable force
  - Maintainable force
  - Evenly distributed force
  - Maintain force for 5 – 30 minutes
  - Provide force 5 N or less[3].
- Reusable
- Able to operate with one hand
- Accommodate hand breadth ranging from 6.5 – 9.5 cm
- Not exceed cost of commercially available clamps ($5000)
- Entire clamp should weigh less than 5 lbs.

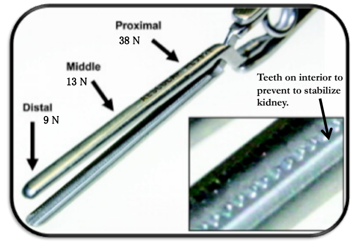

Figure 2 shows the variation of force generated by current clamps on the market. The inlaid picture shows an example of the texture desired to stabilize the kidney.

Final Design

Clamp

- Made from spring stainless-steel
- 1.75 mm x 6 mm x 110 mm[4]
- Maximum 12 mm width when closed

Arm

- 600 mm length
- 10 mm outer diameter
- 8 mm inner diameter
- Flexible

Handle

- Ratchet to lock into place
- Familiar to surgeons
- Connected to clamp through wire and bike brake mechanism

Figure 3 shows the handle for our final design.[1]

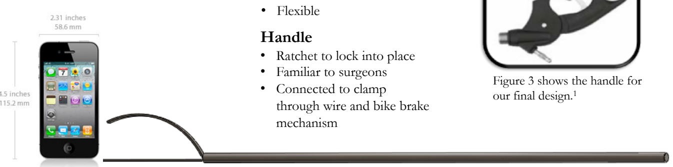

Figure 4 shows a Solidworks model of our clamp and arm.

Design Analysis

5 N Load: Compression | Tension
20 N Load: Compression | Tension

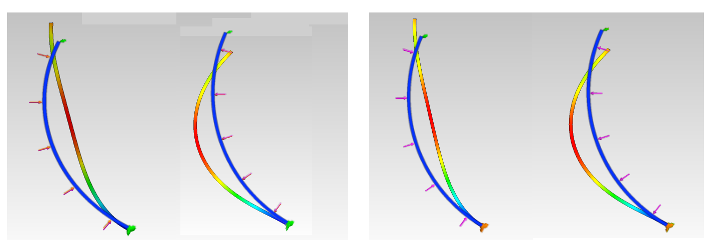

Figure 5 shows Solidworks stress analysis of the curved clamp. One end was fixed as a pin while the other was fixed as a roller. Force was applied evenly across the surface of the clamp with different loads.

Results

5 N Load	Deformation (mm)	Stress (kPa)
Tension	12	44
Compression	11.5	45

20 N Load	Deformation (mm)	Stress (kPa)
Tension	12	179
Compression	11.5	181

Yield Strength of Stainless Steel (ferric): 172 MPa

- 950x greater than our highest experimental stress

Based on our results the total width of the clamp when compressed will be 11 mm, therefore it will fit through the trocar.

Future Work

Testing:

- Occlusion force
- 5 points along clamp
- Compare to pressure needed to occlude kidney
  - Ranges up to 5 N
  - Kidney breaks at 20 N
- Check for leak point pressure
- Use A 2.2 mm button style compression load cell transducer (Interface Advanced Force Measurement)
- Test Satinsky clamp from client for comparison
- Test final prototype in pig lab.

Figure 6 shows the handle for our final design.[5]

Acknowledgements

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