Kidney Clamp for Laparoscopic Partial Nephrectomy

Jeff Hlinka, Shannon Hynes, Kayla Stankevitz
Client: Dr. E Jason Abel, Department of Urology, UW–Madison
Advisor: Mitch Tyler, Department of Biomedical Engineering, UW–Madison

Abstract

Laparoscopic Partial Nephrectomy (LPN) surgery is indicated for removal of kidney tumors. The current technique involves clamping the renal artery and vein. This procedure prevents all blood from entering the kidney tissue, causing the tissue to become ischemic which is risky for the patient. A new method of performing LPN surgery has been requested that would use a clamp to occlude blood flow in the kidney only to the portion of the organ being removed in an effort to maintain blood flow to the healthy tissue. An adjustable surgical clamp was designed and a prototype was manufactured using ABS. Preliminary testing was performed via simulations and it was determined that the device will not fail due to normal and maximum expected loading. 5 N and 20 N respectively. Further testing should be completed on a patient steel prototype before final conclusions can be drawn.

Motivation

• More than 46,000 patients undergo nephrectomy surgery each year.
• 32,000 new cases of renal cancer are diagnosed each year in the United States.
• 1/3 of patients who undergo kidney resection will have a recurrence.
• 32,000 new cases of renal cancer are diagnosed each year in the United States.
• More than 46,000 patients undergo nephrectomy surgery each year.

Background

The Kidney: Filters around 20% of body’s blood per minute.
Blood flow rate essential to maintain homocysteine 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
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.

Figure 1a (left) shows the current method of tumor removal with clamps applied at the source of blood flow. Figure 1b (right) shows the proposed method, which employs a clamp around the portion of the kidney being removed in an effort to maintain blood flow to the healthy tissue.

Client

Our client Doctor E. Jason Abel at the University of Wisconsin – Madison hospital specializes in localized advanced kidney cancer. His philosophy is to “provide minimal 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
• Provide enough strength to occlude renal blood flow
  • Without causing harm to kidney
  • Adjustable force
  • Maintaminable force
  • Easily distributed force
  • Maintain force for 5 – 30 minutes
  • Provide force 5 N or less
  • Reusable
• Able to operate with one hand
• Acommodate hand breadth ranging from 6.5 – 9.5 cm
• Not exceed cost of commercially available clamps ($3000)
• Enlarge clamp should weigh less than 5 lbs.

Analysis and Results

Solidworks Analysis
• Similitude analysis show displacement and stress distribution

Future Work

Stainless Steel Prototype:
• Proof of concept complete
• Fabricate stainless steel prototype
Additional Function:
• Need to design and fabricate a flexible arm
• Control arm flexibility
• Incorporate RJ ablation guide

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Materials

AISI 316 Annealed Stainless Steel
• Yield Strength: 137.8 MPa
• 5%0.900 lbs
• 0.031 cm
• Corrosion resistant $7.99/30 ft

304 Stainless Steel Wire
• 10 – 900 lbs
• 0.031 cm
• Corrosion resistant

References


Ankle
• Shortened and released via handle
• Jaws controlled via 2 wires
• Connected to clamp
• Familiar to surgeons
• Ratchet to lock into place
• Flexible
• 4 mm inner diameter
• 5 mm outer diameter
• 350 mm length

Testing:
• Verify occlusion force
• Compare to pressure needed to occlude kidney
• Ranges up to 5 N
• Kidney ruptures at 20 N
• Check for leak point pressure
• Test final prototype in pig lab.