Renal Occlusive Clamp for Laparoscopic Partial Nephrectomy

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Client: E Jason Abel, M.D.

Abstract

Our client, Dr. Abel, has requested that our team develop a selective renal occlusive clamp for robotic, laparoscopic, partial nephrectomy surgery. Partial nephrectomies are becoming more popular to surgeons in order spare functional tissue. Our product will optimize the partial nephrectomy by selectively occluding blood flow to part of the kidney, while allowing normal blood flow in the other parts of the kidney. This clamp will prevent global kidney ischemia which can lead to tissue damage and complications. This semester, the design will focus on the clamp end of the surgical instrument, with the laparoscopic arm being designed in future. Four different designs were developed: loop, modified bulldog, zip-tie, and crisscross. These designs were analyzed with criteria from the client and from published data about partial nephrectomy. The final design chosen from these criteria was the loop design. This design was partially modified by adding a stiff back plate, and a prototype was constructed. Three different experiments were completed with the prototype; clamp force testing, excised porcine kidney testing, and texture testing. Additionally, compression testing on excised porcine kidney was completed to determine the material properties of kidney. Next semester, testing will be completed in a live porcine model to receive feedback from the client on how the clamp performs in a surgical setting. The laparoscopic arm and handle will also be developed and tested.

Background

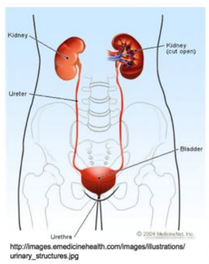

Figure 1. Depiction of kidneys within the body

- Renal cell carcinoma affects 32,000 people in the United States every year[1]
- Tumors do not normally respond to non-surgical treatments[1]
- Partial nephrectomy: open and closed options
- Current procedure uses vessel clamping of renal artery and vein[2]
- Vessel clamping causes global renal ischemia[3]
- Satinksy Clamp is used for open partial procedure

Laparoscopic Procedure

1. 3-4 1cm Incisions are made in the abdomen[1]
2. Abdominal cavity is inflated
3. Blood flow is occluded to the kidney
4. The tumors are excised
5. The kidney is sutured closed

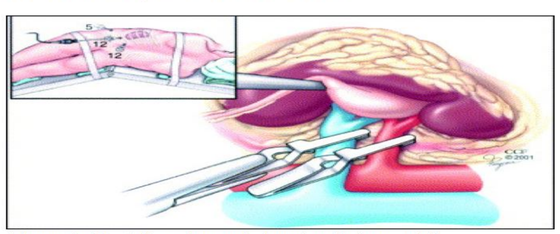

Figure 2. Depiction of vessel clamping during partial nephrectomy[4]. Our prototype utilizes a method of parenchymal clamping

Final Design

Specifications:

- Composed of three sections: shaft, base plate, and flexible ribbon
- Stainless steel construction
- Total Design Length 61.0cm

Figure 3. Image of Final Design Compressing Porcine Kidney

Advantages:

- Greater surface area than Satinsky clamp
- Adjustable base plate allows for variances in kidney size
- Functions with laparoscopic procedure

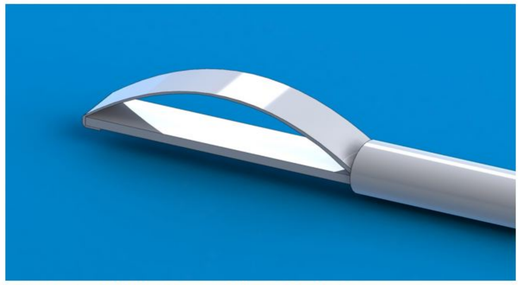

Figure 4. Solidworks rendering of final design.

Testing

Friction Testing

- Testing was performed on the stainless steel ribbon and 5 different textured patterns to determine an active force

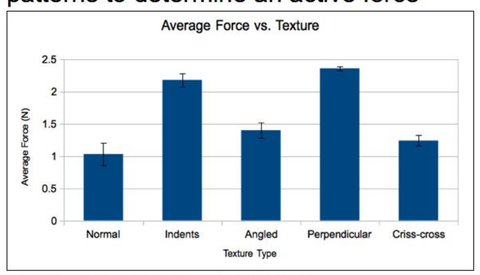

Figure 5. Results of friction testing

Pressure Testing

- Pressure measured with various base plate lengths

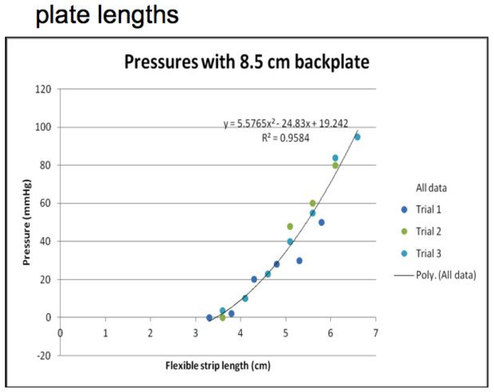

Figure 7. Clamp force testing with 8.5cm base plate.

Compression Testing

Figure 6. Image of compressive testing setup

- Porcine kidney samples placed in load frame. Force and displacement were measured.
- Average Young's Modulus: 1411.865±574.246KPa
- Average strain of failure: 0.344± 0.051
- Average pressure of failure: 303.183 ±32.476KPa

Porcine Kidney Test

- A balloon attached to a sphygmomanometer was inserted inside a porcine kidney
- No significant difference in pressure applied (p-value=0.45356)

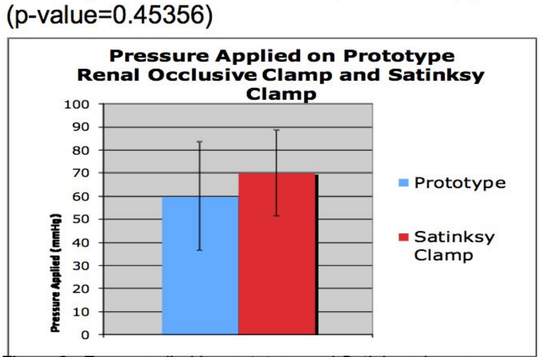

Figure 8. Force applied by prototype and Satinksy clamps.

Mission

Our client, Dr. Abel, requests that our team develop a selective renal occlusive clamp for robotic, laparoscopic, partial nephrectomy surgery. Surgeons are performing more partial nephrectomy surgeries in order to spare functional tissue. Our product will optimize the partial nephrectomy by selectively occluding blood flow to part of the kidney, while allowing normal blood flow in the other parts of the kidney. This clamp will prevent global kidney ischemia which can lead to tissue damage.

Materials

Stainless steel alloys

304-2B	430
Base Plate	Flexible Ribbon
Cr-Ni	Does not contain Ni
Least expensive medical alloy	Cheaper than 300 series

Competition

- Satinsky clamp is used for open partial nephrectomy
- Simon renal pole clamp is used for laparoscopic partial nephrectomy
  - Uneven pressure distribution[3]

Future Work

- Test Prototype in live porcine experiment
- Design control mechanism for device
- Create new prototype utilizing medical-grade stainless steel
- File a patent on design

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[2] Martin, G.L., Warner, J.N., et. al. Comparison of Total, Selective, and Nonarterial Clamping Techniques During Laparoscopic and Robot-Assisted Partial Nephrectomy Journal of Endourology. February 2012, Vol. 26, No. 2: 152-156

[3] Abel, E. 2012. Personal Communication

[4] Haber, G. 2006. Laparoscopic Parital Nephrectomy: Contemporary Technique and Outcomes. European Urology.