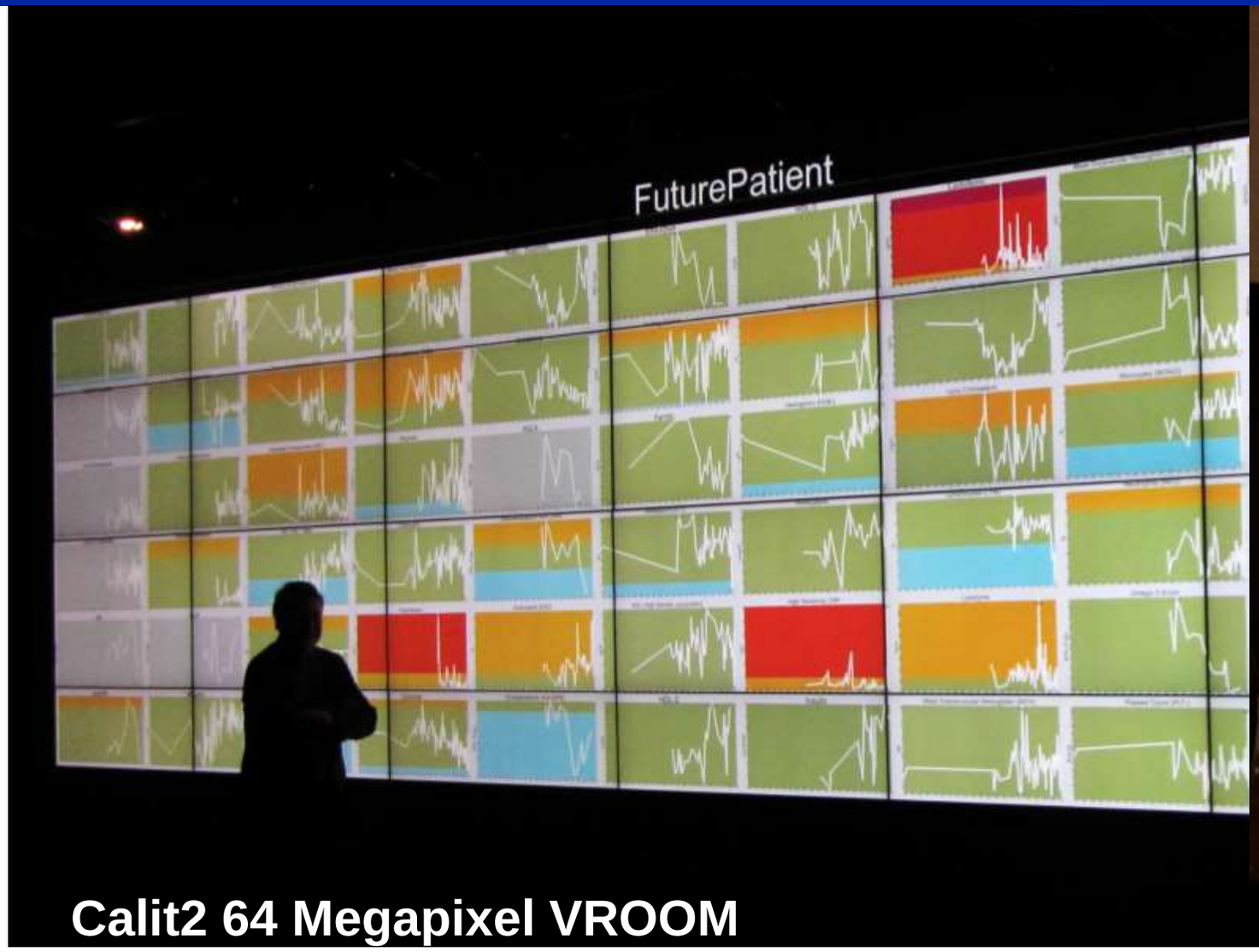
“From Quantified Self to Quantified Surgery”

Surgery Grand Rounds
University of California, San Diego
February 22, 2017

Dr. Larry Smarr
Director, California Institute for Telecommunications and Information Technology
Harry E. Gruber Professor,
Dept. of Computer Science and Engineering
Jacobs School of Engineering, UCSD
http://lsmarr.calit2.net

Quantifying the Need for Surgery

I Have Been Tracking My Internal Biomarkers For A Decade To Understand My Body's Dynamics

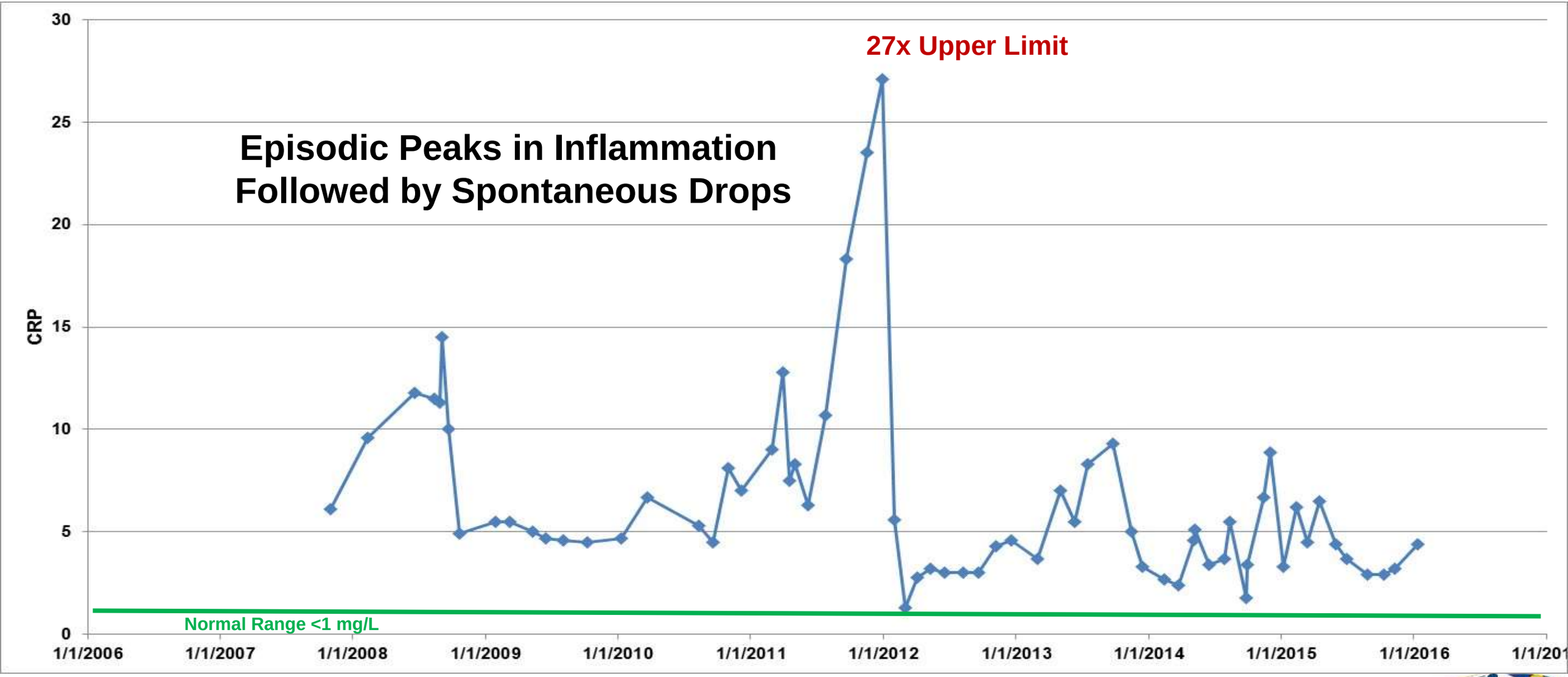


Calit2 64 Megapixel VROOM



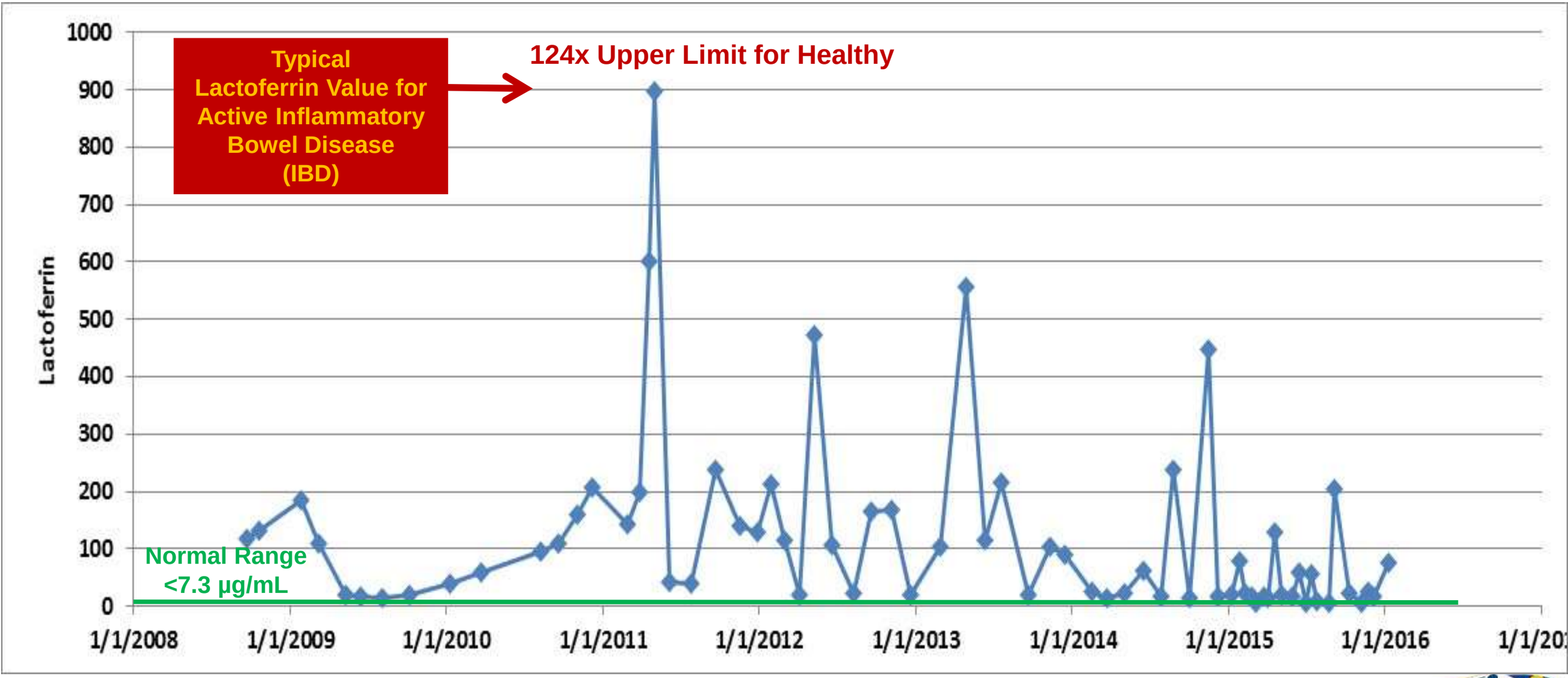
My Quarterly Blood Draw

Only One of My Blood Measurements Was Far Out of Range--Indicating Chronic Inflammation



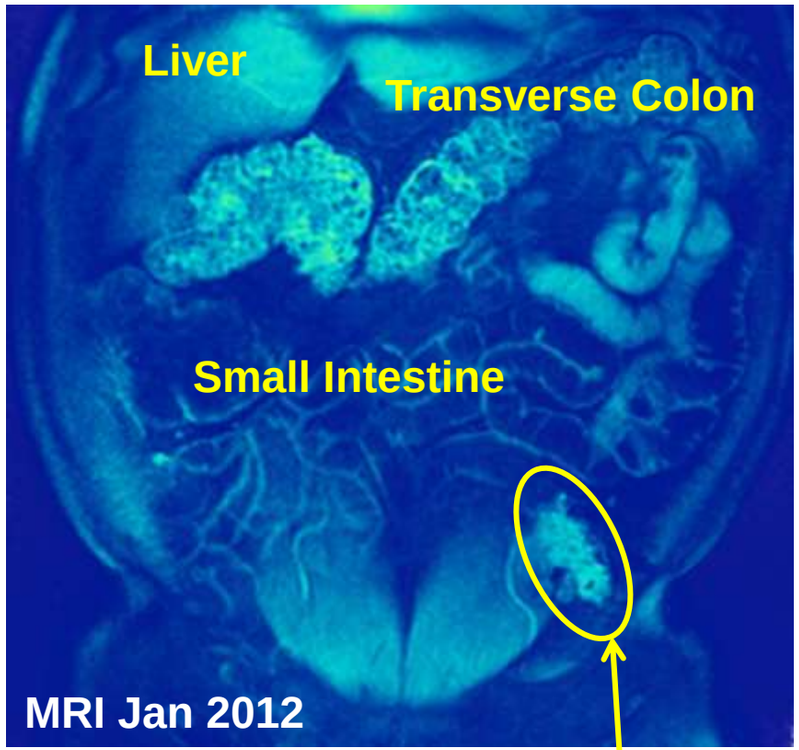
Complex Reactive Protein (CRP) is a Blood Biomarker for Detecting Presence of Inflammation

Adding Stool Tests Revealed
Oscillatory Behavior in an Immune Variable Which is Antibacterial



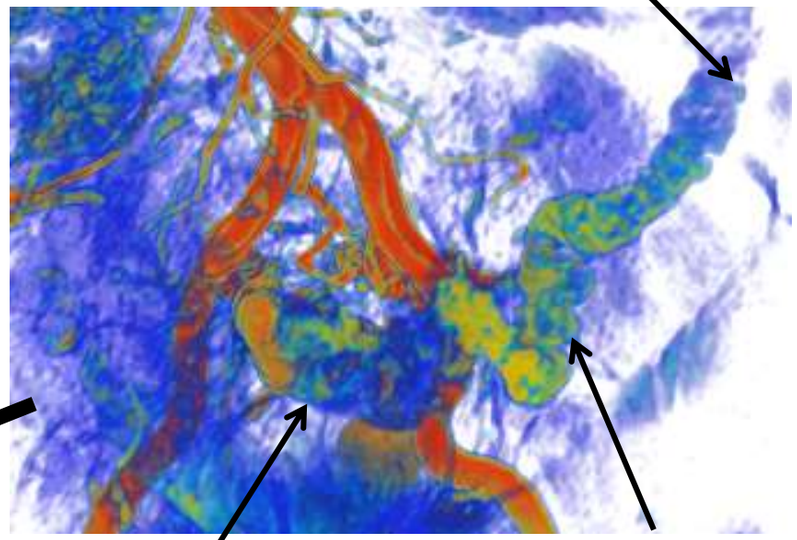
Lactoferrin is a Protein Shed from Neutrophils -
An Antibacterial that Sequesters Iron

Confirming the IBD (Colonic Crohn's) Hypothesis: Finding the "Smoking Gun" with MRI Imaging



I Obtained the MRI Slices From UCSD Medical Services and Converted to Interactive 3D Working With Calit2 Staff

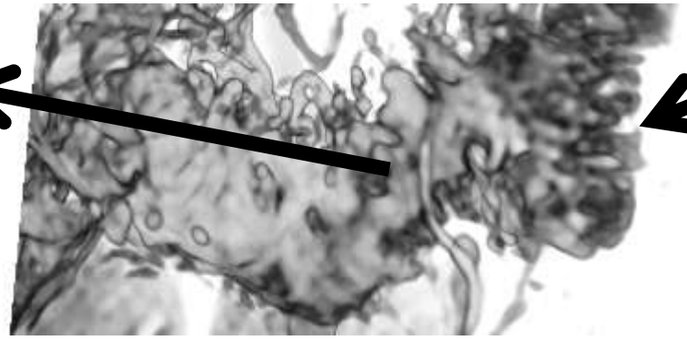
Descending Colon



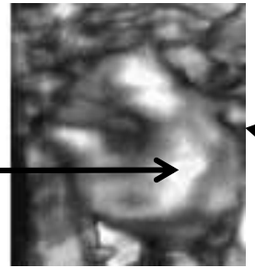
Major Kink

Sigmoid Colon
Threading Iliac Arteries

Diseased Sigmoid Colon

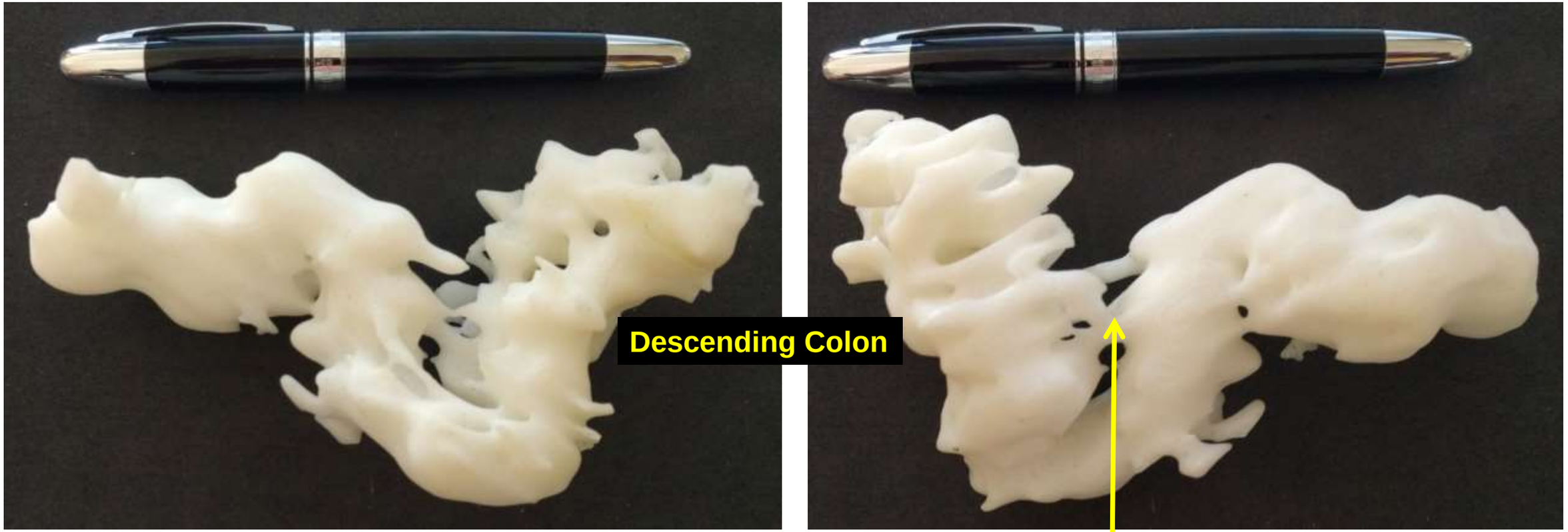


Cross Section



Severe Colon
Wall Swelling

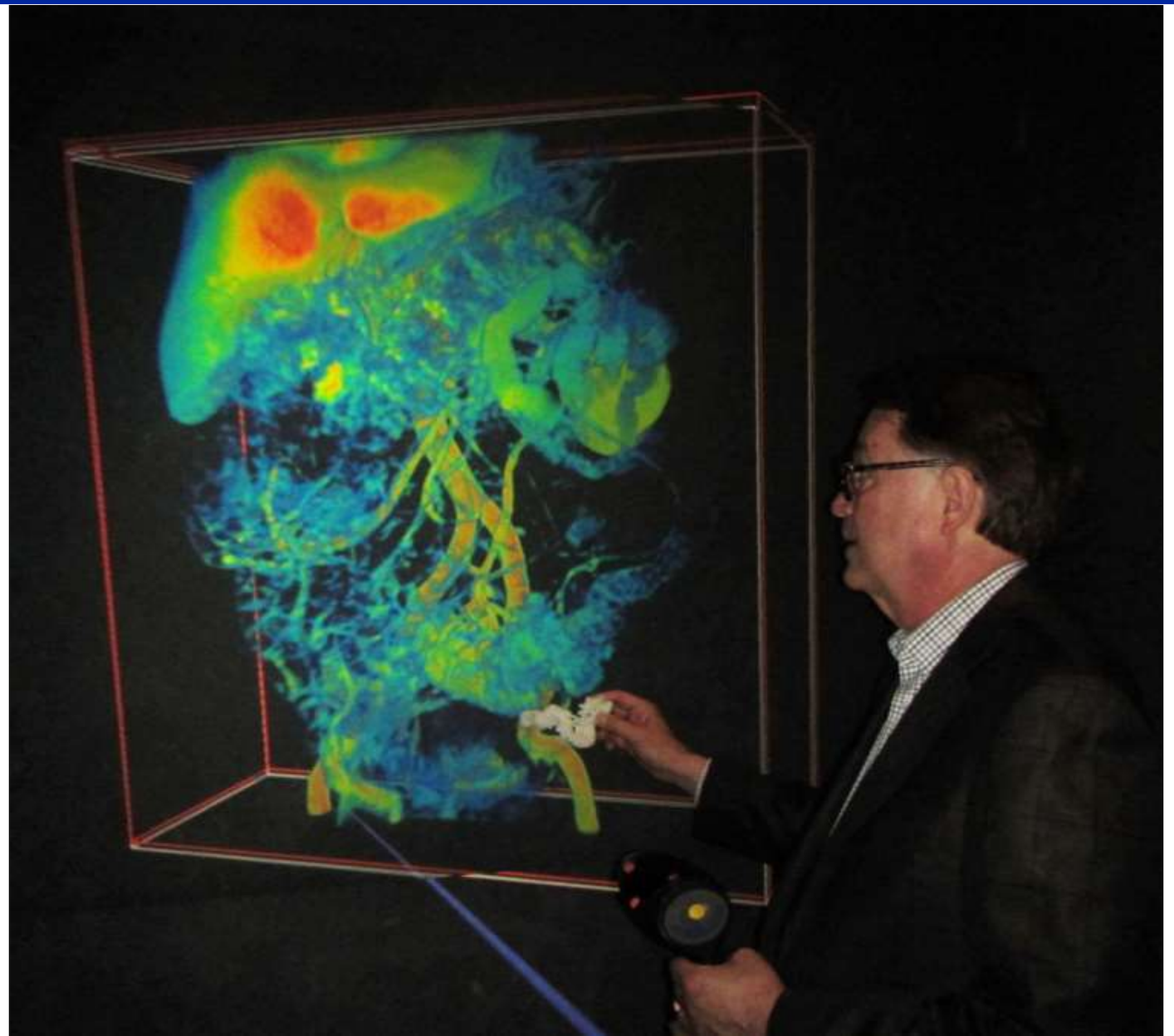
MRI 2d DICOM Slices Converted to 3d Volumetric Imaging and Sigmoid Colon 3d Printed



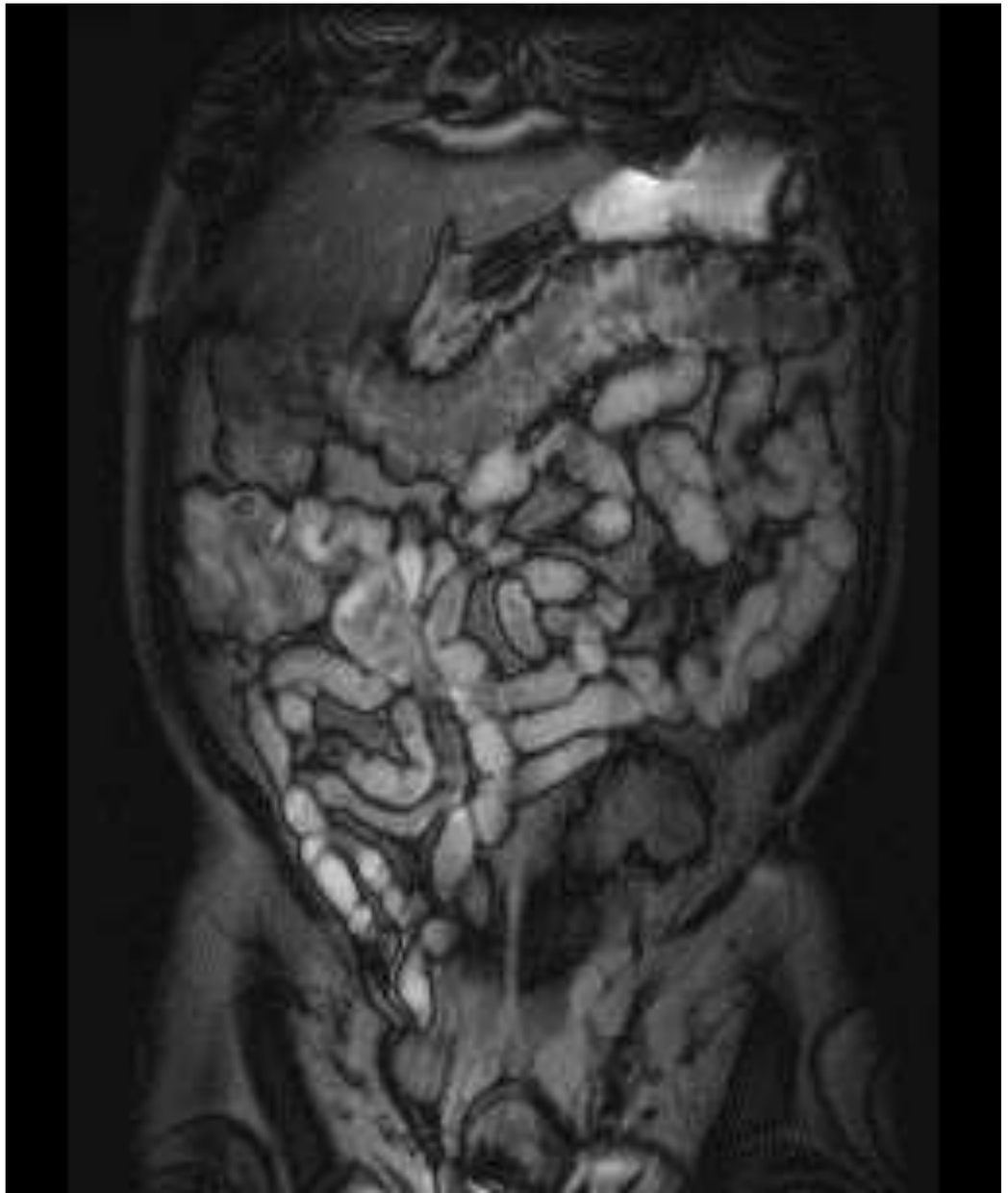
3d software: Jurgen Schulze, Calit2, UCSD
3d printing: Philip Weber, Calit2, UCSD

3D Volumetric Visualization From MRI In Calit2 Virtual Reality StarCAVE

3D Volumetric Visualization Created by Calit2's Jurgen Schulze from January 2012 MRI



2012 MRI Video Reveals Diseased Sigmoid Colon



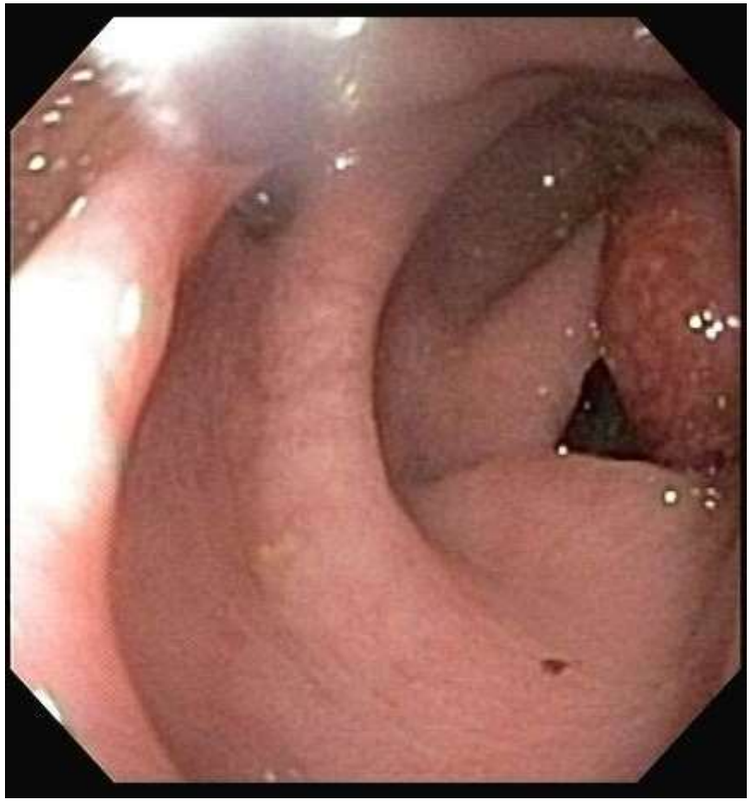
Source: Cynthia Santillan, MD Radiologist, UCSD

Colonoscopy Images Shows Growth of Inflamed Pseudopolyps in 6 inches of Sigmoid Colon Over Six Years

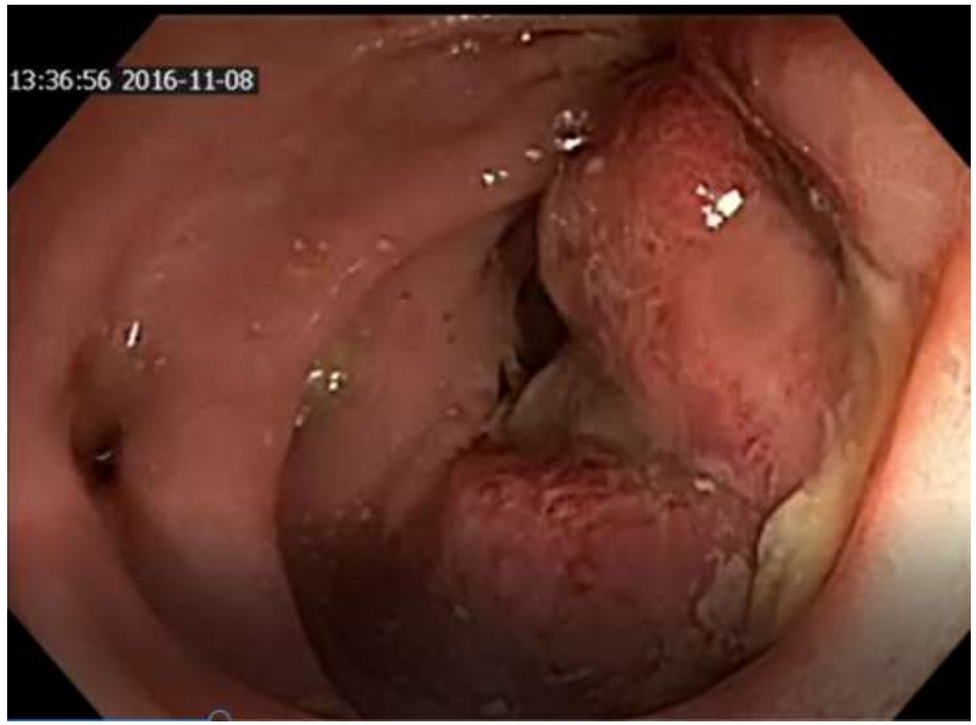
"Patient does have a moderate degree of diverticular disease in the sigmoid colon, and there are 3 or 4 areas of mild inflammation of colonic mucosa with erythema and edema."
Dr. Parviz Foroozan, Scripps, May 30, 2006



Dec 2010



Jan 2012



Nov 2016

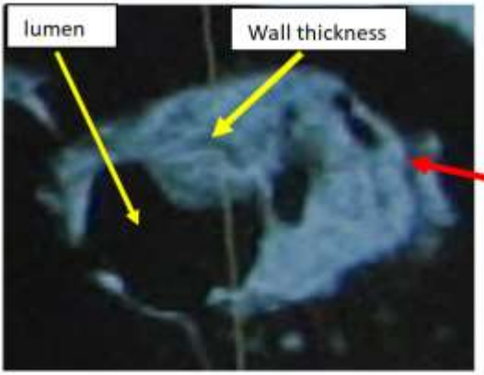
"Tiny lumen, extreme tortuosity, had to use a 9.8 mm video gastroscope rather than the 11.9 mm pediatric colonoscopy to traverse the lesion."-Bill Sandborn, Nov 8, 2016

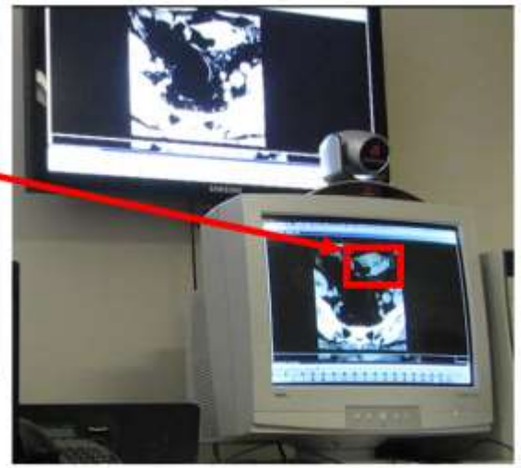
I Asked Dr. Ramamoorthy to Laparoscopically "Fly Over" My Sigmoid Colon, While Dr. Bryan J. Sandler Was Doing an Inguinal Hernia Repair Surgery

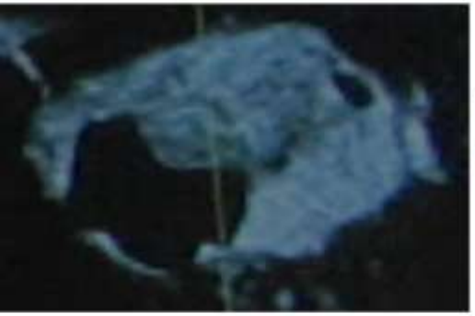
The sigmoid colon appears to be relatively normal.
There was one area where it was adherent
to the left pelvic sidewall.
There was some creeping fat in this area
and on palpitation of the area,
there was some mild inflammation,
but no other abnormalities seen.
-UCSD EMR, Sonia Ramamoorthy 8/22/2014

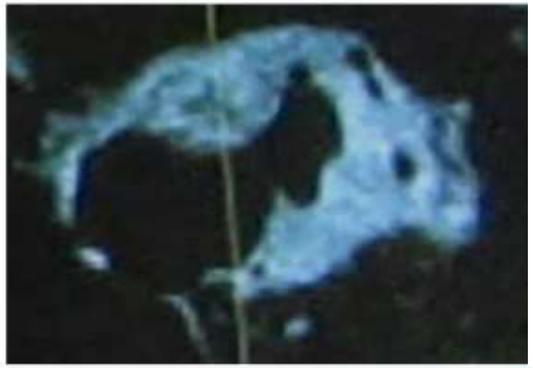
Laparoscopic View Alone Did Not Reveal Serious Problem

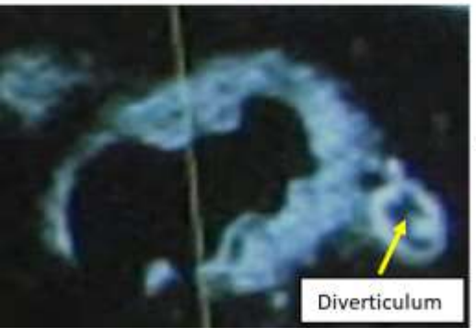
Full Body CAT Scan at mm Resolution, Including Virtual Colonoscopy June 2016 Convinced Me Time Had Come for Surgery

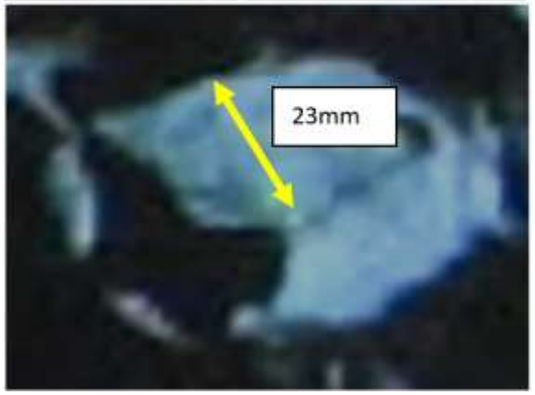


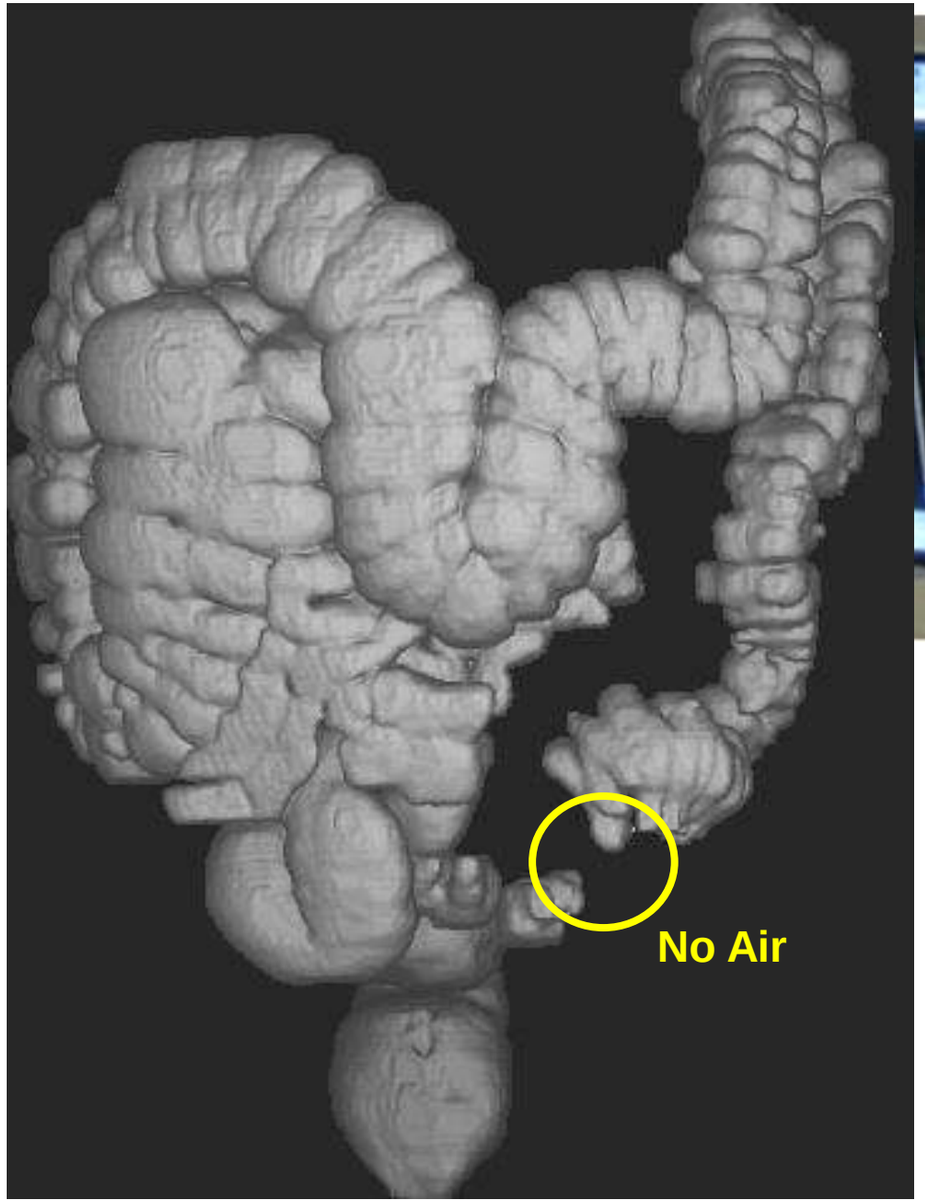












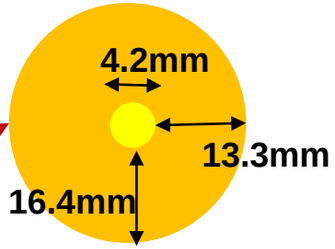


Source: June 2016
Dr. Harvey Eisenberg,
Body Scan Intl., Irvine, CA

Slice Through Sigmoid Colon Reveals Thick Walls and Very Narrow Lumen



Source: Smarr MRI Oct. 25, 2016
Reading by Cynthia Santillan,
MD Radiologist, UCSD



Normal opening (bright yellow) is 40mm, so mine is 1/10 the diameter it should be.

Normal wall thickness (dark yellow) is 3mm, so wall thickness is 4-5 times as thick as it should be.

Pre-Surgical Planning

Smarr Met with Intuitive Surgical's Dr. Catherine Mohr at Exponential Medicine October 10, 2016

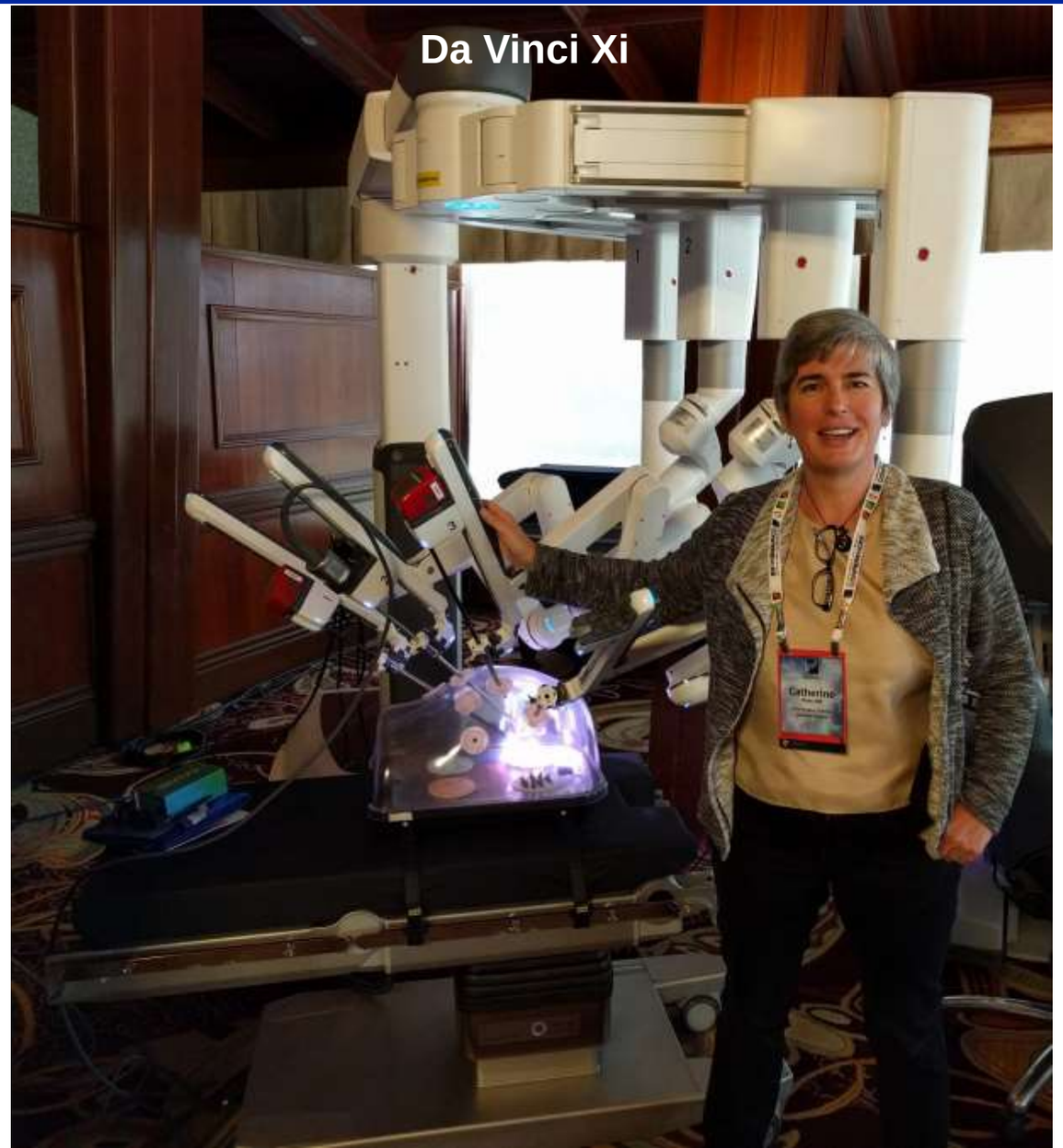


Photo by Larry Smarr

Pre-Surgical Team Meeting With Surgeon and Patient Plus Radiologists and GI MDs, DO, Bioengineering, Design, VR, & Robotics

November 4, 2016

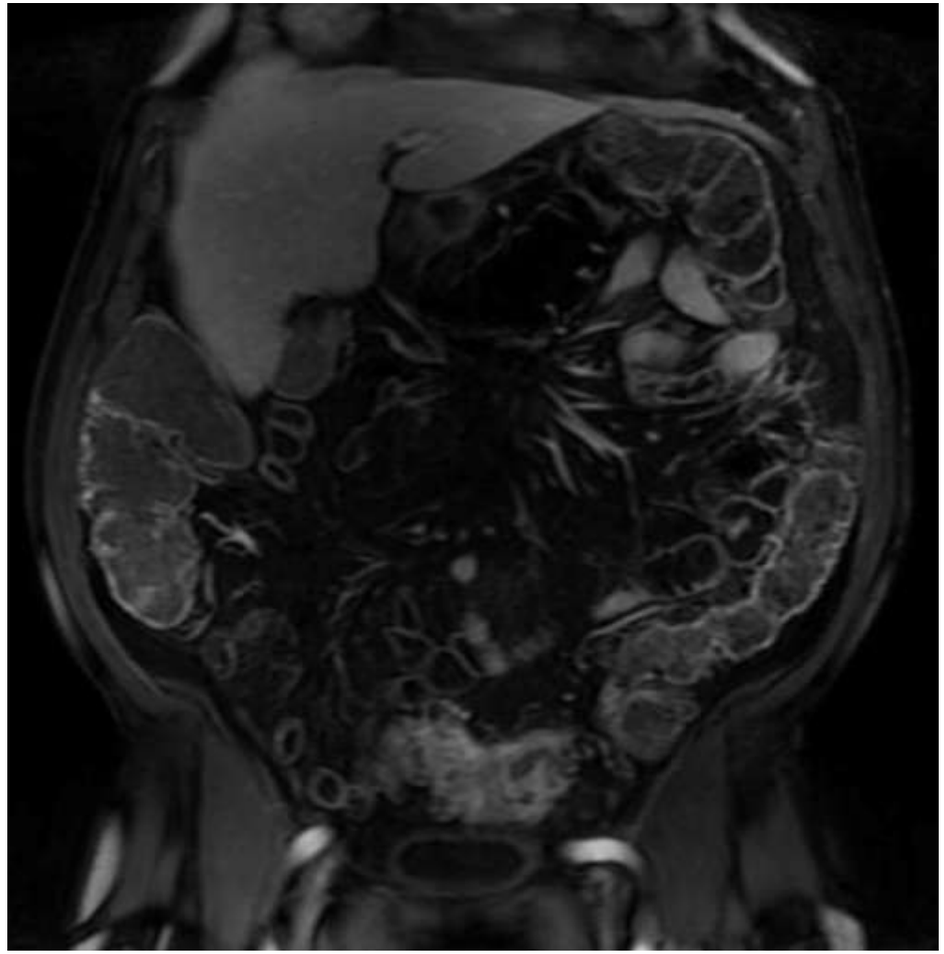




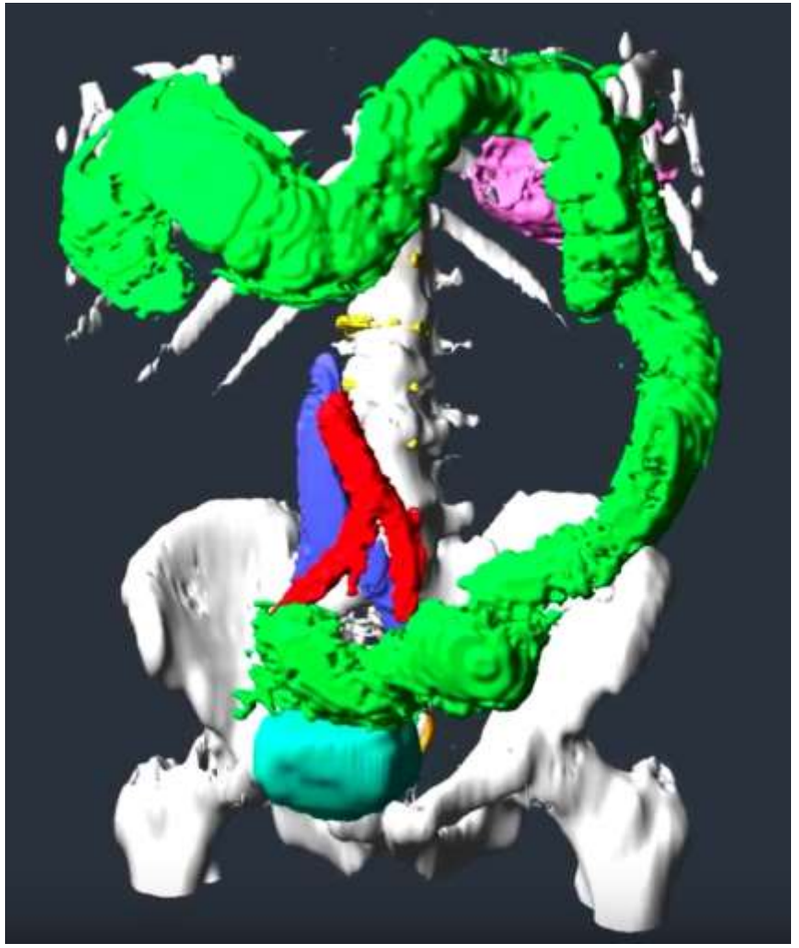
Photos by Dr. Sonia Ramamoorthy

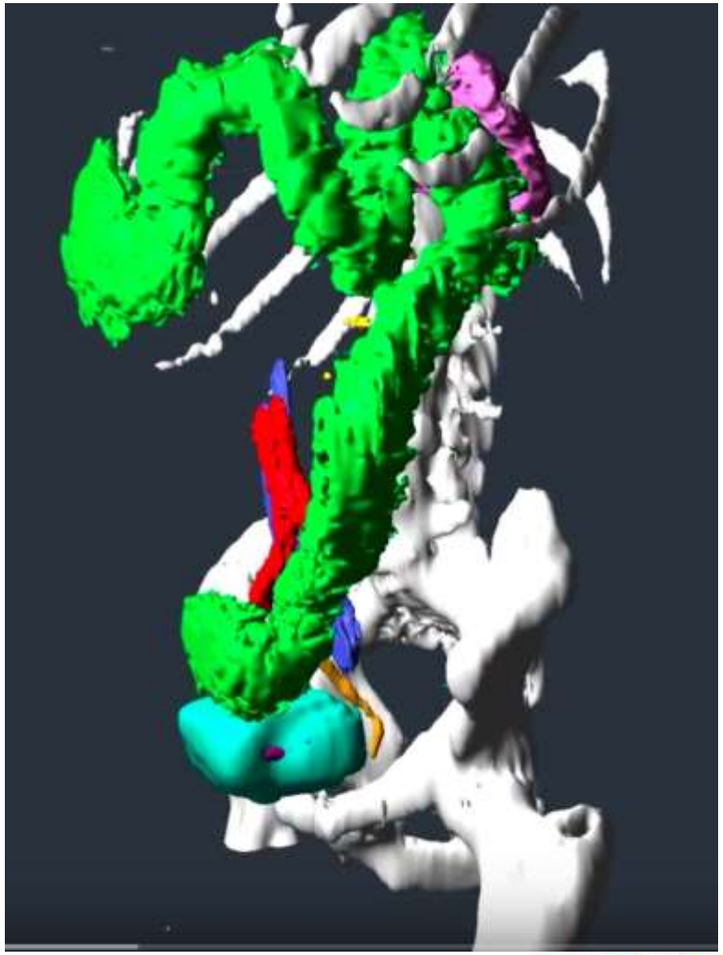
We Converted Abdominal MRI Slices to 3D Organ Segmentation for Surgical Pre-Planning

Images of Patient Smarr's Abdomen
Created by Jurgen Schulze, Calit2



MRI Slice from Dr. Cynthia Santillan





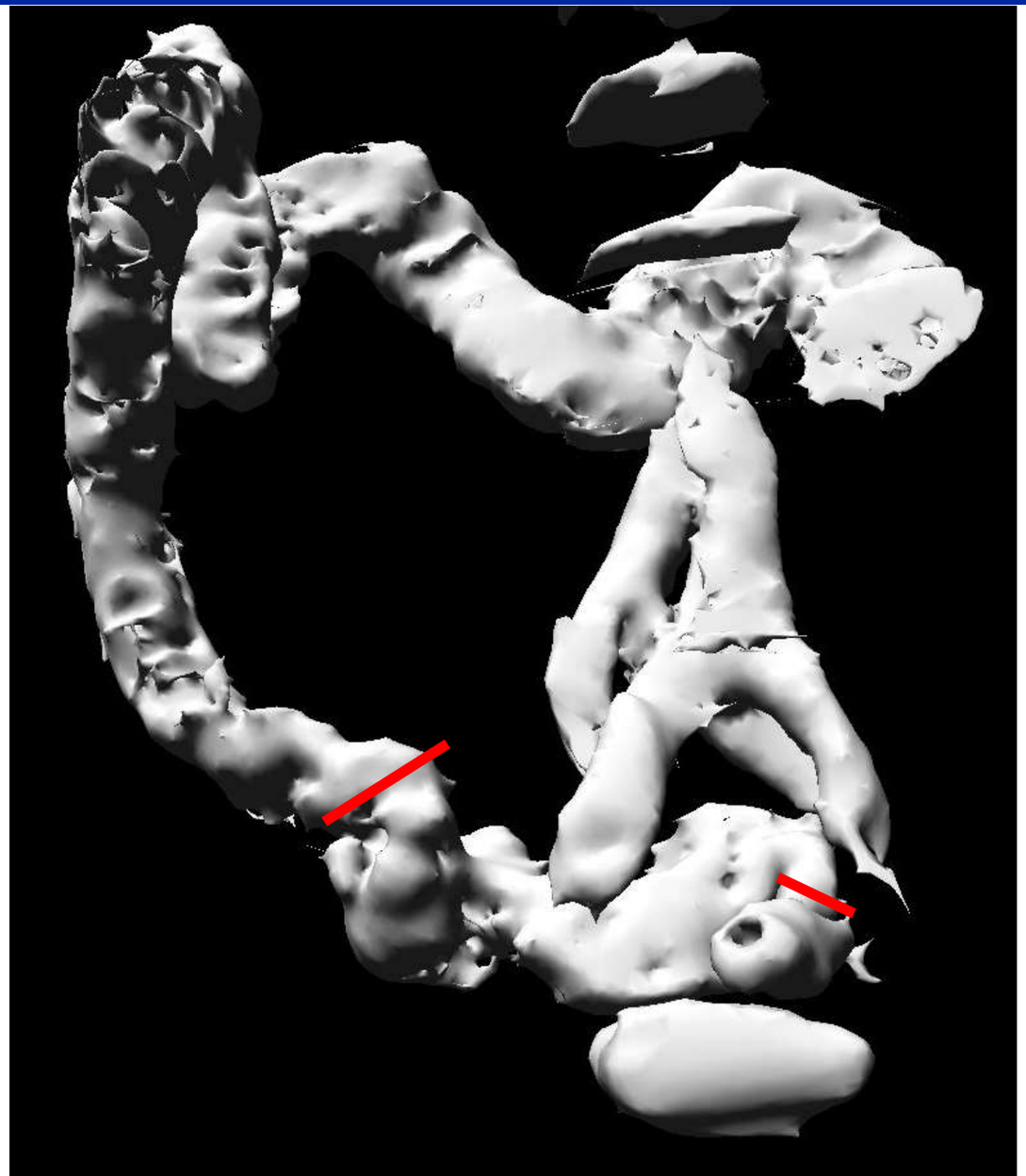
3D Organ Segmentation Made from Dr. Santillan's 150-Slice MRI

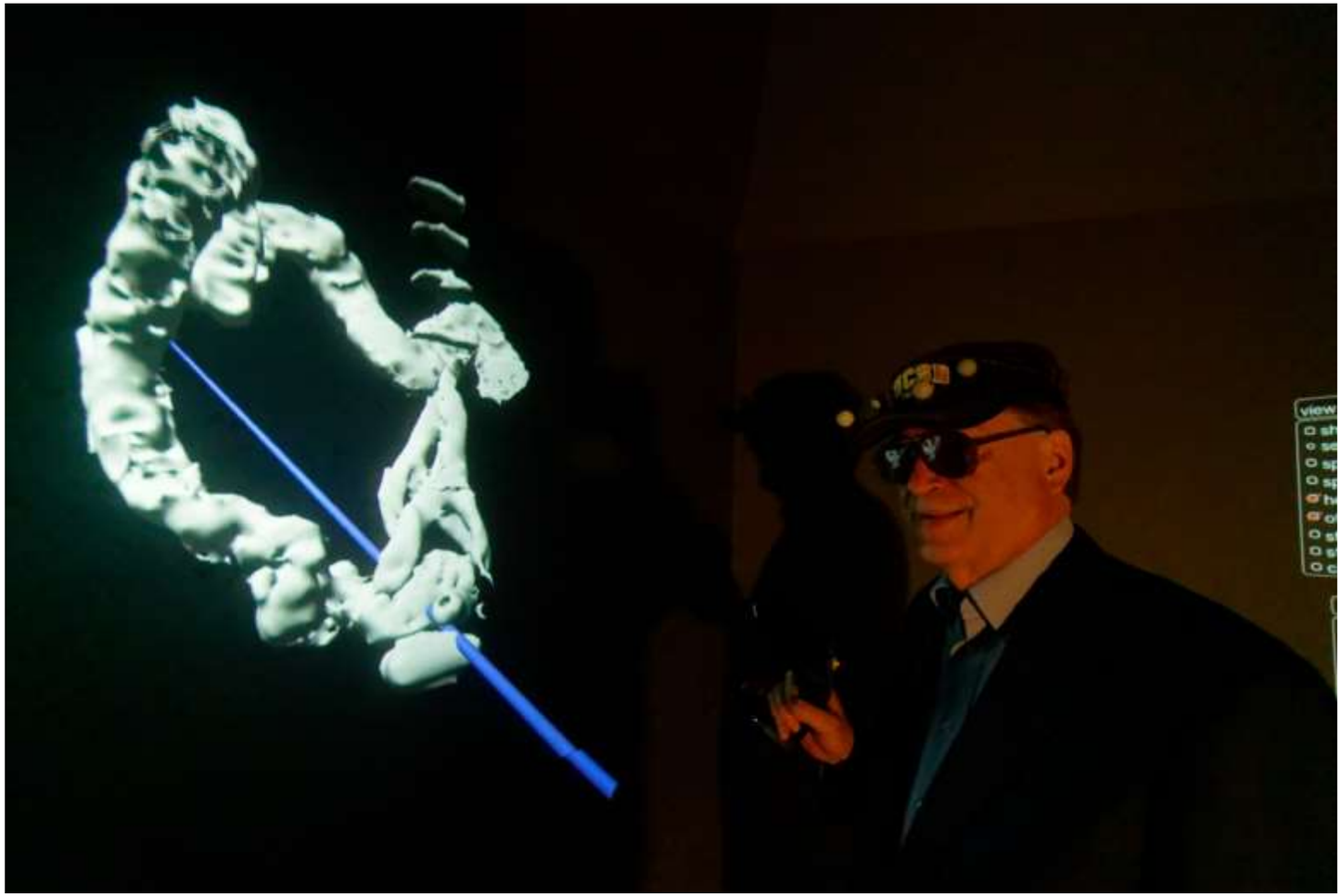
Pre-Surgical Planning in QI Virtual Reality on Friday November 25, 2016

Dr. Ramamoorthy in QI Virtual Reality CAVE Exploring Dr. Smarr's Colon With Dr. Schulze's Software



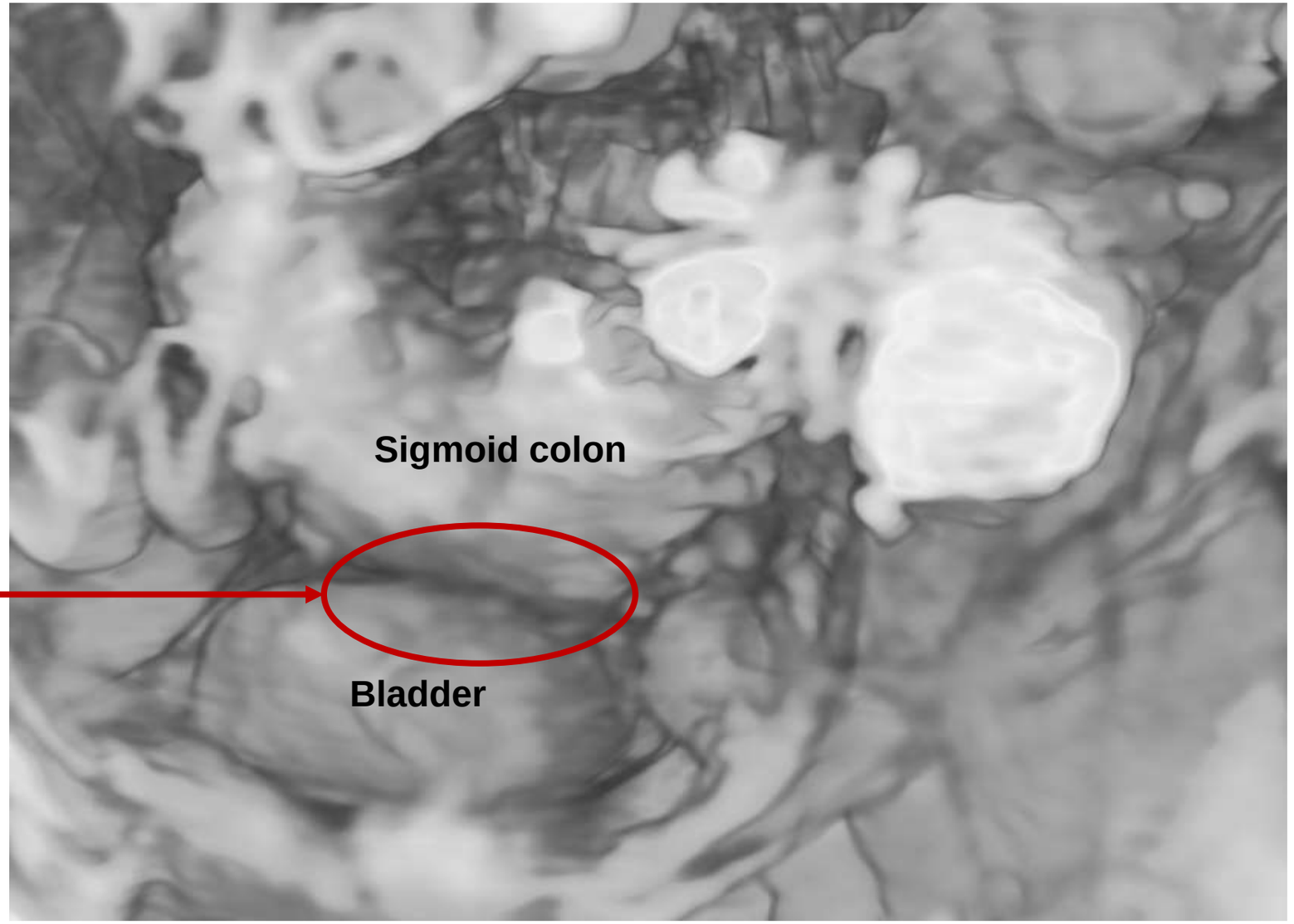
Sigmoid Colon Had Kinks at Both Ends: Using Virtual Reality As Input for Positioning The Two Resection Cuts





Colon visualization by Jurgen Schulze, Calit2;
Photo credit Tom DeFanti, Calit2

Diseased Sigmoid Colon is Sitting on Top of Bladder



Region to Investigate Possible Fistula Between Sigmoid colon and Bladder

Key Outcomes of 3D Presurgical Planning

- **Three Specific Problem Areas Discovered:**
  - **Sigmoid Has Kinks at Both Ends**
  - **Sigmoid Colon is Sitting on Bladder**
  - **Splenic Flexure Colon Has Folds and is Attached to Spleen**

- **Led to Decisions About Surgical Procedures:**
  - **Location of Ports Was Changed on Body**
  - **Sigmoid Colon Resection End Points Were Determined**
  - **Extra Time Will Be Needed Near Spleen**

New Technology Supporting Surgery

UC San Diego Health Communications
Put a Video Crew into the OR



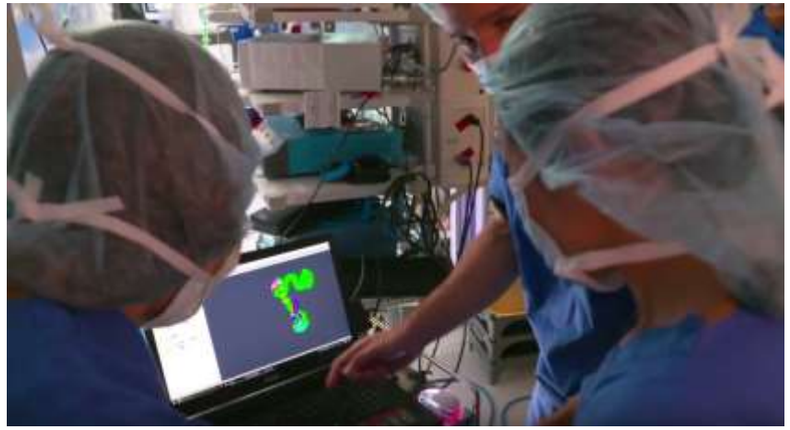
QI Collaboration with Radiology, GI, and Surgery to Support Sigmoid Colon Resection



UC San Diego Health Communications Planning Press Release Early March

Using QI Organ Segmentation in Jacobs OR on Tuesday November 29, 2016

Dr. Schulze Rotating 3D Organs To Match Up With da Vinci Arms and Internal Camera





Patient Smarr With da Vinci Robot Arms Inside Him





Dr. Ramamoorthy Operating Da Vinci Xi Robot During Surgery

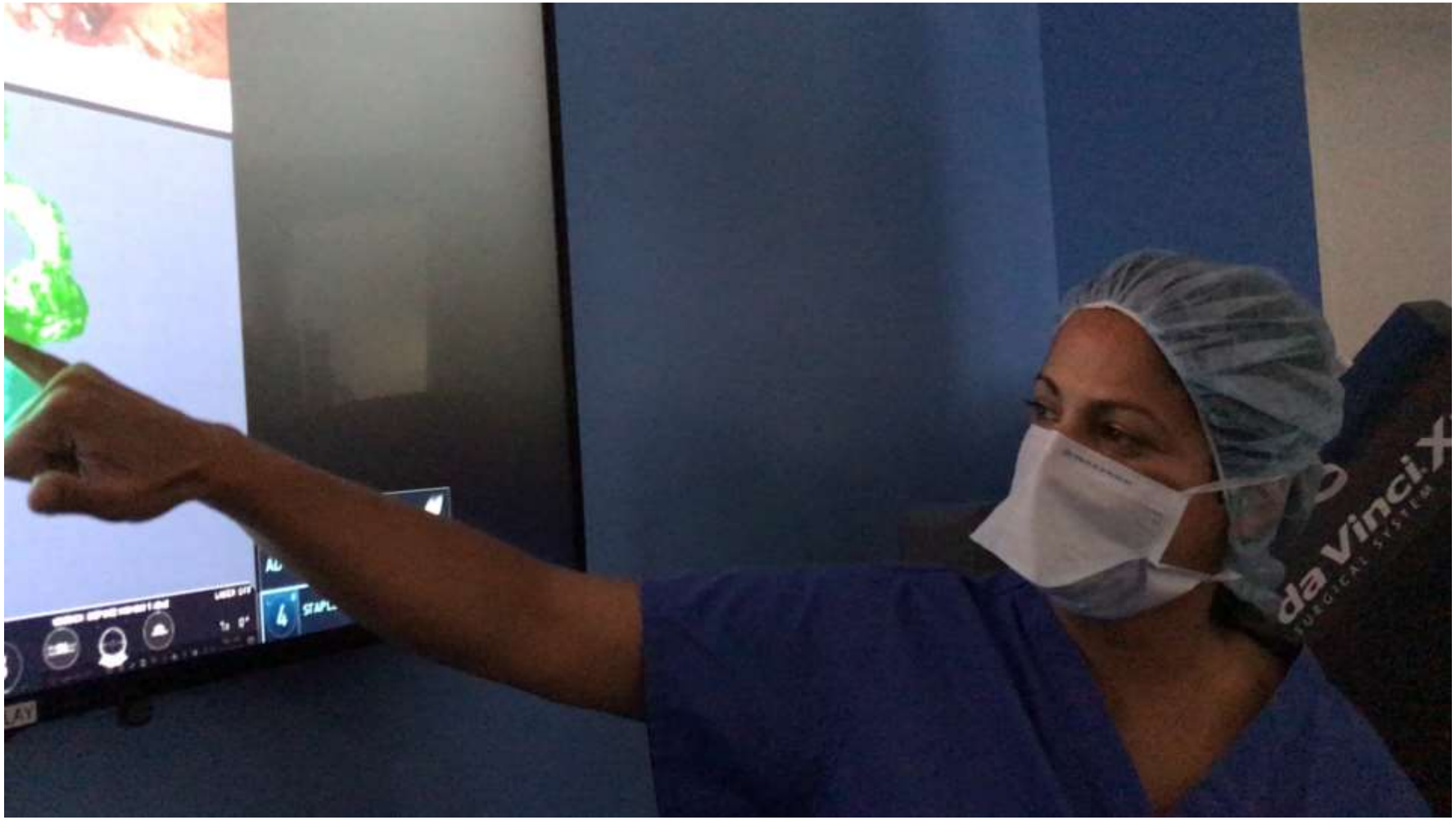


OR Team Using Large Screens To Watch Dr. Schulze's da Vinci Images

Dr. Ramamoorthy Using Interactive 3D Anatomy To Plan Resection of Sigmoid Colon Which is Resting on Top of Bladder



Dr. Ramamoorthy's Use of 3D Interactive Anatomy To Guide Surgical Team on Site For Bowel Division



Dr. William Sandborn Using Colonoscope in OR To Examine Stapled Anastomosis



Dr. William Sandborn Performing Colonoscopy While da Vinci Observes from Inside Abdomen



Dr. Santi Horgan, Director of Minimal Invasive Surgery, Pointing to Stapled Anastomosis

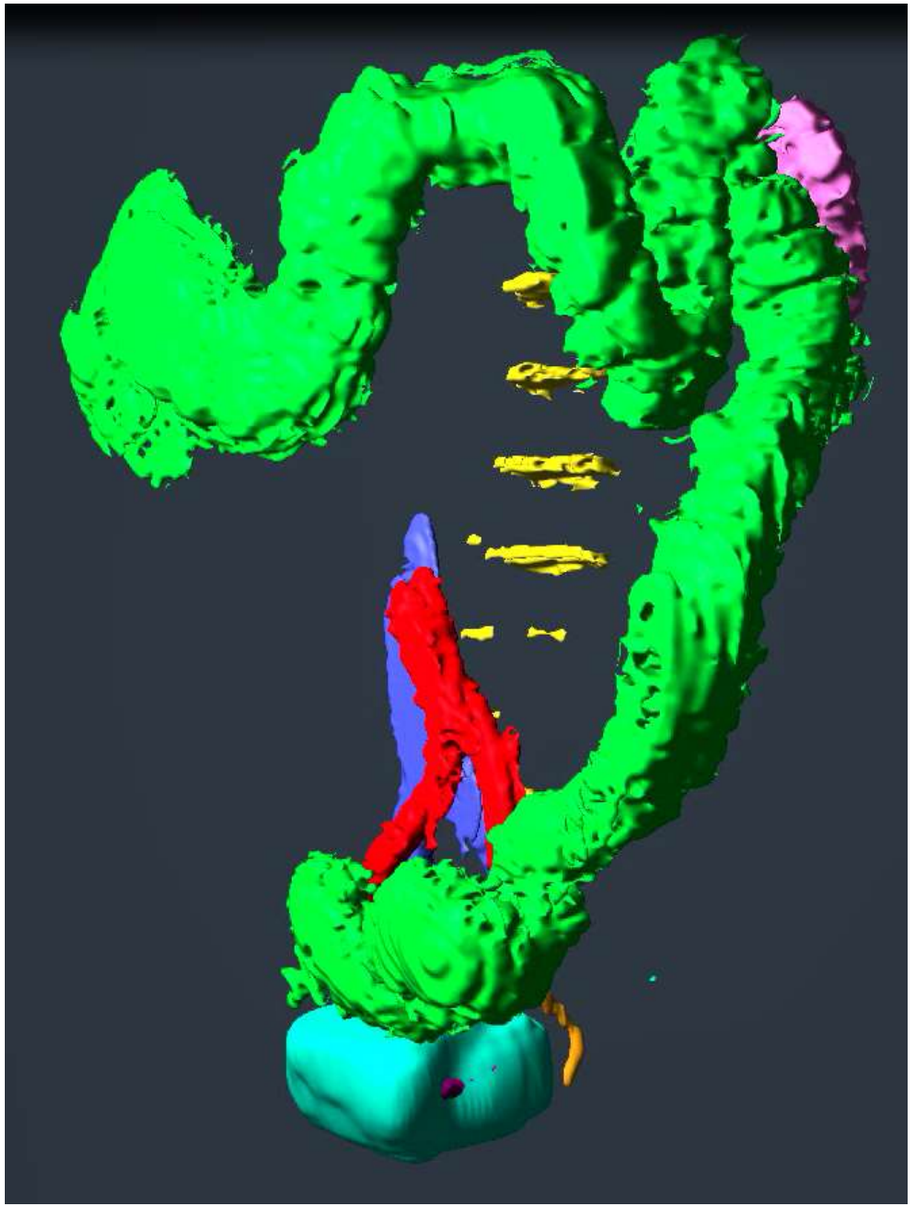
Removing the Resected Colon

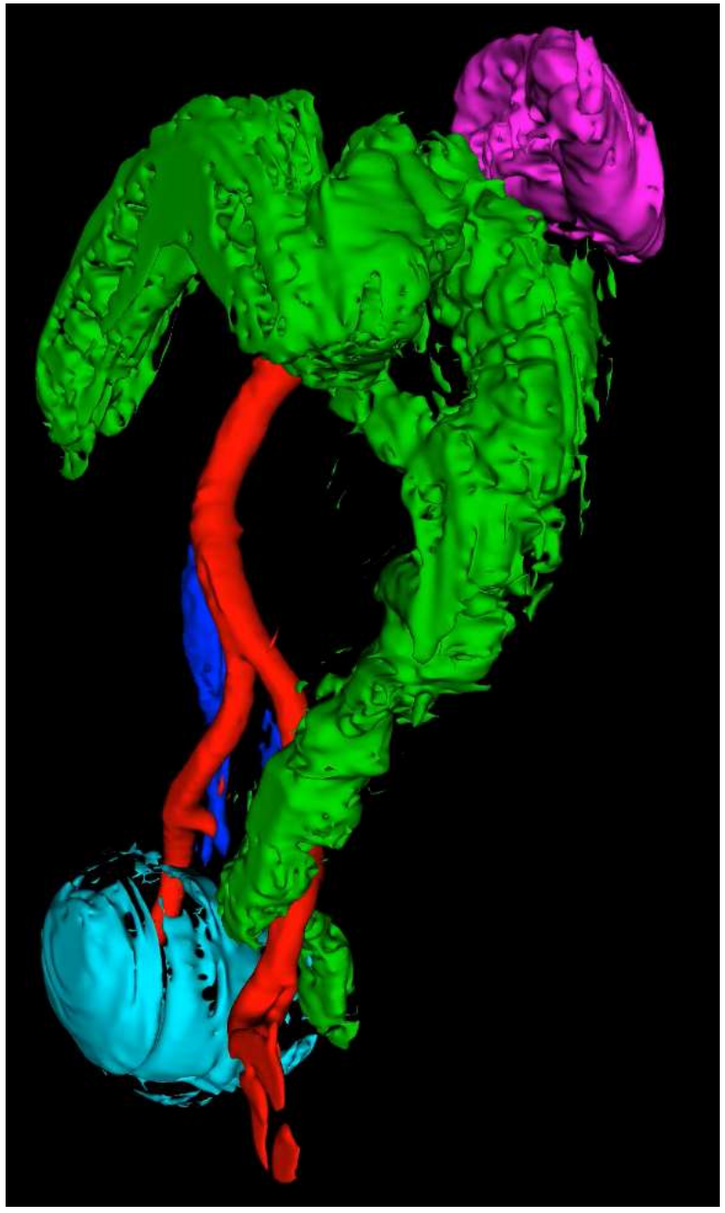




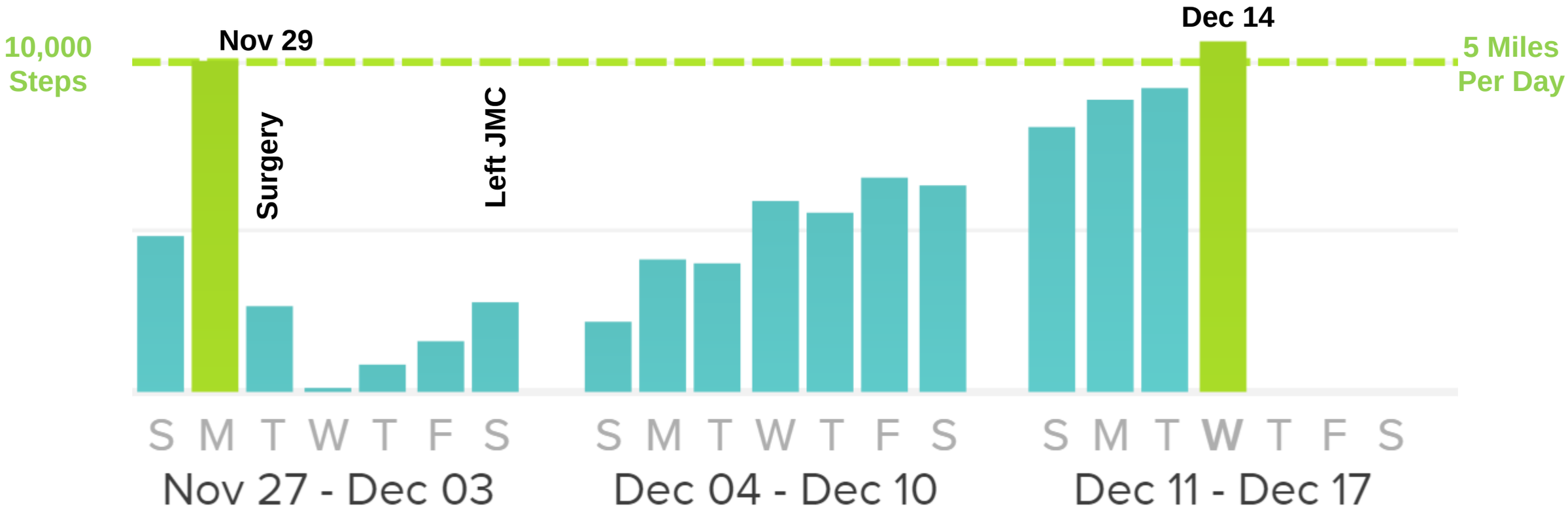
Quantifying Surgery Recovery

Colon Before and After Surgery

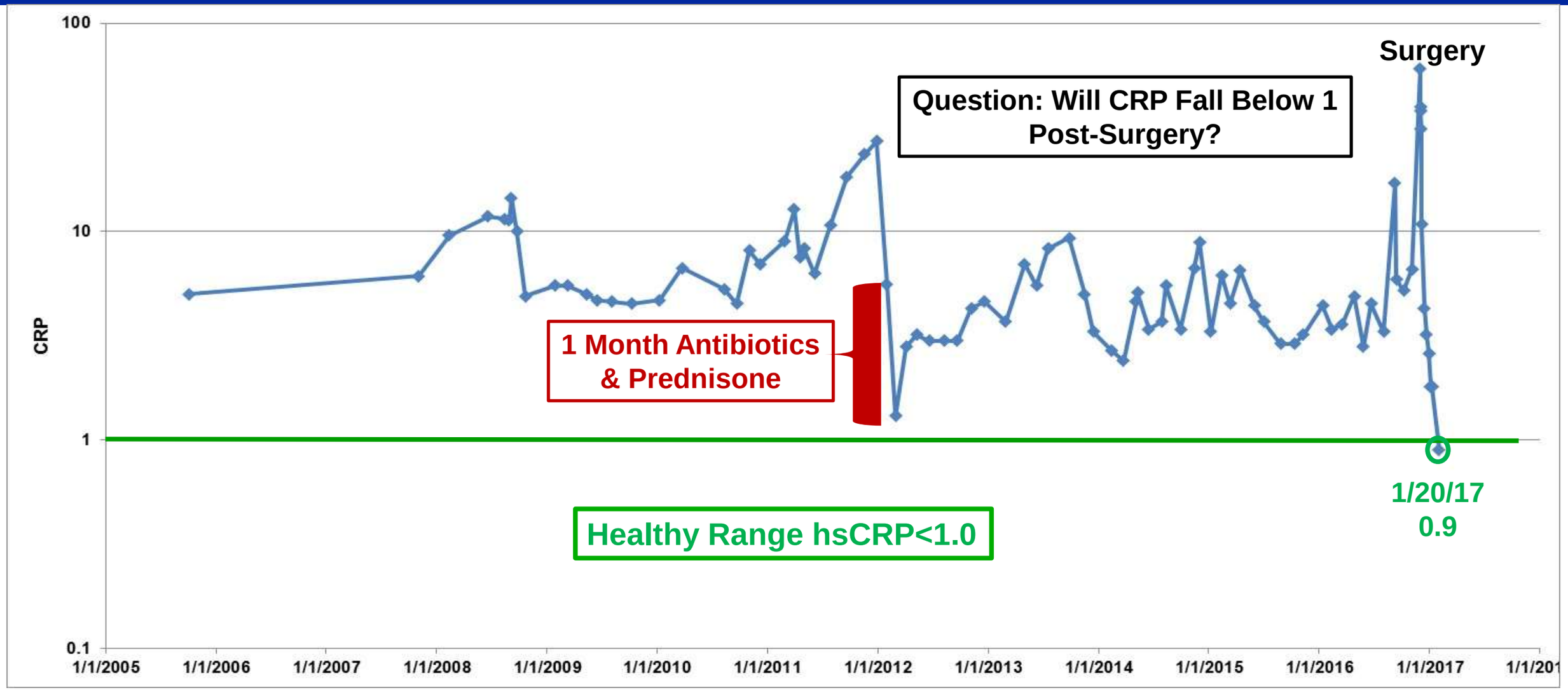




Quantified Recovery (Steps Walked Per Day) - Recovered to Pre-Surgery Level in Two Weeks



CRP Has Not Been Less Than 1.0 in 12 years
Spiked Day After Surgery, Followed by Decrease to a Healthy Level



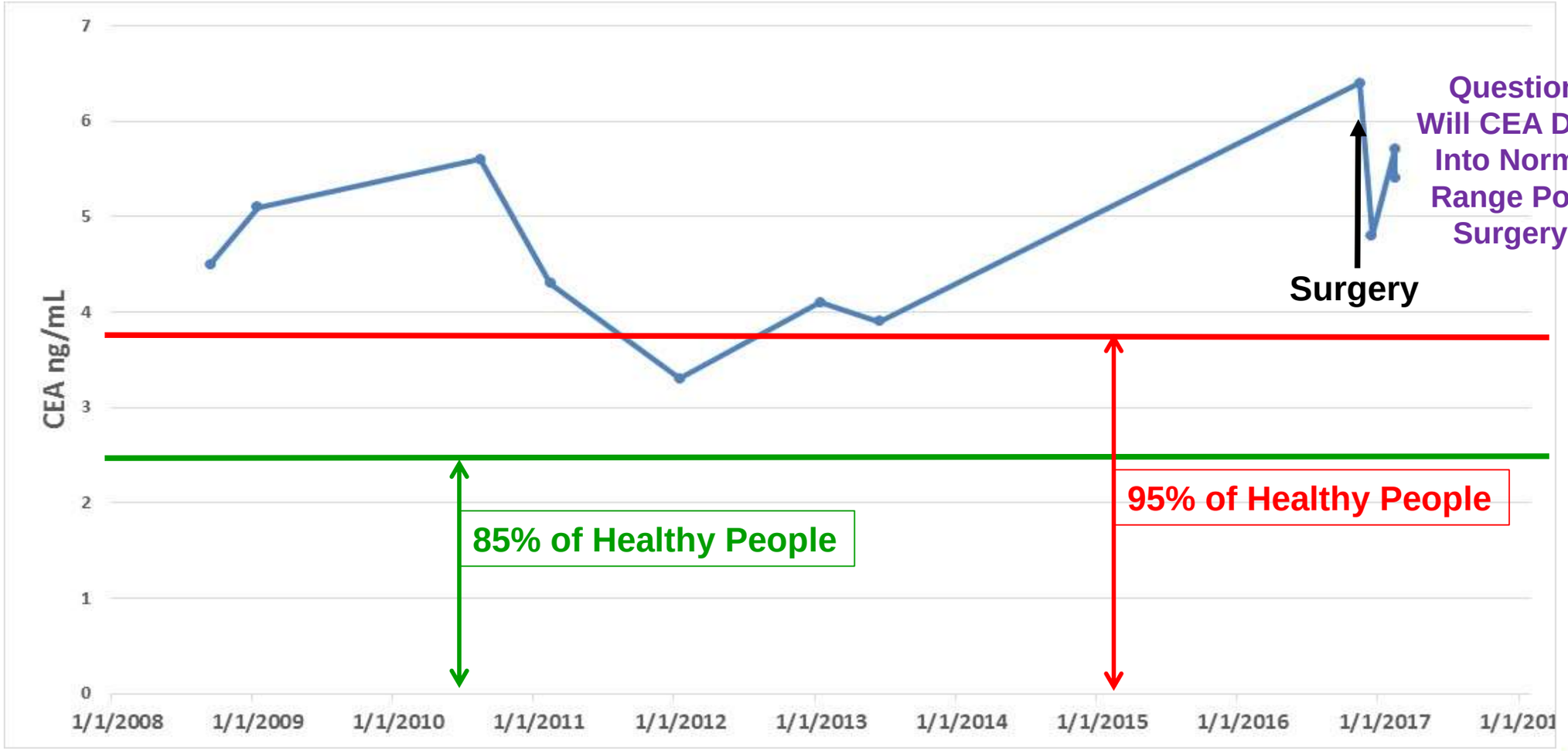
Resected Colon
Stained for Pathology





Carcinoembryonic Antigen (CEA) Screening Test for Cancer Was Elevated and Increasing, Dropped After Surgery

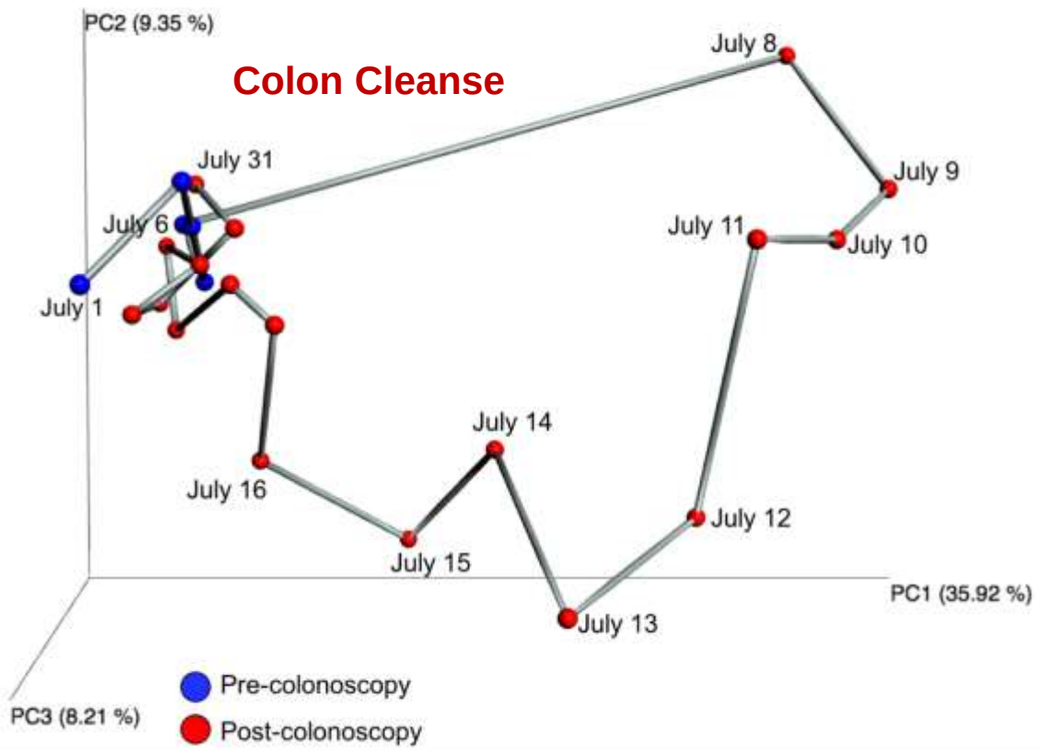
"Elevated levels are also frequently seen in other gastrointestinal diseases including peptic ulcer, pancreatitis, diverticulitis, and inflammatory bowel disease. Benign diseases rarely produce CEA serum levels >10 ug/L."



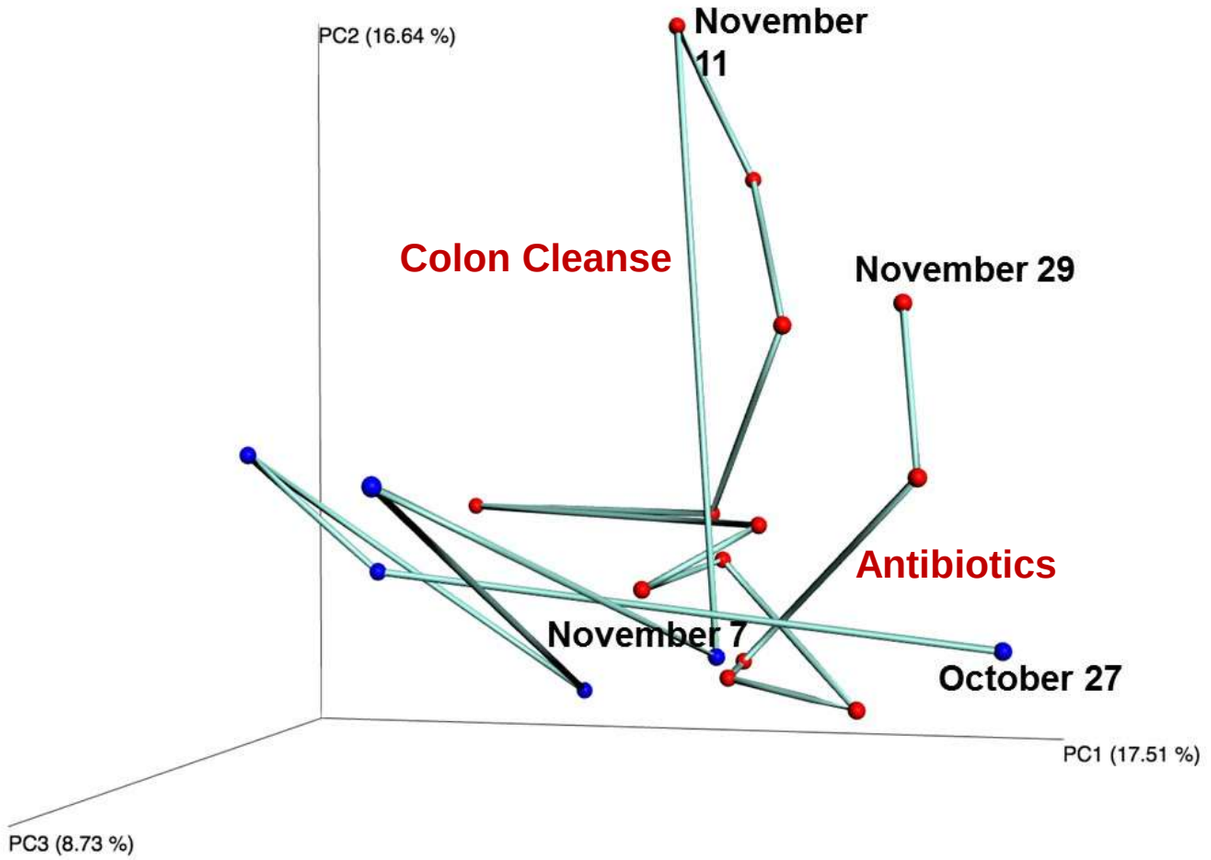
Ranges from Exeter Clinical Labs www.exeterlaboratory.com/test/carcinoembryonic-antigen-cea/

Microbiome Ecology Highly Disrupted by Medical Interventions

July 2015 Colonoscopy

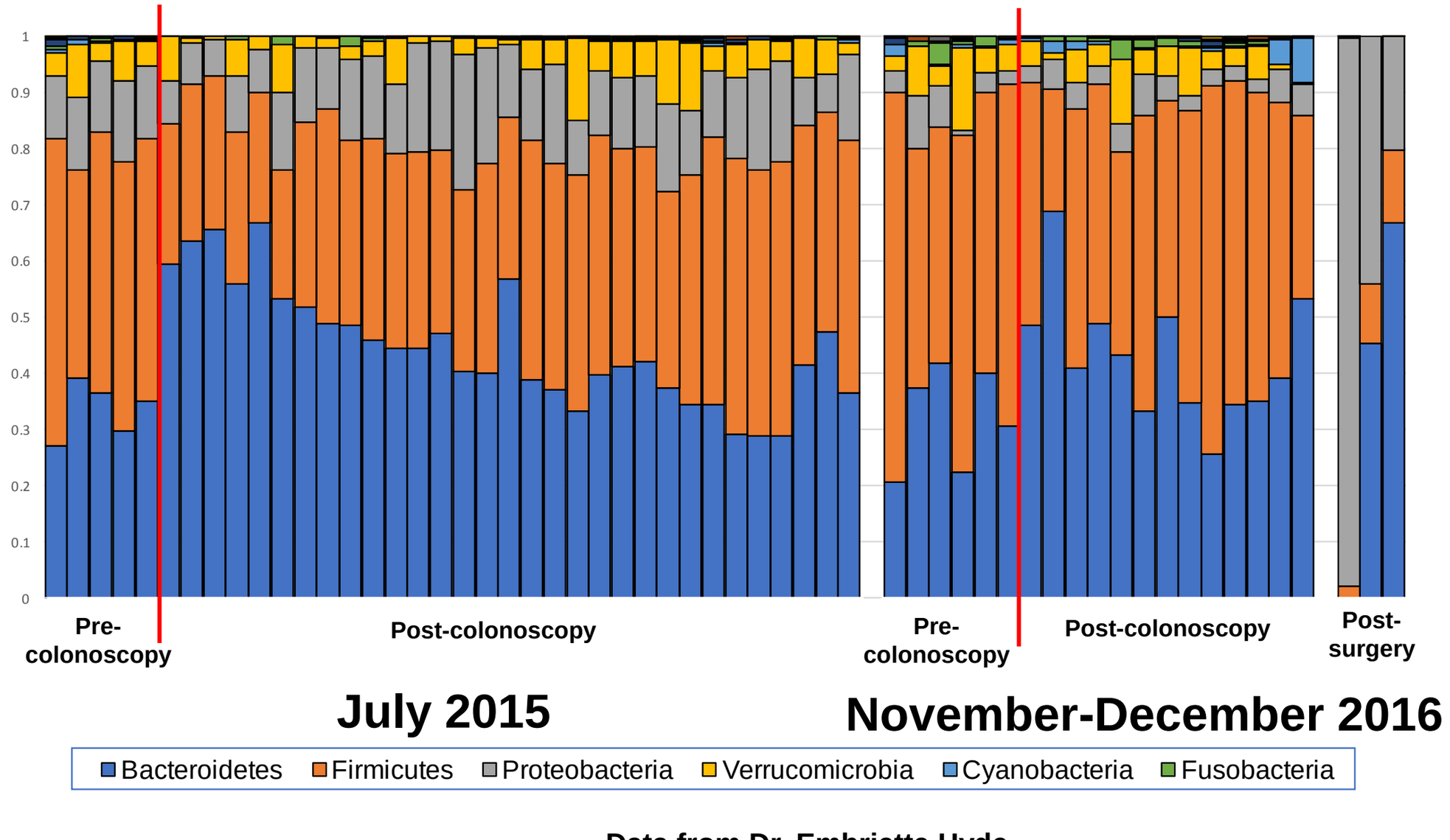


November 2016 Colonoscopy



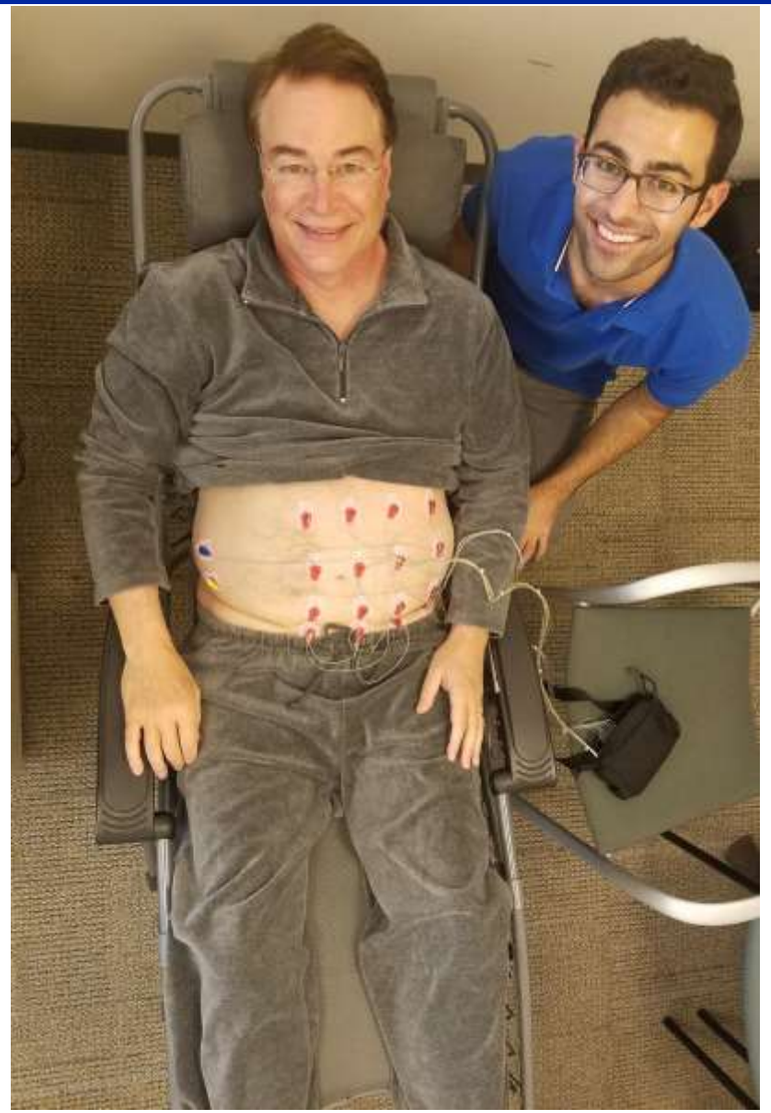
Data from Dr. Embriette Hyde, Rob Knight Group, UCSD

Phylum Level Changes
Associated with Colonoscopy and Surgery



Data from Dr. Embriette Hyde,
Rob Knight Group, UCSD

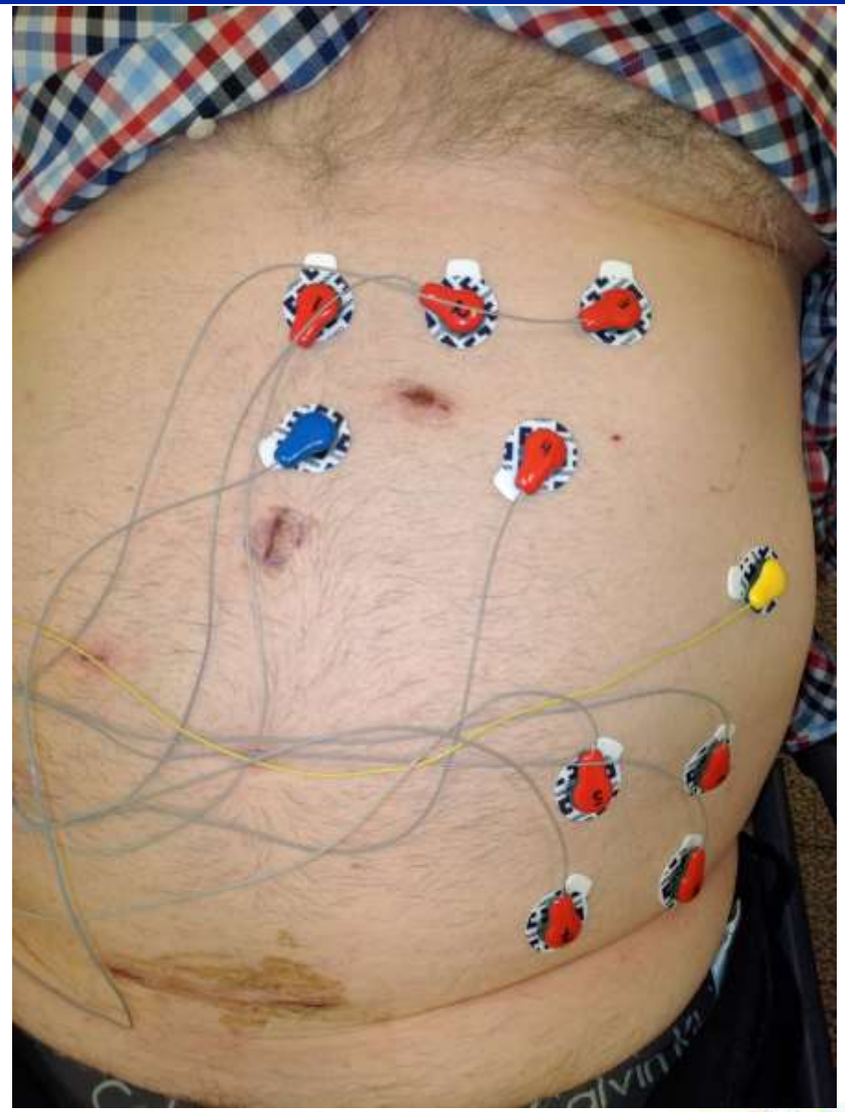
EGG Array in UCSD Professor Todd Coleman's Lab Experiment with PhD Student Armen Gharibans



1 Week Before Surgery



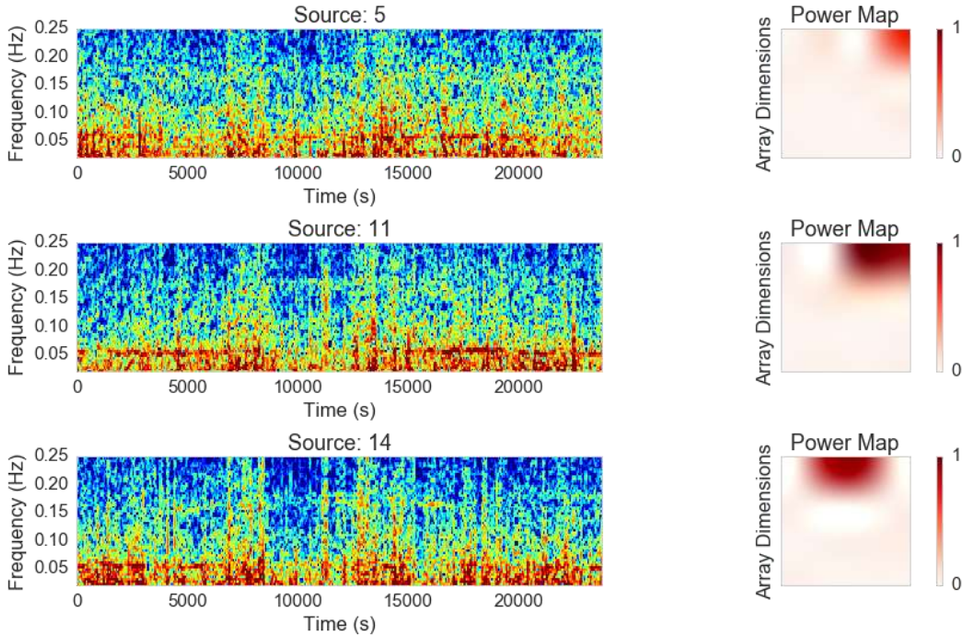
2 Days After Surgery

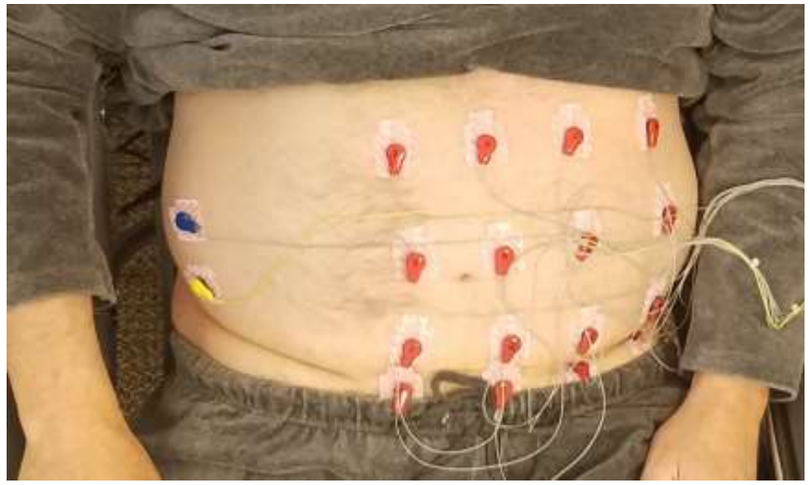


2 Weeks After Surgery

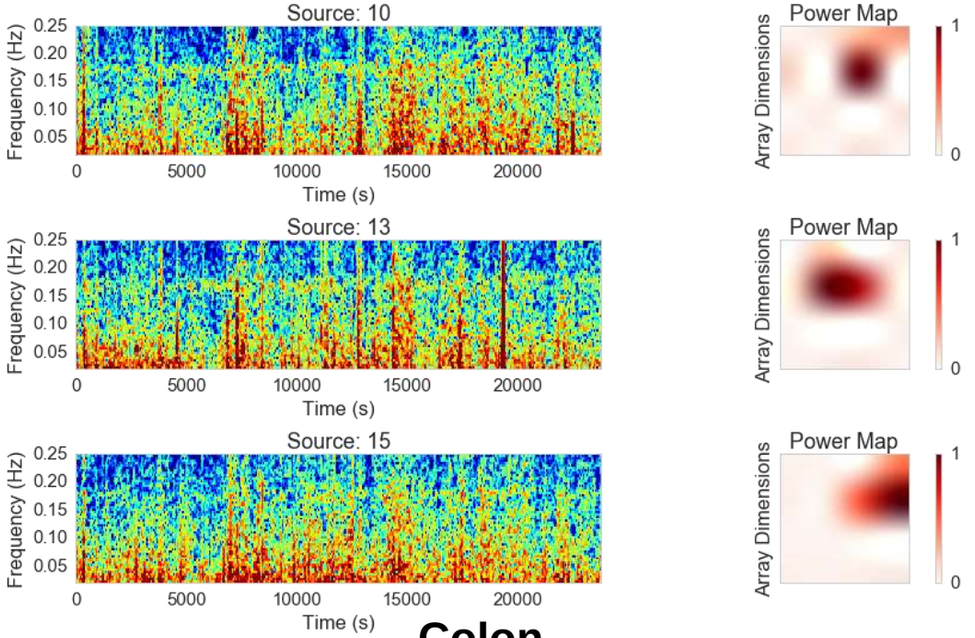
Using EGG to Separate Out the Components of the GI Tract

Stomach (0.05 Hz)

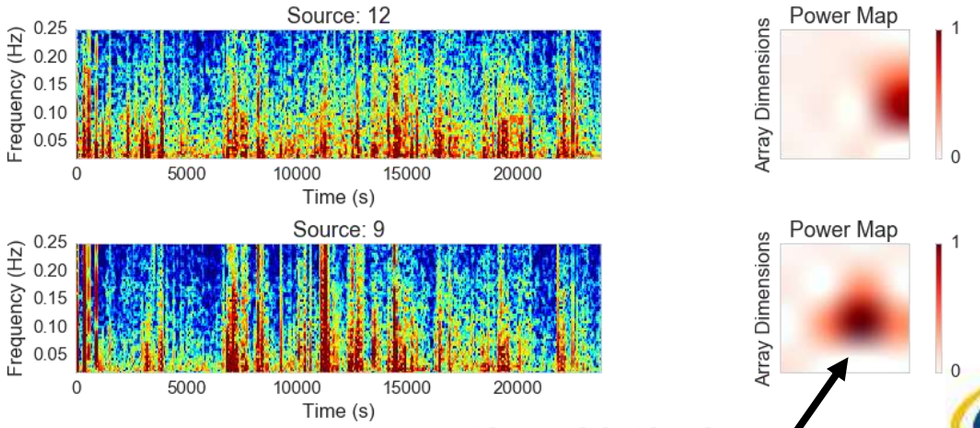




Small Intestines (0.18 Hz)



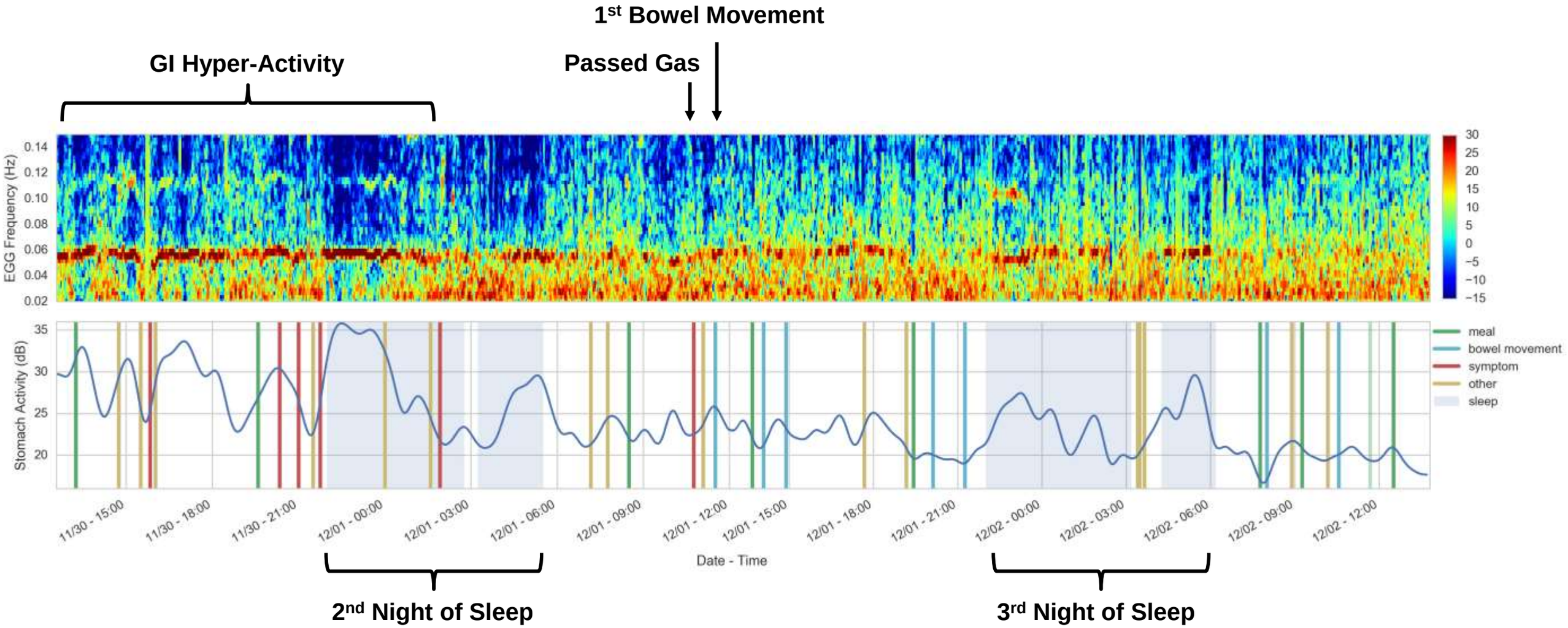
Colon



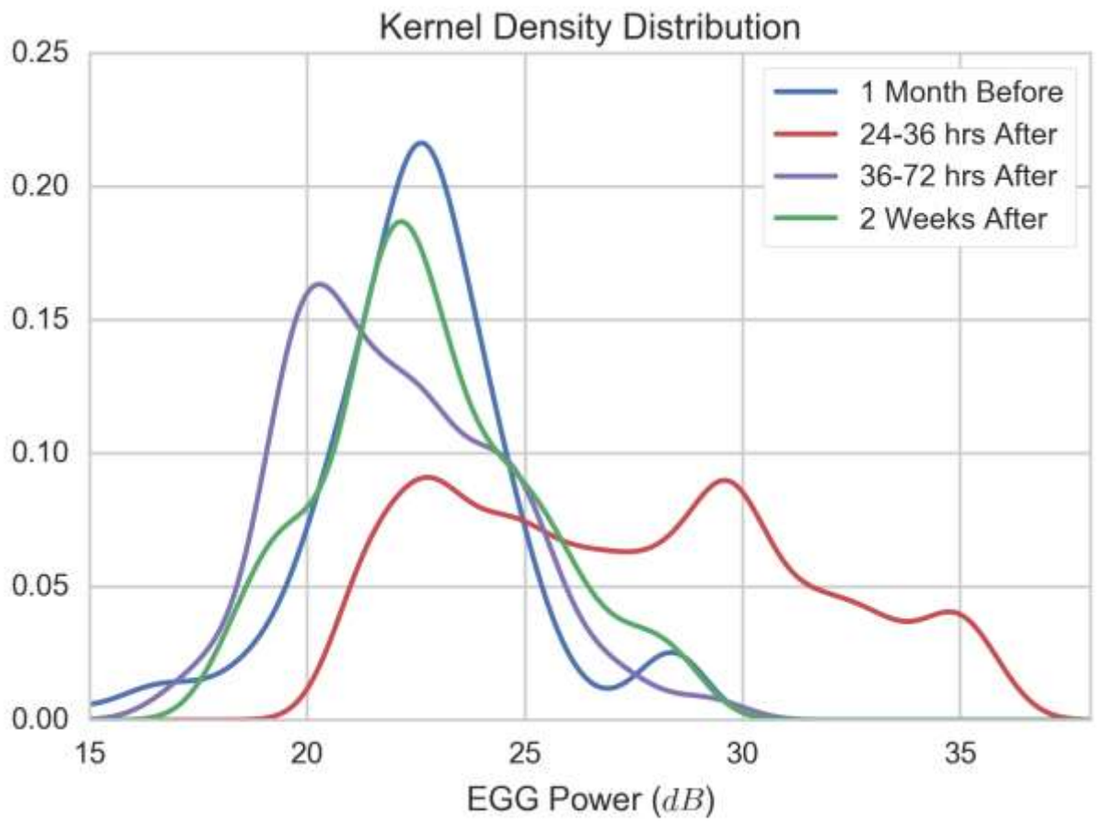
Sigmoid Blockage

Source: Armen Gharibans, UCSD

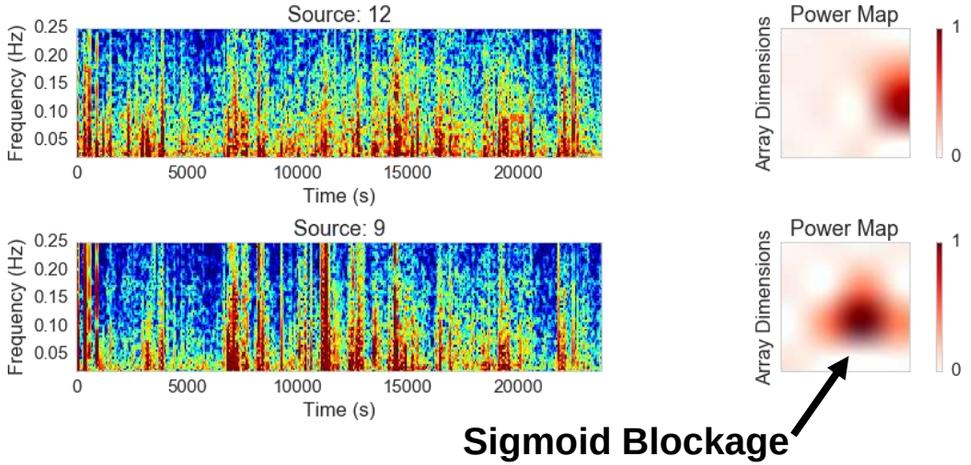
GI Activity 24 to 72 Hours After Surgery



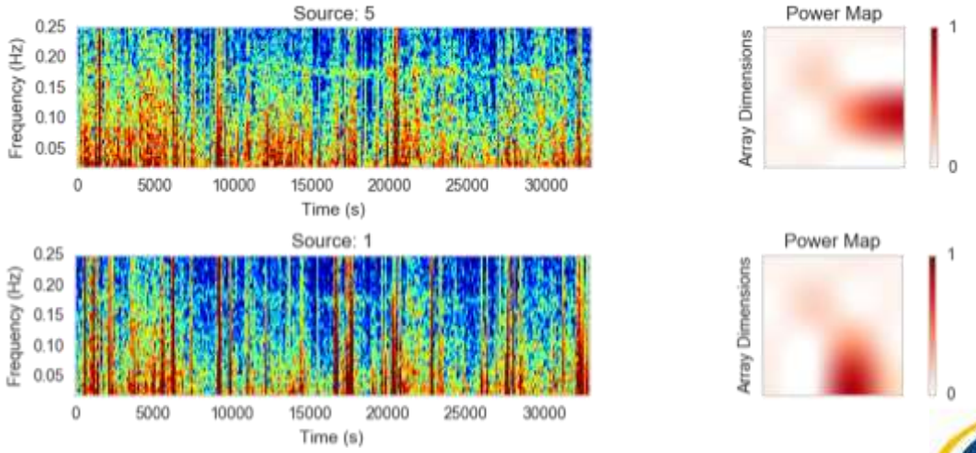
Tracking Recovery of Normal GI Activity After Surgery



Colon Before Surgery

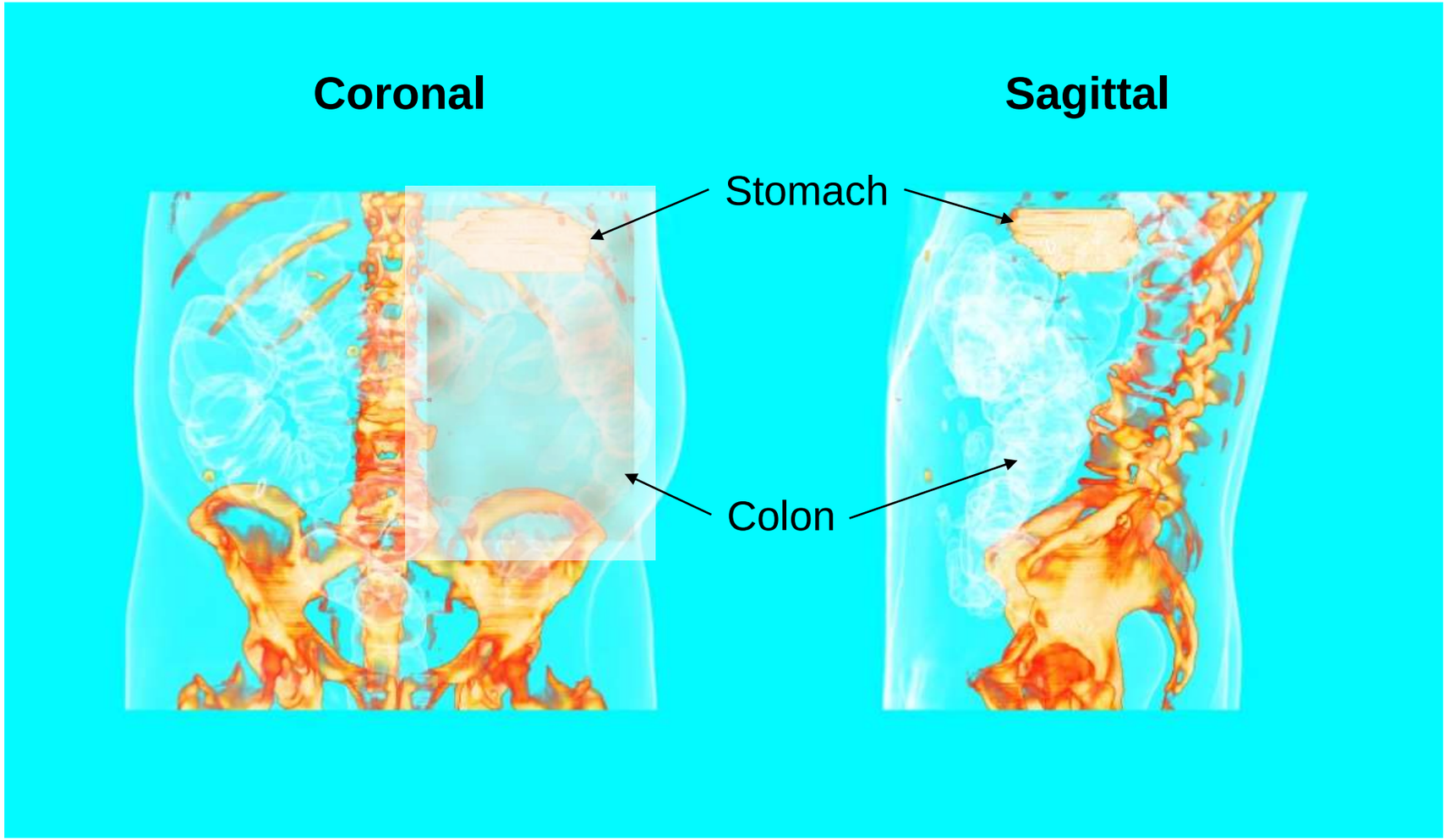


Colon After Surgery



Research Frontier: Combining CT/MRI Imaging with High Resolution EGG





Source: Armen Gharibans, UCSD

Quantified Surgery:
The Path Forward

- **Increased Cross-Campus Collaborations**
- **Calit2 Hub in Altman to Support Translational Medicine**
- **Public / Private Partnerships Focused on OR**
- **More Patient Volunteers for Evaluating Advanced Technologies**