Robotics: Merging of Surgical and Endoscopic Technologies

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Washington University in St. Louis
Director, Robotic Sugery Program, BJC HealthCare
Director, WISE Simulation Center

Outline

Why Robotics?

Current State

Future Directions

Disclosures

Educational Grants

- Applied Medical, Bard, Baxter, Ethicon, Intuitive, Medtronic, Stryker

Consultant

- Ethicon, Intuitive, Medtronic

Minimally Invasive Surgery

Fewer Incisions

Smaller Incisions

No Incisions

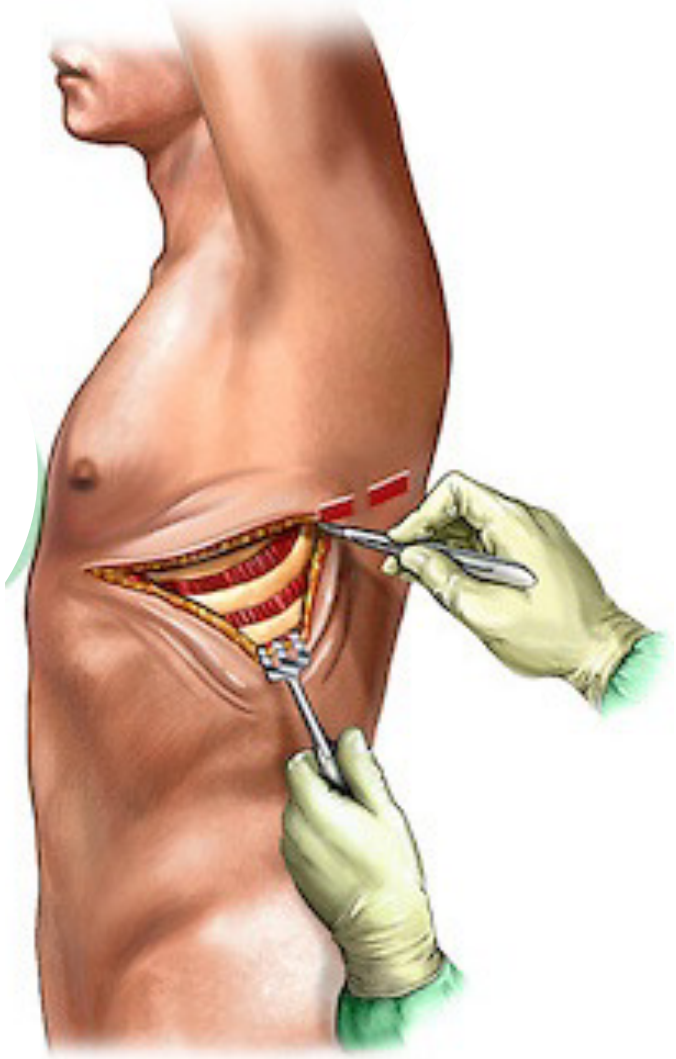
Minimally Invasive Surgery

SURGICAL TREATMENT OF ACHALASIA

Pre – 1991

Heller Myotomy

Thoracotomy



Minimally Invasive Surgery

SURGICAL TREATMENT OF ACHALASIA

1991-present

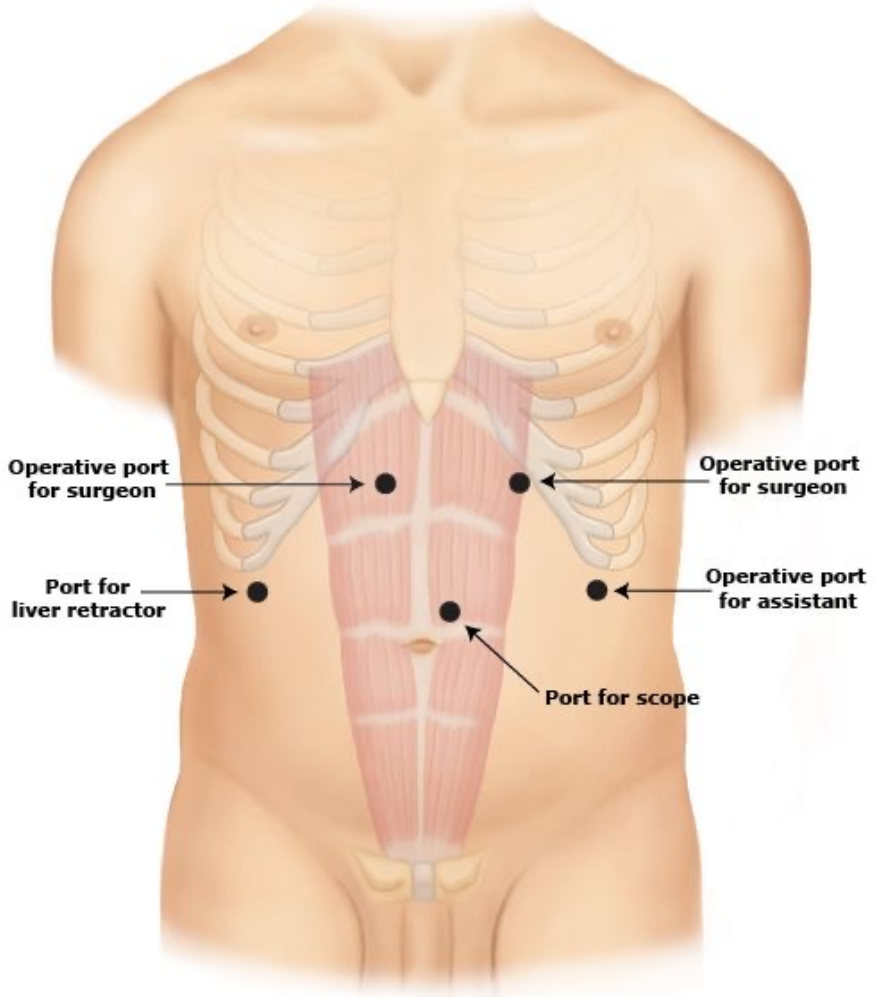
Laparoscopic

Heller Myotomy

⇩ **PAIN**

⇩ **MORBIDITY**

⇧ **RECOVERY**



Minimally Invasive Surgery

SURGICAL TREATMENT OF ACHALASIA

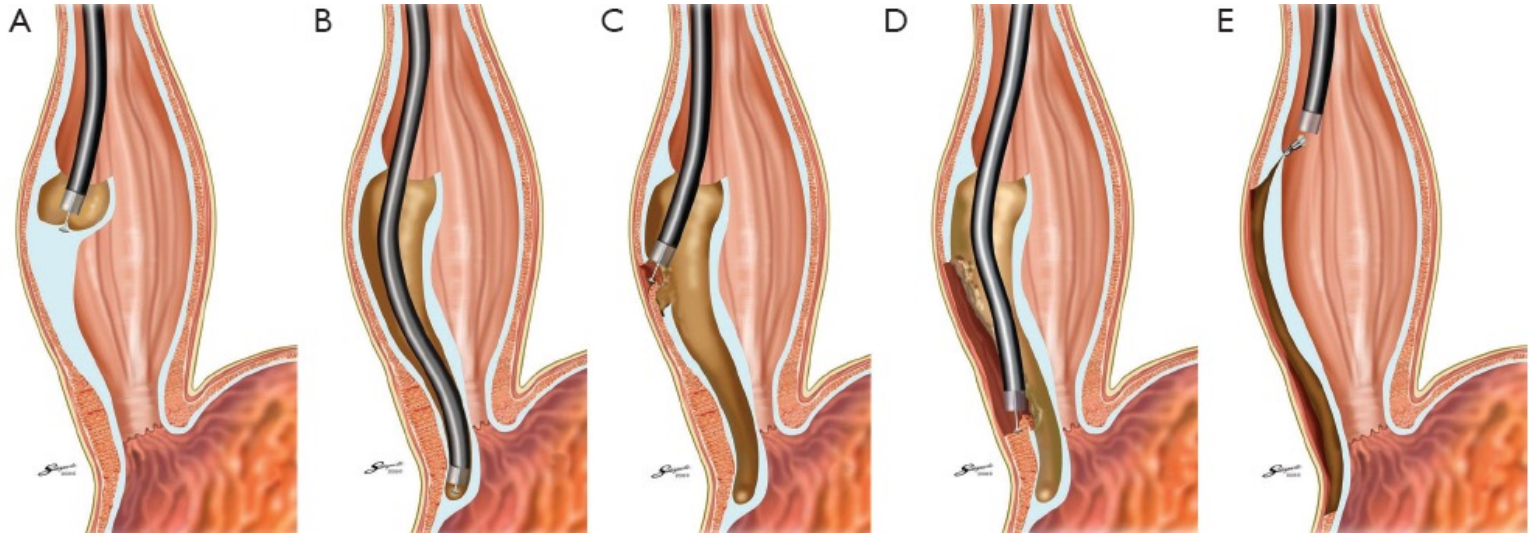
POEM Procedure

2009-present

PAIN

MORBIDITY

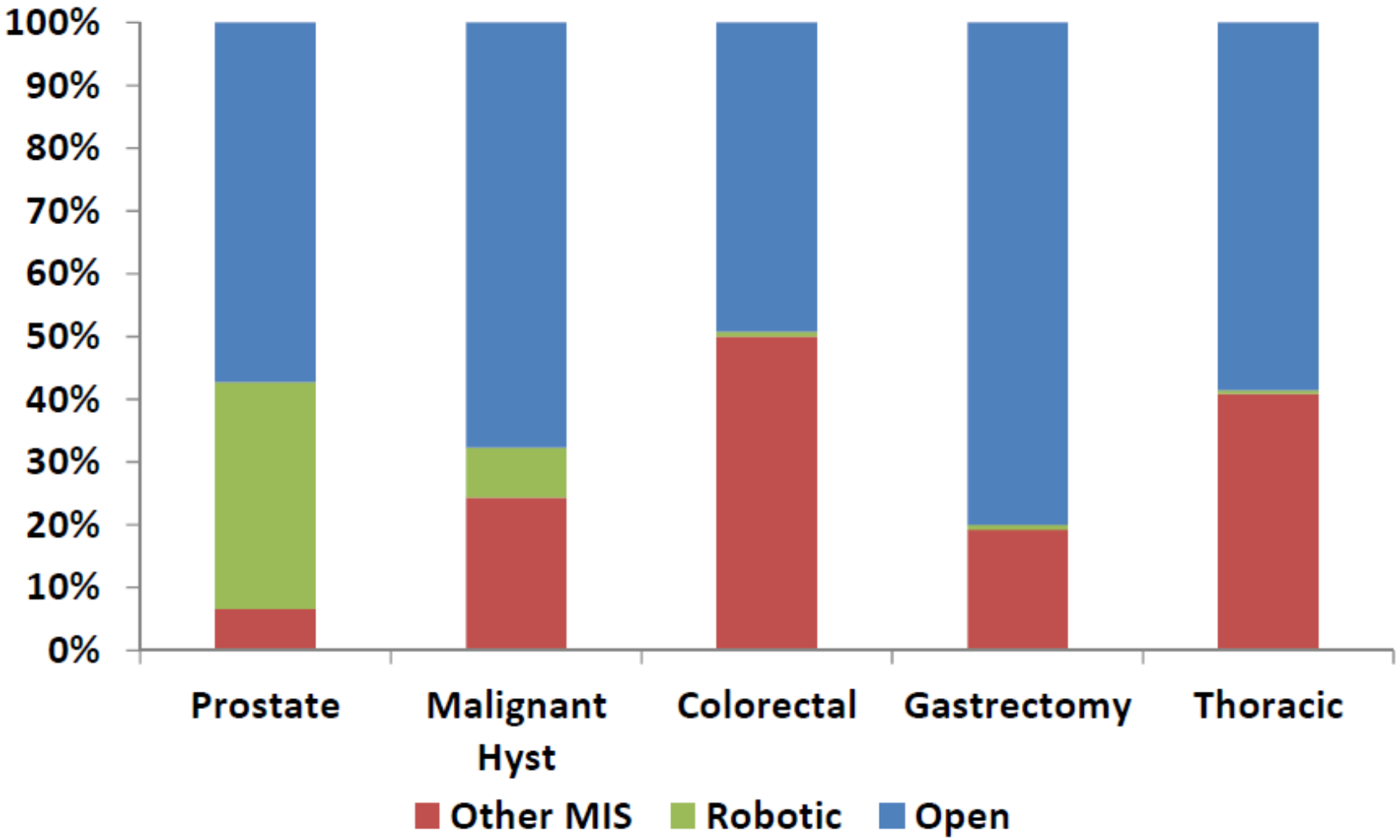
RECOVERY



Minimally Invasive Surgery

SOUNDS GREAT, BUT…

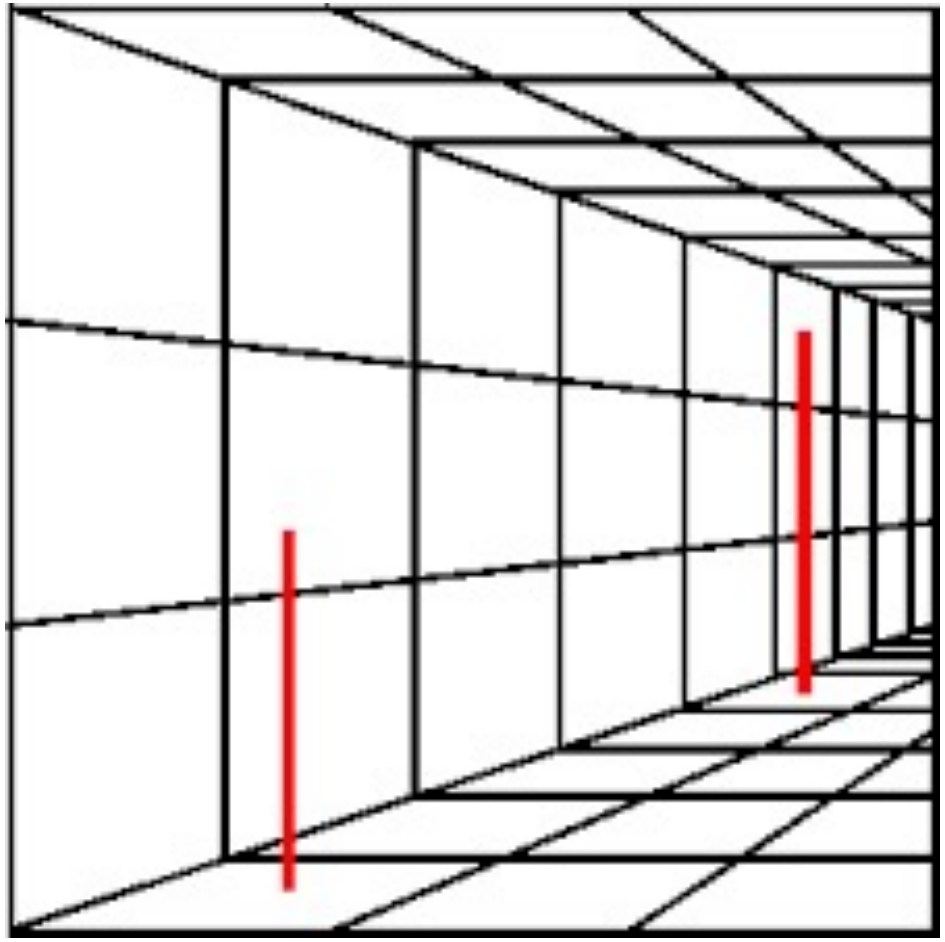
Penetration of Laparoscopy in World (2020)



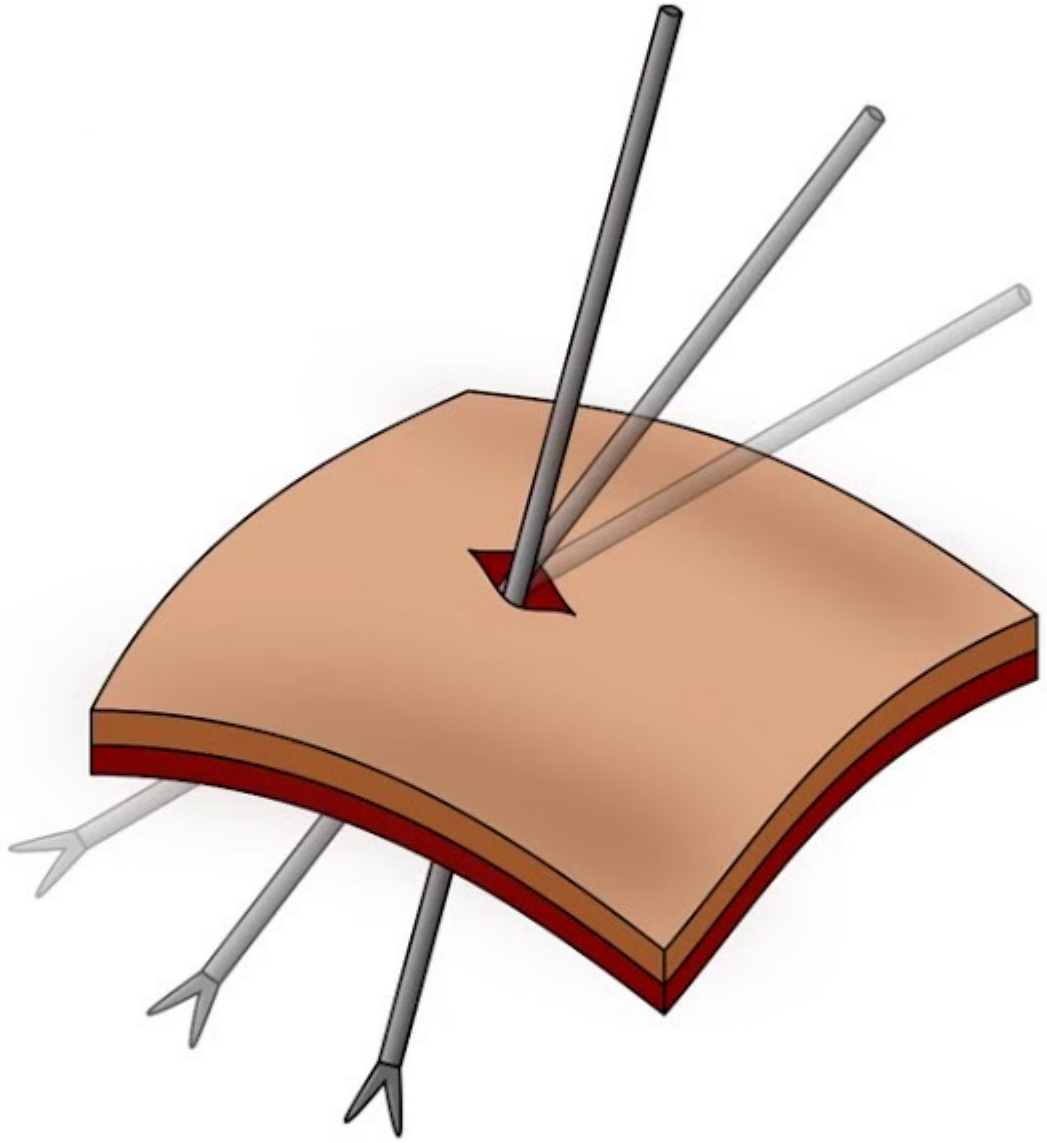
Minimally Invasive Surgery

What makes it difficult?

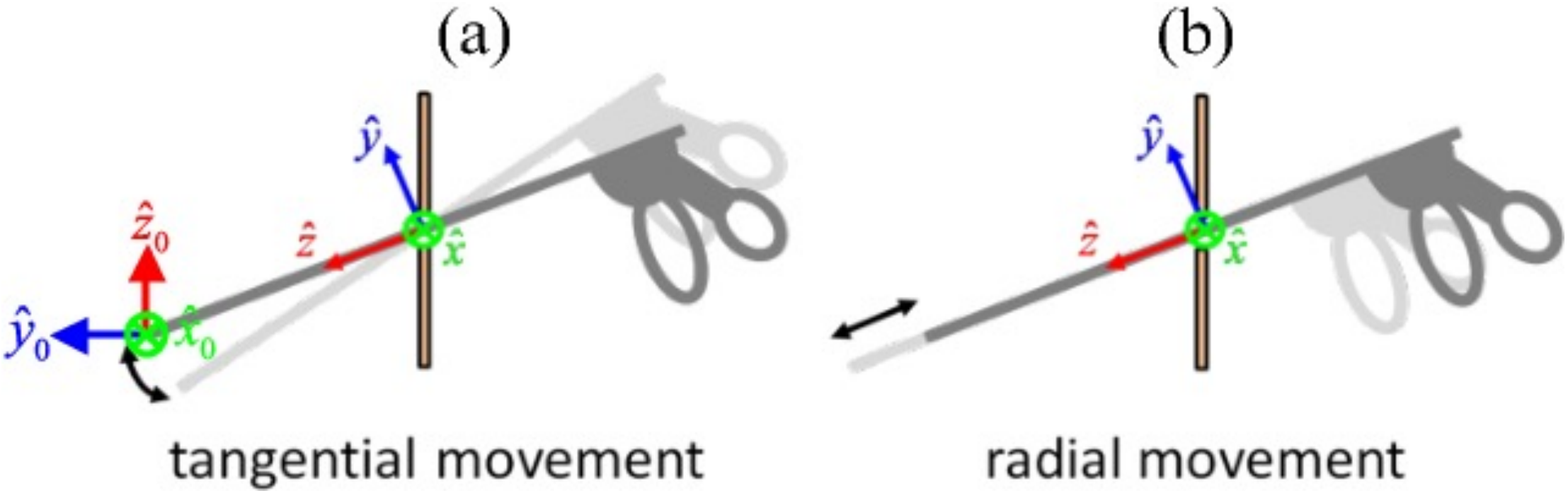
3D → 2D; Loss of Depth Perception



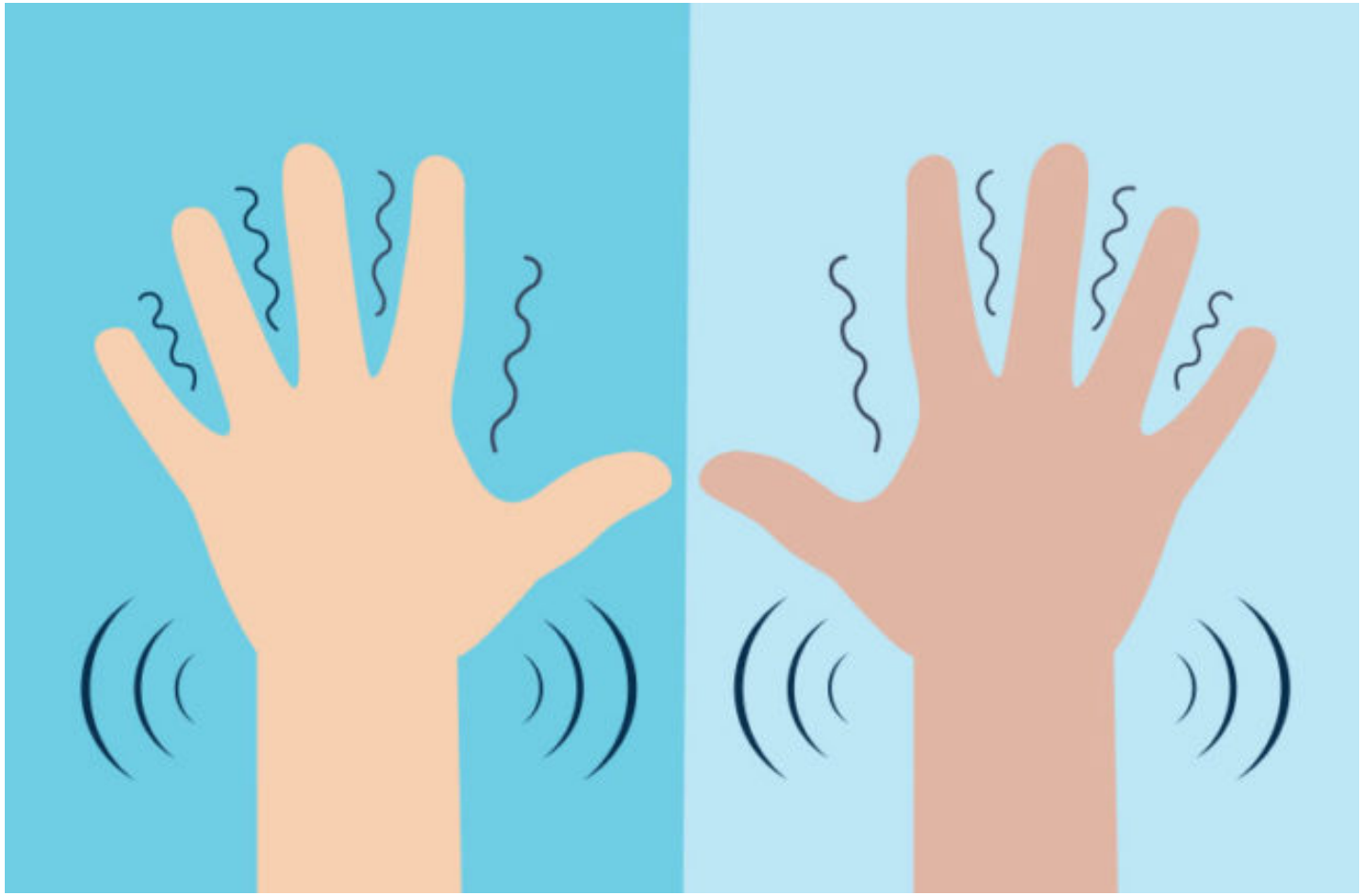
Fulcrum Effect



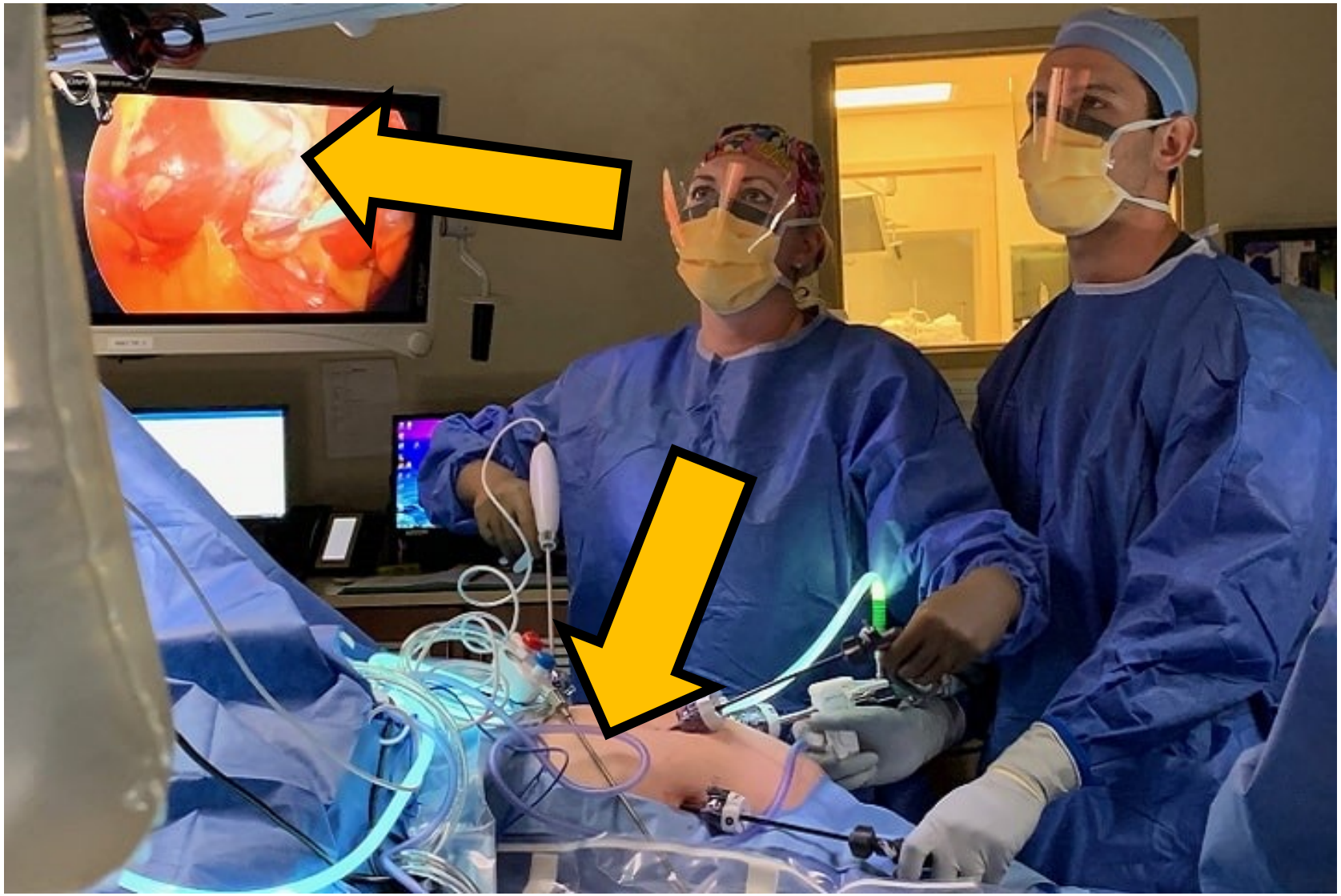
4 Degrees of Freedom



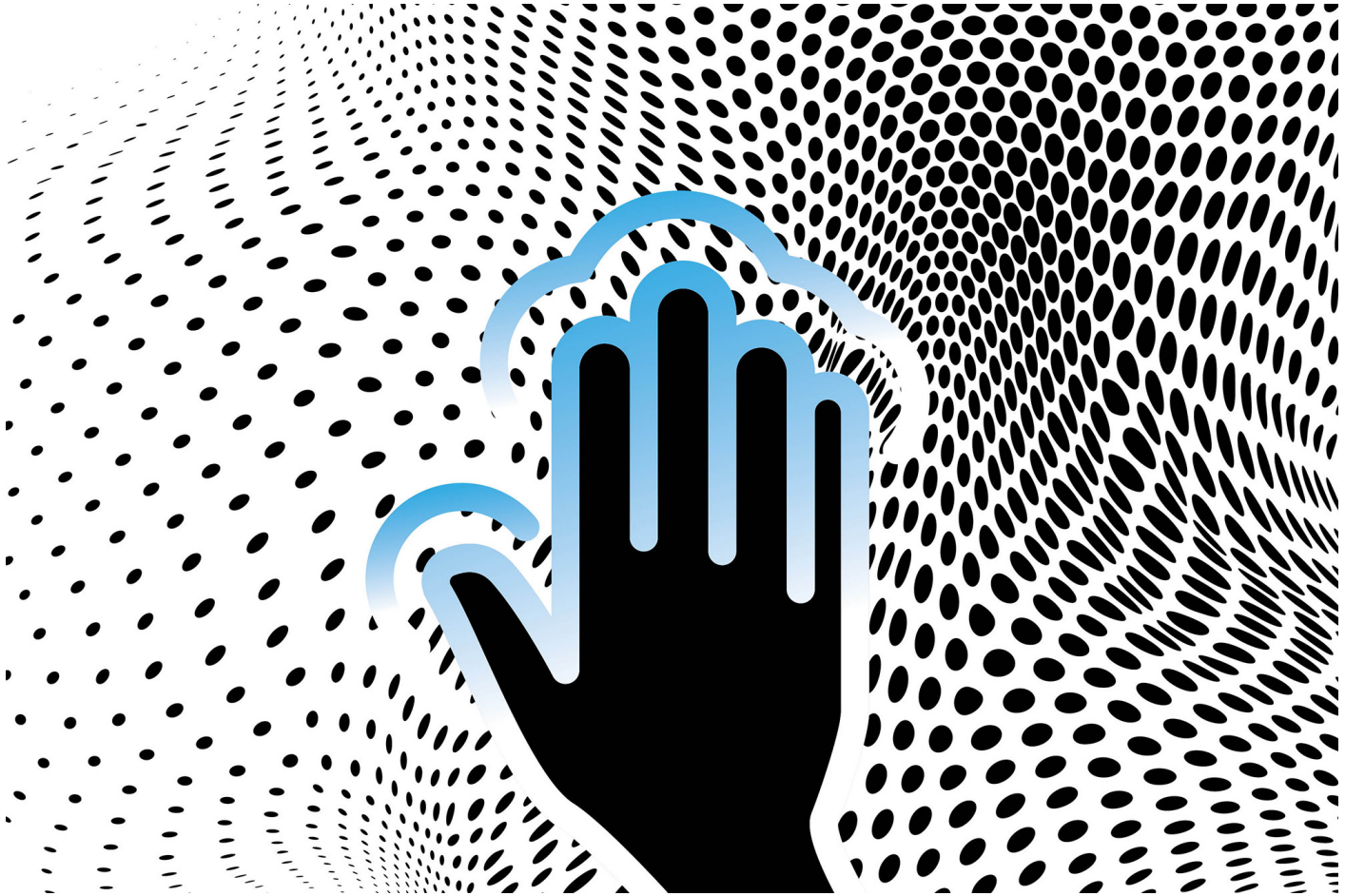
Tremor Exaggeration



Decoupling of Motor and Visual Axes



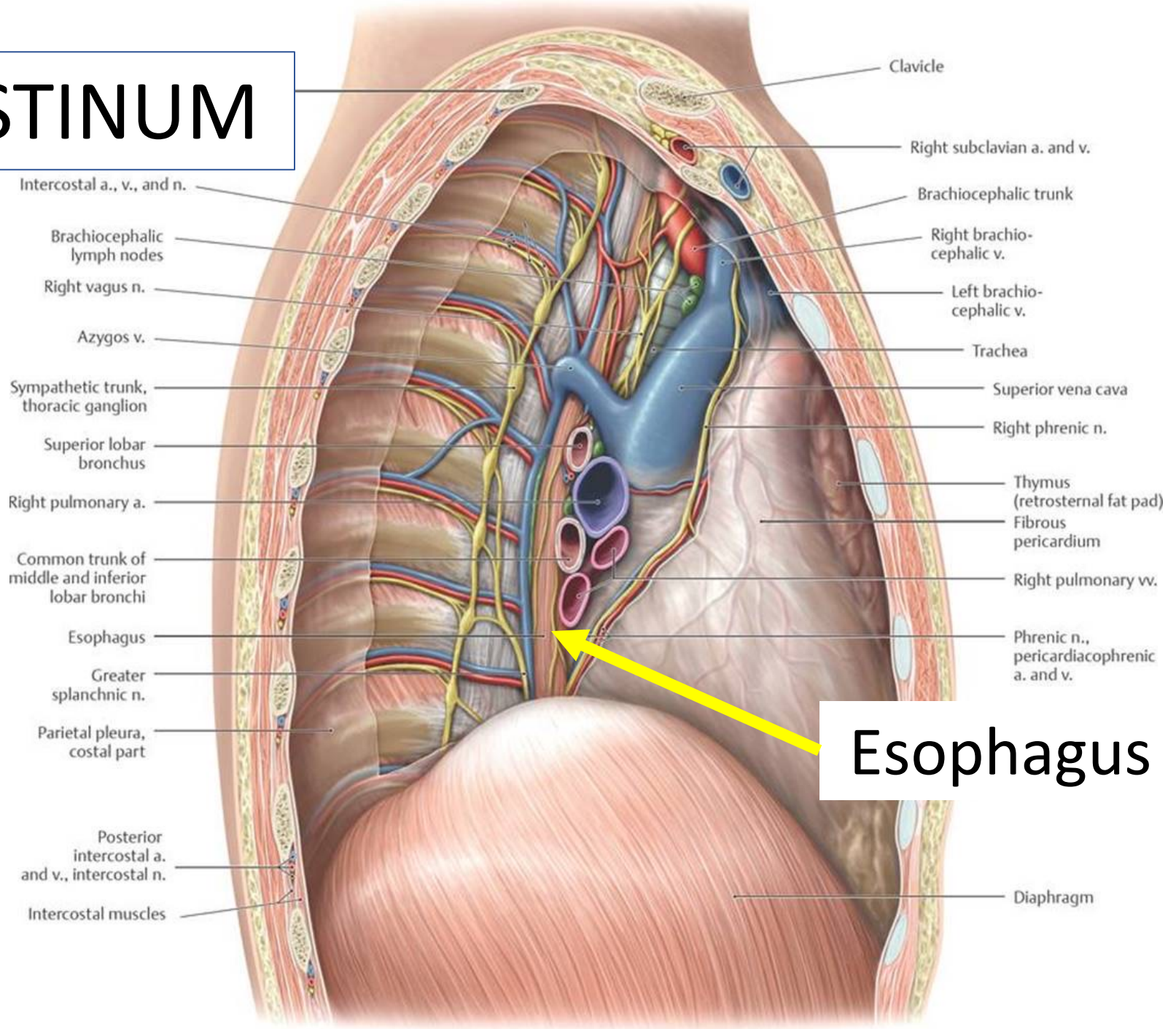
Loss of tactile sensation (“haptics”)



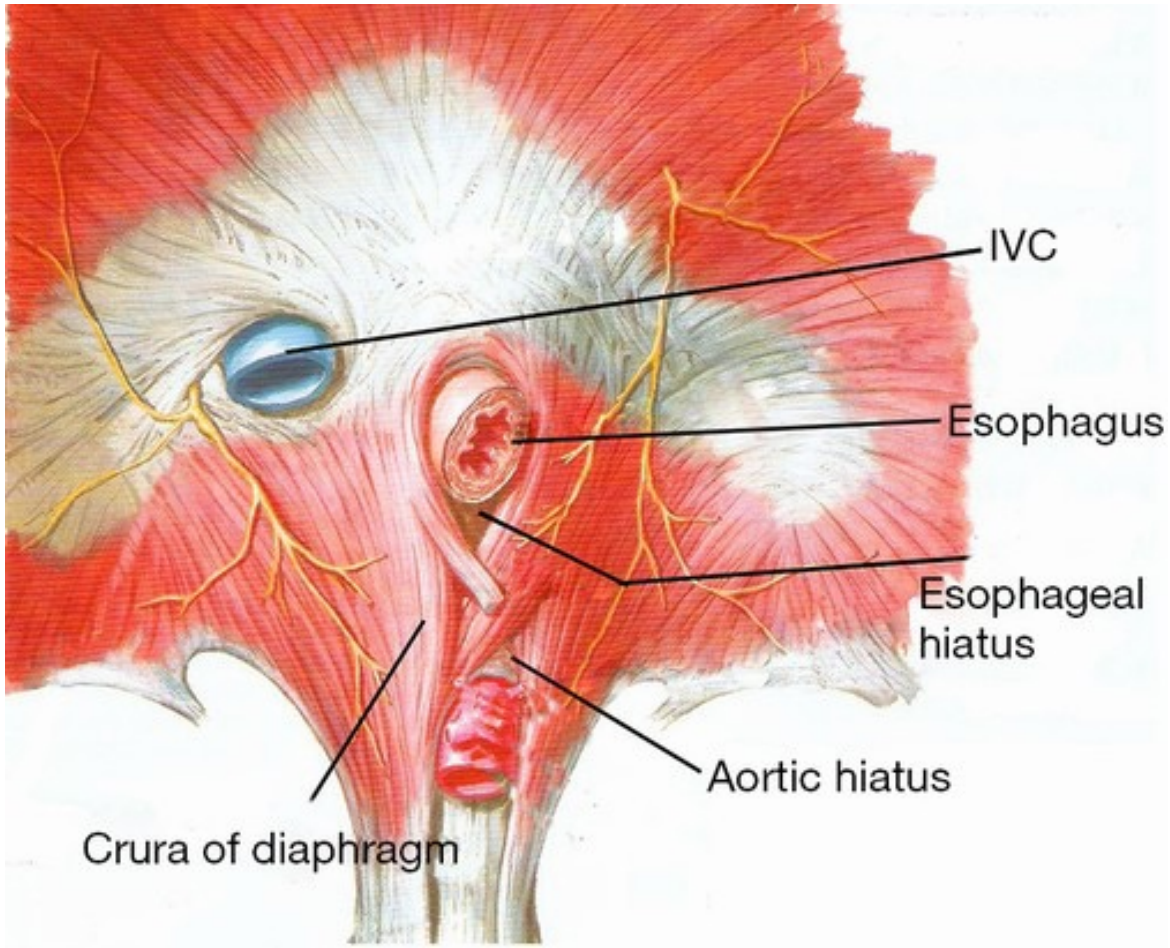
Camera not under surgeon’s control

Static posture

MEDIASTINUM



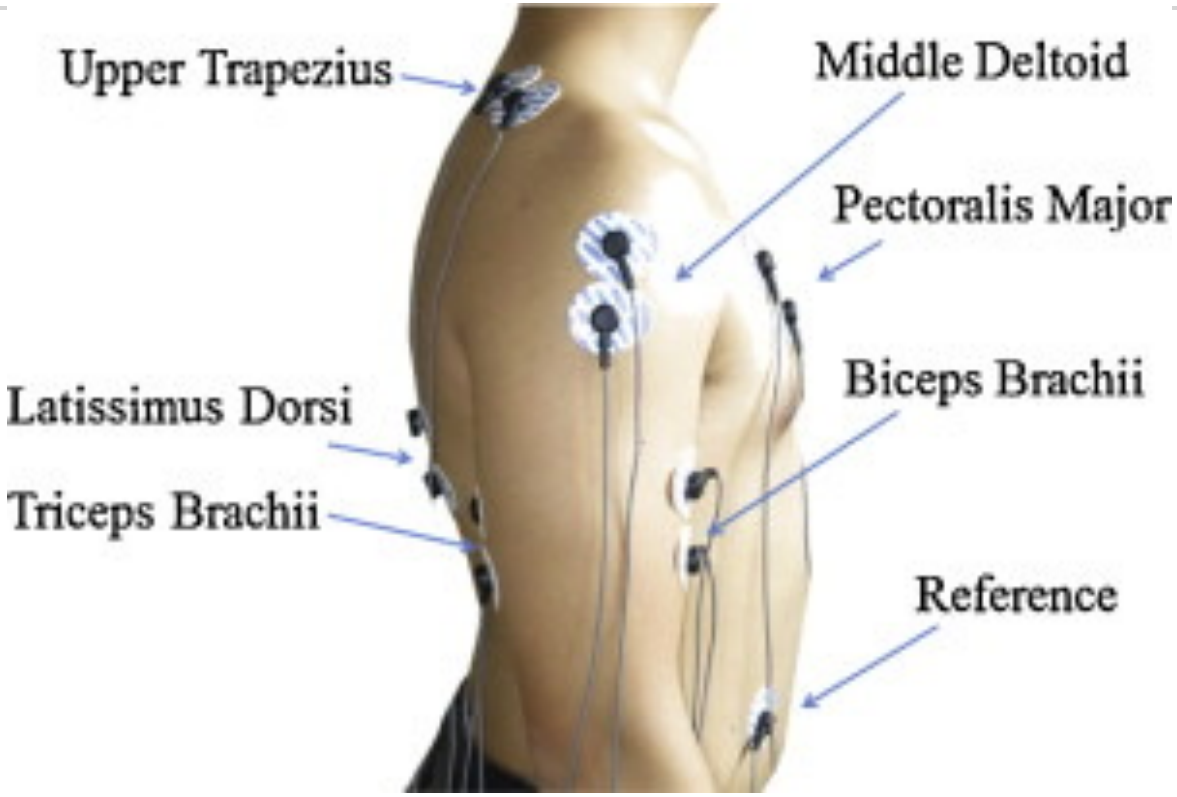
Esophageal hiatus
1.5cm-2cm



PAIN

Poor Ergonomics Is An Occupational Hazard

Awad Ergonomics Lab



Objective
Surface electromyography (sEMG)

Subjective
NASA Task Load Index (TLX)

Surg Endosc (2014) 28:2459–2465
DOI 10.1007/s00464-014-3497-7

FLS tasks can be used as an ergon
between laparoscopic and robotic

Ahmed M.
Jaime A. C
Michael M

Surg Endosc (2017) 31:3286–3290
DOI 10.1007/s00464-016-5360-5

Which causes more ergonomic stress: Lap
surgery?

Robert Wang[1] · Zhe Liang[1] · Ahmed M. Zihni[1] · Shuddhadeb R
Michael M. A[1]

Surgical Endoscopy (2019) 33:1938–1943
https://doi.org/10.1007/s00464-018-6478-4

Ergonomic analysis of laparoscopic and robotic surgical task
performance at various experience levels

rge G. Zárate Rodriguez[1] · Ahmed M. Zihni[2] · Ikechukwu Ohu[3] · Jaime A. Cavallo[4] · Shuddhadeb Ray[1] ·
hyung Cho[5] · Michael M. Awad[1]

ived: 30 August 2018 / Accepted: 11 October 2018 / Published online: 22 October 2018
inger Science+Business Media, LLC, part of Springer Nature 2018

Obesity Surgery (2019) 29:1709–1713
https://doi.org/10.1007/s11695-019-03748-0

ORIGINAL CONTRIBUTIONS

Effect of Patient Body Mass Index on Laparoscopic Surgical Ergonomics

Zhe Liang[1] · William D. Gerull[1] · Robert Wang[2] · Ahmed Zihni[1] · Shuddhadeb Ray[1] · Michael Awad[1]

Published online: 2 February 2019
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journal homepage: www.JournalofSurgicalResearch.com

ELSEVIER

Surg Endosc (20
DOI 10.1007/s00

Ergonomic analysis of robot-assisted and traditional laparoscopic
procedures

Ahmed M. Zihni · Ikechukwu Ohu · Jaime A. Cavallo ·
Sohyung Cho · Michael M. Awad

Ergonomic analysis of primary and assistant
surgical roles

Ahmed M. Zihni, MD, MPH,[a,*] Jaime A. Cavallo, MD, MPHS,[a]
Shuddhadeb Ray, MD, MPHS,[a] Ikechukwu Ohu, MS,[b] Sohyung Cho, PhD,[b]
and Michael M. Awad, MD, PhD, FACS[a]

[a] Department of Surgery, Section of Minimally Invasive Surgery, Washington University School of Medicine, St. Louis, Missouri
[b] Department of Industrial and Manufacturing Engineering, Southern Illinois University Edwardsville, Edwardsville, Illinois

Comparison Groups

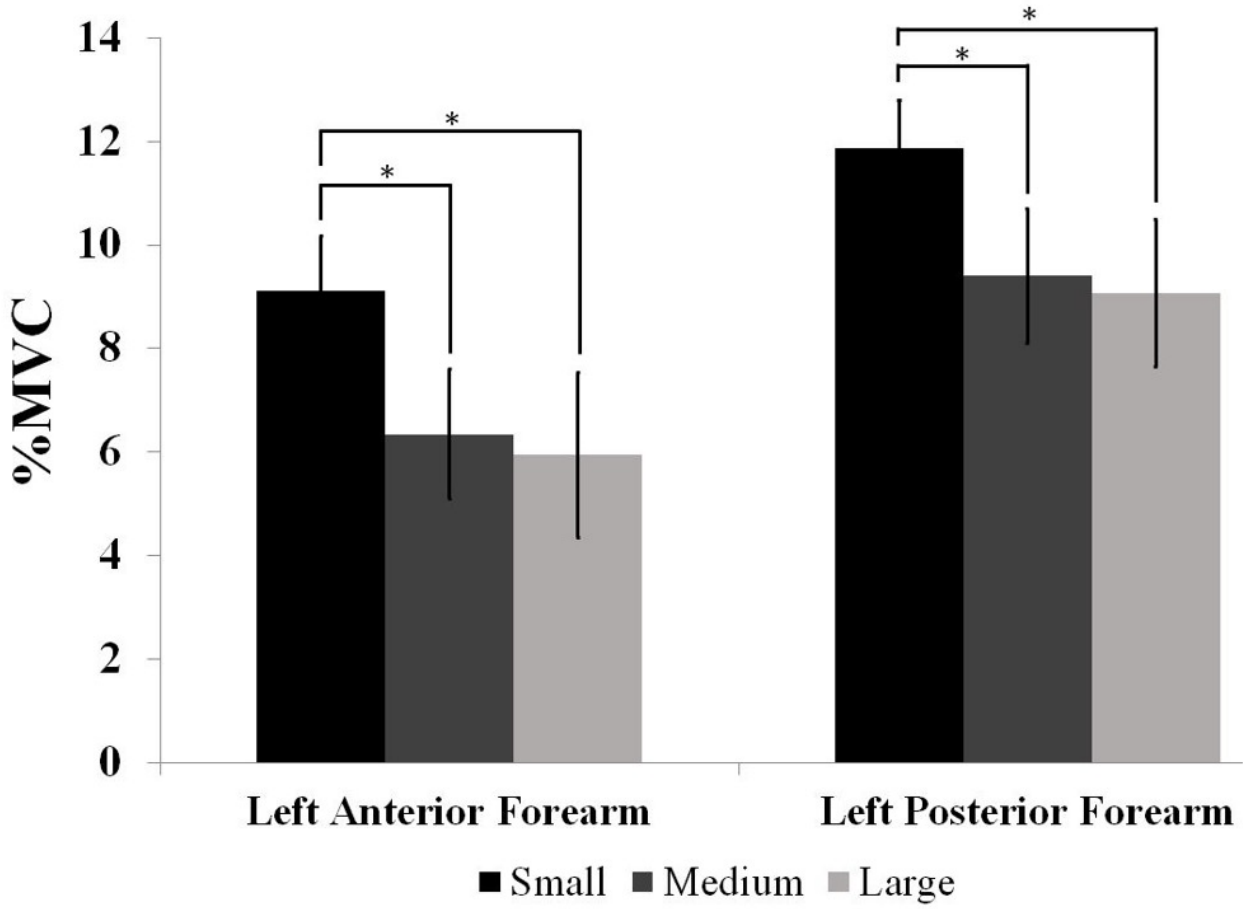
Procedure	Provider	Patient
• Open • Laparoscopic • Robotic • Endoscopic	• Level of training • Specialty area • Hand size	• BMI • Prior Surgery

Advanced Endoscopic Procedures Can Also Be Difficult

- Endoscope was initially designed as a diagnostic tool
- Limited degrees of freedom
- Scope and therapeutic instruments are aligned in the same axis
- Dials present ergonomic challenges

Ergonomics in Endoscopy – Hand Size

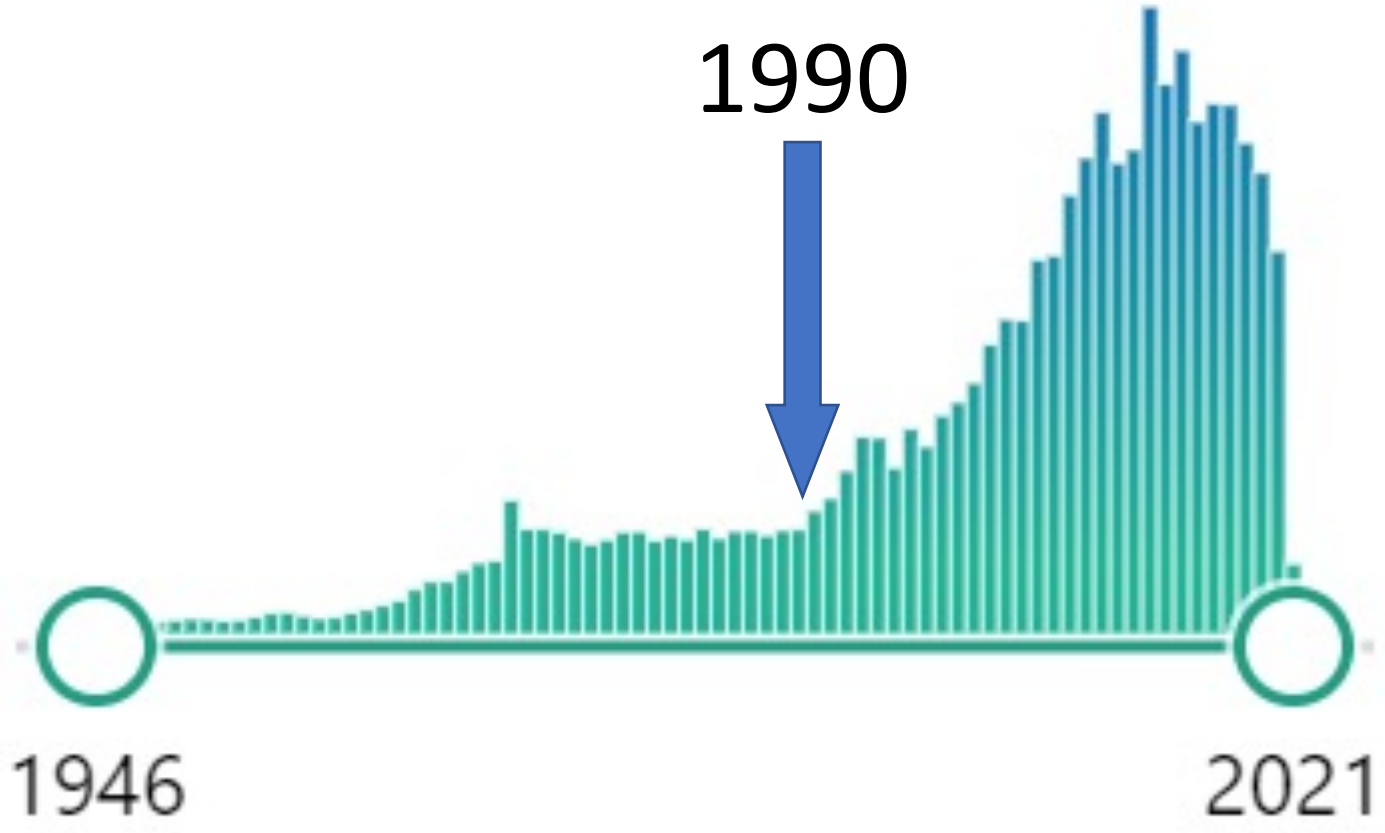
- 165 upper and lower endoscopies
- Hand (glove) size:
  - Small (5-6)
  - Medium (6.5-7.0)
  - Large (7.5-8.0)
- All small hand size were female endoscopists



Shiang and Awad, Gastro *in press*, 2021

Surgical Ergonomics Research

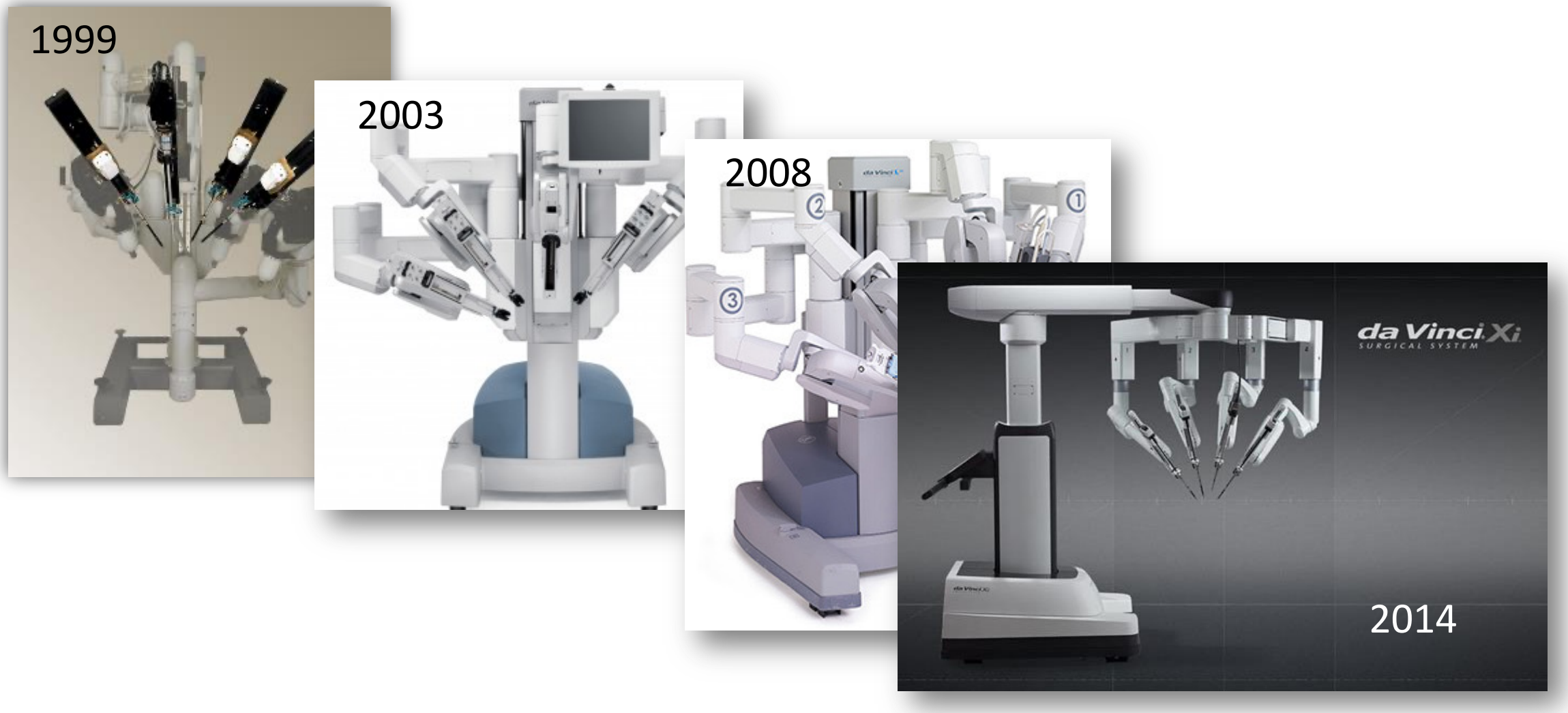
PubMed Results – February 2021



Surgical Robotics History

First introduced in early 1990s

Surgical Robotics History

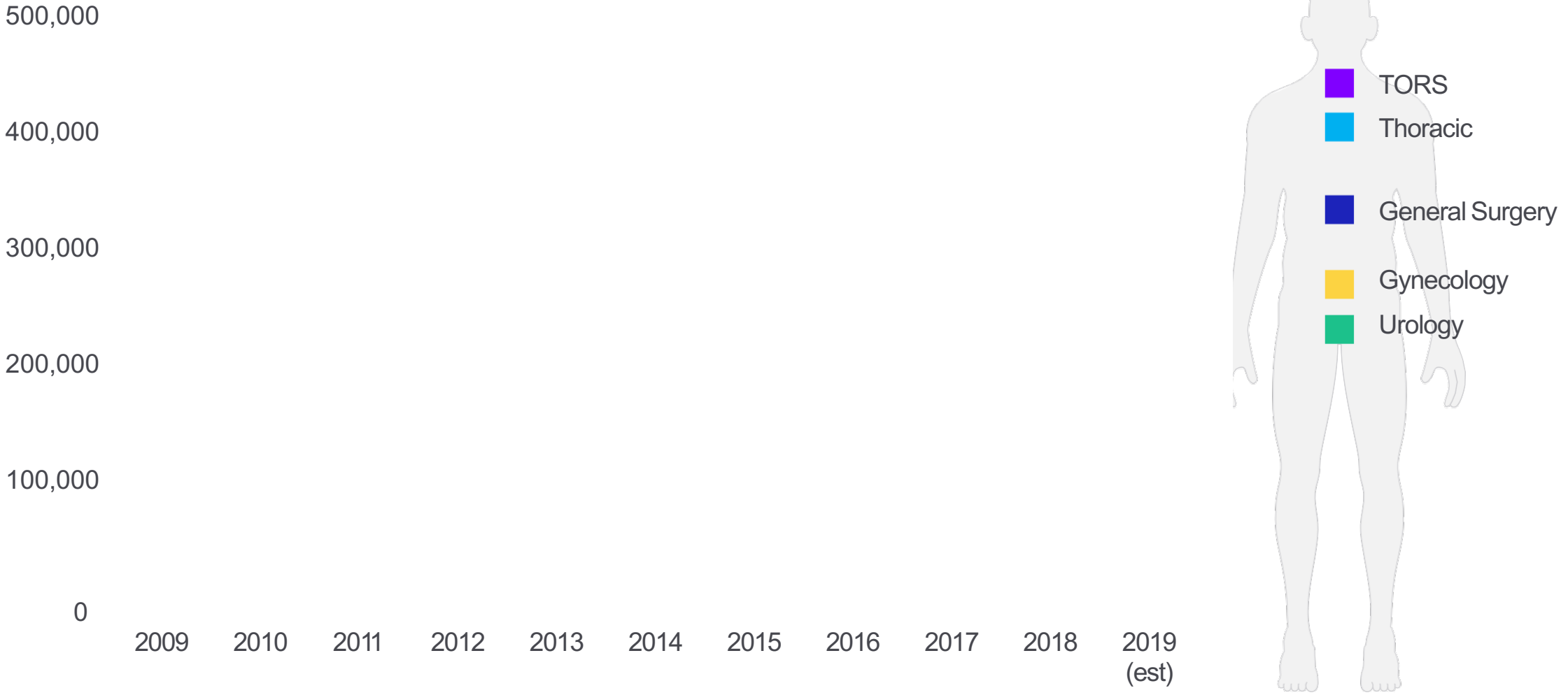


Robotics to Overcome Challenges of Laparoscopy

- ✓ 2D
- ✓ Limited degrees of freedom
- ✓ Fulcrum effect
- ✓ Tremor exaggeration
- ✓ Decoupling of Motor and Visual Axes
- ✗ Loss of haptics
- ✓ Camera not under surgeon’s control
- ✓ Static standing posture

Growth in procedure categories

Global over past 10years



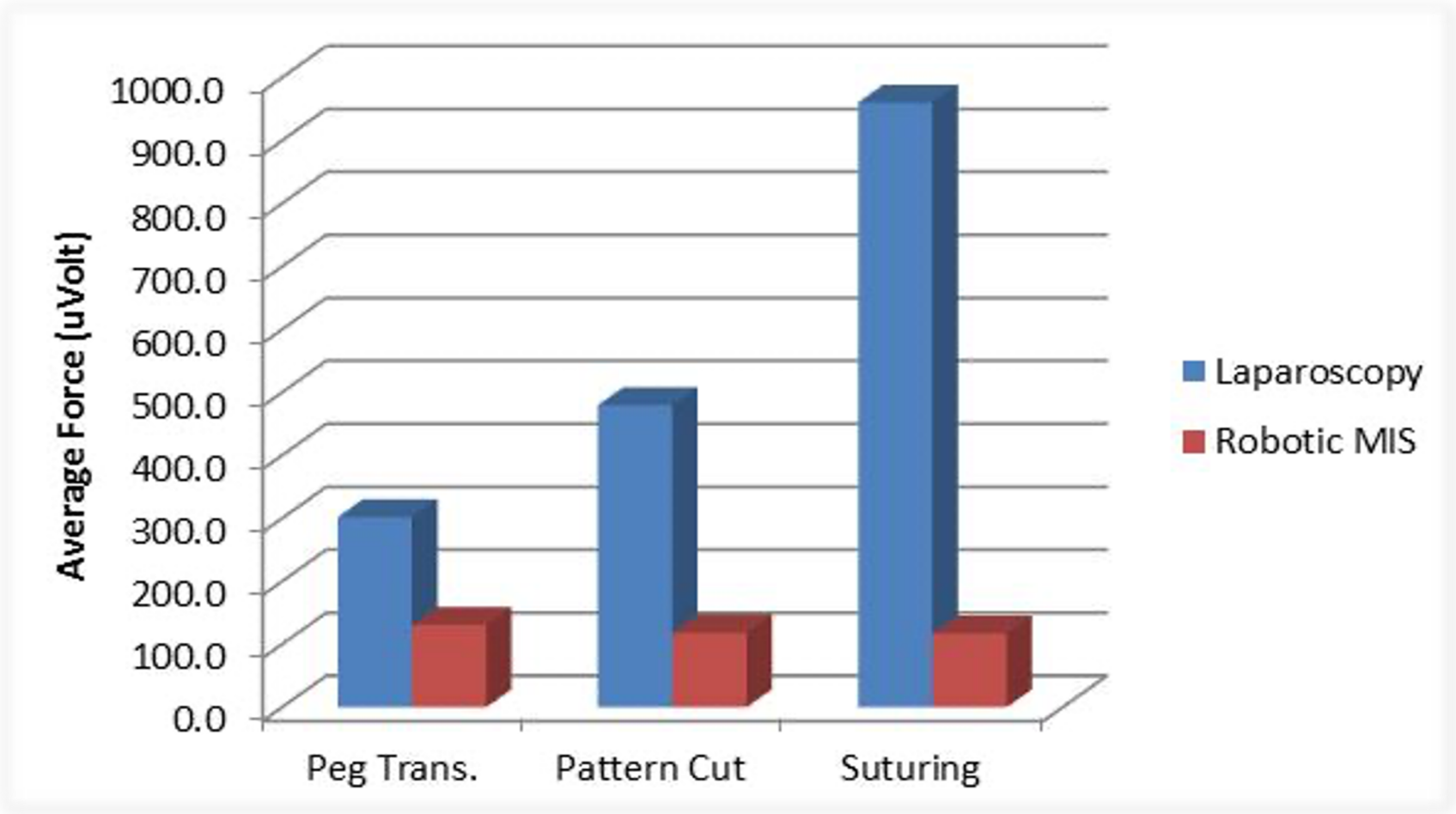
Source: Intuitive 2019 earnings report

Procedure Factors – Lap vs Robot

Can robotic surgery help ameliorate laparoscopic ergonomic challenges?

Wang and Awad, Surg Endo, 2016

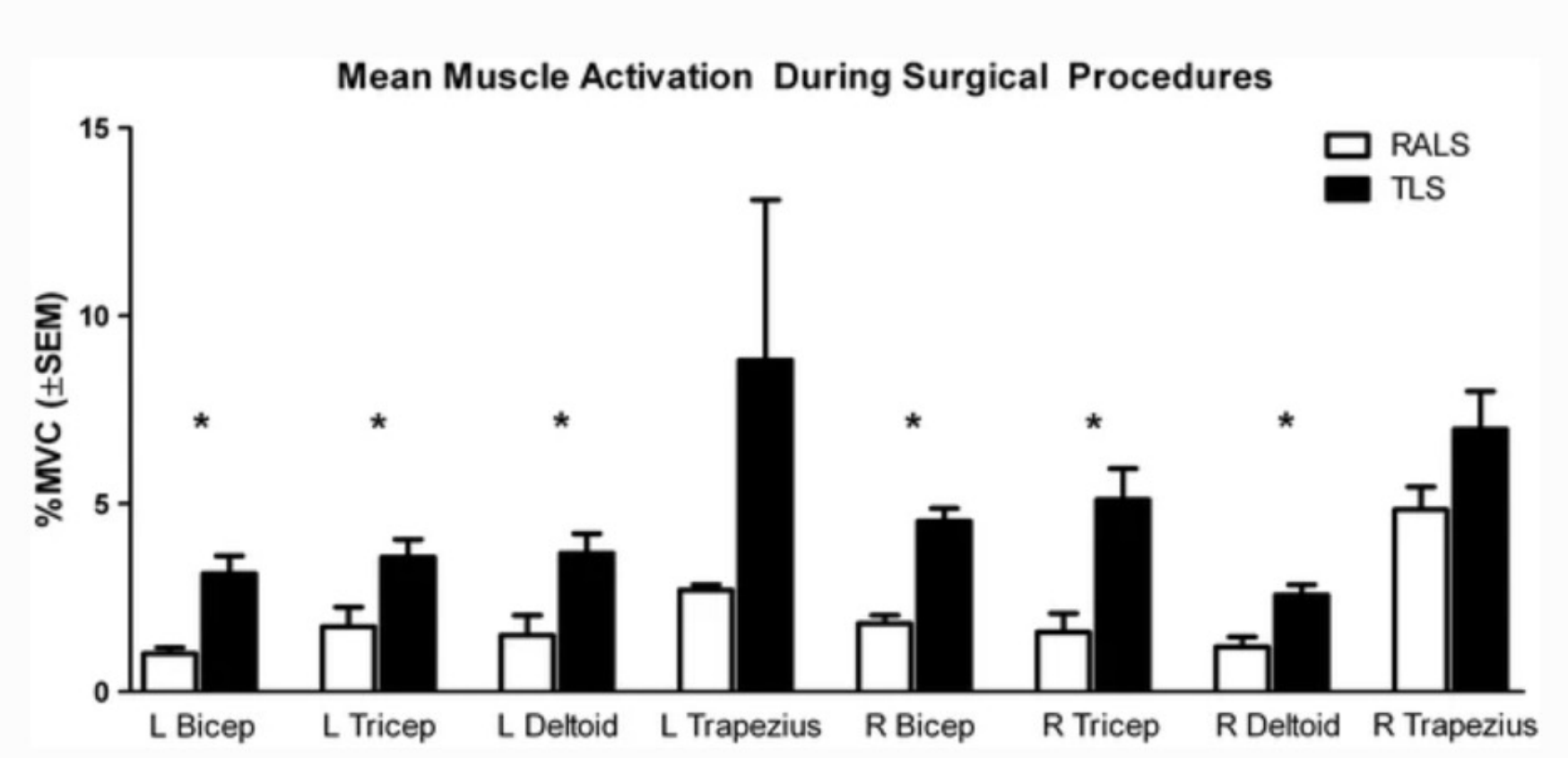
Procedure Factors – Lap vs Robot (Sim)



Zihni, Awad. Surg Endosc, 2014

Procedure Factors – Lap vs Robot (Clinical)

- Comparable lap and robot procedures (e.g., inguinal hernia)



Zihni and Awad, Surg Endo, 2014

SHORT-TERM OUTCOMES DATA

Surgical Endoscopy
https://doi.org/10.1007/s00464-020-07700-7

2020 SAGES ORAL

Favorable peri-operative outcomes observed in paraesophageal hernia repair with robotic approach

William D. Gerull[1] · Daniel Cho[2] · Saeed Arefanian[3] · Bradley S. Kushner[1] · Michael M. Awad[1]

Received: 4 April 2020 / Accepted: 9 June 2020

- Prospective, IRB-approved database
- PEH Repairs (Sliding Type 1 hiatals excluded)
- 2009-2019
- Single center
- All expert surgeons with over 1000 lifetime foregut cases

Robotic Paraesophageal Hernia Repair

Short-term Outcomes

Peri-operative outcomes	Robotic $N=830$	Laparoscopic $N=1024$	P-value
✓ Operative time (min)	174.1 (±63.8)	187.3 (±65.3)	<0.001
✓ Esophageal lengthening procedure performed (Collis gastroplasty/wedge fundectomy)	1 (0.1%)	113 (11.0%)	<0.001
✓ Conversion to open (abdominal or thoracotomy)	0 (0.0%)	72 (7.0%)	<0.001
= Intra-operative equipment costs (USD)	2147 (±312.5)	2058 (±345.5)	0.012
✓ EBL (mL)	27.3 (±5.9)	89.3 (±27.8)	<0.001
✓ Intra-operative injury	5 (0.6%)	28 (2.7%)	<0.001
Thromboembolic complications	4 (0.5%)	6 (0.6%)	0.761
✓ Length of stay (days)	1.8 (±0.6)	2.9 (±1.4)	<0.001
Re-operation within 30 days	2 (0.2%)	8 (0.8%)	0.114
30 day in-hospital mortality	0 (0.0%)	5 (0.5%)	0.104

LONG-TERM OUTCOMES DATA

ORIGINAL SCIENTIFIC ARTICLE

Robotic Approach to Paraesophageal Hernia Repair Results in Low Long-Term Recurrence Rate and Beneficial Patient-Centered Outcomes

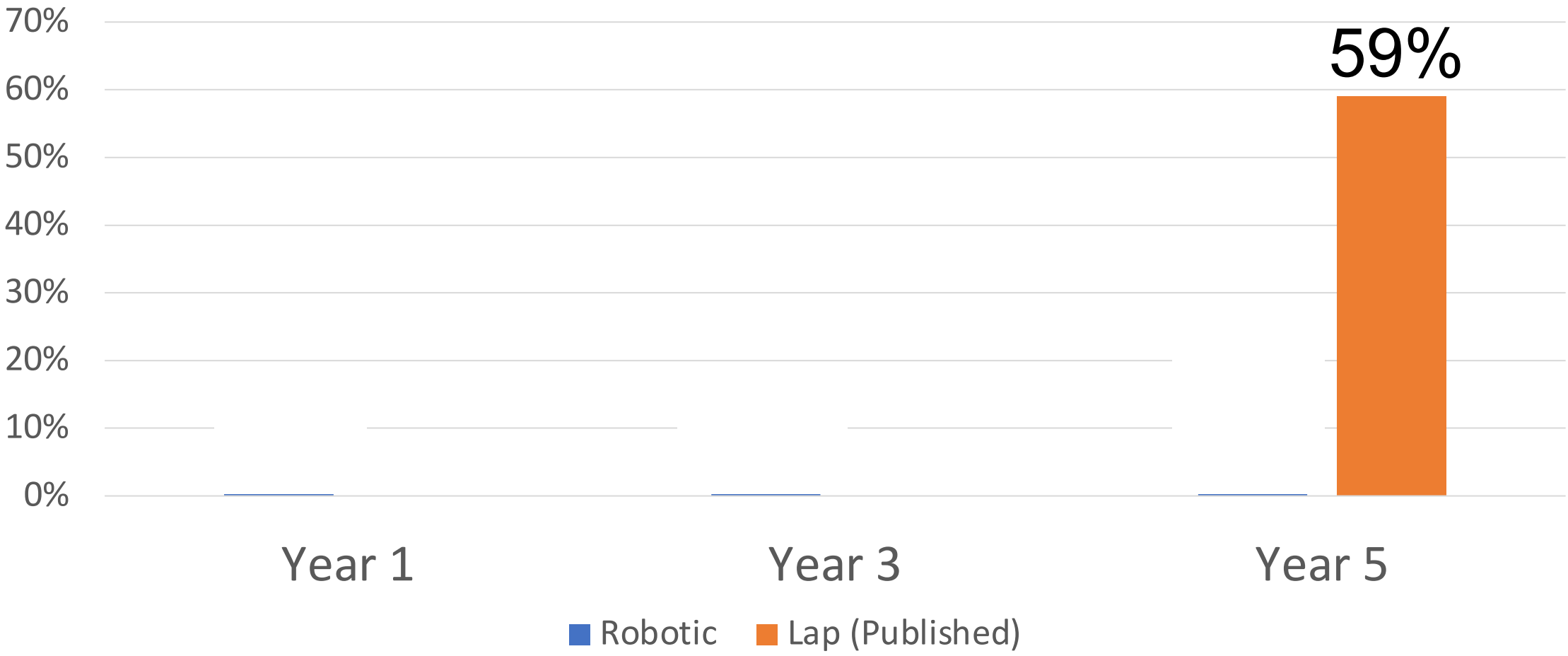
William D Gerull, MD, Daniel Cho, BA, Iris Kuo, BA, Saeed Arefanian, MD, Bradley S Kushner, MD, Michael M Awad, MD, PhD, FACS

https://doi.org/10.1016/j.jamcollsurg.2020.07.754
ISSN 1072-7515/20

- Prospective, IRB-approved database
- PEH Repairs (Sliding Type 1 hiatals excluded)
- Patients with at least 5 year follow-up
- 2010-2014

RAL Paraesophageal Hernia Repair

Long-term Recurrence Rates



* Recurrence defined as >2cm on esophagram

77 Companies

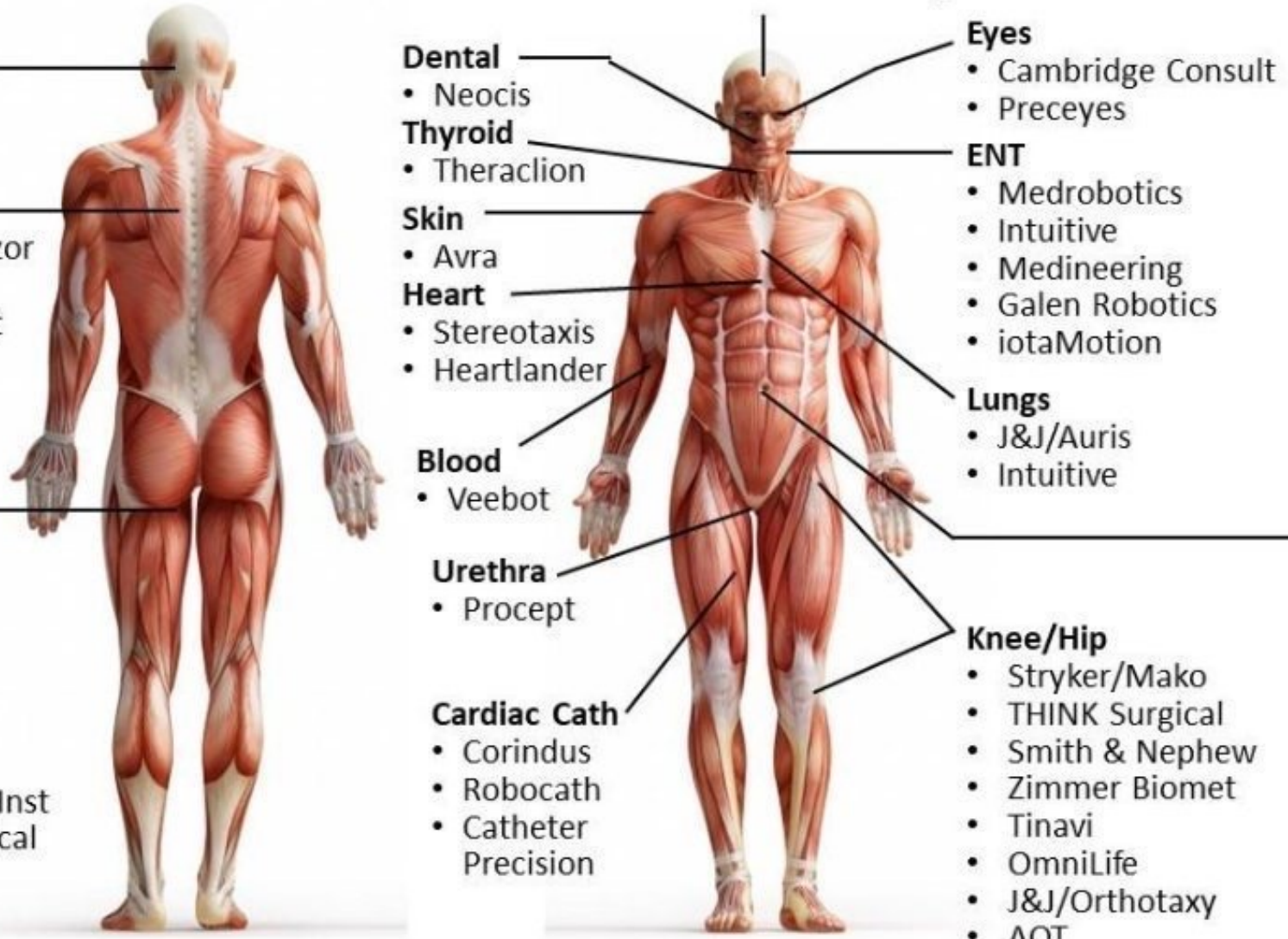
Neuro
- Medtronic
- Synaptive
- Zimmer
- Monteris
- Elekta
- Renishaw
- AiM Medical
- BrainLab
- Varian
- IMRIS
- Remebot
- Insightec
- ColubrisMX
- XCath

Hair
- Restoration Robotics

Spine
- Medtronic/Mazor
- Globus
- Zimmer Biomet
- Nuvasive
- Dupuy

Transanal
- EDAP TMS
- Medrobotics
- NISI

General
- Kuka
- Microsure
- Medical Micro Inst
- Microbot Medical
- Histosonics



Dental
- Neocis

Thyroid
- Theraclion

Skin
- Avra

Heart
- Stereotaxis
- Heartlander

Blood
- Veebot

Urethra
- Procept

Cardiac Cath
- Corindus
- Robocath
- Catheter Precision

Eyes
- Cambridge Consult
- Preceyes

ENT
- Medrobotics
- Intuitive
- Medineering
- Galen Robotics
- iotaMotion

Lungs
- J&J/Auris
- Intuitive

Knee/Hip
- Stryker/Mako
- THINK Surgical
- Smith & Nephew
- Zimmer Biomet
- Tinavi
- OmniLife
- J&J/Orthotaxy
- AOT

Abdomen
- Intuitive
- Transenterix
- Accuray
- CMR Surgical
- Titan Medical
- Meere Co.
- Micro Hand S
- Verb Surgical
- Medtronic
- Medicroid
- Virtual Incision
- Vicarious Surgical
- Memic Med
- Distal Motion
- Kongduo
- Avatera
- Lapara Surgical
- EndoControl
- USMI
- MST
- AKTORmed
- Riverfield
- Human Xtensions
- ACTIV Surgical
- XACT
- Perfint
- Freehand
- Endomaster
- Dexterite Surgical

FDA-approved Platforms

Intuitive Surgical da Vinci® Surgical System	Transenterix Senhance®	Medrobotics Flex® Robotic System
Auris Monarch Robotic Endoscopy System (ARES)	Intuitive ION system (510k)	Sensei X Robotic Catheter System
FreeHand v1.2	In endoscopy E200 System	NeoGuide Endoscopy System

Flexible Robotic Systems

Robotics in flexible endoscopy: current status and future prospects

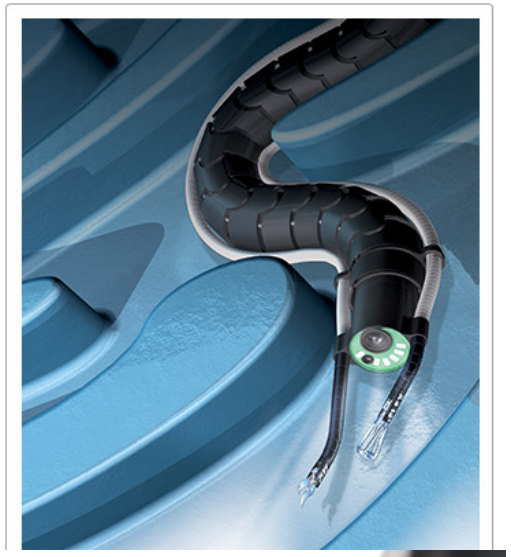
Barbara Seeliger[a,b] *and Lee L. Swanström*[a]

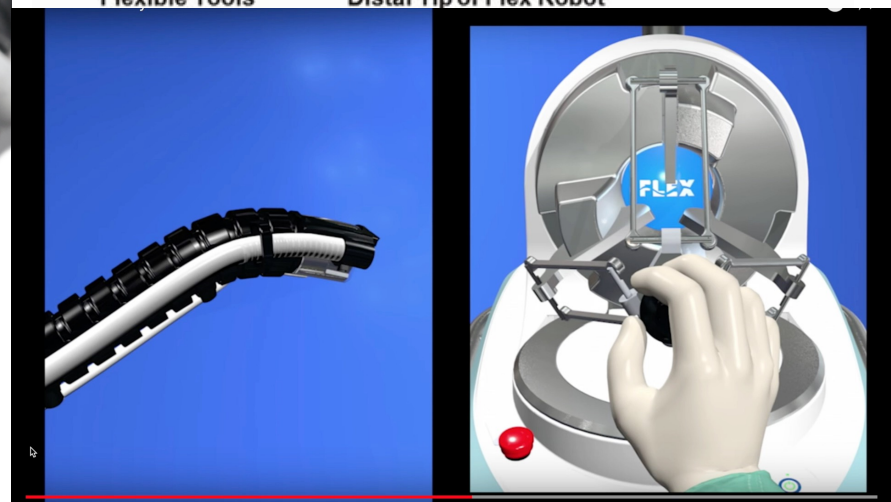
Curr Opin Gastroenterol 2020, 36:370–378
DOI:10.1097/MOG.0000000000000670

Volume 36 • Number 5 • September 2020

Flex Robot

- Medrobotics Corp
- Oropharynx/hypopharynx/larynx
- Used by ENT / colorectal
- Approved for abdominal procedures
- Use mechanical instruments

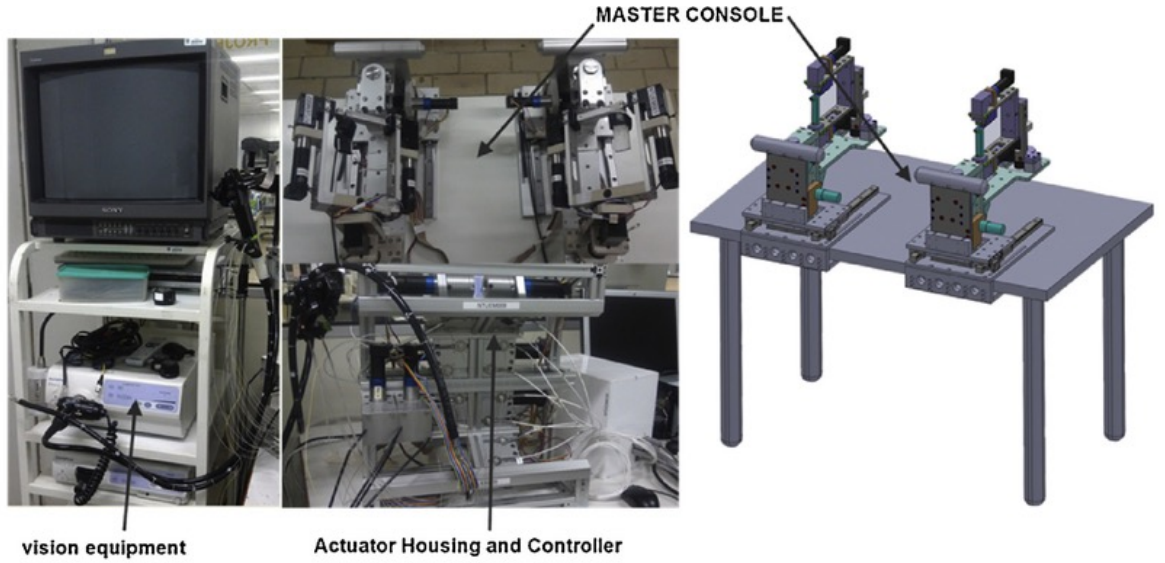


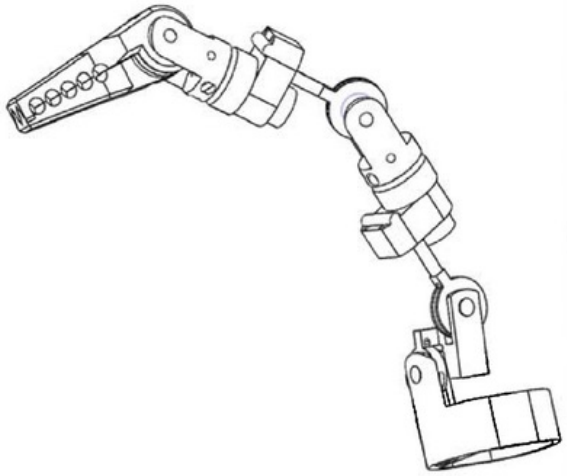


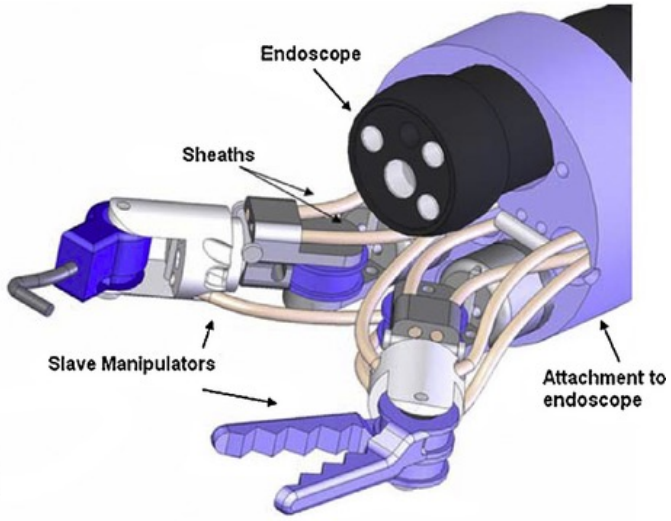
Ion Robot
Intuitive

Nanyang Technological University

- MASTER
- Natural orifice procedures
- Endoscopy based
- Controllers, image mapping and guidance systems







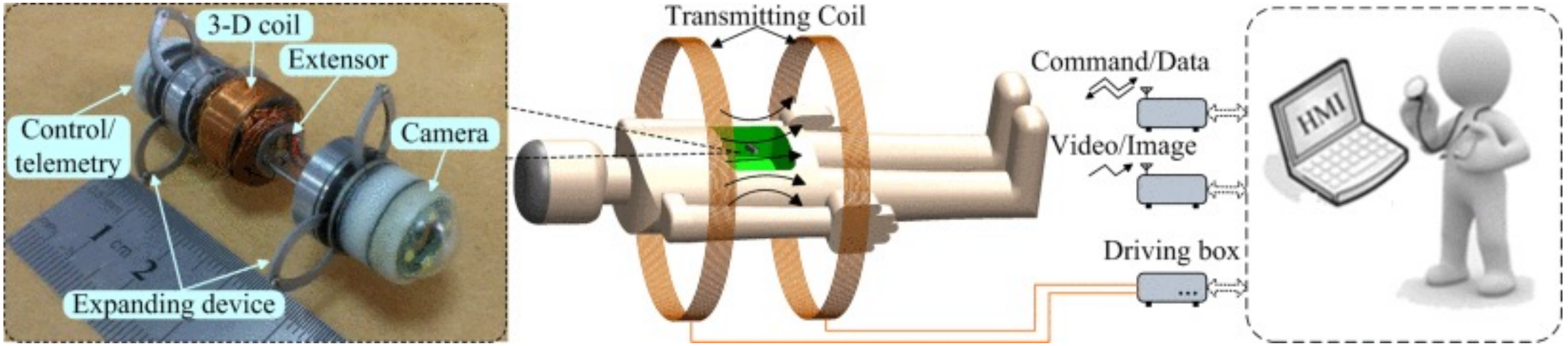
CARPE
Compliant Actuation Robotic Platform for Endoscopy

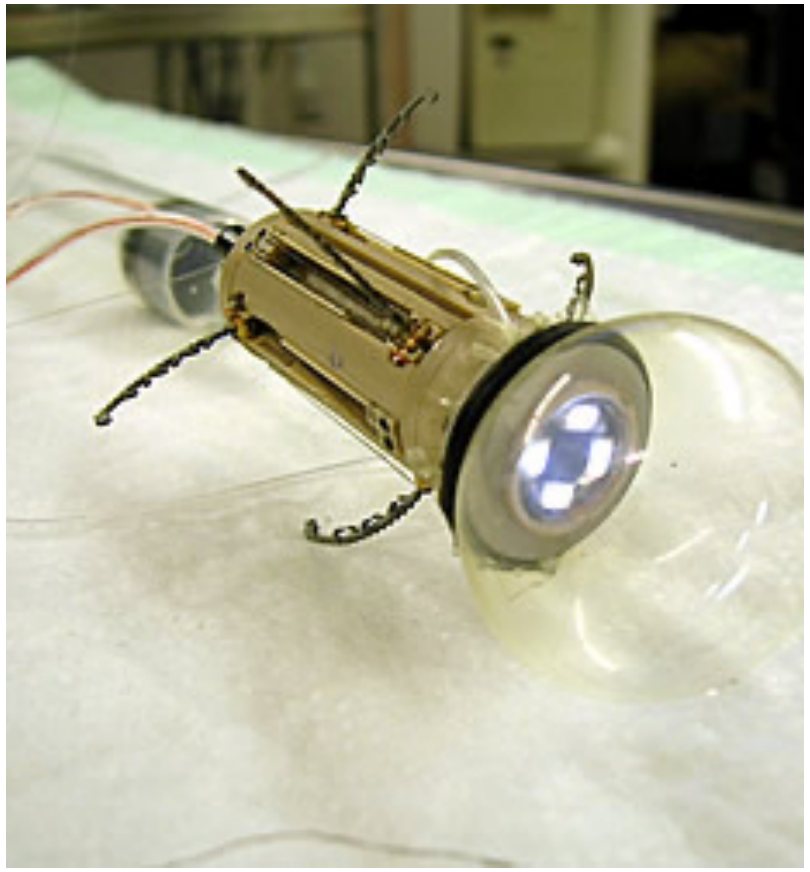
NaviCam – ANX Robotica

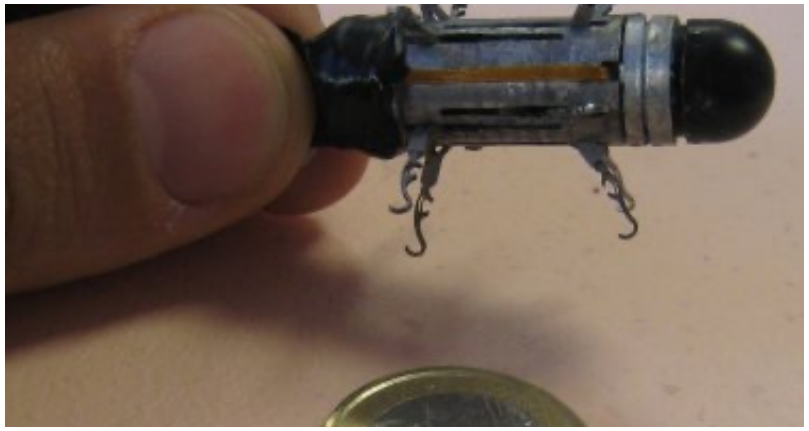
- Controlled via external magnet robotically
- 160 degrees vision
- 27 mm x 11.8 mm
- Resolution 640x480
- Battery: 12 hrs
- Frame rate: 0.5-12 fps

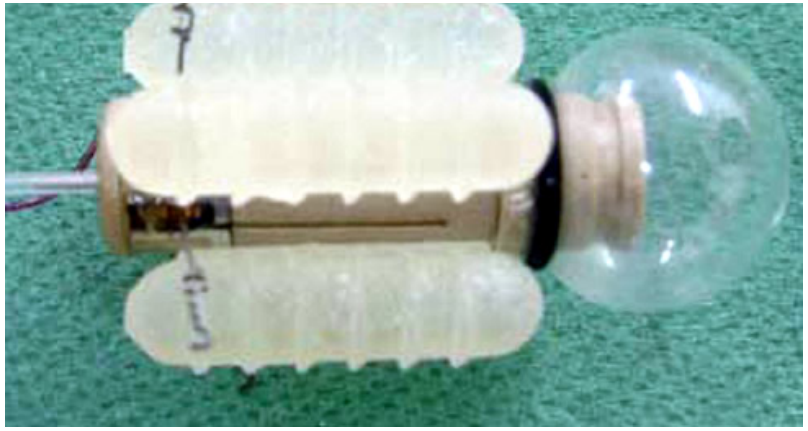
Motor-based Capsule

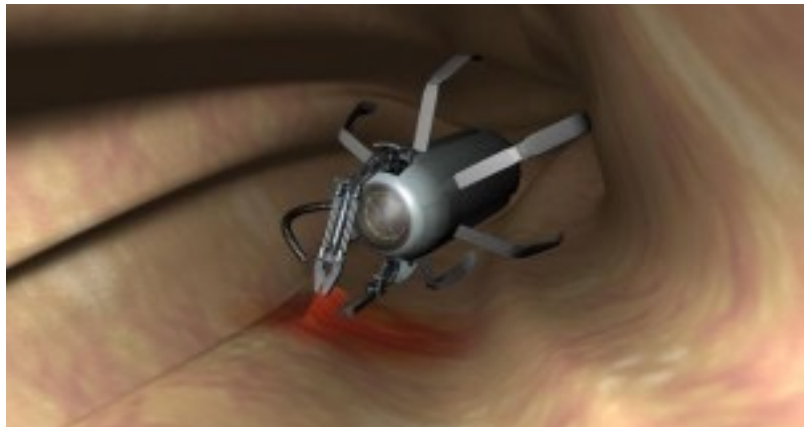
- Capsule endoscope with active locomotion to traverse the intestine
- Movement powered by wireless power transmission consisting of a one-dimensional transmission coil and three-dimensional receiving coil
- Robot was able to travel through a collapsed porcine intestine in ex vivo testing
- Potential to reduce pain and discomfort in endoscopy and allow more control over the endoscope
- Future work could incorporate other modules for drug delivery, grasping, and biopsy



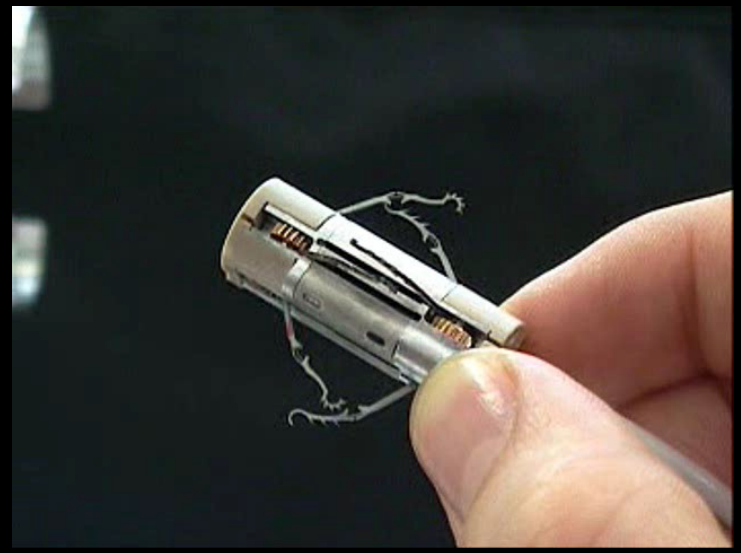


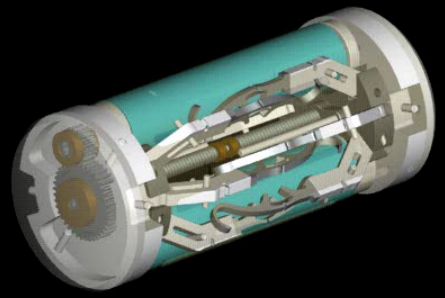






ARAKNES-Vector

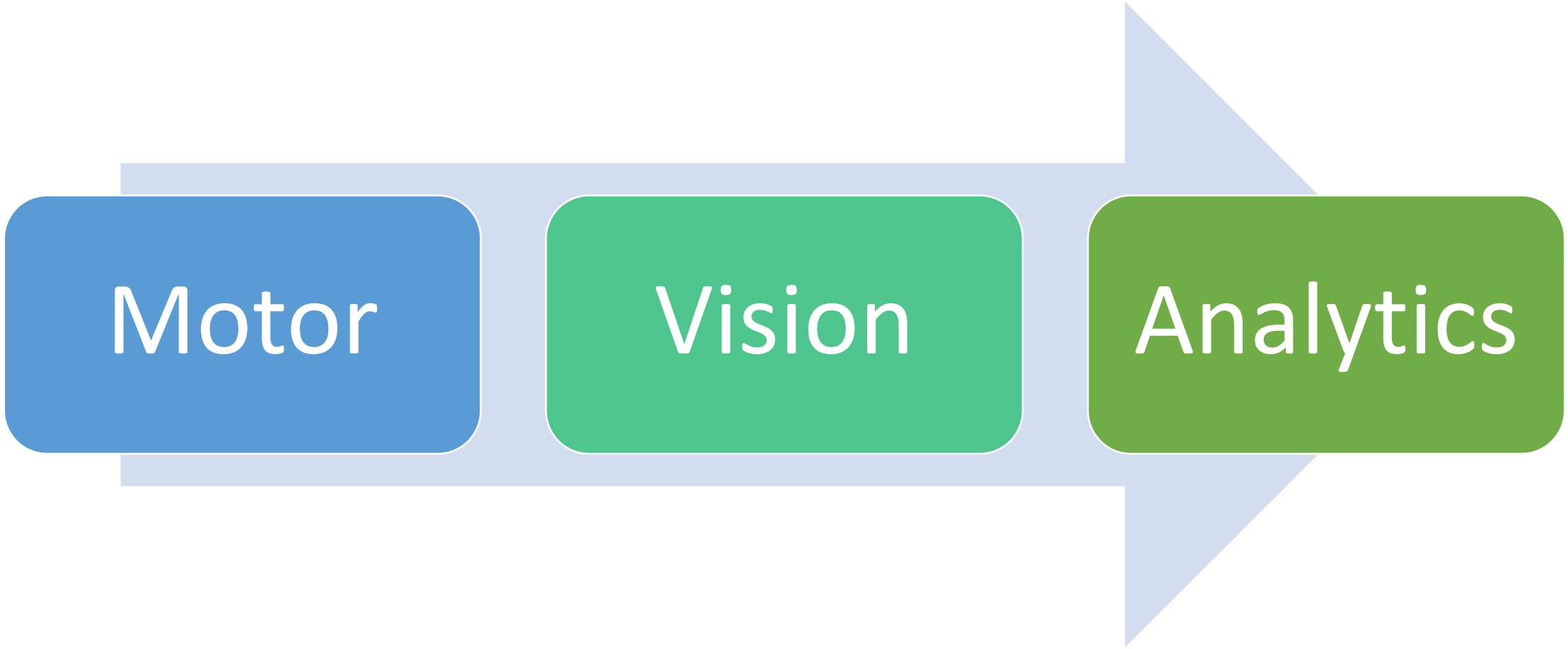




ARAKNES-Vector

Future Directions

Evolution of Robotics

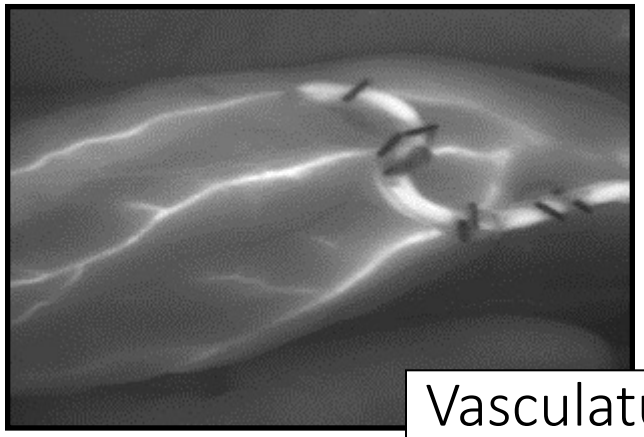


Robotics → Computer-Assisted Procedures

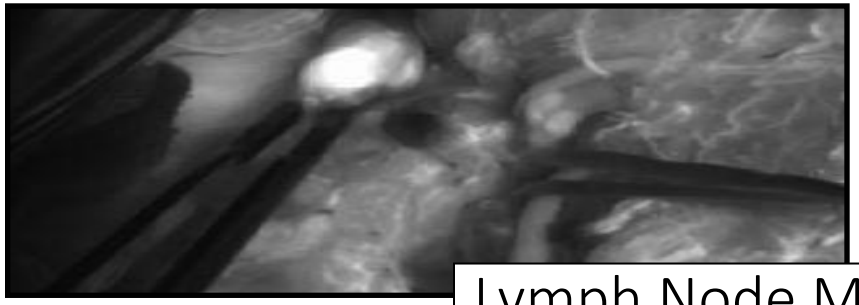
Image Guidance - Fluorescence

ICG

- Central venous
- Interstitial

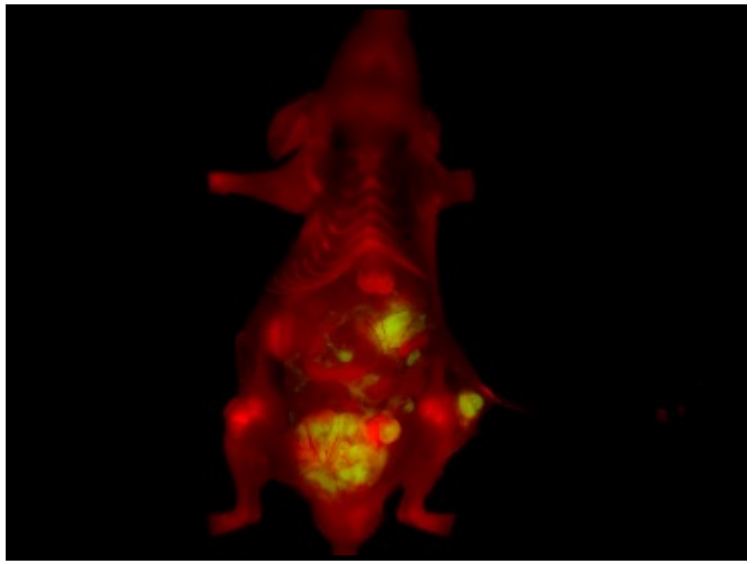


Vasculature



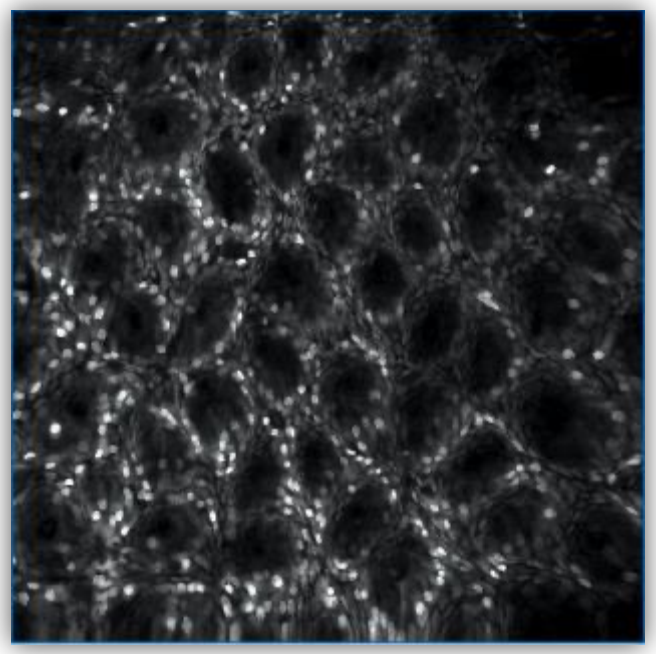
Lymph Node Mapping

- Specific antibodies plus fluorescing markers



In-Vivo Microscopy

- Sub-micron in-vivo histology
- Real-time functional and molecular imaging and diagnosis
- Tissue information (cancer, endometriosis, etc)



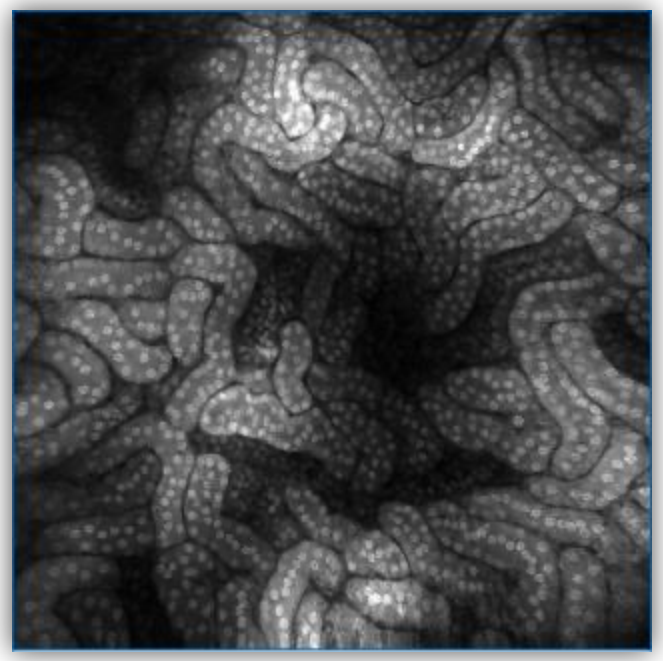
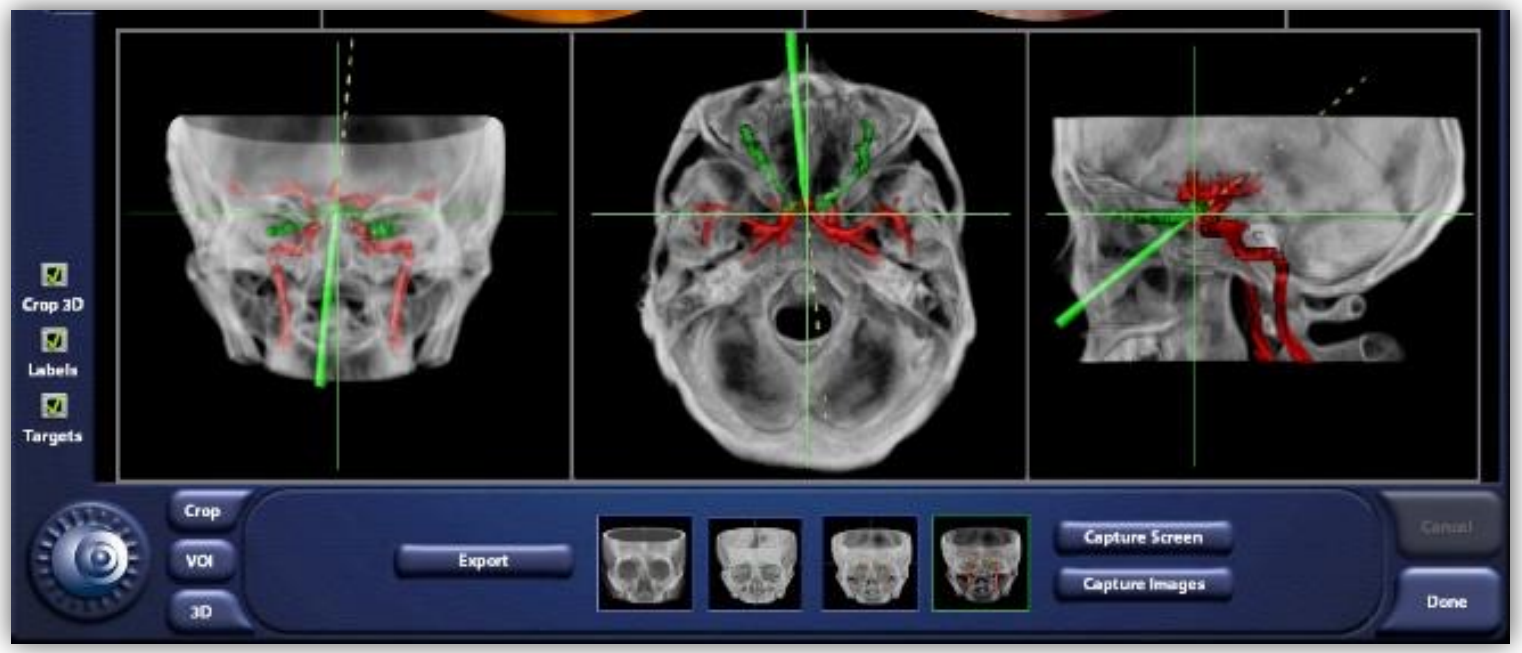
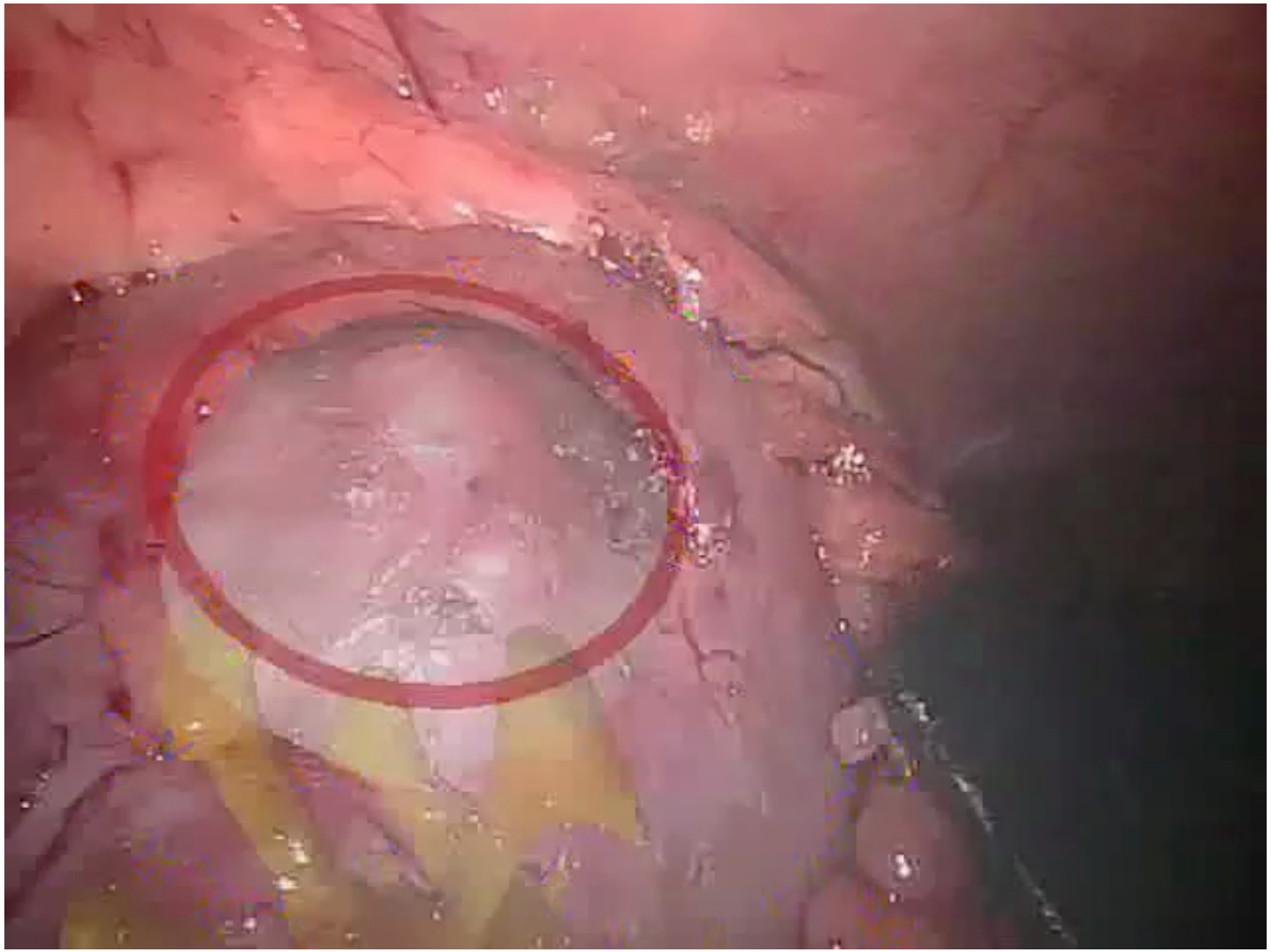


Image Guidance

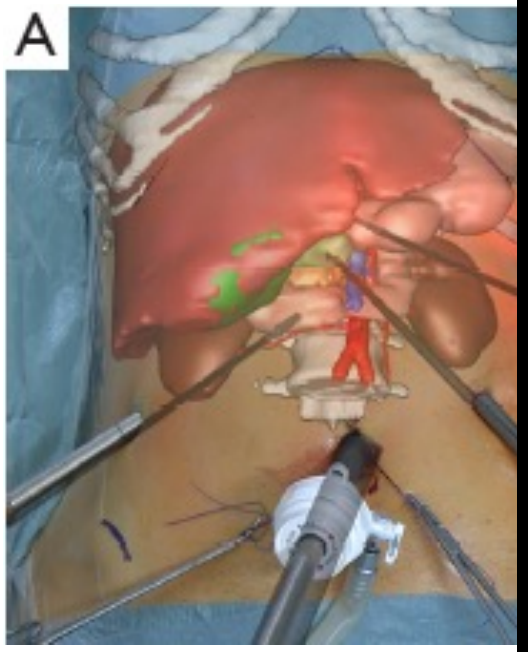
- Pre-operative images + tracking hardware/software
- Rigid anatomy from pre-op to OR
- “No-Fly” surgical zones

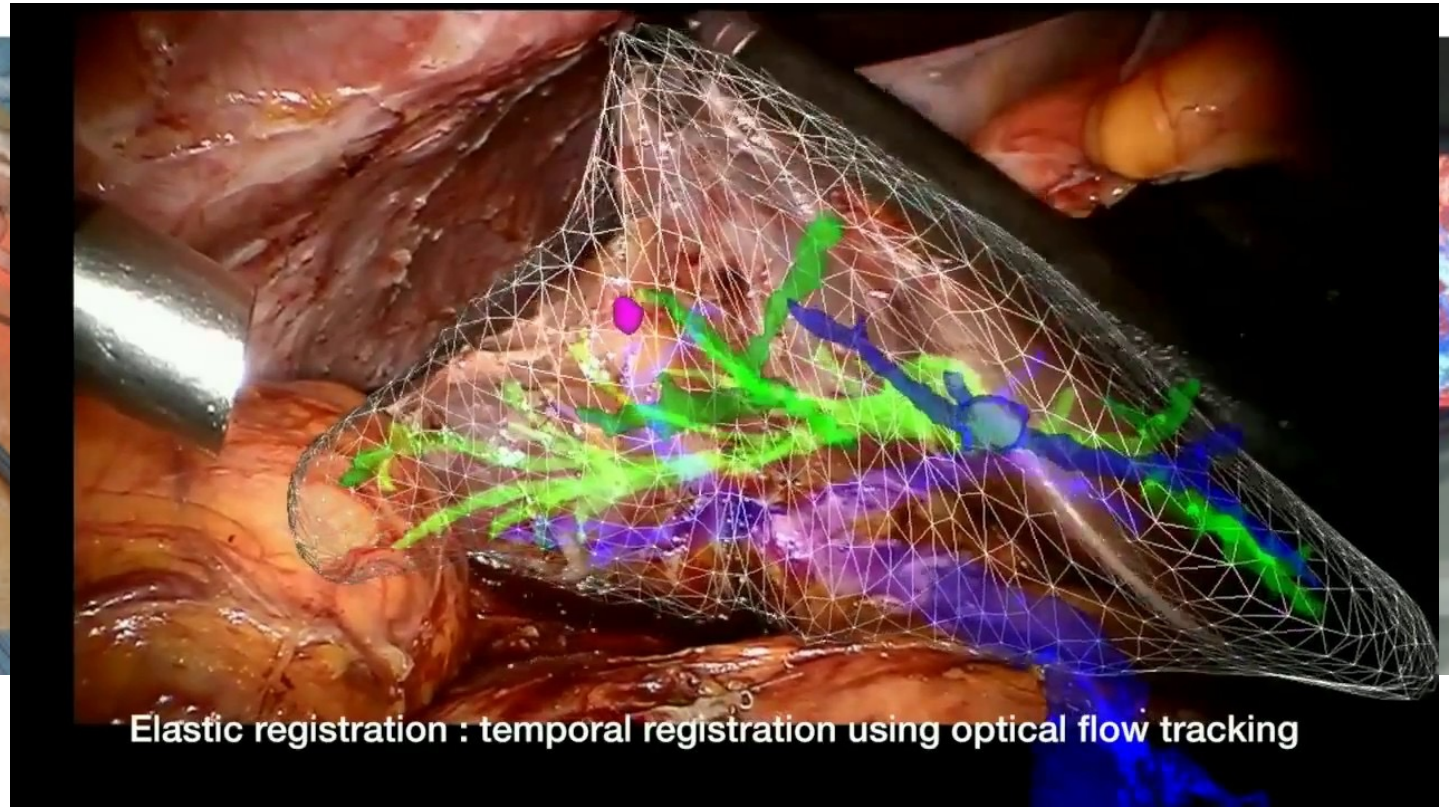


Augmented Reality

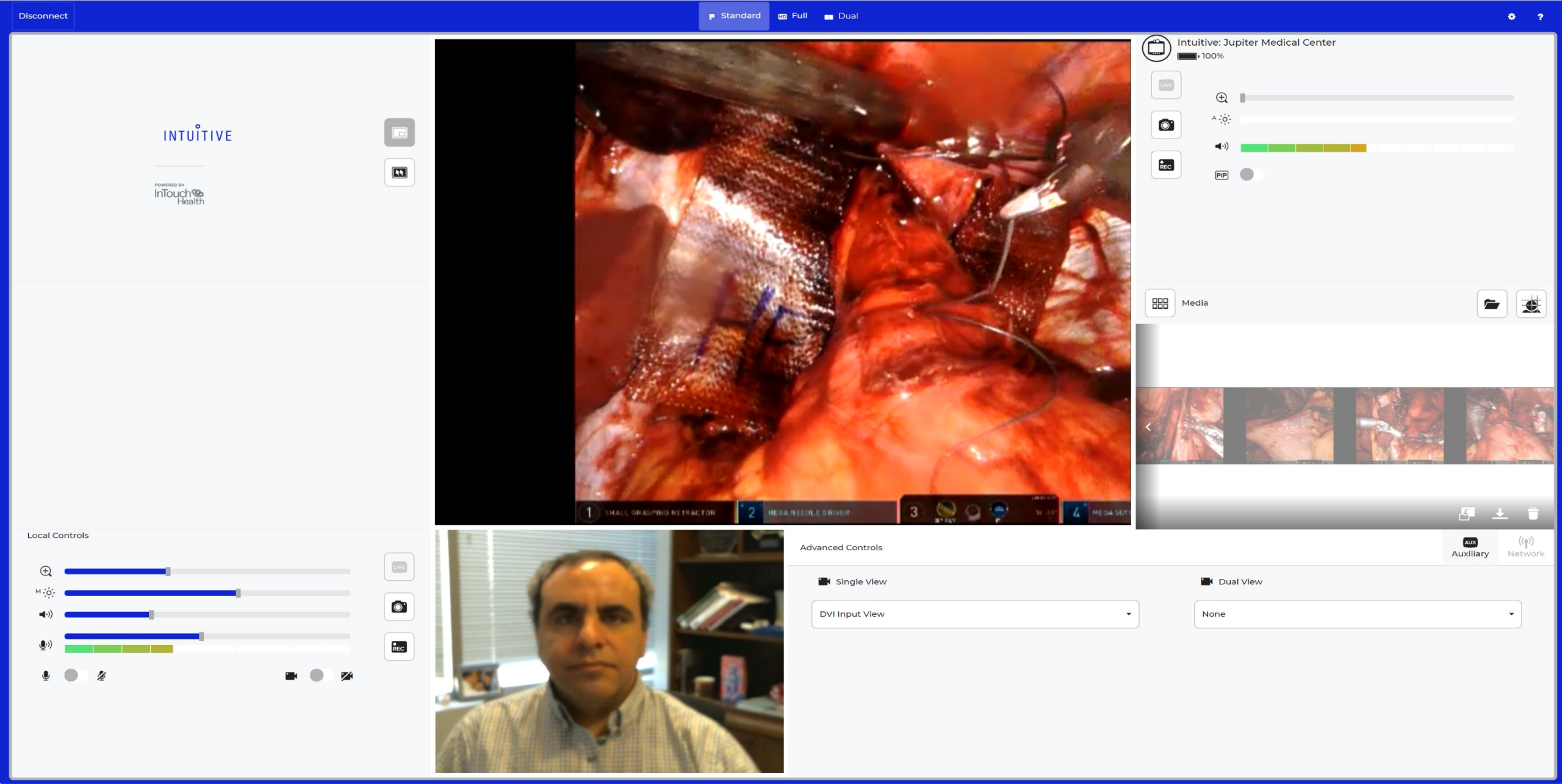


Cybernetic Surgery





Education - Telementoring



Washington University Physicians • Barnes-Jewish Hospital

Remote Foregut Case Observation

AMERICAN FOREGUT SOCIETY

2021 American Foregut Society Robotic Mentorship Program

- For surgeons with moderate experience in foregut and some experience with the DaVinci robotics. **Must have commitment to developing expertise in both.**
- A unique opportunity to participate in a **mentored pathway** to master foregut procedures utilizing da Vinci robotic technology.
- All participants will follow a **six month curriculum under the guidance of a dedicated AFS mentor** designed to help surgeons meet their goals while learning a new modality.
- The mentees will have the opportunity to work with the **same mentor surgeon throughout** their learning curve/experience.
- Participants will work together to **share learnings** and build professional relationships throughout the curriculum and beyond.

APPLY NOW

INTUITIVE

THANK YOU

awadm@wustl.edu

2021 AFS Robotic Mentors;
Dr. Reginald Bell, Dr. Caitlin Houghton, Dr. Tanuja Damani, and Dr. Michael Awad