Royal Academy of Engineering

Makerere University

Bridging the Continuum: Engineering Solutions for the Future of Modern Medicine

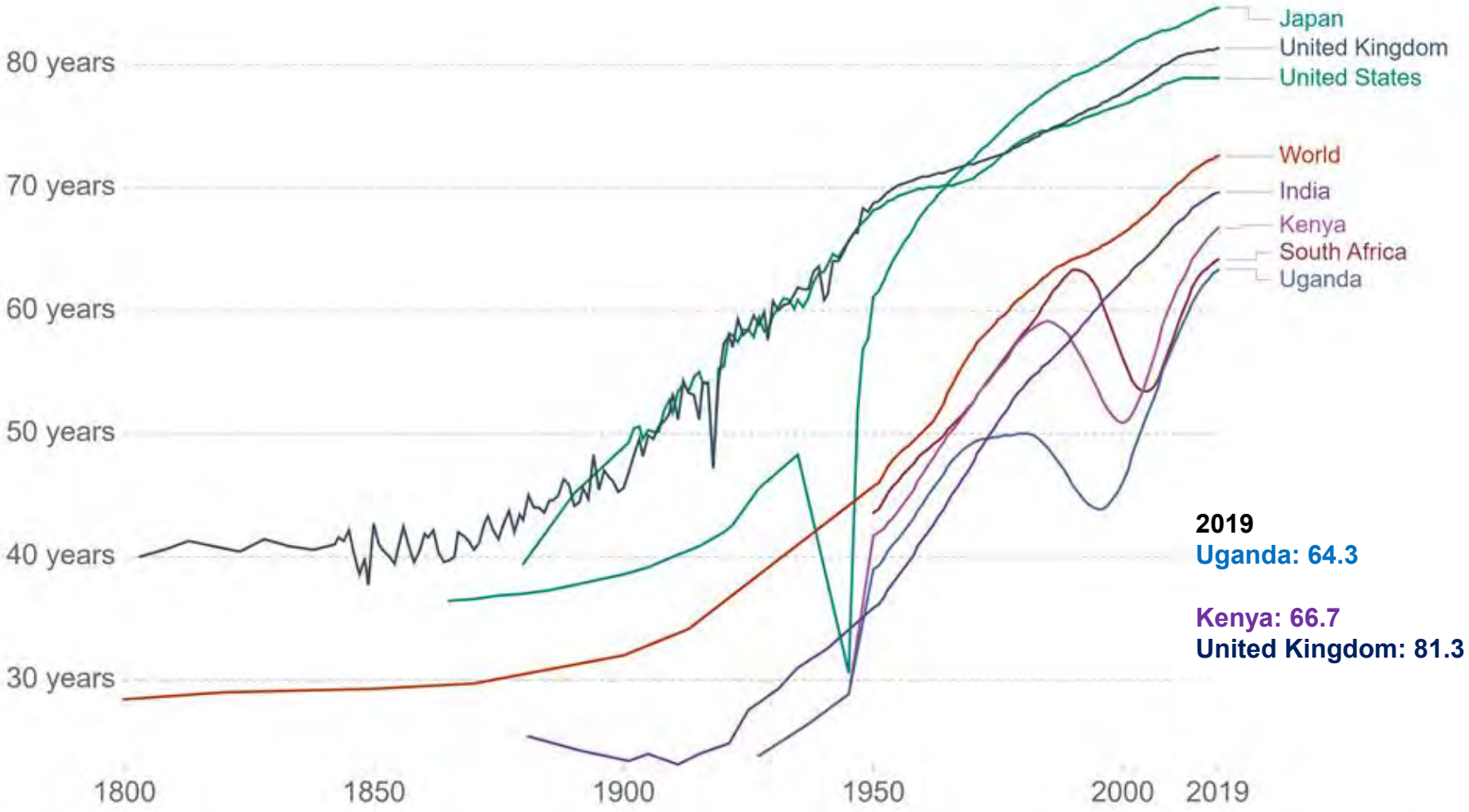
Cosmas Mwikirize, PhD

2nd HEPSSA Workshop, July 16, 2021

Our Agenda

- What diseases/conditions should worry us?
- The close link between Medicine and Engineering
- The role of Engineering in Modern Medicine:
  Emphasis on point-of-care

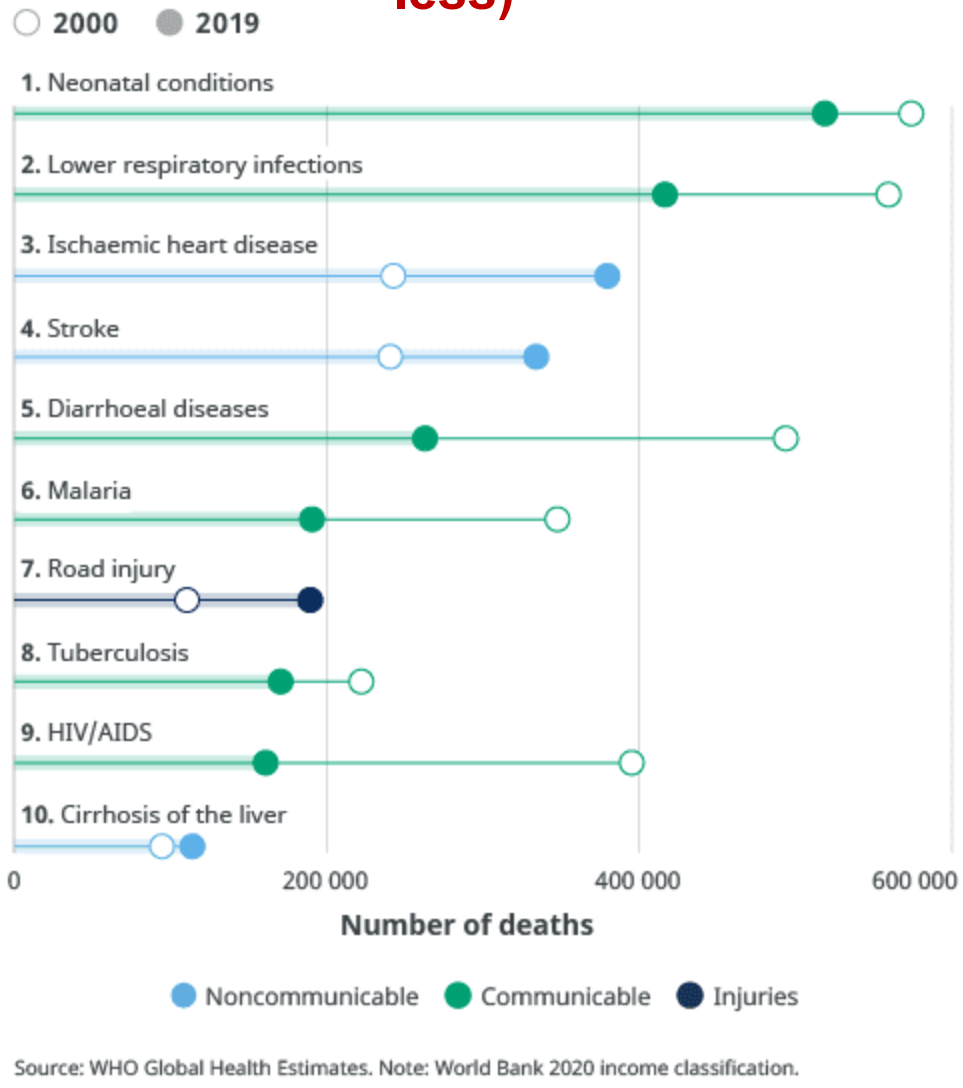
Life Expectancy: 1800 to 2019



Source: Riley (2005), Clio Infra (2015), and UN Population Division (2019) OurWorldInData.org/life-expectancy • CC BY

Note: Shown is period life expectancy at birth, the average number of years a newborn would live if the pattern of mortality in the given year were to stay the same throughout its life.

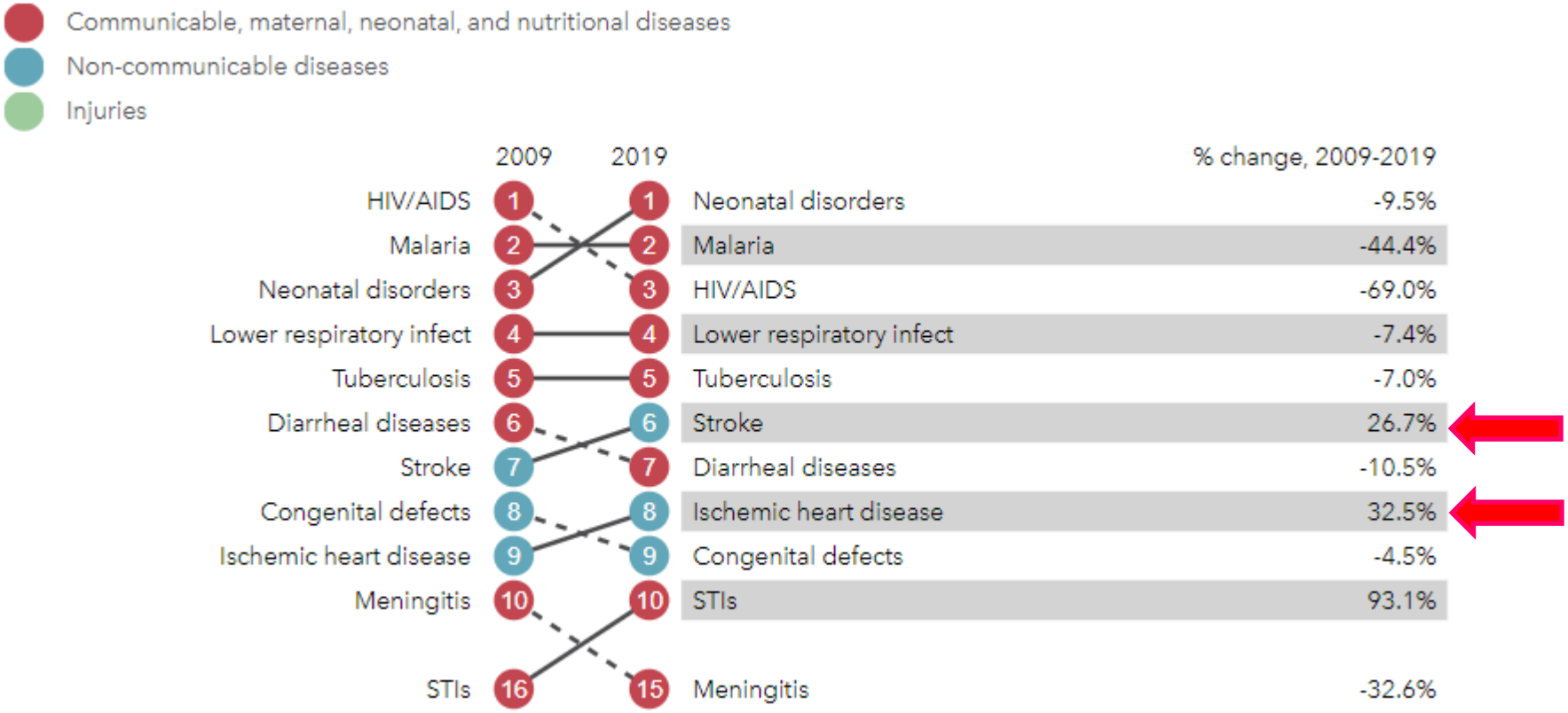
Top Causes of Deaths: Low Income Countries (GNI per capita of $1,045 or less)



Source: WHO Global Health Estimates. Note: World Bank 2020 income classification.

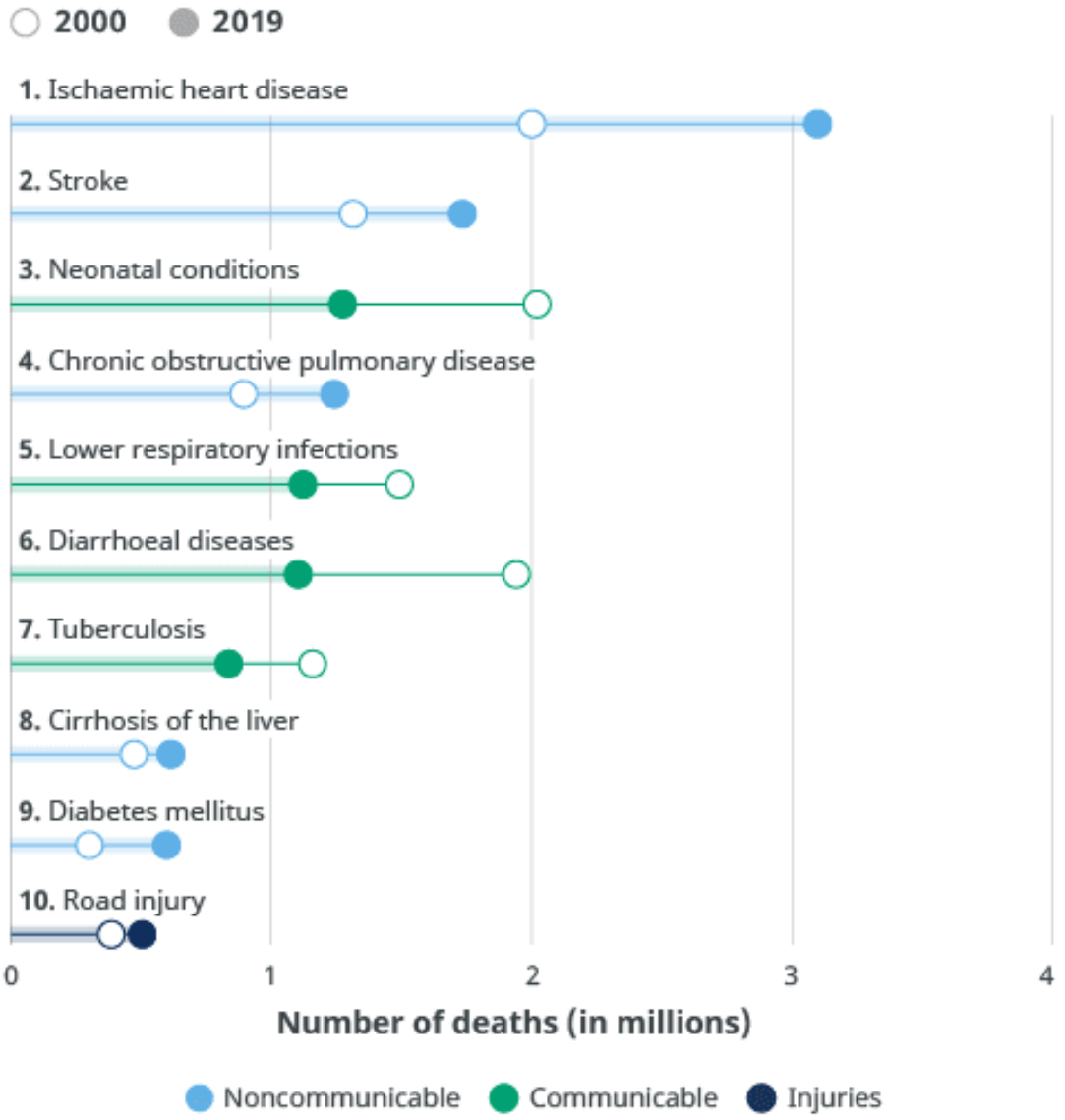
GNI=Gross National Income

Top Causes of Deaths: Uganda



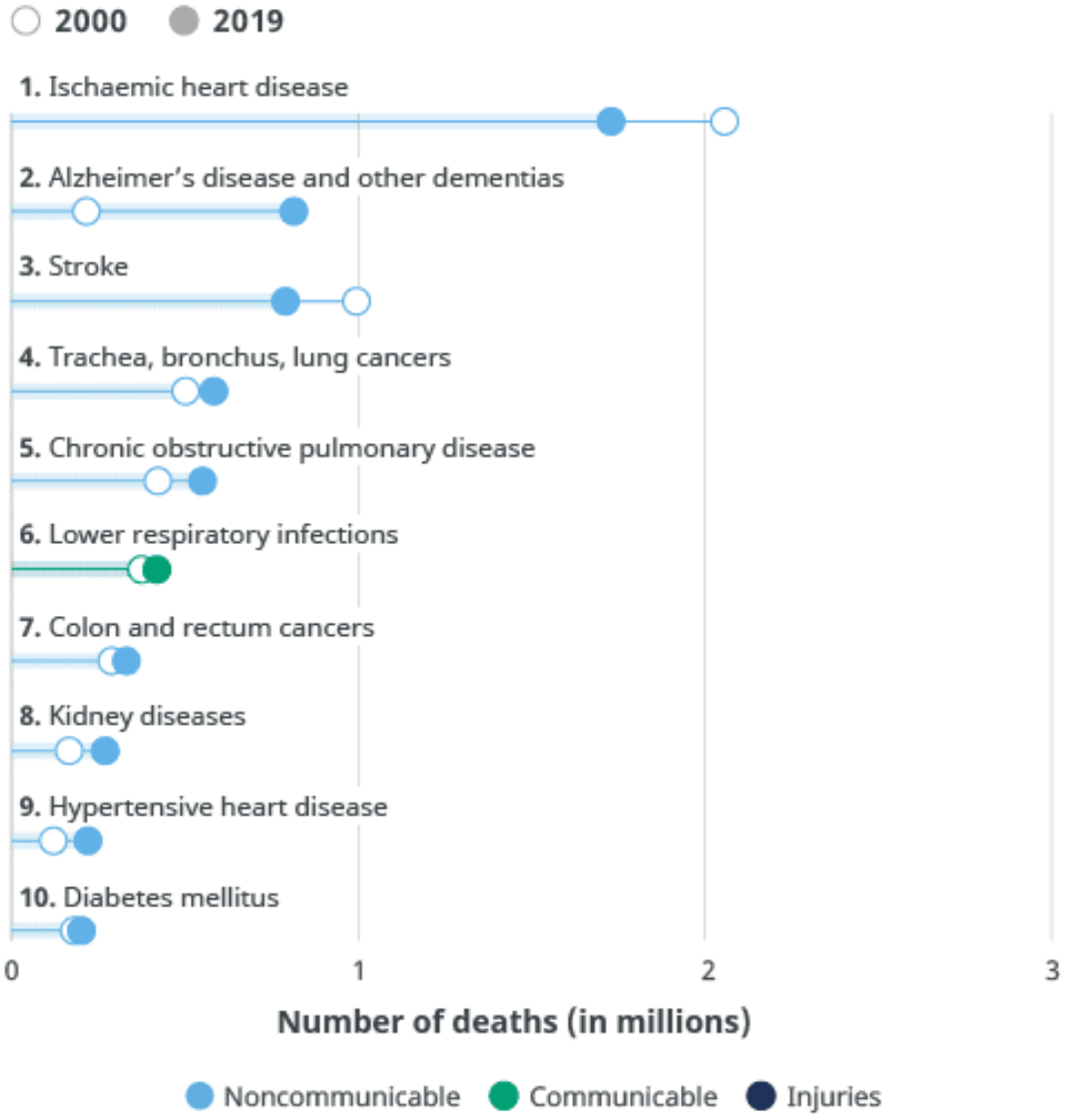
http://www.healthdata.org/uganda

Top Causes of Deaths: Lower-Middle-Income Countries (GNI per capita of $1,045 to $4,095)



Source: WHO Global Health Estimates. Note: World Bank 2020 income classification.

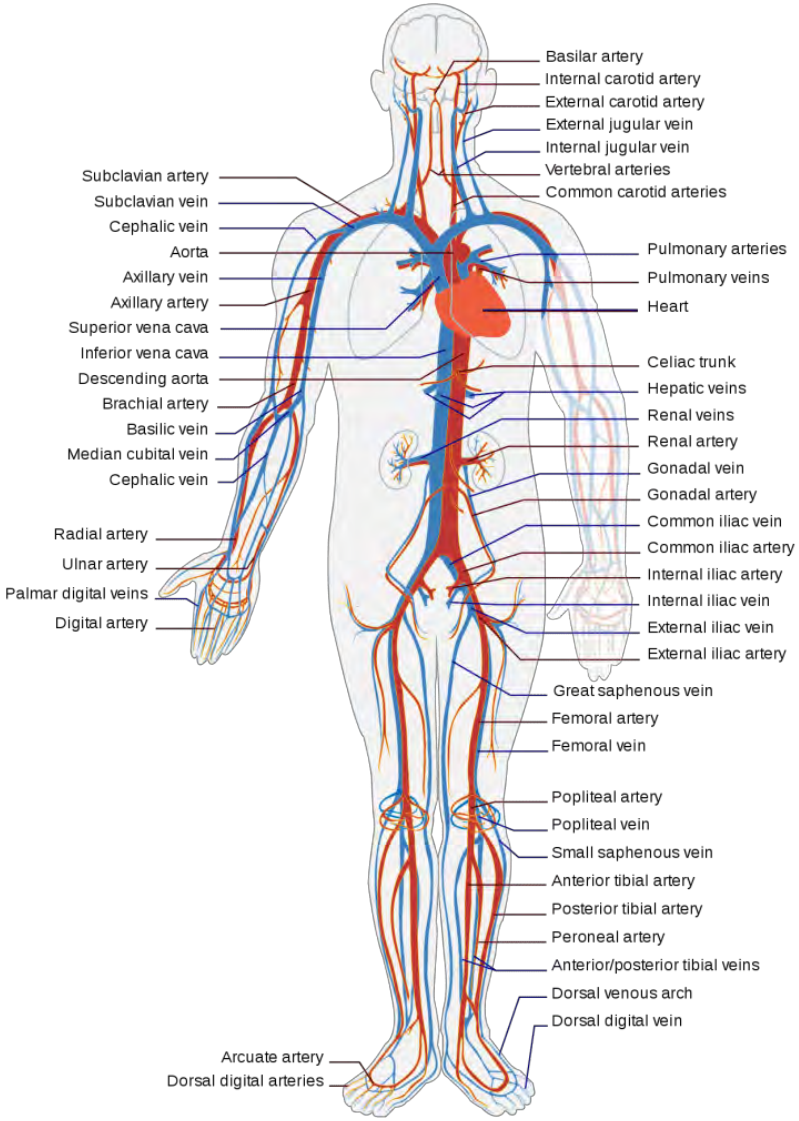
Top Causes of Deaths: High Income Countries (GNI per capita of > $12,696)



Source: WHO Global Health Estimates. Note: World Bank 2020 income classification.

Most Diseases Have an Engineering Basis/Analogy

The Cardiovascular System

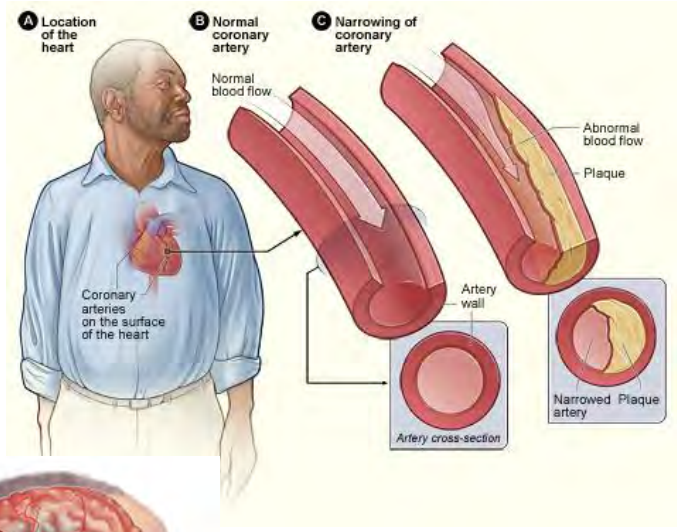


https://www.timeofcare.com/the-circulatory-system/

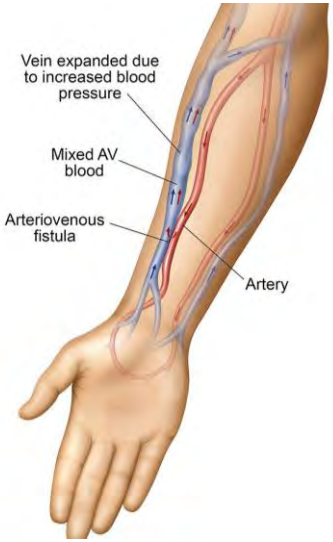
What can go wrong?

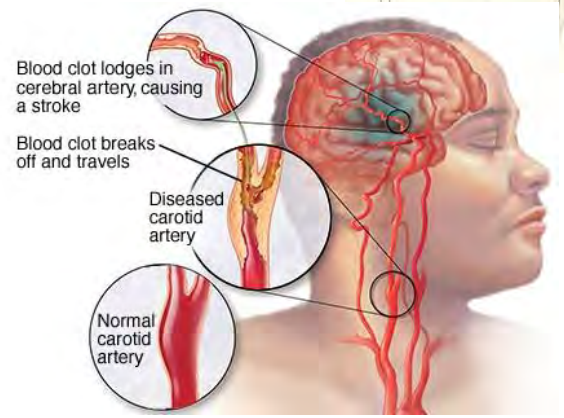
Chronic Total Occlusion/Stenosis

Coronary artery disease



Atriovenous fistula





Carotid artery disease = stroke

https://www.nhlbi.nih.gov/health-topics/coronary-heart-disease

Interventional procedures are required to remove this plaque and restore normal blood flow

- cardiovascular interventions

Some Mathematics

Solution of Navier Stoke's Equation for a tubular microfluidic flow device (no external force):

$$Q \sim \nabla P * R^4$$

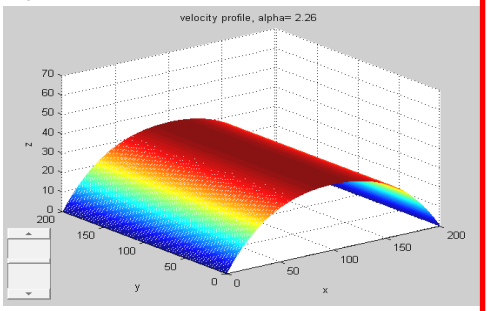
Q-Flow rate
∇P-Pressure Gradient
R-Radius

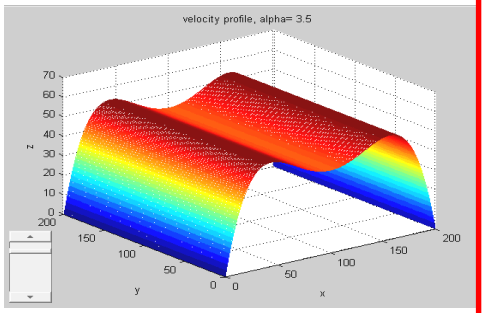
For a half reduction in radius, to maintain the same flow rate, the pressure must go up 16 times!!!

Blood flow with periodic pulsations from the heart:

$$u = \frac{u_{max}}{i\alpha^2}\left[1 - \frac{J_0(i^{3/2}\alpha\eta)}{J_0(i^{3/2}\alpha)}\right]$$

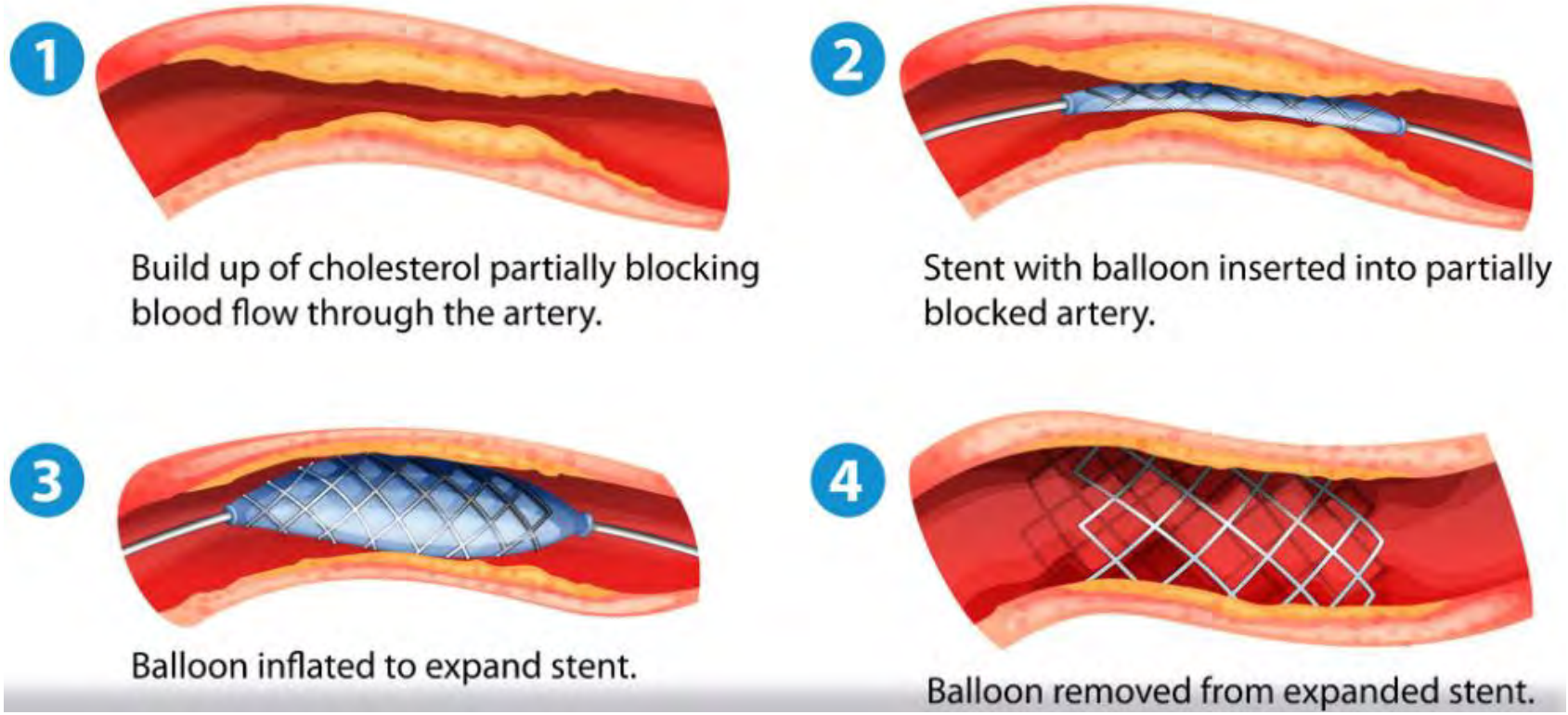
u-velocity parameter
$\eta = r/R$
α –Reynold's like parameter (vessel diameter, heart rate)
J_o – Bessel function





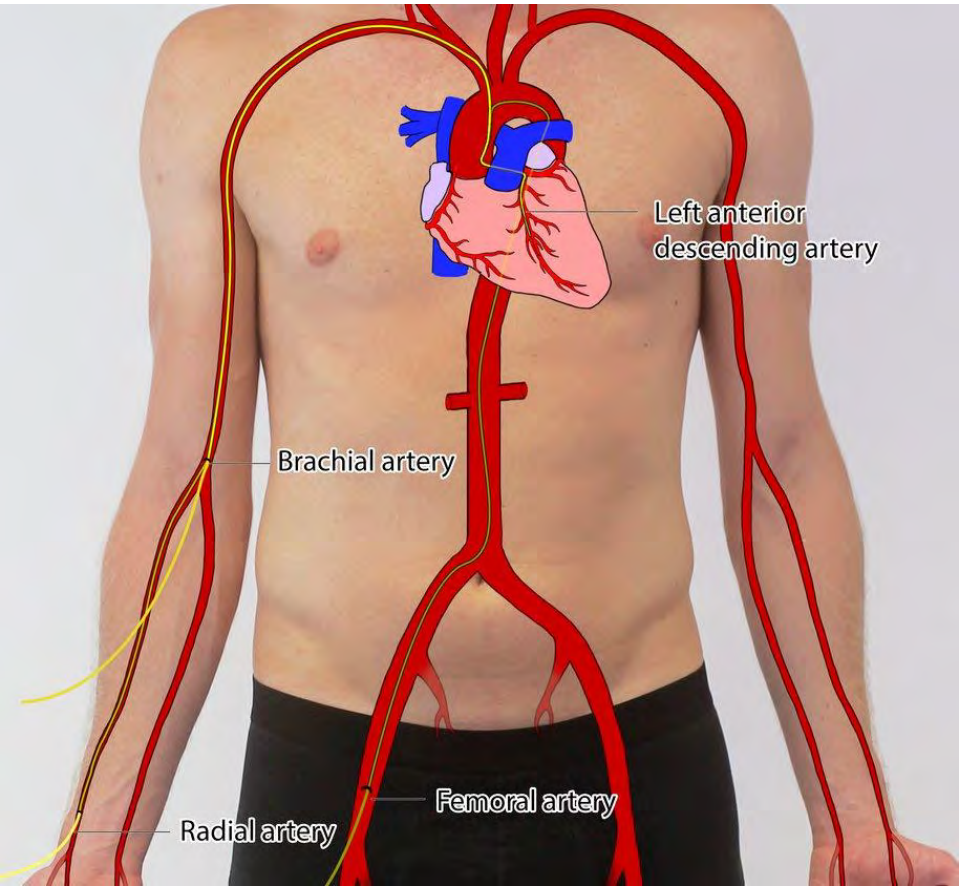
Vascular Interventions

Angioplasty/Stenting

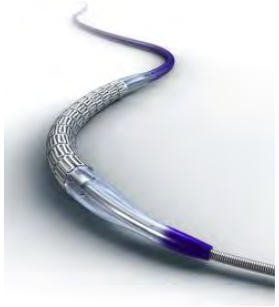


Vascular Interventions

What you need



Guidewire



Catheters

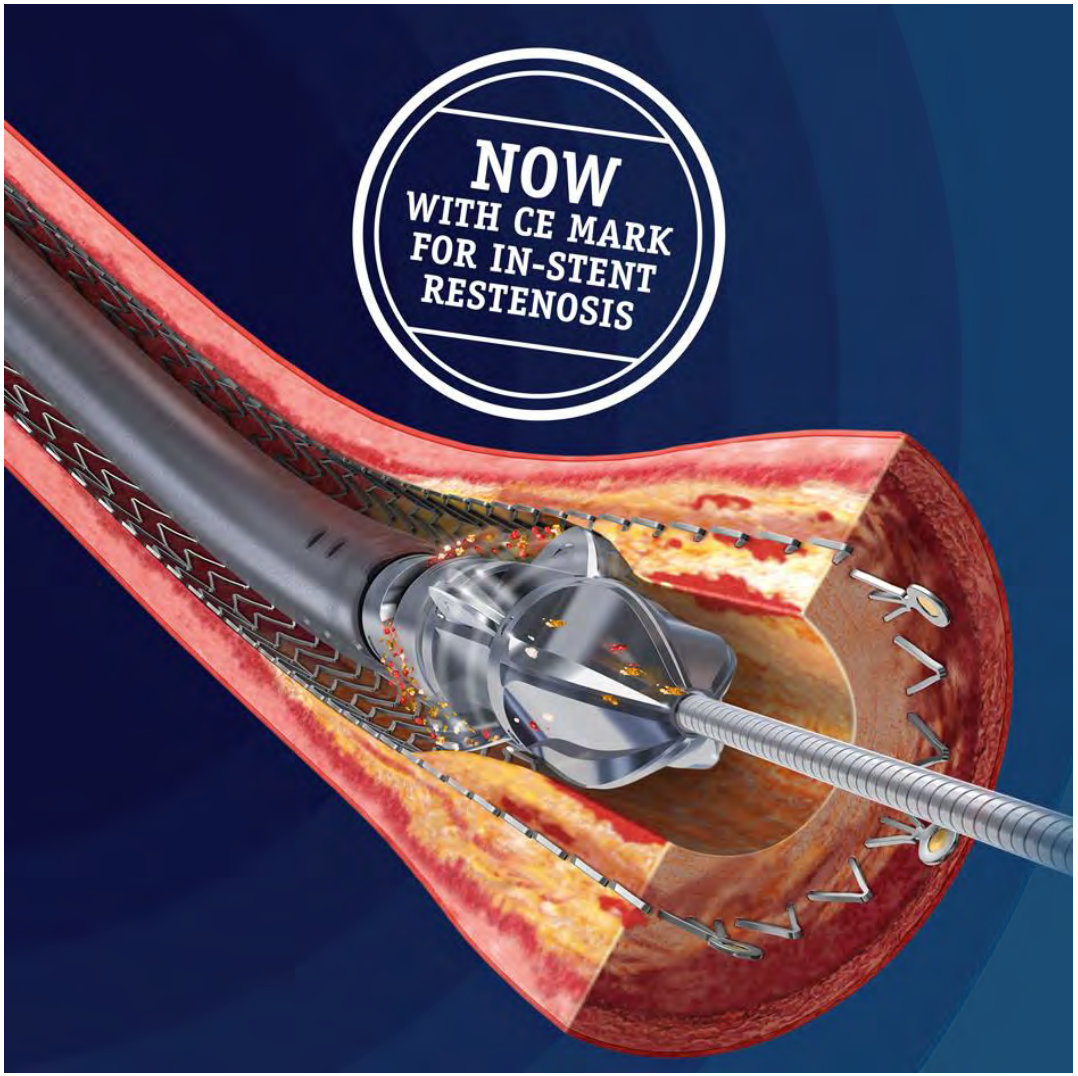
Vascular access needle

Stent

https://www.amboss.com/us/knowledge/Cardiac_catheterization/

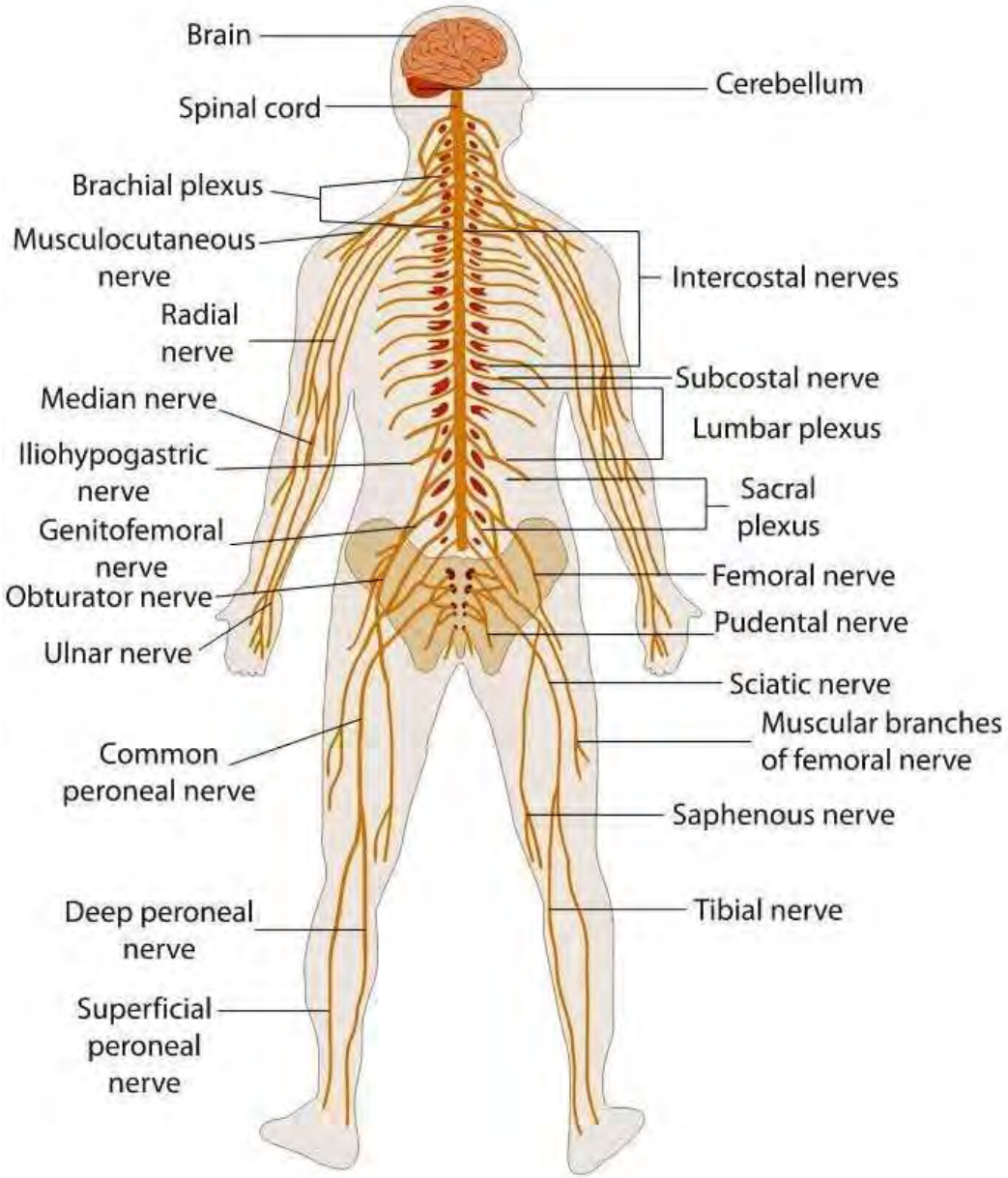
Vascular Interventions

Atherectomy



https://www.bostonscientific.com/en-EU/products/atherectomy-systems/jetstream-atherectomy-system.html

The Nervous System

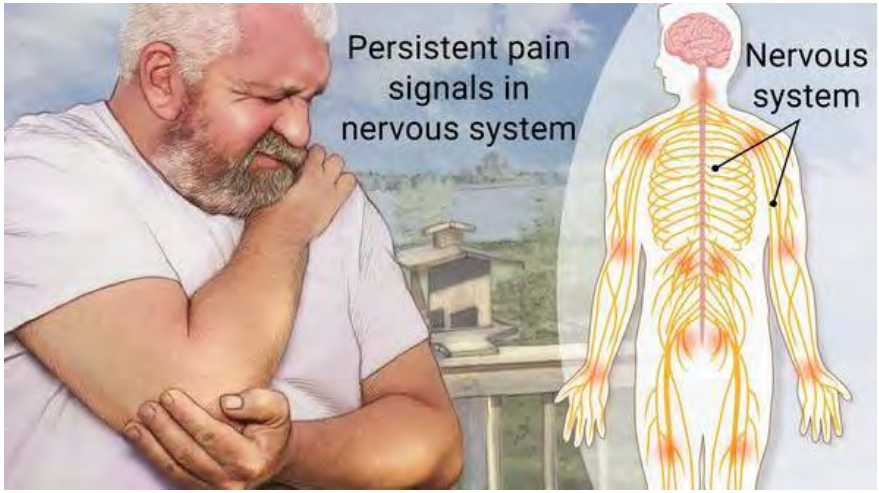


https://en.wikipedia.org/wiki/Nervous_system

What can go wrong

Nociceptive pain: injury to body tissues e.g., cuts, burns.
Fractures/postoperative pain/cancer pain

Chronic pain



- ~80% of adults experience lower back pain
- Interventional procedures are required to disrupt the pain pathway
- Regional anesthesia: makes a specific part of the body numb to relieve pain or allow surgical procedures to be done.

Regional anesthesia

Spinal Anesthesia

Ankle block

https://parenting.firstcry.com/articles/spinal-anesthesia-for-c-section-advantages-and-disadvantages/

Imaging Systems

X-ray

Computed Tomography (CT)

Magnetic Resonance Imaging (MRI)

Fluoroscopy

Ultrasound

Limitations of 2D Ultrasound

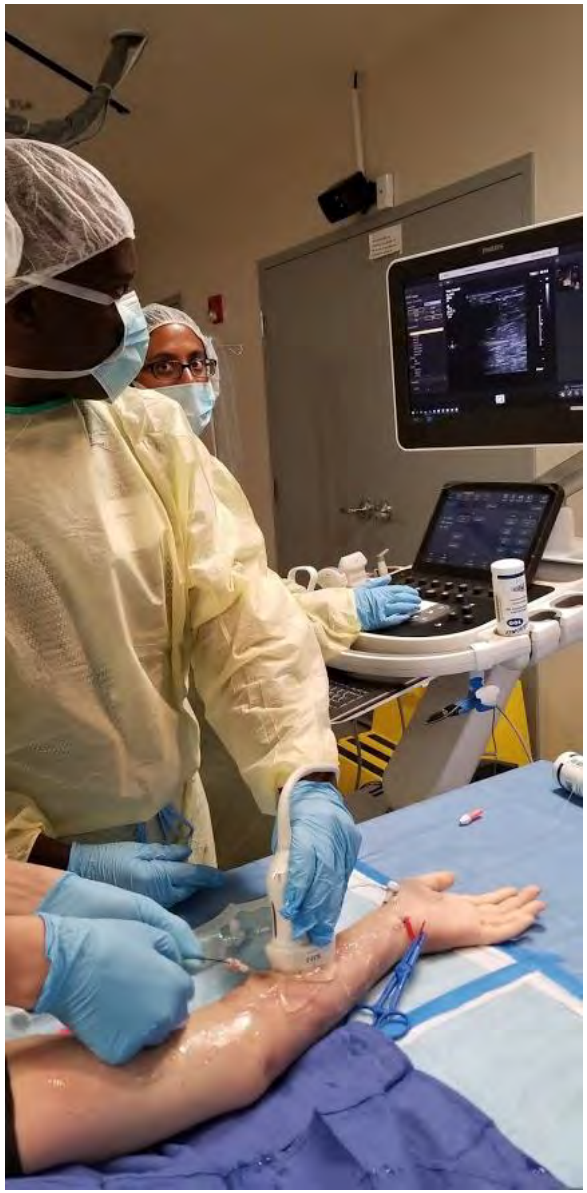
Ultrasound (US), 2D, hand-held: powerful technology, difficult workflow

Ultrasound is…

✓ **Safe** zero ionizing radiation, zero contrast

✓ **Low-cost** office-based labs

✓ **Real-time** Flexible



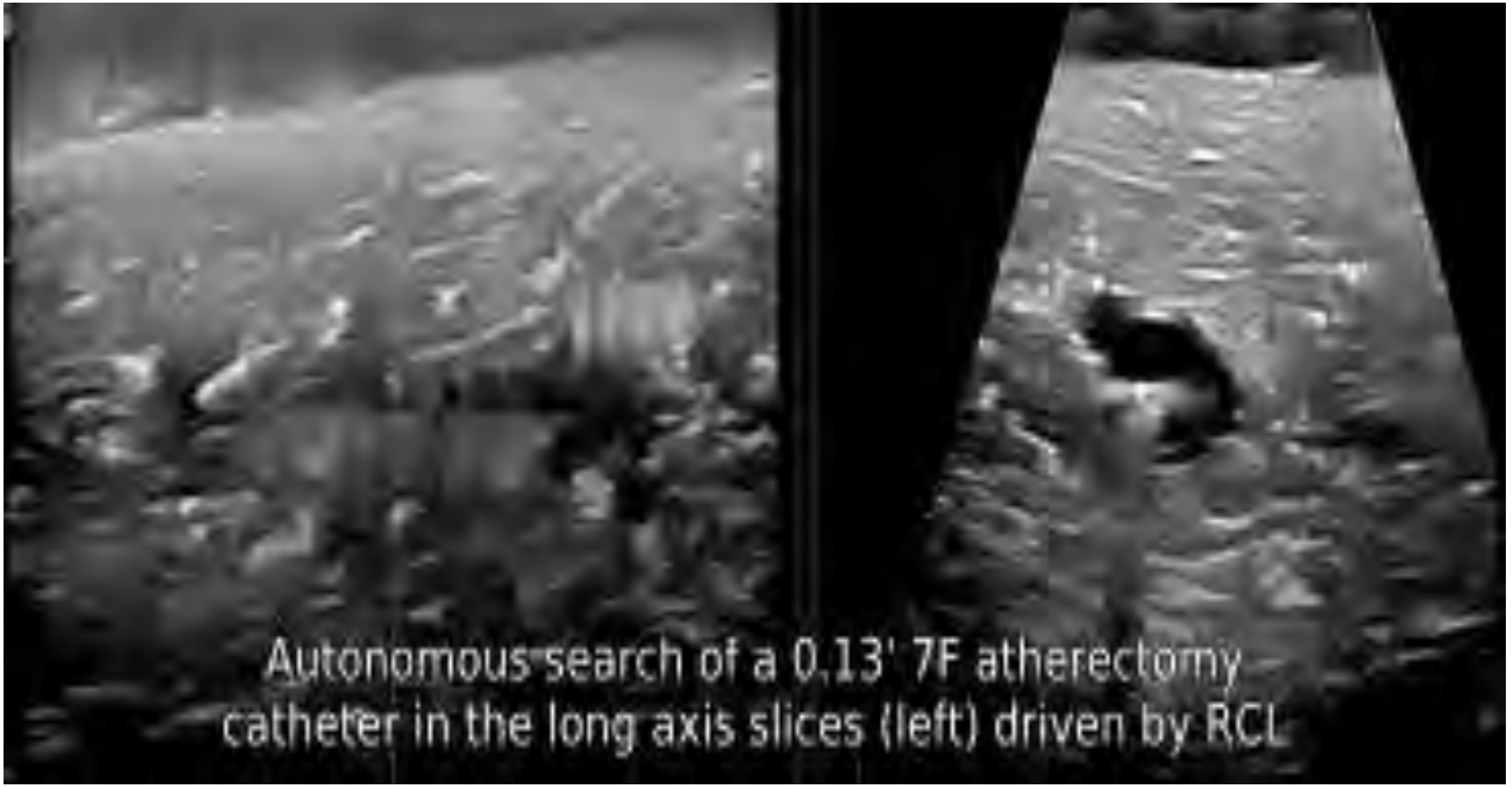
✕ **Difficult to use**

- Limited field-of-view
- **Two-person workflow**

19

Research Area: Making Ultrasound Imaging Smarter

Smart search of device in 3D ultrasound



WO2021058288A1 (WIPO PCT). Automatic Closed Loop Ultrasound Plane Steering for target localization in ultrasound imaging and associated devices, systems, and methods. Alvin Chen, Cosmas Mwikirize, Mingxin Zheng, Kunal Vaidya, Shyam Bharat. April 1, 2021.

Taking it to Another Level--

The da Vinci Robot-Assisted Surgery System

https://www.davincisurgery.com/

Taking it to Another Level--

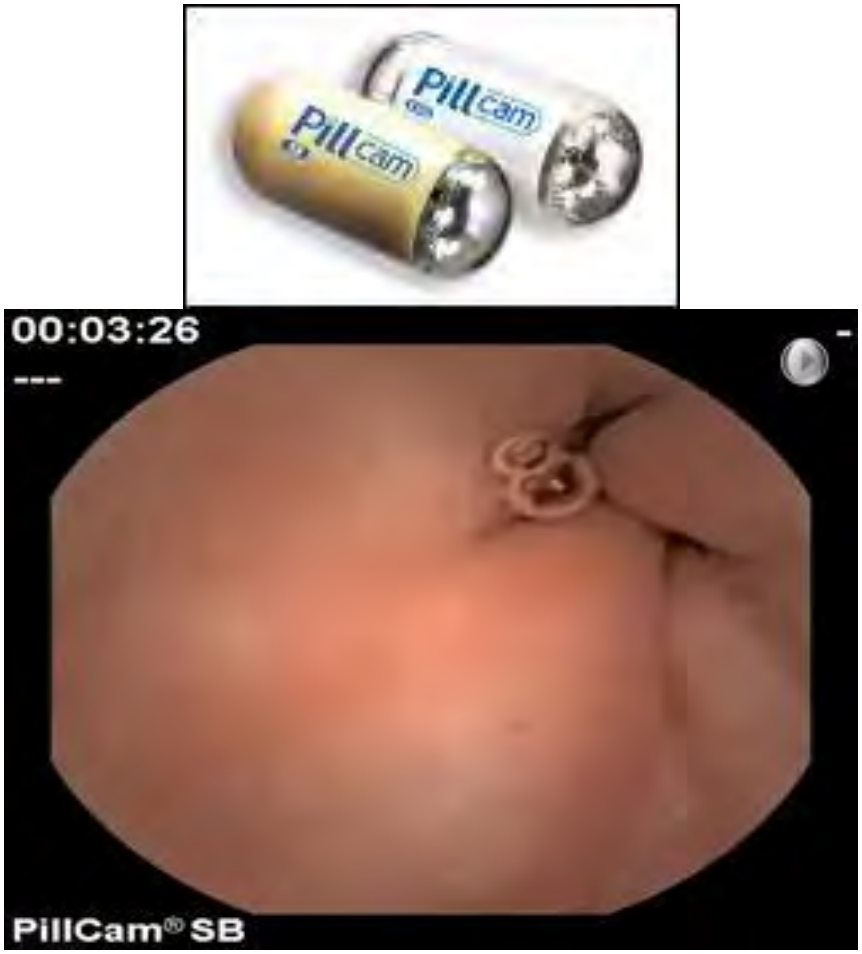
Robots for Blood Draws

https://www.rutgers.edu/news/robot-uses-artificial-intelligence-and-imaging-draw-blood

Research Area: Specialized Imaging Systems

Philips X8-2t Transesophageal (TEE) probe

Wireless Capsule Endoscopy: with a digital wireless transmitter



Research area: Portable, Low-Cost Imaging Systems

https://clarius.com

https://www.usa.philips.com/healthcare/sites/lumify

Delft Easy DR stationary X-ray equipment
(Image credit: Delft Imaging)

The Bigger Picture…