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## 3D Printed Liver in Surgery Education

Sara Belko

David Gordon

Yash Shah

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SIDNEY KIMMEL MEDICAL COLLEGE

# 3D Printed Liver in Surgery Education

Sara Belko  
David Gordon  
Yash Shah



**Jefferson**  
Thomas Jefferson University

# Introductions

# Our Team



Sara Belko  
MS2



David Gordon  
MS1



Yash Shah  
MS1

# Background

# Current Trainee Education

MRI, CT, and US-based understanding of liver anatomy in didactic lectures and for individual patient cases

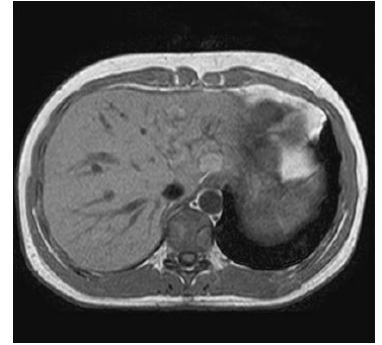
**Open issue:** resident understanding of hepatic venous anatomy and biliary tree (lots of patient variability)

# Anecdotes from current residents

Difficulty of reading MRI or CT slices

Even for attendings

Difficulty of cutting blindly given patient anatomic variations  
(dodging vessels)



# Previous Literature

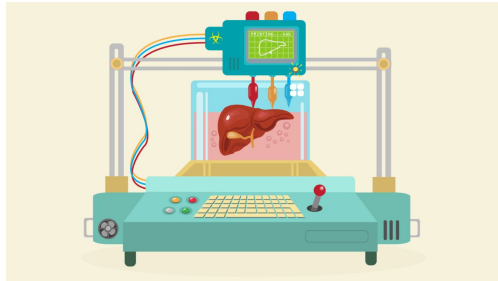
Improved sense of spatial orientation for surgeons

Anecdotally, more rapid and reliable surgical planning

Improved test performance by medical students and residents

Shorter procedure time

Improved patient satisfaction with informed consent



## **3D Printed replica of articular fractures for surgical planning and patient consent: a two years multi-centric experience**

Nicola Bizzotto <sup>1</sup>, Ivan Tami <sup>2</sup>, Attilio Santucci <sup>3</sup>, Roberto Adani <sup>4</sup>, Paolo Poggi <sup>5</sup>, Denis Romani <sup>6</sup>,  
Guilherme Carpeggiani <sup>6</sup>, Filippo Ferraro <sup>7</sup>, Sandro Festa <sup>8</sup>, Bruno Magnan <sup>6</sup>

## **3D-Printing of Arteriovenous Malformations for Radiosurgical Treatment: Pushing Anatomy Understanding to Real Boundaries**

Alfredo Conti <sup>1</sup>, Antonio Pontoriero <sup>2</sup>, Giuseppe Iati <sup>2</sup>, Daniele Marino <sup>1</sup>, Domenico La Torre <sup>1</sup>,  
Sergio Vinci <sup>3</sup>, Antonino Germanò <sup>1</sup>, Stefano Pergolizzi <sup>2</sup>, Francesco Tomasello <sup>4</sup>

## **Virtual reality and 3D printing improve preoperative visualization of 3D liver reconstructions—results from a preclinical comparison of presentation modalities and user's preference**

Florentine Huettl <sup>1</sup>, Patrick Saalfeld <sup>2</sup>, Christian Hansen <sup>2</sup>, Bernhard Preim <sup>2</sup>, Alicia Poplawski <sup>3</sup>,  
Werner Kneist <sup>1, 4</sup>, Hauke Lang <sup>1</sup>, Tobias Huber <sup>1</sup>



# Previous Work at Jefferson

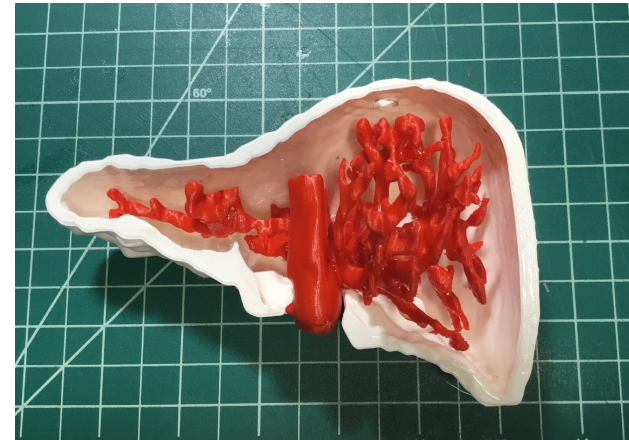
Patient education



Visualize the distance from the liver's edge to large vessels

Visualize tumor location

Tactile advantages over CT



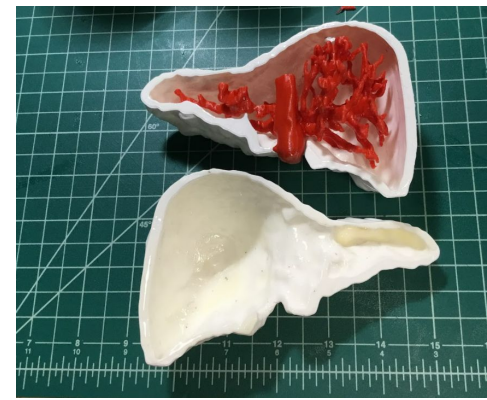
# Process of printing

CT scans with contrast

3-D Slicer to render liver and vasculature imaging

Meshmixer to cut liver in half and visualize inside/ underlying vasculature

Ultimaker- printer



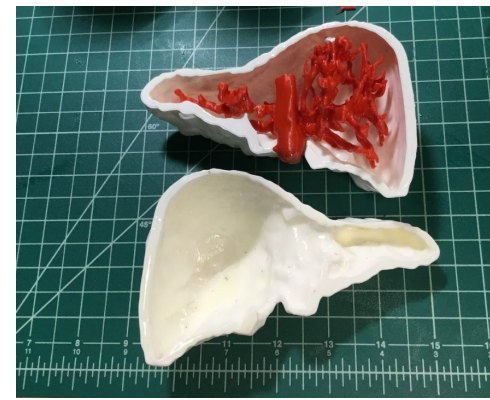
# Process of printing

3 hours processing time

31 minutes of model editing

48 hours of printing

Big time commitment for each patient!



# Benefits and Costs

Reduced complications and improved outcomes

Reduced OR time

Reduced blood loss

Financial savings for patients

Each red blood cell unit costs between \$522 and \$1183

**Liver resection using cavitron ultrasonic surgical aspirator (CUSA) versus harmonic scalpel: a retrospective cohort study**

Adam S Bodzin <sup>1</sup>, Benjamin E Leiby <sup>2</sup>, Carlo G Ramirez <sup>3</sup>, Adam M Frank <sup>3</sup>, Cataldo Doria <sup>4</sup>

## Next Steps

Transition from individual patient-specific printing to a broader educational approach for trainees

# Problem

# The problem

Visualization is difficult on 2-D imaging

Patients, medical students, residents, and physicians are all stakeholders in optimal understanding of anatomy prior to a procedure

Visual skills and spatial awareness are important for surgical trainees

# Opportunities to Improve Spatial Fluency Education

**EDUCATION**

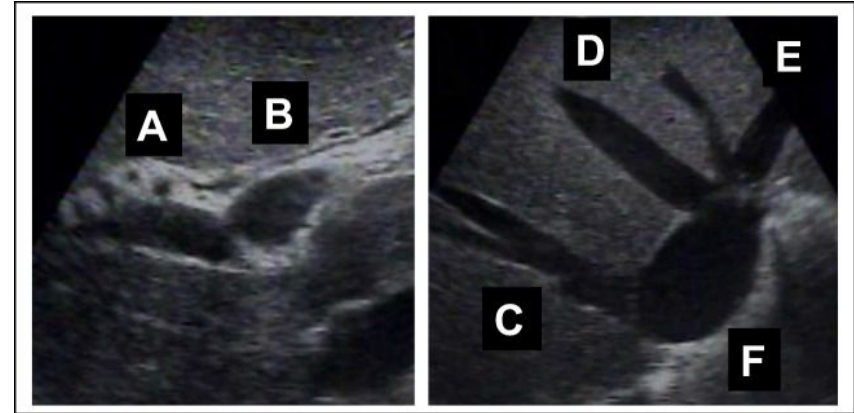
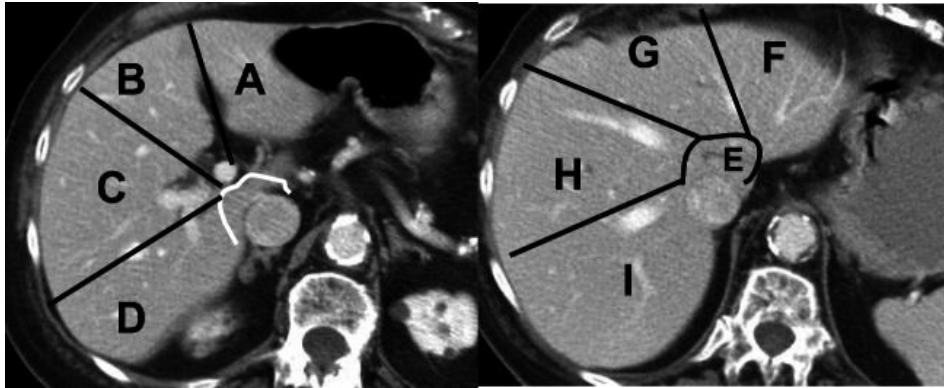
**CLINICAL MEDICINE**

**CARE ECONOMICS**



# A Clinical Question

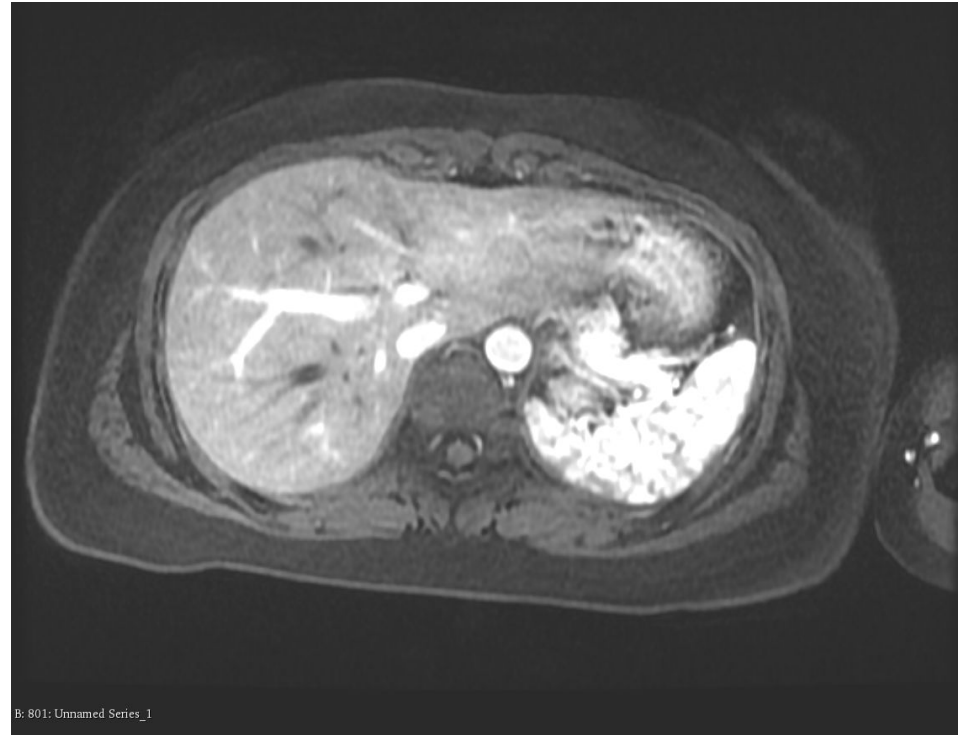
Match the liver segments on CT with US



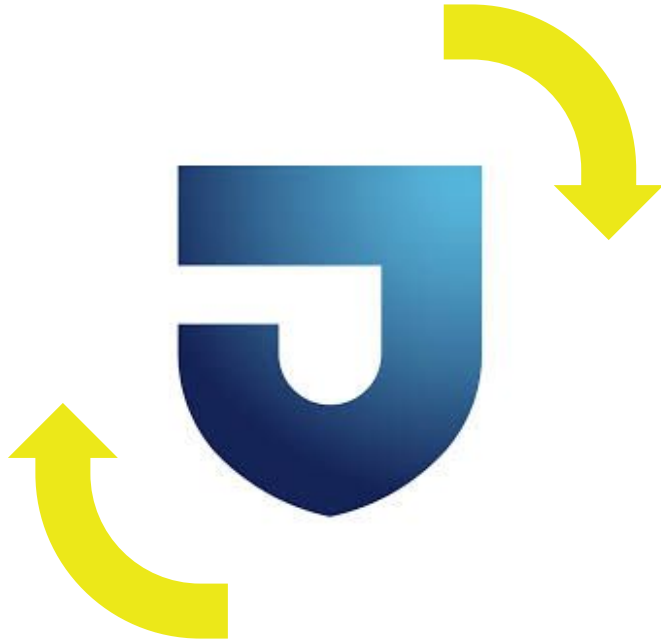
# Boards Question

A 47 year old patient undergoes a CT scan for liver imaging to determine vascular anatomy for a transplant donor operation.

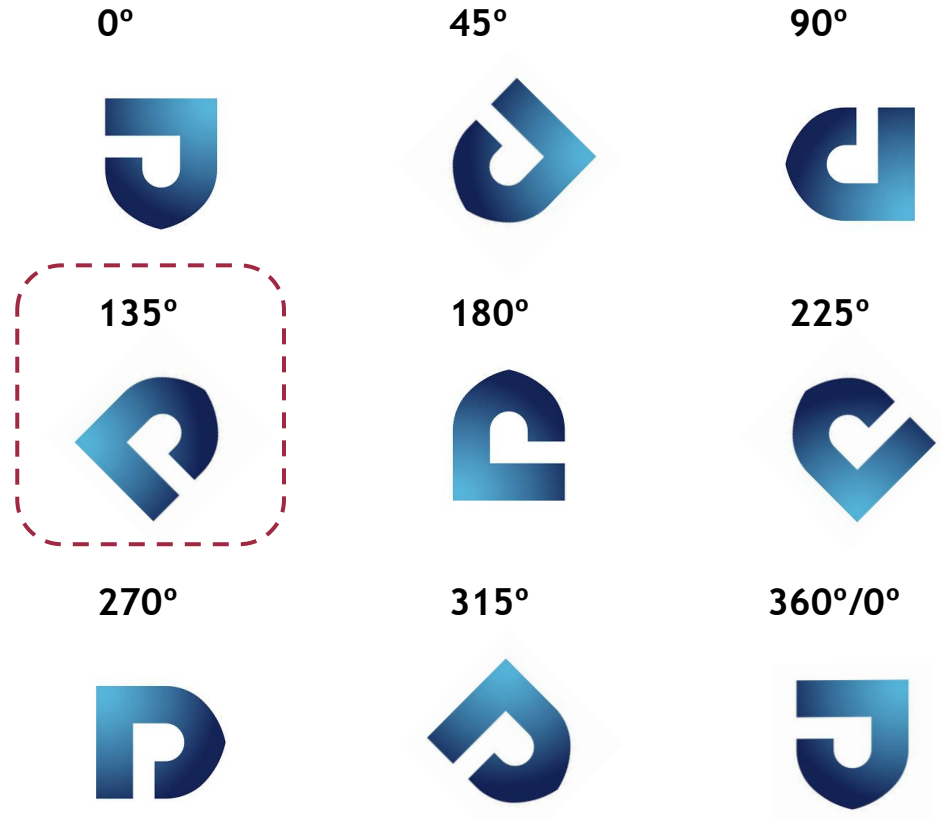
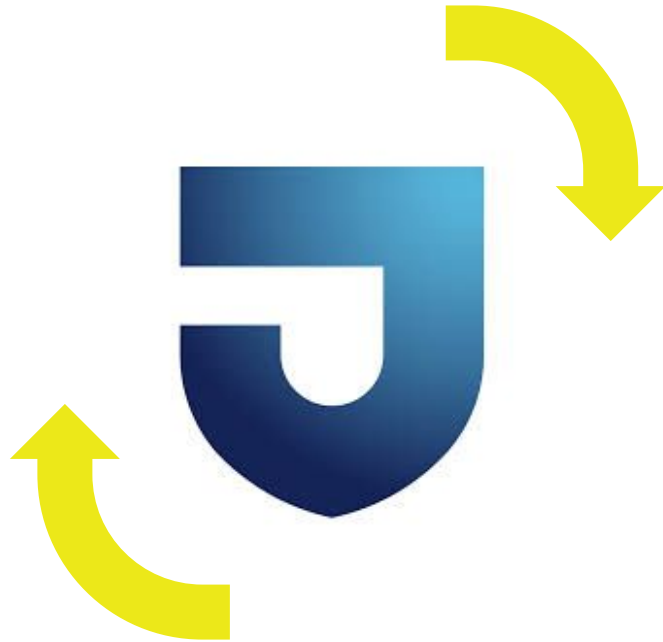
What vertebral level is this scan taken from ?



# Mental Rotation Test



# Mental Rotation Test



# Mental Rotation Test



0°



45°



90°



135°



180°



225°



270°



315°



360°/0°



# Mental Rotation Test



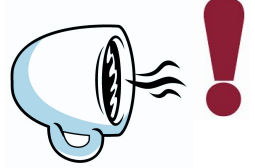
0°



45°



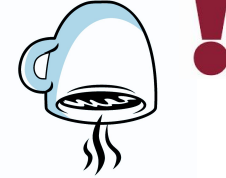
90°



135°



180°



225°



270°

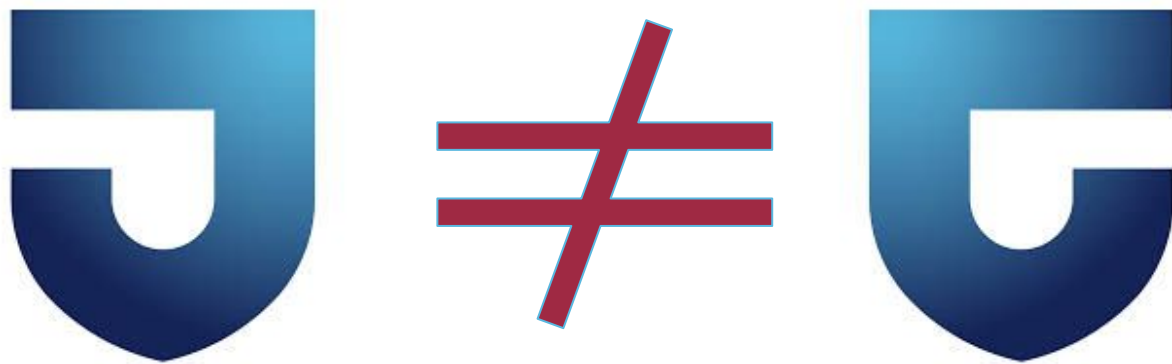


315°



360°/0°





Panel One:

one

Panel Two:

two

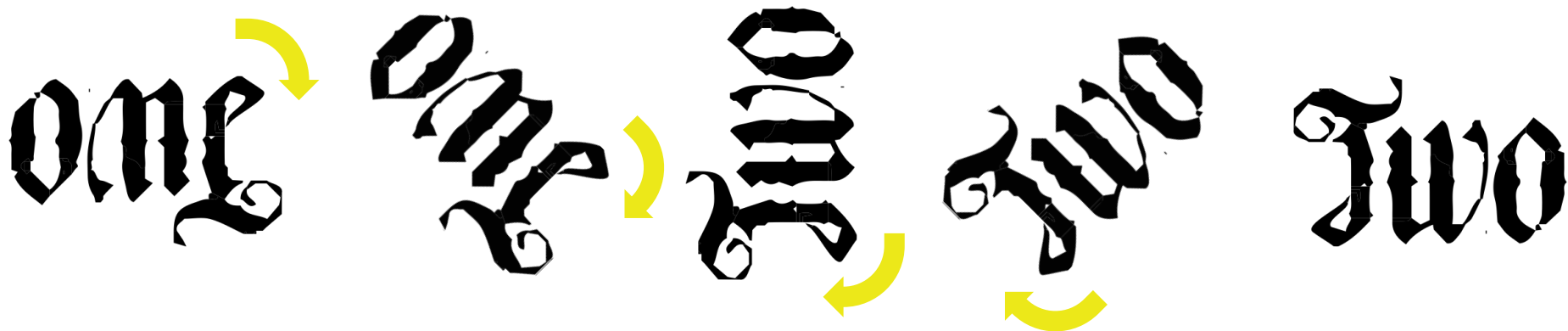


Panel One:

one

Panel Two:

Two



Something Benign.

benign

Something Benign.

benign

benign

benign

benign

Something Cancerous.

malignant

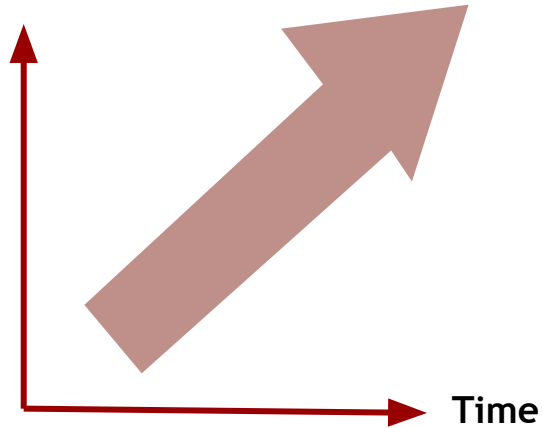
malignant

malignant

# Spatial Fluency

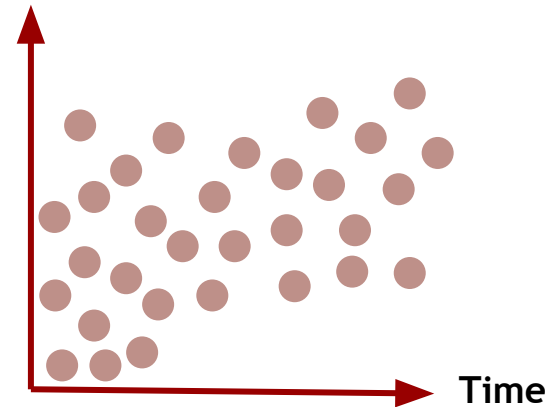
## Expectation

Visual Spatial Ability

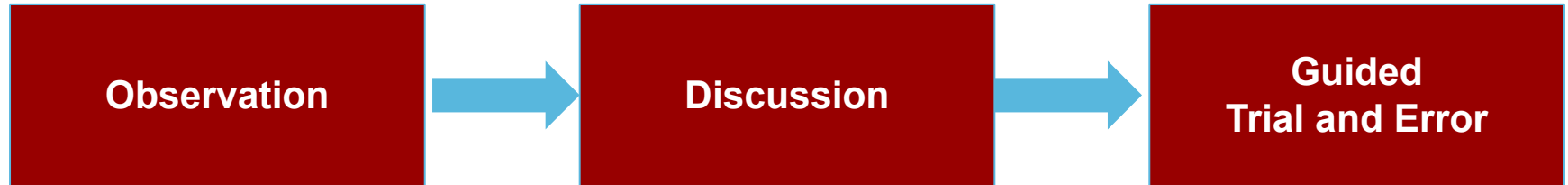


## Reality

Visual Spatial Ability



# How is Spatial Fluency Developed?



# Tools to Develop Spatial Fluency in Medical Education

**Observation**

**Simulation**

**Lecture Based  
Education**

**Trial and Error**

**Mental Rotation Test  
Assessment  
Repetition**

**3D Printing**

# Cost of Education Methods

Resident Time  
Slower Turnover

**Observation**

**Simulation**

High Upfront and  
Recurring  
Operational Cost

Resident Time  
Attending Time

**Lecture Based  
Education**

**Trial and Error**

Possible Harm if  
Error Uncorrected

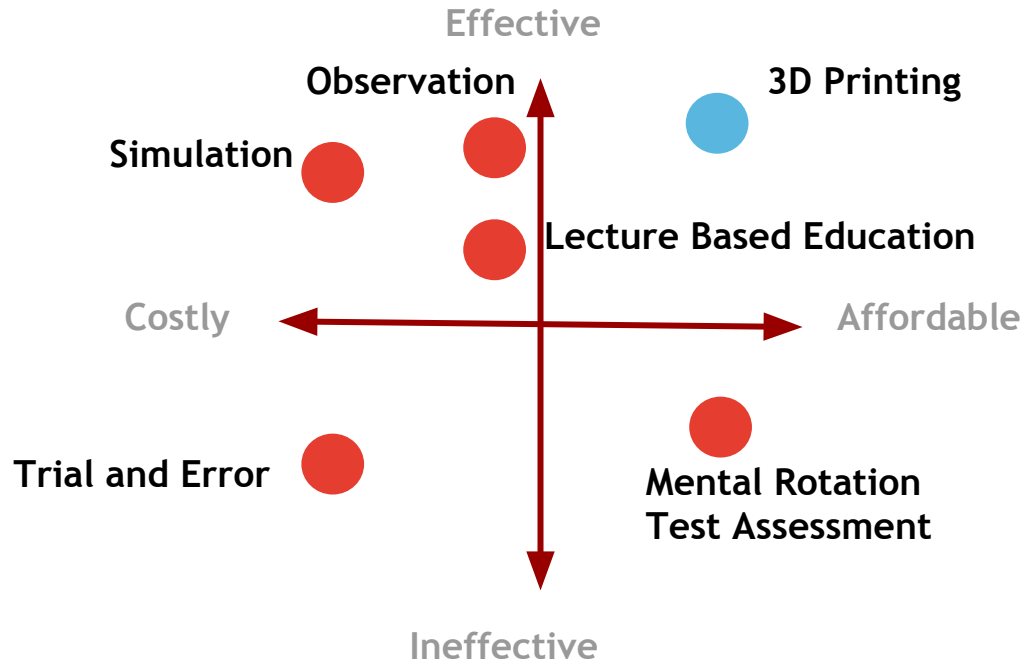
Affordable, but  
lower fidelity

**Mental Rotation Test  
Assessment  
Repetition**

**3D Printing**

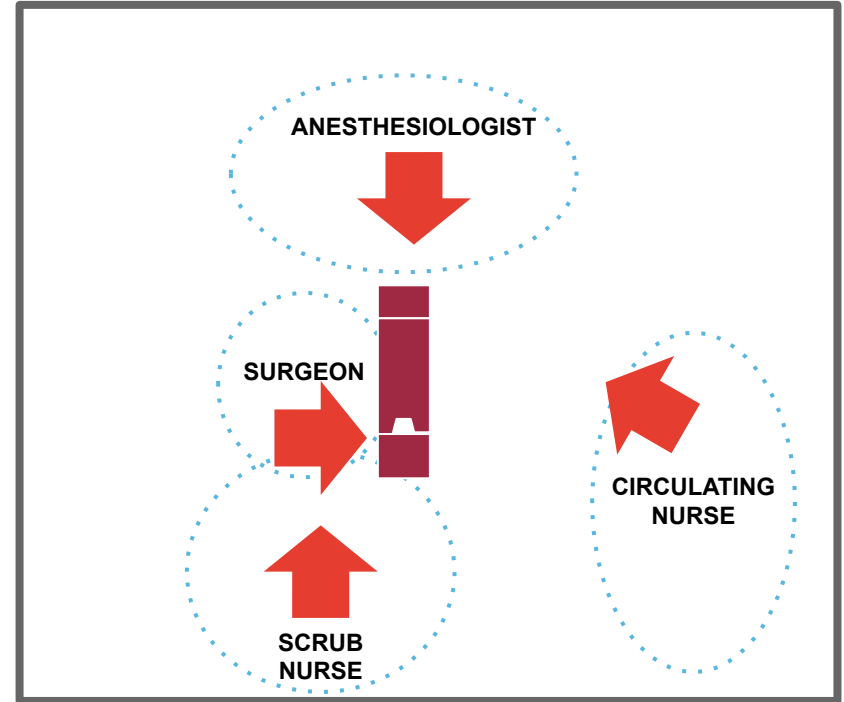
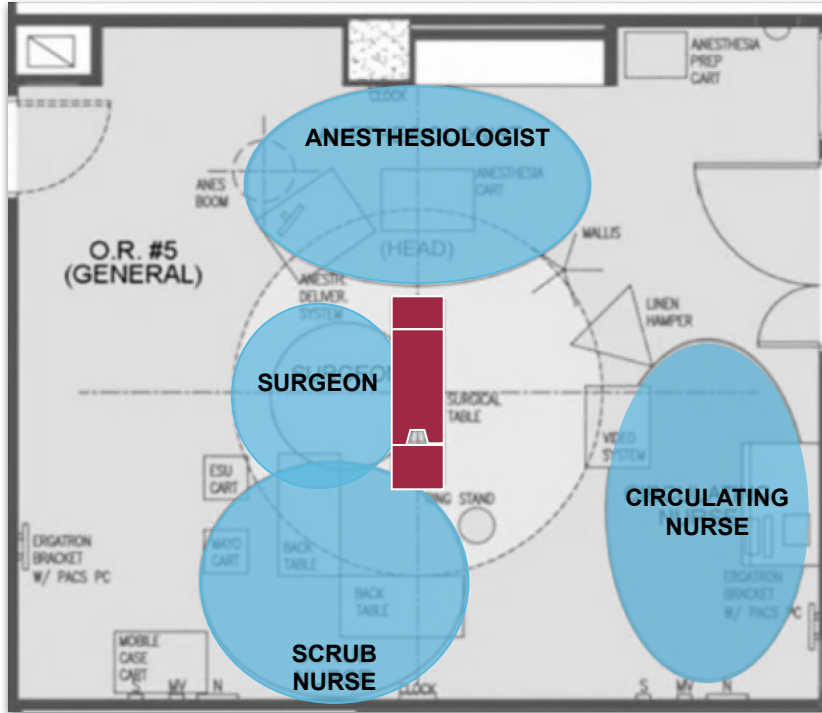
**Affordable &  
Efficient**

# Market Landscape: Surgical Spatial Education





# Spatial Acuity in the Physical Environment



# Clinical Implications of Spatial Awareness

operative time?

intraoperative bleeding?

resection time?

procedure time?



In Milan the 3D printed liver transplant (with the father who gives it to his son)  
<https://www.italy24news.com/local/102076.html>

# Timeline & Anticipated Effect on KPI's



# Opportunity to Improve Spatial Fluency Education

## EDUCATION

- Need for consistent means to develop spatial fluency
- Independent of faculty and procedure time

## CLINICAL MEDICINE

- Improved surgeon and trainee confidence
- improved surgical outcomes
- shorter procedure time

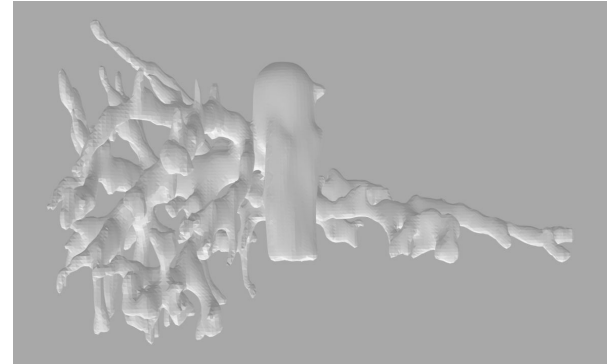
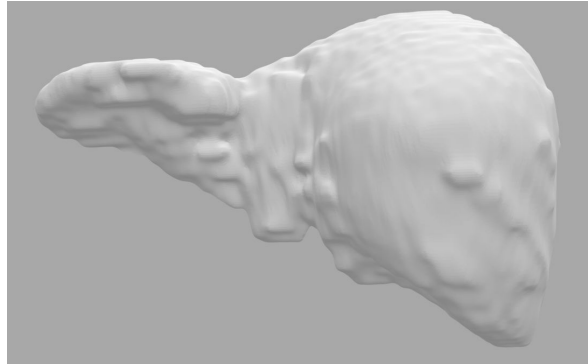
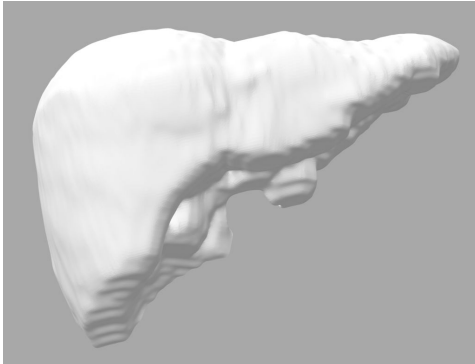
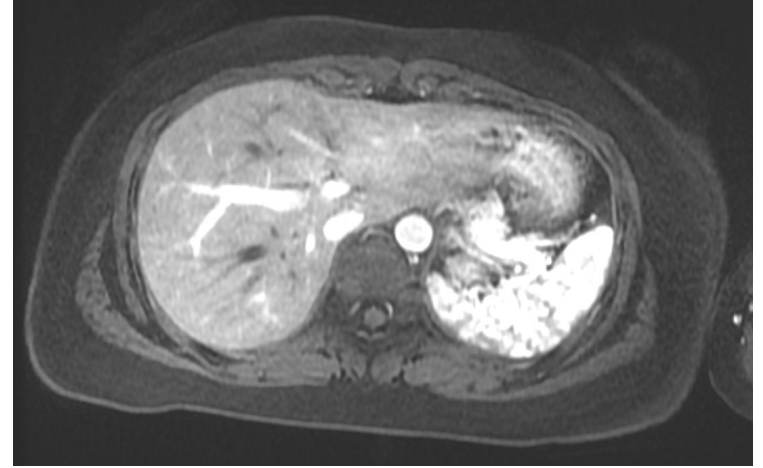
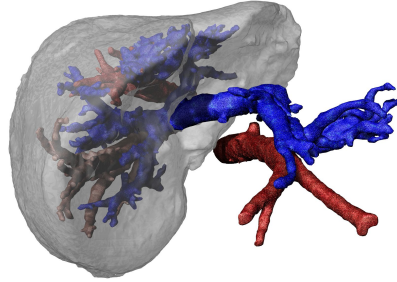
## CARE ECONOMICS

- 3D printed models less costly than other means
- Faster turnaround of OR's yields increased revenue for the hospital

# Solution & Approach

# 3D Printed Liver + CT Scans

- Learn from patient scans



# Methods

## Spatial Acuity/Fluency Pre-test

Group 1:  
Control (no  
intervention)

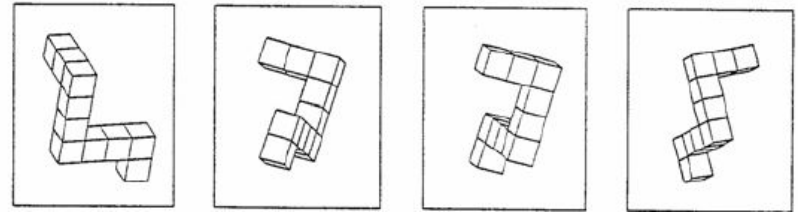
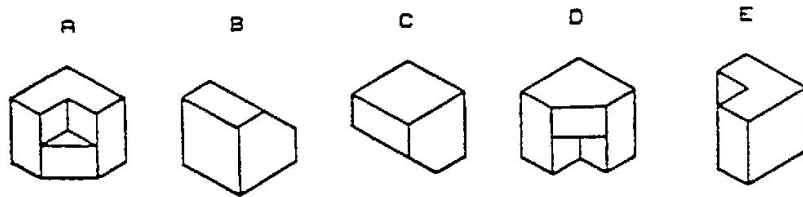
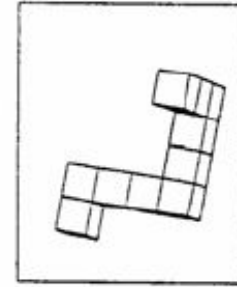
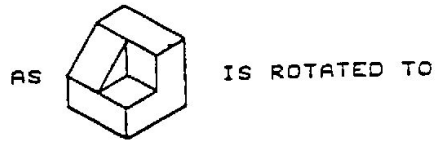
Group 2:  
Traditional (CT  
Scans)

Group 3:  
3D Printed  
Models

## Spatial Acuity/Fluency Post-test + Likert Survey

# Spatial Acuity/Fluency Test

Based off of Purdue Spatial Visualization Test and Vandenberg & Kuse Mental Rotation Test

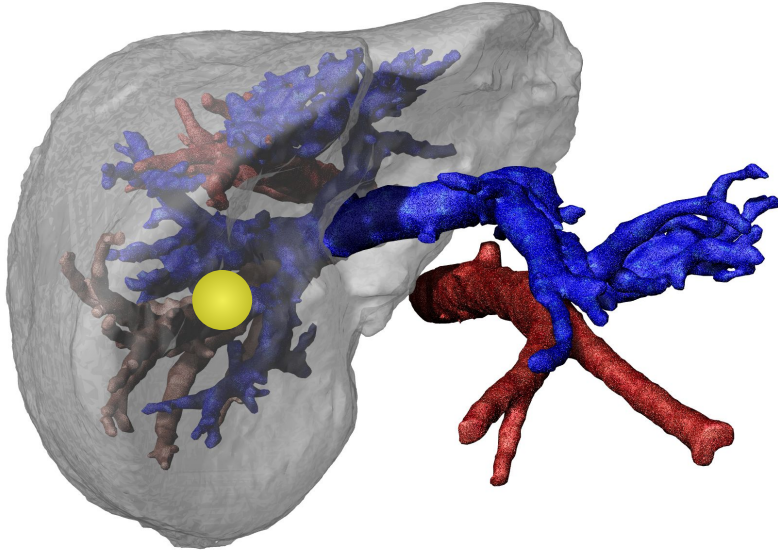




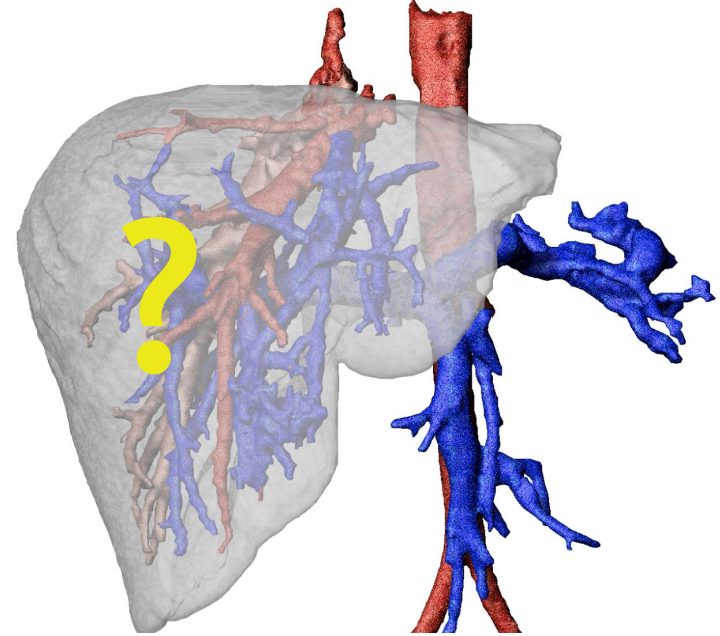
# Likert Survey

1. Prior to the session, I **felt very prepared** to perform this procedure
  - a. After the session, I felt very prepared to perform this procedure
  - b. I feel more prepared to perform this procedure in a live setting
2. I believe that the 3-D model is more effective than review of CT imaging
3. Seeing the model of the liver **helped me clarify** the steps of the procedure
  - a. Seeing the model of the liver helped me understand the location of the surgery
  - b. Seeing the model of the liver helped me clarify relationships with surrounding blood vessels
  - c. Seeing the model of the liver with real physical dimensions helped me clarify true-to-life anatomic relationships
4. The anatomy was **realistic**
5. **Tactile feedback** helped me understand aspects of the live procedure
6. I was **satisfied with this educational session**
  - a. I would like to see a similar 3-D printing based educational session in the future
  - b. I would recommend such a session to my peers
  - c. This model is an effective teaching tool

# Spatial Acuity In Procedural Care: Hepatoma

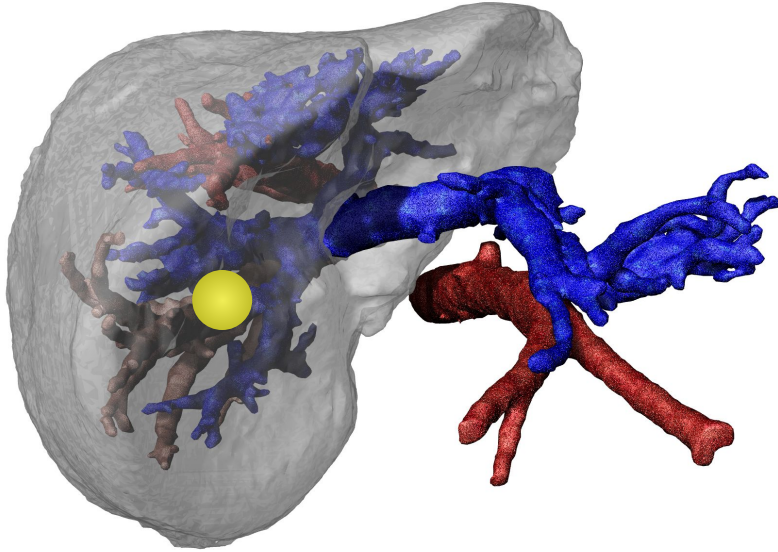


- Transverse Plane View
- Imaging View
- Clear Definition of Hepatoma

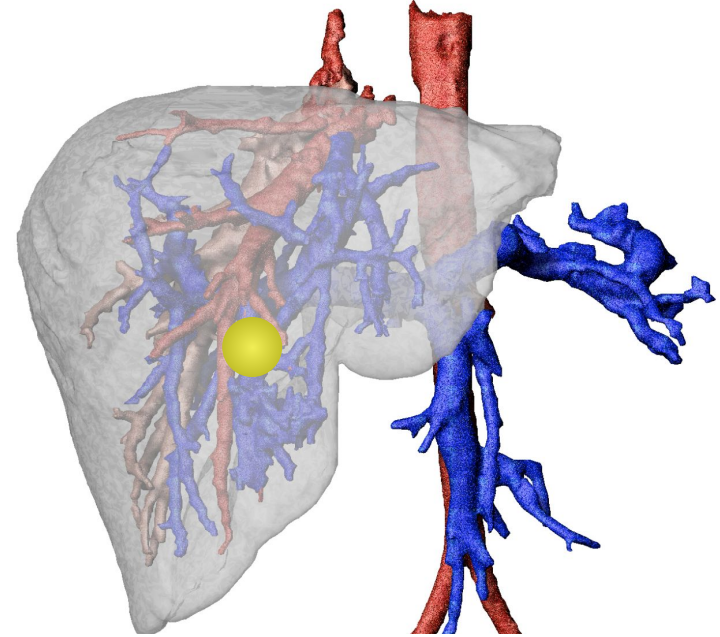


- Coronal Plane View
- Common Surgical Approach
- Overlapping Vasculature

# Spatial Acuity In Procedural Care: Hepatoma

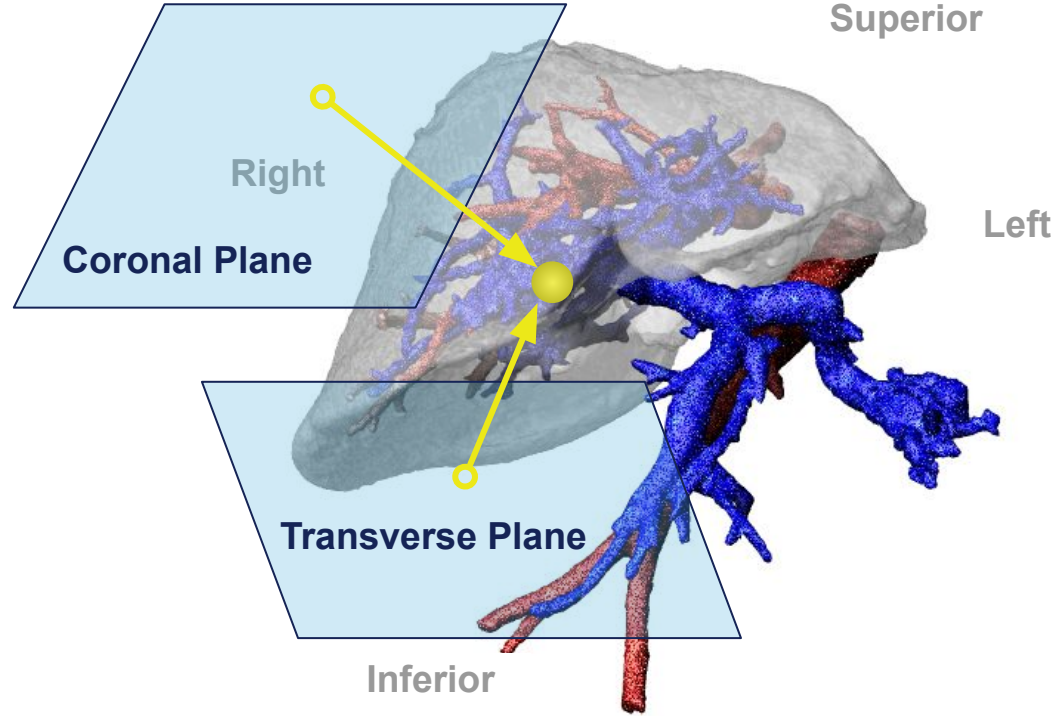
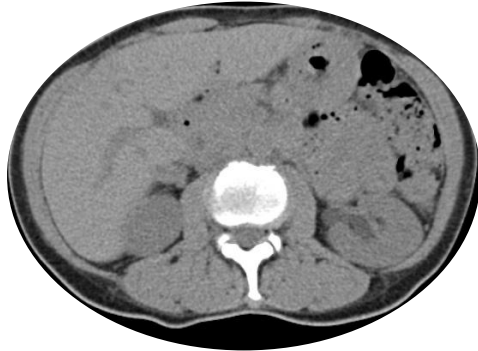
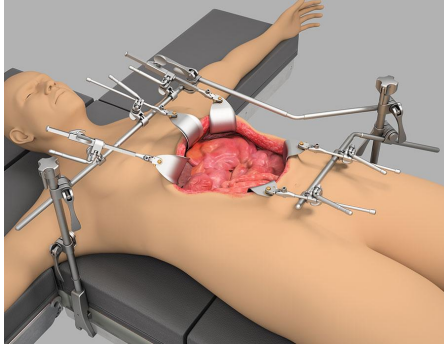


- Transverse Plane View
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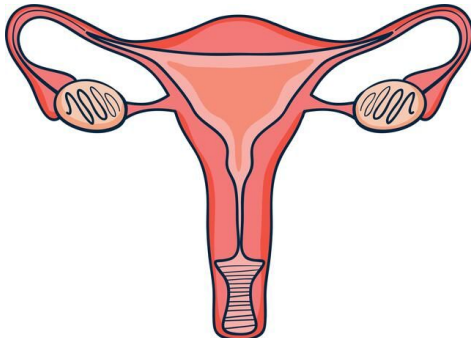
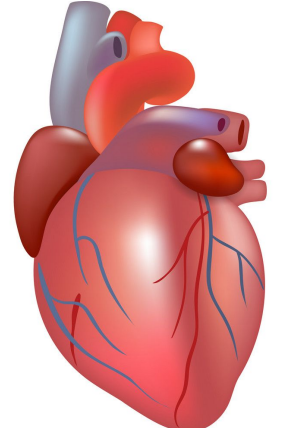
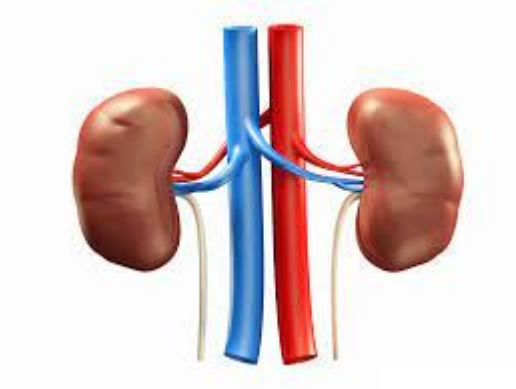
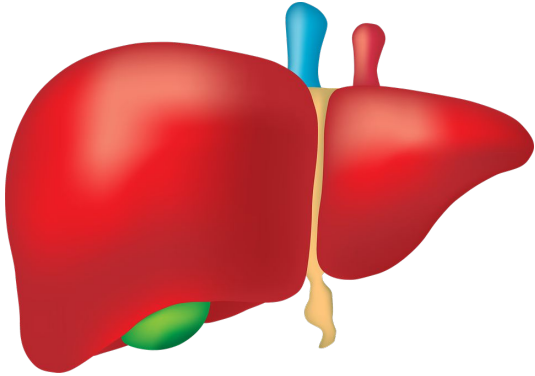


- Coronal Plane View
- Common Surgical Approach
- Overlapping Vasculature

# Spatial Fluency: Integrating Between Planes



# Targeted Populations



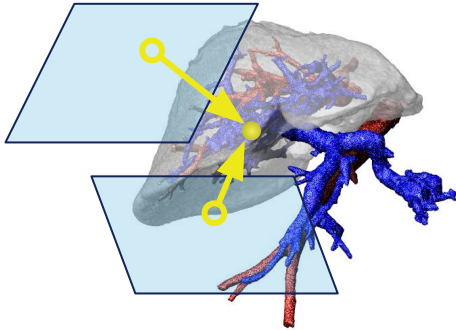
# Implications + Wrap Up



# Implications of 3D Printing Algorithm Integration

## 3D Printed Model in Trainee Integration

### EDUCATION



### CLINICAL MEDICINE



### CARE ECONOMICS



# Our Project Process

Project Kickoff

Literature Search

Project Planning

Stakeholder  
Interviews

Study Planning



# Acknowledgements

Dr. Ashesh Shah

Dr. Adam Bodzin

PEL Program

