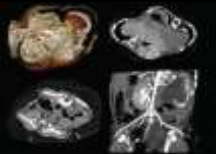


Anna and Hope Richards -- Born on Dec 29, 2016



<http://3dprinttexas.com/news-updates/conjoined-twin-girls-separated-at-texas-childrens/>



Images courtesy of Texas Children's Hospital
note: images from a different set of twins - for illustrative purposes



<http://3dprinttexas.com/news-updates/conjoined-twin-girls-separated-at-texas-childrens/>



<http://3dprinttexas.com/news-updates/conjoined-twin-girls-separated-at-texas-childrens/>



<https://www.click2houston.com/news/2nd-formerly-conjoined-twin-released-from-texas-childrens-hospital>

3D Printing

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University of Ottawa

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Mayo Clinic, Rochester



Engineering with Artistic License

Frank Rybicki, MD, PhD
University of Ottawa

{presented by: Erin Angel, PhD}

Disclosures

- F Rybicki: unknown
- E Angel: Employee, Canon Medical Systems, USA

Michelangelo 1475-1564



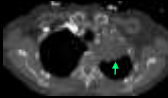
Michelangelo
"Rondanini Pietà"
Milan, Italy





Vesalius, *De Humani Corporis Fabrica, Secundus*, 1543

Present



Definitions

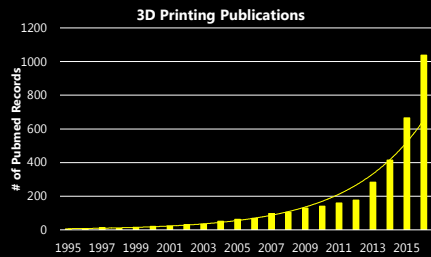
The **physician-scientist** is an individual with an M.D. degree for whom research is a major focus.

The **physician-artist** is a concept derived from this term, but where there is a greater emphasis on art



Reference: Rybicki FJ. Medical 3D Printing and Artistic License. *The Lancet*. 2018; 391(10121):651-652.

Rapid Growth in Biomedical Research



George E et al. Radiographics 2017;116:407.

3D Printing is Entering Clinical Practice



What Are Common Uses of 3D-Printed Models?

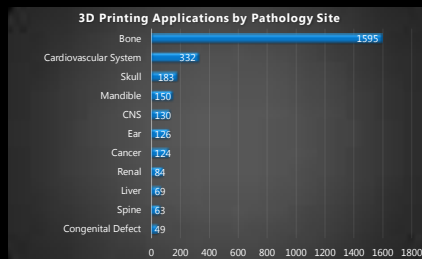






What Models Are in High Demand in an Early Practice?

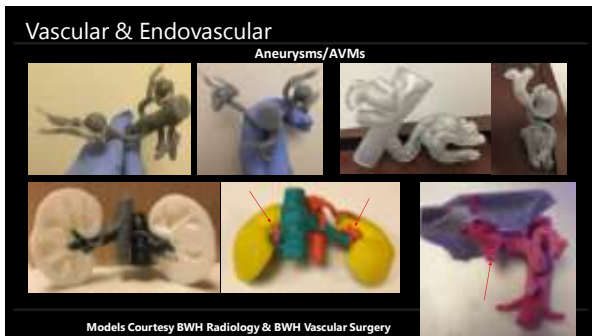
Rapid Growth in Biomedical Research

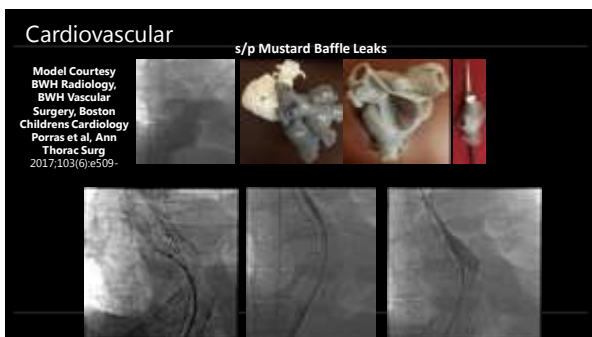


Complex Thoracic & Abdominal Onc



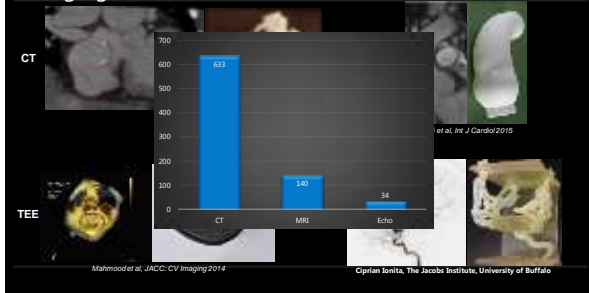




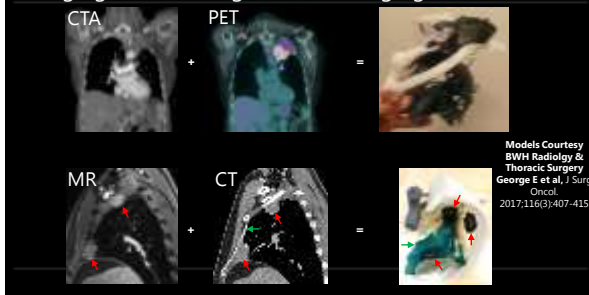


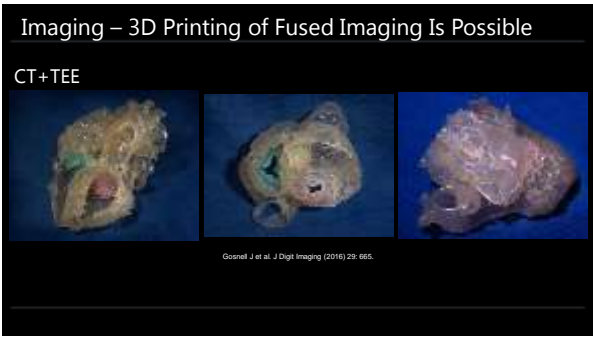
What Images Can we 3D-Print?

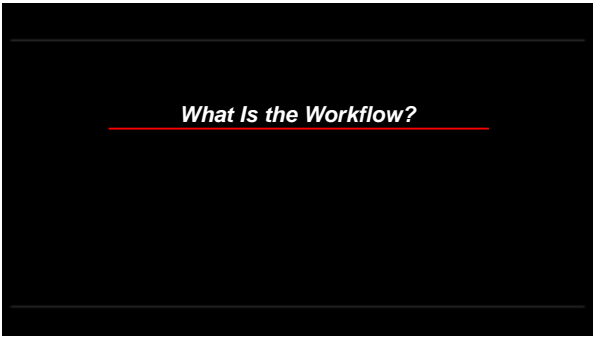
Imaging – What Can be 3D-Printed

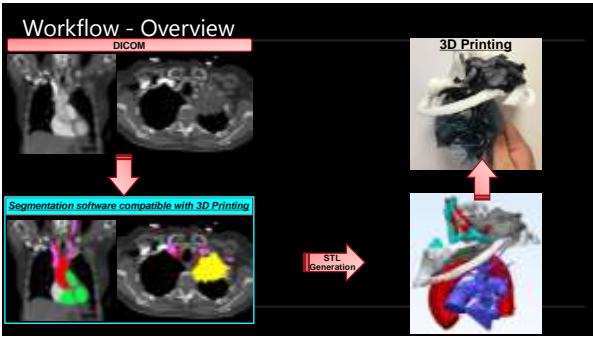


Imaging – 3D Printing of Fused Imaging Is Possible





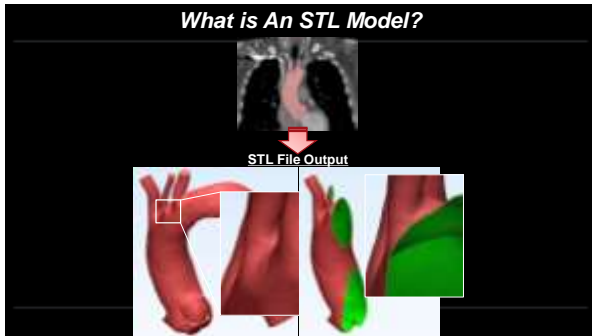




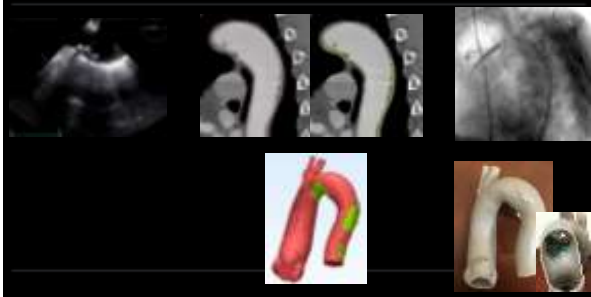
What is An STL Model?



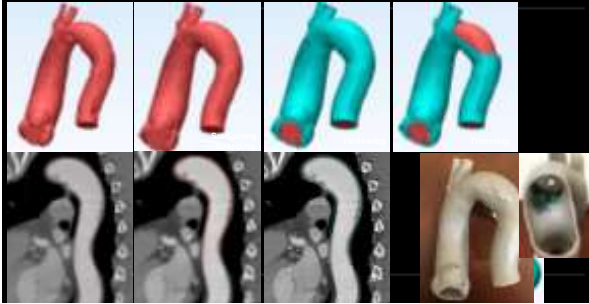
What is An STL Model?



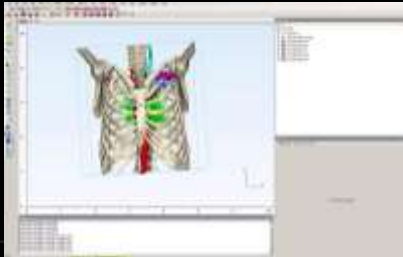
STL Editing to Answer the Specific Clinical Problem



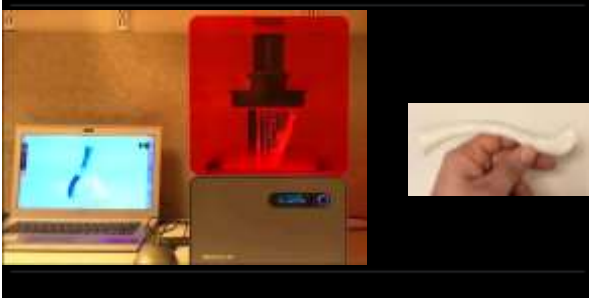
Workflow – STL Manipulations (the Art in 3D Printing)



Workflow – STL Manipulations Computer-Aided Design (CAD) Software



Additive Manufacturing



What Printers Are There and Which Printer Should I Use?

Material Extrusion Printers



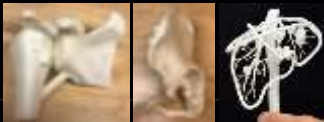
<1k\$ to 75k\$

Material Extrusion Printers



<1k\$ to 75k\$

1 or 2-color
anatomic models
Great for ortho



Stereolithography Printers



<5k\$ to 500k\$

Stereolithography Printers



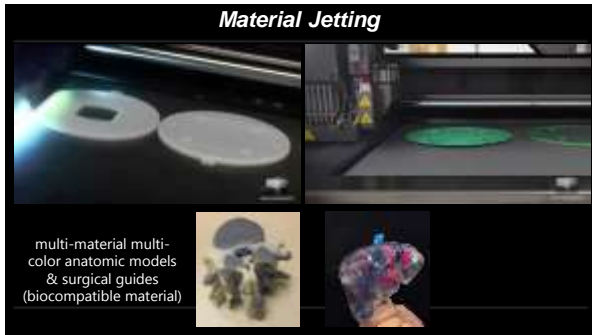
Single material
anatomic & hollow
vascular models
Has biocompatible
materials

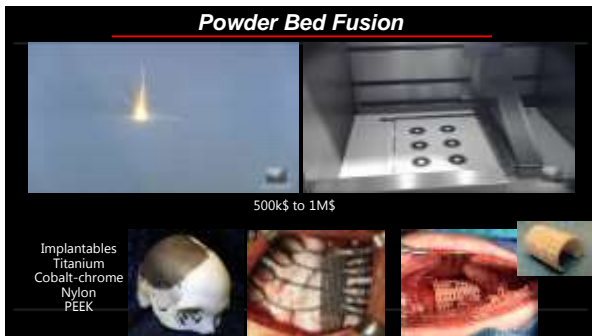


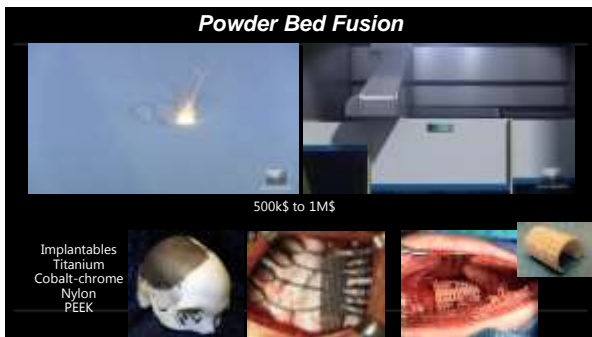
Material Jetting



250k\$ to 750k\$







Some Future Directions

Bioprinting

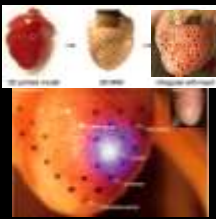


Organovo Novotissues™
Bioprinted human vascular conduit
(human fibroblasts, smooth muscle and endothelial cells)



SMC tubes (Norotte et al
Biomaterials 2009)

Devices with Sensors



Fitted Sensor Membranes (Xu et al, Nature Communications 2014)



Regulatory considerations

Regulatory



Regulatory

- Check with your facilities legal and regulatory teams
(I'm not a lawyer or a regulatory expert. This is my understanding)
- FDA regulates devices that are products
products → devices that are marketed or sold
- 3D printed models generated within the hospital which are part of standard of care are not regulated by the FDA
 - because the FDA does not regulate clinical practice
 - exception: IDE
- So regulatory considerations are primarily:
 - State (medical board) and Local (hospital privileges) management of the practice of medicine in hospital

Rybicki FJ. The Lancet 2018







"What spirit is so empty and blind, that it cannot recognize the fact that the foot is more noble than the shoe, and skin more beautiful than the garment with which it is clothed?"
— Michelangelo



Michelangelo's David (1504)



3D printed prosthetic hand

Credit: U.S. Food and Drug Administration FDA
photo by Michael J. Ermarth

Summary

- 3D Printing is rapidly growing in the healthcare sector, and there are many clinical applications

Physicians are engaged in modeling, and there is a large unmet need for support from the medical physics community. It should be nurtured in a thoughtful way.

- In-hospital 3D printing is here to stay, but there are obstacles to overcome. Both industry and physicians have roles and responsibilities for medical modeling. Physicians must organize and properly regulate one another.
