MRI Liver Phantom for Transarterial Chemoembolization Simulation

Team Members – Justin Schmidt, Benjamin Engel, Ryan Carroll, Eric Printz

Client – Dr. Wally Block PhD – Departments of Biomedical Engineering and Medical Physics

Advisor – Dr. William Murphy PhD – Department of Biomedical Engineering

COLLEGE OF ENGINEERING
UNIVERSITY OF WISCONSIN-MADISON

Abstract

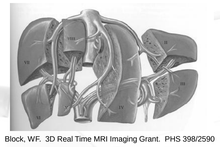
Liver cancer in various forms is a major cause of mortality and current treatment methods are highly ineffective. Transarterial chemoembolization (TACE) is a chemotherapy delivery technique which improves the localization of treatment. Currently, TACE is guided by x-ray imaging but would benefit from utilizing real time MRI. The purpose of this project was to create an MRI phantom of the liver which will allow interventionalists to practice TACE catheterizations. The phantom that was created accurately depicts the eight Couinaud segments of the liver as well as key abdominal arteries. Initial tests indicate that the vasculature can withstand maximum capable flow of the pump (3 L/min) . Additionally, both the phantom vasculature and enclosure are water tight. Finally, the phantom produced minimal artifact allowing for accurate MR imaging. In the future, tube diameter adjustments along with the addition of pulsatile flow will enhance the flow characteristics of the phantom. Additional testing with interventional radiologists will be performed .

Problem Statement

It is proposed to develop a liver phantom that represents the arterial vasculature of the liver and abdomen in an effort to simulate MRI guided catheterizations and train interventional radiologists on the use of the MRI guided technique

Background Information

- Current cancer treatment methods
  - Systemic chemotherapy: 20% response rate
  - 20% of tumors are inoperable
  - More localized / effective method is needed
- Transarterial chemoembolization (TACE)
  - Delivers high concentration of chemotherapy
  - Embolism prevents chemotherapy diffusion
- Liver Anatomy
  - 8 Couinaud Segments
  - 75% of circulation delivered via venous vessels
- Current TACE procudure
  - Pre-op MR/CT scan to locate tumor
  - Catheter guided via 2D X-Ray images
  - Delivers unnecessary radiation dose to patient
- MRI Enhanced TACE Procedure
  - Combines tumor location / catheter guidance
  - Catheter guided via real-time 4D MR image
  - No radiation dose to patient
- Current Phantom
  - Does not model liver
  - Poor construction results in leaks
  - Opaque gel eliminates possibility to see interior



Block, WF. 3D Real Time MRI Imaging Grant. PHS 398/2590

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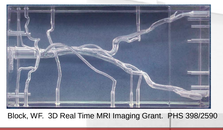

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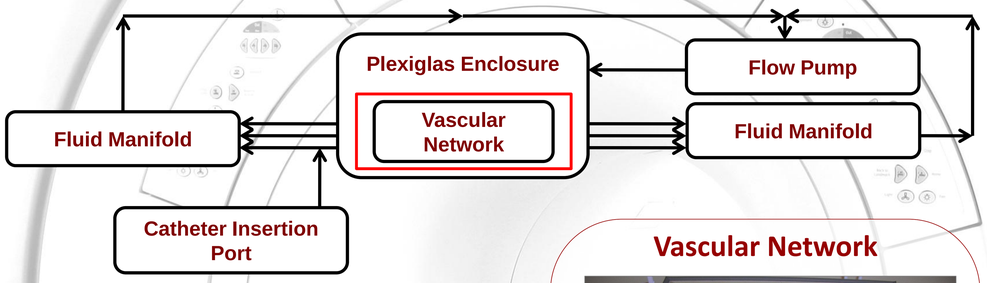
Client Requirements

- Vasculature
  - Includes 8 Couinaud segments of the liver
  - Includes key abdominal arteries
- Material compatible with MRI
  - Minimize image artifacts
  - Three inches between enclosure and vasculature
- Water tight enclosure surrounding vasculature
- Removable lid for enclosure
- Port for catheter entrance into vasculature
- Active flow through vasculature
- Compatible with current phantom setup

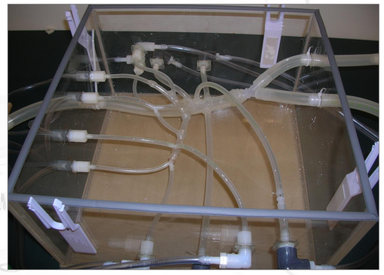
Final Design/Components



Catheter Insertion

- Insertion point in right femoral artery
- Accommodates both catheter and guidewire
- Used for delivery of saline and contrast agent
- Fluid/air tight junction prevents artifact

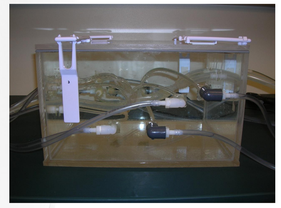
Vascular Network



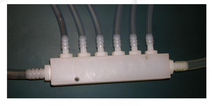
- Includes complete celiac trunk, major abdominal arteries and 8 Couinaud segments
- All comprised of Tygon 2001 ® tubing
- Junctures made of hot plastic melt and silicone caulk
- Simple junctions utilize barbed plastic connectors

Plexiglas Enclosure

- Plexiglas sides joined using Plexiglas cement
- Removable lid with 4 plastic latches for locking in place
- Water tight seal between lid and enclosure prevents leaks
- Multiple barbed connectors and pipe fittings connect vasculature to external tubing



Fluid Manifold



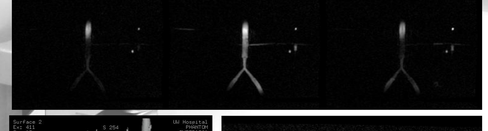
- Two manifolds collect fluid from 14 vessels
- Two additional tubes return fluid to flow pump

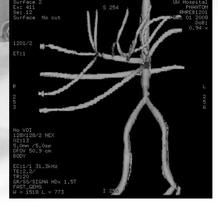
Fluid Flow Pump

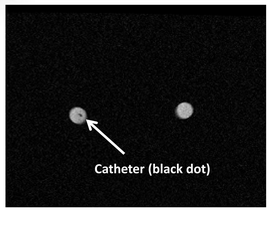
- Materflex® analog control peristaltic pump drive with high performance pump head
- Serial interface allows automatic flow control
- Maximum flow rate approximately 3L/min

Testing

- Injection of red dye coupled with maximum flow indicates adequate flow through all vessels within the phantom
- Test also verifies water tight junctions throughout vasculature
- Leaving box filled with water overnight verified its structural integrity







- Gadolinium injection shows flow characteristics can be imaged using SPGR pulse sequence
- 3D surface rendering clearly shows all vasculature in phantom
- Air-filled catheter shows catheter tracking within the phantom
- Absence of air bubbles seen in 3D view indicates system is air tight
- Materials used for phantom enclosure and vascular junctions do not produce significant artifact
- Adequate SNR is achievable giving clear view of vasculature and catheter

Future Work

- Quantitative flow assessment through each segment using advanced MRI techniques
- Development of control unit for pump to add pulsatile flow capability through use of LabJack DAQ unit
- Investigate upgrading the pump for increased maximum flow rate
- Gather information through usability tests with interventional radiologists
- Develop a substance to mimic the T1/T2 relaxation times for tissue surrounding the liver

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