Cardiovascular Magnetic Resonance Imaging: At the Confluence of Physics and Medicine

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Outline

- 1. Magnetic Resonance (MR) physics
- 2. Non-Contrast-Enhanced MR Angiography
- 3. Quantitative Perfusion
 - a. Cerebral Perfusion
 - b. Myocardial Perfusion
- 4. Circle Cardiovascular Imaging Inc.



MR Imaging of Hydrogen Protons in vivo



Triglyceride: $C_{55}H_{98}O_6$

"People think [stage diving] is dangerous, but not me! Because human beings are 95% water, so the audience is 5% away from a pool." ~ Mitch Hedberg



Fundamental Basis for MR: The Larmor Equation



 $W = \mathcal{G}B$ B = B(x, y, z; t)

Magnetic Field Strengths in MR (*B*₀ Field along *z*)



Earth's Magnetic Field 0.3 Gauss 30 µTesla



Junkyard Magnet 10,000 Gauss 1 Tesla



G.E. Discovery 750 30,000 Gauss 3 Tesla $(\omega_0 = 128 \text{ MHz})$

Bulk Behaviour of Magnetic Moments in MR Imaging



Zeeman Splitting Diagram: "Resonance" Tuning Fork



Manipulation of Bulk Magnetization in MR Imaging



Phenomenological Bloch Equation



Non-Contrast-Enhanced MR Angiography at 3T

- Angiography: imaging large blood vessels
- Non-Contrast-Enhanced: without *iv* injection
- MSc and PhD at the University of Calgary, 2004-2011 (<u>www.mrcentre.ca</u>)
 - Programmed novel MR pulse sequence on 3T clinical scanner (GE Signa VH/*i*)
 - Built a real-time interface software program in C++ for moving-table
 - Undergraduate teaching assistantships in Department of Physics and Astronomy



Arteries in Calves of Healthy Volunteer

RB Stafford et al., Magn Reson Med. 2008; 59: 430–3.

PhD Project Elements Created from Scratch







| 00 | bSSFP Dixon Method CMT Raw Data Acquisition |
|---------------------------------|---|
| Acquisition Parameters | Image Display Currently Deactivated |
| Load Scan Parameters | |
| Scan Parameters | |
| Scan Time (sec): | |
| LFOV (cm) | |
| TR (ms): | |
| Total Number of TR: | |
| Nx: | |
| Ny: | 1 1 1 1 1 1 1 1 1 1 |
| Nz | |
| Fat-Water Phase for Acquisition | OPCIICL |
| In-Phase 🔺 | • |
| Table Motion | |
| Out of the Bore | |
| Use Grad Warp Correction | |
| Reconstruct Image | |
| Show Speedometer | VVIUCCL |
| mage Display Options | |
| atient ID Number: | - |
| TSK | |
| Begin Acquisition | |
| Stop Acquisition | |
| | Com Deconomic |

Perfusion: Microvascular O₂ Delivery



Short-Axis Cine



Credit: Microscopy and Imaging Facility, University of Calgary

Quantitative Perfusion for Cerebral Blood Flow

- Arterial Spin Labeling (ASL): Magnetic tagging of blood upstream from the tissue of interest (*e.g.*, carotid arteries for cerebral blood flow)
- Postdoctoral fellowship at University of Pennsylvania, 2011-2013 (www.upenn.edu)
 - ASL on an Unshielded 7 Tesla
- Postdoctoral fellowship at University of Calgary, 2013-2016 (<u>www.ucalgary.ca</u>)
 - Biomarkers of vascular cognitive impairment and dementia



JA Detre *et al., Magn Reson Med* 1992; 23:37-45.





3-Ch. Tx/Rx Controller

Interface System

TTL Switch

✤ 3-Ch. Label

RF Amplifier

C

b



RB Stafford et al., Int J Imaging Syst Technol 2016; 26(2): 106-115.

Myocardial Quantitative Perfusion with Cardiac MR

- Dynamic passage of gadolinium-based contrast agent injection
- Mapping temporal signal-intensity changes to microvascular concentration delivery
- C++ software developer with Circle Cardiovascular Imaging, Inc. since 2016 (www.circlecvi.com)



LY Hsu, M Jacobs, <u>M Benovoy</u> et al., J Am Coll Cardiol Cardiovasc Imaging. 2018 11(5): 697–707.

Other Clinical Applications for Cardiac MR: Function





Short-Axis Cine



Long-Axis 2-Chamber Cine

Adapted from Villarreal MR, Wikipedia: Arteries

Other Clinical Applications for Cardiac MR: 4D Flow









4D Flow Pathlines

Adapted from Villarreal MR, Wikipedia: Arteries

4D Flow Images Provided by Dr. M. Markl, Northwestern University

At the Heart of **IMAGING**

Circle Cardiovascular Imaging

Circle Cardiovascular Imaging Inc. develops world class, advanced reading and reporting solutions for cardiac imaging. Circle CVI, is a prominent company for the global cardiac imaging community bringing together an experienced and dedicated team of over 150 people offering multi-language support around the globe.



Brief Summary: Indications, contraindications, warnings and precautions can be found in the product labelling. CAUTION: Federal law (USA) restricts these devices for sale by, or on the order of a physician. The system is intended for use only by trained Healthcare Professionals.

cvi42 Platform

Automated with AI for an Integrated, Best-in-Class Solution

4 Clinical Areas and Multiple Modules







Summary

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