Imaging of Spinal Trauma: Can Protons Inform Prognosis and Improve Outcomes?

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Objectives

1. Describe magnetic resonance imaging (MRI) and common MRI sequences.


3. Detail how advanced MRI might be applied to enhance the clinical care for each condition.

4. Hypothesize future clinical applications using advanced MRI.
Disclosures

Our team has no conflicts of interest to disclose
Objective 1: Basic Principles of MRI
An “image” is a one-to-one map of an “object”

B&W photograph: map gray scale of every location

Color photograph: map color & intensity of every location

MRI: map of magnetic property of every location
MR image is a map of the magnetic property of the object location by location (Voxel by Voxel – volume element)
y = Pixel

y = Voxel
Magnetic Property of Atoms
Magnetic Moments

Which nucleus is most commonly used in clinical MRI?

Hydrogen Atom
Magnetic Moments

- Recall, billions of nuclei all randomly spinning or precessing in every direction.
- Many different types of atoms in the body.
- MRI only concerned with the hydrogen atom. An ideal atom for MRI because its nucleus has a single proton and a large magnetic moment.
MRI and Molecular Physics

- Recall, 75% of our body is water

- Your body contains about 4,000,000,000,000,000,000,000,000,000 water molecules
Nuclear Magnetism

- Recall, each H₂O molecule is made of two Hydrogen atoms and one Oxygen atom

- So, you contain about 8,000,000,000,000,000,000,000,000,000 NUCLEAR MAGNETS in your body

- Wonderful for MR Imaging!
From Protons to Resonant Images
What happens in the magnet?

- Patient is placed in the magnet, hydrogen nuclei align in direction of the main magnetic field. (i.e. longitudinally)

- Each hydrogen nucleus precesses in a circular path, like a spinning top.
Intro to MRI Physics

Kandel, Schwartz, and Jessell, 4th ed.
Image Creation-summary

- Protons align with the magnetic field

- Pulsed radio frequency causes resonance (precessional frequency (Hz))

- Radio wave shut off and proton signal decay recorded with production of image (s)
Spinal Cord Injury

• Review imaging guidelines and utilization for SCI

• Describe current practice patterns in SCI

• Hypothesize future clinical practice using advanced MRI
What typically happens after SCI...

[insert picture of patient with SCI in the ICU]
Add routine imaging for SCI here
Clinical Problem: Prognosis

- Scenario: “Bill” is a 20 y.o. male with traumatic C6 AIS C SCI enters inpatient rehab
- Bill: “Will I walk again?”
- PT: “It depends…”
Prognosis for Ambulation: using motor scores

- Quad strength $\geq 3/5$ at 2 months predicts functional ambulation at 6-12 mo (Crozier 1994)
- LEMS $>10$ at 1 month predicts community ambulation at 1 year (Waters)
- 92% with AIS C SCI were able to walk at 6 months after engaging in intense locomotor training (Dobkin 2006)
Prognosis for Ambulation: Clinical Prediction Rule

- 5-variable CPR (van Middendorp 2011): age, L3 and S1 motor scores, L3 and S1 light touch scores

- 3-variable CPR (Hicks 2017): age, L3 motor score, S1 light touch score
  - Outcome: independent walking (6 or 7 locomotion item of FIM)
  - 76% sensitivity, 90% specificity
Prognosis for Ambulation Using Motor Scores: Limitations

• Lack of Specificity in Outcome

• Determining Plan of Care
Prognosis for Ambulation: Imaging

• Add some historical context here.
WHAT IF?

• we had imaging that could tell us more about what damage had been done to the SC?

• adding this new information to clinical information (e.g., motor and sensory testing results) could allow more accurate and specific prognosis?
WHAT IF?

• More accurate and specific prognosis and identification of specific injury to the SC allowed clear clinical pathways for SCI Rehab?
Advanced MRI for Spinal Cord Injury
T2-weighted spinal cord images

Standard mid-sagittal images

Axial images
Higher resolution axial images
Beyond edema length: damage ratio

Find slice with maximum axial edema:

Damage ratio = area of edema / surrounding cord area
Our iSCI study details

N = 14

6 Minute Walk Test

WISCI II

FIM-L

Smith et al, Spinal Cord, 2017
\[ R = -0.61, \ P = 0.02 \]

\[ R = -0.68, \ P = 0.01 \]

\[ R_s = -0.72, \ P < 0.01 \]

\[ R_s = -0.69, \ P < 0.01 \]

\[ R_s = -0.62, \ P = 0.02 \]
Clinical Evaluation

Advanced Imaging

Favorable

Less-Favorable
INSERT SCI GAIT TRAINING VIDEOS HERE
Present epidural stim studies for complete SCI
Traumatic Neck Pain clinical cases (including chronic neck pain)
Traumatic Neck Pain

- Review imaging guidelines and utilization for traumatic neck pain
- Describe current practice patterns in traumatic neck pain
- Hypothesize future clinical practice using advanced MRI
Cervical Spondylotic Myelopathy clinical cases
Discuss the possible future of physical therapy practice using advanced MRI
Q and A session