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14. ABSTRACT: This study seeks to improve monitoring of spinal cord health after injury using magnetic resonance imaging (MRI) in the presence of commonly encountered implanted hardware. In an effort to improve monitoring, this study will enhance technological imaging capabilities targeting diagnostic-quality MRI near implanted metal hardware in the spinal cord and demonstrate the medical utility of metal-artifact reduction techniques in patients with spinal cord injury and degenerative cord damage. A multidisciplinary team of surgeons, spinal cord scientists, and physicists will then deploy these methods to injured, degenerated, and control cohorts. We hypothesize that morphological and diffusion-weighted MRI will provide useful quantitative imaging biomarkers for assessment of treatment effectiveness and recovery progress.					
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REPORT OUTLINE

The text of the report must include all sections addressed in the table of contents to include the following. DO include the bolded section headings, but DO NOT include the italicized descriptions of section contents in your submitted reports.

- 1. Introduction:** This study seeks to improve monitoring of spinal cord health after injury using magnetic resonance imaging (MRI) in the presence of commonly encountered implanted hardware. In an effort to improve monitoring, this study will enhance technological imaging capabilities targeting diagnostic-quality MRI near implanted metal hardware in the spinal cord and demonstrate the medical utility of metal-artifact reduction techniques in patients with spinal cord injury and degenerative cord damage. A multidisciplinary team of surgeons, spinal cord scientists, and physicists will then deploy these methods to injured, degenerated, and control cohorts. We hypothesize that morphological and diffusion-weighted MRI will provide useful quantitative imaging biomarkers for assessment of treatment effectiveness and recovery progress.
- 2. Keywords:** MRI – Magnetic Resonance Imaging, DWI – diffusion weighted imaging, MSI – multi-spectral imaging, ROI – region of interest, 3D – 3 dimensions.
- 3. Accomplishments:** In the first year, our initial development of MRI morphological protocol has allowed human subject testing which was implemented to develop morphological image analysis. The construction of data extraction and management pipeline for segmenting discs transfers the data to a remote storage server and viewing station for radiologist evaluation and raw MRI data storage. The quantitative pipeline allows the radiologist to analyze the data to perform scoring, measurements, and ROI for statistical analysis. To date, we have scanned 15 subjects (6 controls, 7 instrumented myelopathy subjects, and 2 SCI cases). We have performed preliminary quantitative morphological image analysis on 11 subjects (controls and myelopathy) and performed in-depth diffusion-based analysis of the SCI cases.

Preliminary analysis displayed a clear depiction of the hardware surfaces in the 3D-MSI and compromised resolution and contrast relative to the conventional acquisition. Also noted in the analysis is the cord deformation due to artifact in the conventional acquisition and the isotropic 3D-MSI acquisitions display accurate cord geometries. We have found preliminary trends in diffusion-weighted data, confirming our previous findings in instrumented subjects whereby ADC values in the cord near fusion instrumentation are reduced relative to un-instrumented cord values. In our preliminary analysis have also identified interesting outlier behavior, whereby the ADC vs cord aspect ratio (morphological measurement) shows strong deviations in regions of substantially reduced ADC. Finally, our initial investigations of diffusion measurements in SCI have found interesting evidence of strong heterogeneity of diffusion in the cord cross-section adjacent to fusion hardware. These measurements have never before been possible, and highlight an interesting pivot towards local segmentation of the cord (based on morphological degradation) and possible radiomic analysis of ADC maps.

- 4.** The progress this year was greatly affected by the COVID-19 pandemic. While our medical facility took efforts to reduce the spread of the illness, our campus went into an on-site human-subjects research hibernation on March 24, 2020 and our team was cleared to re-instate in-person research activities for this project on June 16, 2020. As a result of this, our recruitment activity was placed on hold and delayed additional acquisition of subjects. During the course of the hold on recruitment, our team continued to refine, test, and validate our multitude of quantitative analytics of previously acquired spinal cord MRI data. In particular, our technical team was able to develop web-based image-curation collaboration tools which have substantially improved our efficiency in collaboration, particularly in the ongoing pandemic whereby many of our staff-members are working in remote locations. As a result of this technical development, our remote work environment is having negligible negative impact on our study's analysis plan.

To date, our team has analyzed the aforementioned ten participants' imaging data to refine analytics pipelines. We continue recruitment of both control and instrumented participants and observing several

potential SCI instrumented subjects. We hope to recruit additional instrumented subjects to catch up to timeline goals by the mid-point of the second year of the project.

- **What were the major goals of the project?**

- Relate spinal cord morphology at the site of injury in the instrumented spine to neurological outcomes by exploiting metal hardware artifact-reduction MRI.
- Compare quantitative diffusion weighted imaging (DWI) of the instrumented spinal cord to atrophy-based biomarkers at the site of instrumented SCI.

	Timeline	Work Completed
Major Task 1: Regulatory Approvals		
Subtask 1: Local IRB protocol construction and submission	Y1Q1-Y1Q2	Submitted protocol to local IRB, OCRICC, and MRI Safety on 6/20/19, 5/22/19 and 5/20/19, respectively
Subtask 2: HRPO submission	Y1Q2-Y1Q3	Submitted documents to HRPO on 8/26/19; revisions requested on 11/17/19. Revisions submitted to HRPO on 11/25/19.
Milestones Achieved:		
Local IRB Approval	Y1Q1	IRB, OCRICC, and MRI Safety approvals received on 8/5/19, 8/20/19 and 8/5/19, respectively
HRPO Approval	Y1Q2	Received HRPO approval on 12/12/19
Specific Aim 1: Relate spinal cord morphology at the site of injury in the instrumented spine to neurological outcomes by exploiting metal hardware artifact-reduction MRI.		
Major Task 2: Development of MRI morphological protocol		
Subtask 1: Construct Morphological MRI protocol	Y1Q1-Y1Q2	complete
Subtask 2: Human subject tests of protocol: 3 healthy volunteers	Y1Q2-Y1Q3	complete
<i>Milestone Achieved: Successful human subject test using finalized protocol</i>	Y1Q3	complete
Major Task 3: Development of morphological image analysis pipeline		
Subtask 1: Construction of data extraction and management pipeline	Y1Q1-Y1Q2	complete
Subtask 2: Development of morphological cord segmentation pipeline	Y1Q1-Y1Q2	completed

Subtask 3: Development of morphological cord analytics pipeline, including measurements and radiologist scoring	Y1Q2-Y1Q3	completed.
<i>Milestone Achieved: Demonstration of morphological analytics pipeline on test subjects, and first instrumented subjects</i>	Y1Q4	completed.
Major Task 4: Collection of SCI and control human morphological imaging data		
Subtask 1: Collection of SCI sub-acute imaging and neurological data (5 human SCI subjects)	Y1Q3-Y2Q2	Due to COVID scanning shutdown, we were forced to cancel our first SCI cases in Q4 of Year 1. Scanning has resumed and we are back on target to meet our milestones, having acquired 2 datasets.
Subtask 2: Collection of control imaging data (5 human control subjects)	Y1Q3-Y2Q2	Completed
<i>Milestones Achieved:</i>		
<i>4 SCI datasets collected; 5 controls collected</i>	Y2Q2	6 controls, 2 SCI
<i>8 SCI datasets collected; 10 controls collected</i>	Y2Q4	6 controls, 2 SCI
<i>12 SCI datasets collected; 15 controls collected</i>	Y3Q2	6 controls, 2 SCI
Major Task 5: Morphological analysis of SCI and control human imaging data along with SCI neurological testing data		
Subtask 1: Statistical test design and pipeline development	Y1Q3-Y2Q1	Internal database management and region of interest (ROI) pipeline designed and functional. Pipeline to export and analyze ROI to create a feature map for statistical analysis.
Subtask 2: Data analysis of SCI morphological and control cohort data	Y1Q2-Y3Q2	Initial analysis of 2 subjects and more thorough analysis of 7 controls included in this report
<i>Milestones Achieved:</i>		
<i>Preliminary statistical tests completed on year 1 cohort</i>	Y2Q2	not yet initiated
<i>Completed morphological data analysis on SCI study cohort</i>	Y3Q3	Initial analysis performed on 15 subjects.
<i>Final statistics on study cohort</i>	Y3Q3	not yet initiated
Major Task 6: Results dissemination and publication		
Subtask 1: Results analysis	Y3Q3-Y3Q4	not yet initiated
Subtask 2: Manuscript Preparation	Y3Q3-Y3Q4	not yet initiated
<i>Milestone Achieved: Manuscript on correlation of morphological imaging data and neurological testing submitted</i>	Y3Q4	not yet initiated

Specific Aim 2: Compare quantitative diffusion weighted imaging (DWI) of the instrumented spinal cord to atrophy-based biomarkers at the site of instrumented SCI.		
Major Task 7: Development of DWI protocol for assessment of instrumented cord		
Subtask 1: Phantom testing, DWI protocol optimization	Y1Q1-Y1Q2	Completed
Subtask 2: Human subject tests of protocol (N=3 control subjects)	Y1Q2-Y1Q3	Completed.
<i>Milestone Achieved: Successful human subject test using diffusion-weighted protocol</i>	Y1Q3	Completed
Major Task 8: Development of diffusion image analysis pipeline		
Subtask 1: Construction of data extraction and management pipeline	Y1Q1-Y1Q2	Completed
Subtask 2: Development of diffusion quantification pipeline (corrections, metric computation)	Y1Q1-Y2Q2	Basic pipeline completed. Continuing fine-tuning of curation and DWI analysis methods
<i>Milestone Achieved: Demonstration of diffusion analytics pipeline on test subjects, and first instrumented subjects</i>	Y1Q3	Complete
Major Task 9: Collection of SCI diffusion and control human imaging data		
Subtask 1: Follow human subject MRI acquisition pipeline outlined in Aim 1	Y1Q2-Y3Q2	
<i>Milestones Achieved:</i>		
<i>4 SCI DWI datasets collected; 5 controls collected</i>	<i>Y2Q2</i>	6 controls and 2 instrumented SCI collected
<i>8 SCI DWI datasets collected; 10 controls collected</i>	<i>Y2Q4</i>	6 controls and 2 instrumented SCI collected
<i>12 SCI DWI datasets collected; 15 controls collected</i>	<i>Y3Q2</i>	6 controls and 2 instrumented SCI collected

Major Task 10: Analysis of diffusion SCI Imaging Data		
Subtask 1: Statistical test design and pipeline development	Y1Q3-Y2Q1	Diffusion analysis pipeline completed. Refining morphological and diffusion pipelines on incoming data.
Subtask 2: Data analysis of SCI and control cohort DWI data	Y2Q2-Y3Q2	Initial analysis of first 2 subjects, as discussed in this report
<i>Milestones Achieved:</i>		
<i>Preliminary statistical tests completed on year 1 cohort</i>	<i>Y2Q2</i>	Initial analysis of first 2 subjects, as discussed in this report
<i>Complete DWI data analysis on SCI study cohort</i>	<i>Y3Q3</i>	in progress
<i>Final DWI statistics on study cohort</i>	<i>Y3Q3</i>	in progress
Major Task 11: Results dissemination and publication		
Subtask 1: Results analysis	Y3Q3-Y3Q4	not yet initiated
Subtask 2: Manuscript Preparation	Y3Q3-Y3Q4	not yet initiated
<i>Milestone Achieved: Manuscript on diffusion imaging of instrumented cord submitted</i>	<i>Y3Q4</i>	not yet initiated
Specific Aim 3: Establish the utility of MSI MRI in assessing spinal cord health after surgical repair of cervical degenerative		
Major Task 12: Collection of imaging data on cervical myelopathy (CM) cohort		
Subtask 1: Collection of diffusion and morphological imaging and neurological data on CM cohort. (N=25)	Y1Q2-Y3Q2	7 instrumented cervical myelopathy subject scanned.
<i>Milestones Achieved:</i>		
<i>6 CM datasets collected</i>	<i>Y2Q2</i>	7 myelopathy subject scanned
<i>20 CM datasets collected</i>	<i>Y2Q4</i>	7 myelopathy subject scanned
<i>25 CM datasets collected</i>	<i>Y3Q2</i>	7 myelopathy subject scanned

Major Task 13: Analysis of instrumented myelopathy and control human imaging data		
Subtask 1: Statistical test design and pipeline development	Y1Q3-Y2Q1	Completed.
Subtask 2: Data analysis of SCI and control cohort DWI data	Y2Q2-Y3Q2	Initial analysis of 11 subjects included in this report.
<i>Milestones Achieved:</i>		
<i>Preliminary statistical tests completed on year 1 cohort</i>	<i>Y2Q2</i>	11 subjects analyzed thus far, included in this report.
<i>Complete data analysis on CM study cohort</i>	<i>Y3Q3</i>	11 subjects analyzed thus far, included in this report.
<i>Final statistics on CM study cohort</i>	<i>Y3Q3</i>	not yet initiated
Major Task 14: Results dissemination and publication		
Subtask 1: Results analysis	Y3Q3-Y3Q4	not yet initiated
Subtask 2: Manuscript Preparation	Y3Q3-Y3Q4	not yet initiated
<i>Milestone Achieved: Manuscript on morphological and diffusion imaging of CM instrumented cord submitted</i>	<i>Y3Q4</i>	not yet initiated

- **What was accomplished under these goals?**

- In an effort to accomplish our first goal to relate spinal cord morphology at the site of injury in the instrumented spine to neurological outcomes by exploiting metal hardware artifact-reduction MRI we constructed a pipeline to collaborate with radiologists. Our initial development of MRI morphological protocol has allowed human subject testing which was implemented to develop morphological image analysis. The construction of data extraction and management pipeline for segmenting discs transfers the data to a remote storage server and viewing station for radiologist evaluation and raw MRI data storage. The quantitative pipeline allows the radiologist to analyze the data to perform scoring, measurements, and ROI for statistical analysis.
- Our next goal was to compare quantitative diffusion weighted imaging (DWI) of the instrumented spinal cord to atrophy-based biomarkers at the site of instrumented SCI. To date, we have scanned 15 subjects (6 controls, 7 instrumented myelopathy subjects, and 2 SCI cases). We have performed preliminary quantitative morphological image and diffusion-weighted analysis on 11 subjects (controls and myelopathy) and performed in-depth diffusion-based analysis of the SCI cases.
- To establish the utility of MSI MRI in assessing spinal cord health after surgical repair of cervical degenerative myelopathy, we performed preliminary analysis to display a clear depiction of the hardware surface in the 3D-MSI and compromised resolution and contrast relative to the conventional acquisition. Also noted in the analysis is the cord deformation due to artifact in the conventional acquisition and the isotropic 3D-MSI acquisitions display accurate cord geometries. We have found preliminary trends in diffusion-weighted data, confirming our previous findings in instrumented subjects whereby ADC values in the cord near fusion instrumentation are reduced relative to un-instrumented cord values. In our preliminary analysis have also identified interesting outlier behavior, whereby the ADC vs cord aspect ratio (morphological measurement) shows strong deviations in regions of substantially reduced ADC. Finally, our initial investigations of diffusion measurements in SCI have found interesting evidence of strong heterogeneity of diffusion in the cord cross-section adjacent to fusion hardware. These measurements have never before been possible and highlight an interesting pivot towards local segmentation of the cord (based on morphological degradation) and possible radiomic analysis of ADC maps.

Major Activities: Regulatory approvals:

- 1) Received local IRB approval on 8/5/19
- 2) Received HRPO approval on 12/12/2019.

Major Activities: Experimental setup

After regulatory approvals the proposed imaging protocol were optimized and tested on 3 healthy subjects.

A pipeline for segmenting out the disk and cord has been designed and implemented.

Scoring sheets for radiologist analysis were developed

Pipelines for quantitative image analysis have been developed and preliminarily tested on the subject cohort collected in Year 1.

- Analysis of diffusion-weighted imaging data at each evaluated level of the cervical spine
- Aspect ratio measurements of the cord at each evaluated level

- Radiomic analysis of segmented cord at each evaluated level
- Lesion identification and classification at each evaluated level

A RedCap database for study data elements has been constructed and is in use.

Major Activities: Data Collection

In the first year, we collected 7 instrumented myelopathy subjects, 6 control subjects, and 2 SCI subjects. We also had one recruited cervical myelopathy subject that was unable to complete the imaging exam. MJOA symptom reports were collected on the myelopathy subjects, and acute ASIA scores have been collected on the SCI subjects.

All imaging data has been placed into our research archiving system and is actively being analyzed by the study team.

Major Activities: Preliminary Data Curation and Analysis

To date, our team has analyzed 11 subjects, with varying levels of completion for each of the specific analysis aims. The following analytics pipelines were finalized, tested, and analyzed in preliminary fashion:

1. Scoring of conventional and MSI MRI in hardware setting
 - Instrumented subjects will also have each level scored using the VGA image quality scale (Smedby, Ö., & Fredrikson, M. (2010). Visual grading regression: analysing data from visual grading experiments with regression models. *British Journal of Radiology*, 83(993), 767–775. <http://doi.org/10.1259/bjr/35254923>
 - Our scoring process uses a range of 1 to 3, with categories 1=unusable, 2=flawed, but diagnostic, 3) pristine. Scores will be focusing on diagnostics of cord integrity, nerve roots, foramen, and cord compression. The full cohort scoring is performed by 3 radiologists. Below is a sample scoring grid, performed by members of the technical team, to indicate hypothesized areas of performance difference between the two approaches.

		FSE				MAVRIC			
Subjects	Level	Cord Integrity	Nerve Roots	Foramen	Cord Compression	Cord Integrity	Nerve Roots	Foramen	Cord Compression
DoD_HW_01_SCI	C1-2	3	3	3	3	3	2	2	3
	C2-3	3	3	3	3	3	2	2	3
	C3-4	3	3	3	3	3	2	2	3
	C4-5	3	3	3	3	3	2	3	3
HW	C5-6	2	1	1	1	3	2	2	3
HW	C6-7	2	1	1	1	3	2	2	3
	C7-T1								
Image Quality Scoring 1=non-diagnostic, 2=flawed, but diagnostic, 3=pristine									

Sample scoring of the hardware case shown above. Highlighted areas show where the scoring of the conventional FSE techniques are severely compromised by the image deformations illustrated in the slice-selective dimension. The overall appearance of the MAVRIC MSI approach is inferior, but allows for diagnostic assessment of in regions where the conventional technique fails (at the fused levels).

In performing this preliminary test of the scoring process, the technical team realized that it is possible to objectively quantify the spatial integrity of each of these indicated regions. As a result, we plan to add an analytic component of this analysis to the subjective scoring by radiologists, which was originally proposed. Specifically, we plan to utilize MAVRIC SL 3D-MSI magnetic field maps to analytically derive the amount of distortion of each of these regions, based on known physical spatial encoding principles. Using the radial-basis function analysis described later in this report, we can they analytically derive the morphological geometric disruptions that are performed in each of these anatomic regions. This additional step will require anatomic segmentations performed by the study team (cord, nerve root, foramen), but will fit well into our existing analysis pipeline that has been constructed for the study.

2. Reslicing of T2w advanced MSI MRI data for cord dimensional measurements and cord segmentation.
 - a. We have developed workflows that provide orthogonal axial reslices of the cord at each level using the isotropic MSI MRI measurements. Based on our early tests, we have now developed a method to do this automatically, using the geometry from the axial diffusion-weighted acquisitions as a template. Tests of this newly automated approach are ongoing. Preliminary analyses contained in this report utilize the manual re-slicing process.
3. Cord segmentation and analytic measurements.
 - a. We developed a research archiving visualization system, leveraging the web-based XNAT OHIF open-source framework, to accomplish these segmentations and measurements. This approach has been a crucial development by our technical team, as it has allowed for continual uninterrupted analysis of our datasets during our remote COVID-19 impacted research infrastructure, and now allows our radiologists to seamlessly perform or validate our curation efforts.
4. Diffusion segmentation
 - a. This also uses the above OHIF viewer infrastructure and allows for ADC measurement extraction
5. Extraction of radiomic features from anatomic spine images.
 - a. This is a novel concept that we have developed in the context of our pipeline construction. Briefly, radiomics uses established quantitative texture or image feature capture methods to quantitatively characterize the properties of regional tissues in diagnostic images.
 - b. In our project, we are performing this analysis on the imaging data of the spinal cord at each level. Eventually, we will perform this analysis on the T2, T1, and diffusion weighted images, though our preliminary analyses have been performed on a small subset of T2 weighted images.
6. Analysis and visualization of subject data at all analyzed cervical spinal cord levels, including correlations

Specific Objectives:

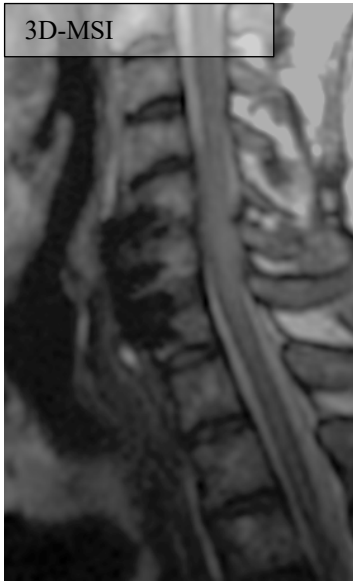
In the first year of the study, we have been focused on the following specific objectives:

1. Regulatory approvals and implementation of study plan logistics, including subject recruitment, subject on-site management, data curation, data archiving, and data analysis.
2. Collection of test human subjects to optimize the MRI protocol
3. Initial recruitment of control, myelopathy, and SCI subjects, following the milestone targets outlined in our statement of work .
4. Testing of data curation and analysis pipelines

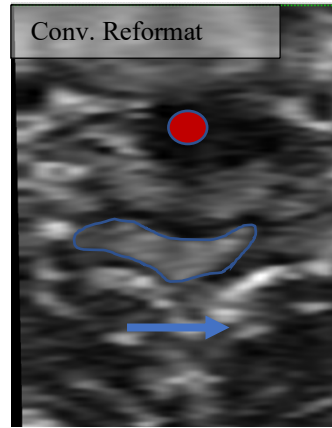
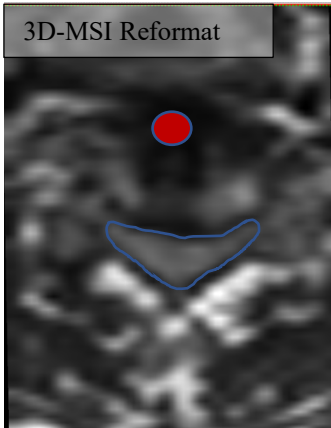
Significant Findings:

Geometrical impact of metal-artifacts in conventional MRI:

On our first study subject, the technical team and radiologists did a deep-analysis to investigate the capabilities and viability of our imaging protocol to provide accurate geometrical analysis of the spinal cord. To our surprise, even at a distance from the fusion hardware, the imaging distortions cause substantial warping of the spinal cord geometry. Because this is a nuanced effect that can only be seen in the MRI datasets are reformatted (as the distortions are predominantly in the slice-selective dimension of conventional techniques), it was of great surprise to our radiologist team. Analysis such as that shown below has never been published in the radiological literature and will be an early targeted publication from this study. This early finding supports our approach at using the isotropic 3D-MSI as our main morphological analysis tool, as the 3D-MSI fundamentally has more accurate delineation of geometry around metal hardware.



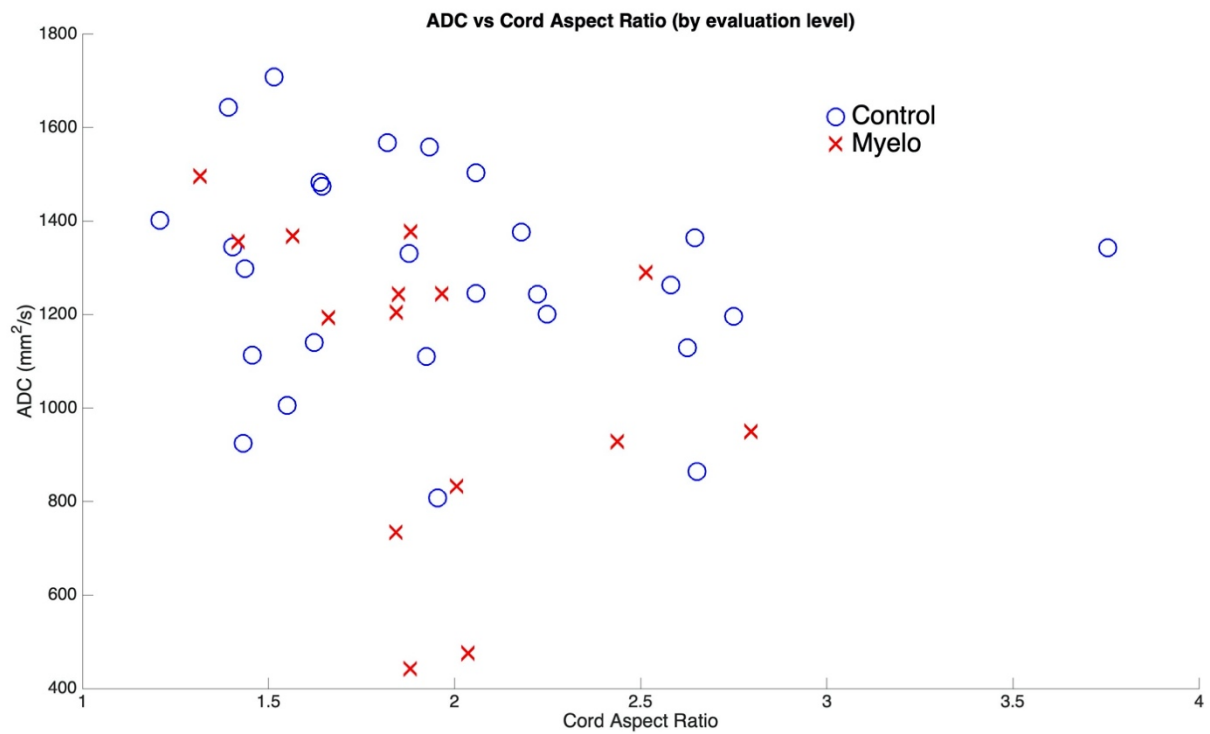
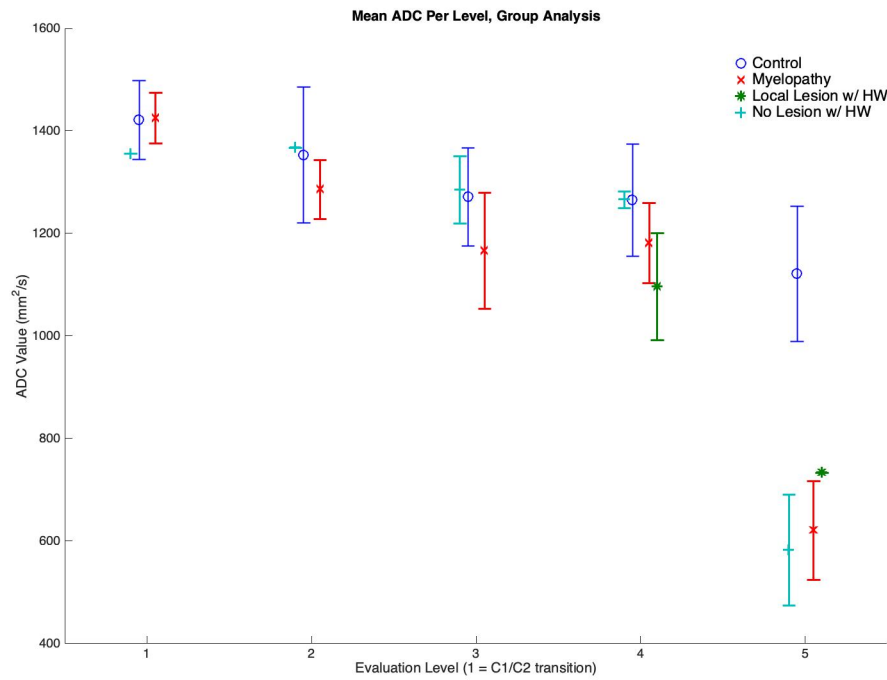
Conventional and isotropic 3D-MSI sagittal images of a degenerative myelopathy subject with anterior fusion. Note the clear depiction of the hardware surfaces in the 3D-MSI. Also note the compromised resolution and contrast of the 3D-MSI relative to the conventional acquisition. However, in this study we seek to perform measurements and analysis of the cord in the vicinity of the hardware, which we will see in the next figure requires the use of the 3D-MSI images.



Demonstration of cord deformation due to artifact in conventional images. Though it is difficult to see the cord deformation in the sagittal conventional image, a reformat of this acquisition into the axial plane shows the shearing of the image in the slice-selective dimension (arrow). Note the disruption of the cord geometry relative to the accurate 3D-MSI reference – despite the relative distance from the hardware (around red dot). This is why our isotropic 3D-MSI acquisitions are so important for this application, as any morphological analysis of the cord at fused levels will require accurate cord geometries.

Preliminary diffusion restriction findings in some myelopathy subjects:

Though highly preliminary, our results on the first 11 subjects (7 controls and 4 myelopathy cases) have identified some outlier trends that are specific to the cervical myelopathy subjects. These results are displayed below, whereby the data points are broken down by each evaluation level, and the points/bars indicate the mean and standard deviations of each indicated group (at each level). The myelopathy group is presented in total, and broken down at each evaluation level by the presence of a lesion (in the T2w 3D-MSI) and instrumentation hardware. Interestingly, the restricted diffusion observed in the myelopathy cohort appears to be correlated with the presence of a lesion. This is a surprising finding that will require further analysis as our cohort size increases, and may require segmentation of the lesions that facilitate more focused analysis of diffusivity at each level.

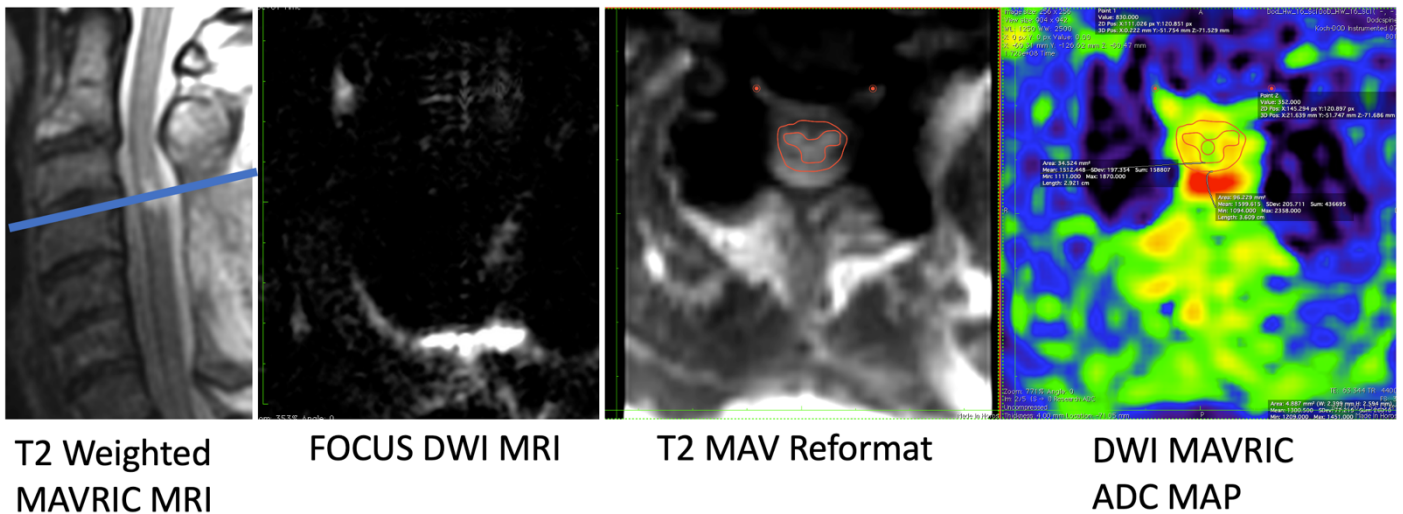


Preliminary trends of diffusivity and cord aspect ratio

In our first 11 subjects (7 control and 4 instrumented myelopathy cases), we also performed measurements of the spinal cord at each evaluation level (on the T2 weighted 3D-MSI images – which are the geometrically accurate images shown above). We then looked at the correlation of these measurements with the diffusivity in each evaluated level. Interestingly (somewhat to our surprise), for the most part, we found a preliminary trend ($r = -0.41$, $p = 0.12$) of diffusivity reduction with increased cord aspect ratio (effectively a normalized measure of cord narrowing) in the myelopathy group ($n=15$ evaluated levels in 4 subjects for this analysis). A similar trend was found in the controls ($n=27$ evaluated levels in 7 subjects), with a weaker effect ($r=-0.21$, $p = 0.22$). We will watch this preliminary trend as our study cohort increases over the next year.

Heterogeneity of cord DWI at instrumented levels of SCI :

We have thus far scanned 2 SCI subjects. One subject had substantial visible cord damage at the levels of instrumentation. Using our MSI DWI technology, we were able to perform a detailed analysis of the diffusivity in the cord, both immediate to the hardware (site of injury), and distant from this injury site. This preliminary analysis has already demonstrated the exciting potential that our study offers in probing the diffusivity changes immediately adjacent to injury sites (even in the presence of instrumentation).



The above image provides sample images on subject SCI02 of our study cohort. The indicated MAVRIC SL isotropic T2W image presents clear damage to the cord near the site of injury. The stabilizing fusion instrumentation is directly at this level, which renders the conventional diffusion imaging (FOCUS DWI) completely artifacted and of no quantitative value. The reformatted MAVRIC T2w image shows clear heterogeneity of signal within the cord (indicated segmentations). The MAVRIC DWI ADC map reproduces this heterogeneity, as indicated in the overlaid segmentations.

This initial analysis provides important information on the future needs of our study as we begin to develop more intricate measures of SCI image markers near hardware. First, we have shown the feasibility of producing DWI signal near the hardware – which is a novel and crucial component of our study. In the above

images, fusion hardware is directly adjacent to the cord region of interest. Second, we have good alignment with the morphological imaging (for segmentation of cord pathology). Third, the ADC heterogeneity of the cord in these regions is severe and suggests that we will require more detailed local analysis. In light of this discovery, we will begin exploring such regional diffusion-based measurements and explore image processing mechanisms to improve the conspicuity of the segmentation of important regions within the ADC maps. This will be a key topic of discussion between our radiologist, imaging physics, and surgical teams as we begin our in-depth analysis of the incoming study data.

- **What opportunities for training and professional development has the project provided?**

Nothing to Report.

- **How were the results disseminated to communities of interest?**

Nothing to Report.

- **What do you plan to do during the next reporting period to accomplish the goals?**

- Continue data collection, per designated milestone targets for control, instrumented cervical myelopathy, and instrumented SCI.
- Continue performing basic processing, curation, and scoring of data in near real time as it comes in to our archiving and analysis system.
- Perform advanced radiomic analysis on morphological and diffusion maps of the spinal cord to explore the heterogeneity and texture cord features.
- Refine diffusion-analysis pipelines to enable more localized analysis at each level, within the spinal cord for both the myelopathy and SCI subjects.
- Begin analysis of cord and lesion segmentations using radial basis function decompositions to generate imaging biomarkers related to morphological pathology observations.
- Begin preliminary correlation analyses of derived imaging biomarkers with clinical symptoms (ASIA and MJOA scores)

5. IMPACT: *Describe distinctive contributions, major accomplishments, innovations, successes, or any change in practice or behavior that has come about as a result of the project relative to:*

- **What was the impact on the development of the principal discipline(s) of the project?**

- We believe that our findings that clarify the geometric warping of spinal cord measurements near fusion hardware are going to be of substantial value to the radiological and scientific communities.

- **What was the impact on other disciplines?**

- Nothing to report.

- **What was the impact on technology transfer?**

- Nothing to report

- **What was the impact on society beyond science and technology?**

- Nothing to report.

6. CHANGES/PROBLEMS: *The Project Director/Principal Investigator (PD/PI) is reminded that the recipient organization is required to obtain prior written approval from the awarding agency Grants Officer*

whenever there are significant changes in the project or its direction. If not previously reported in writing, provide the following additional information or state, "Nothing to Report," if applicable:

- **Changes in approach and reasons for change**

Nothing to Report.

- **Actual or anticipated problems or delays and actions or plans to resolve them**

Nothing to Report.

- **Changes that had a significant impact on expenditures**

Nothing to Report.

- **Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents**

Nothing to Report.

- **Significant changes in use or care of human subjects**

Nothing to Report.

- **Significant changes in use or care of vertebrate animals.**

Nothing to Report.

- **Significant changes in use of biohazards and/or select agents**

Nothing to Report.

7. PRODUCTS: *List any products resulting from the project during the reporting period. If there is nothing to report under a particular item, state "Nothing to Report."*

- **Publications, conference papers, and presentations**

Report only the major publication(s) resulting from the work under this award.

- **Journal publications.** *List peer-reviewed articles or papers appearing in scientific, technical, or professional journals. Identify for each publication: Author(s); title; journal; volume: year; page numbers; status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).*

Nothing to Report.

- **Books or other non-periodical, one-time publications.** *Report any book, monograph, dissertation, abstract, or the like published as or in a separate publication, rather than a periodical or series. Include any significant publication in the proceedings of a one-time conference or in the report of a one-time study, commission, or the like. Identify for each one-time publication: Author(s); title; editor; title of collection, if applicable; bibliographic information; year; type of publication (e.g., book, thesis or dissertation); status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).*

Nothing to Report.

- **Other publications, conference papers, and presentations.** *Identify any other publications, conference papers and/or presentations not reported above. Specify the status of the publication as noted above. List presentations made during the last year*

(international, national, local societies, military meetings, etc.). Use an asterisk () if presentation produced a manuscript.*

Nothing to Report.

○ **Website(s) or other Internet site(s)**

List the URL for any Internet site(s) that disseminates the results of the research activities. A short description of each site should be provided. It is not necessary to include the publications already specified above in this section.

Nothing to Report.

○ **Technologies or techniques**

Identify technologies or techniques that resulted from the research activities. In addition to a description of the technologies or techniques, describe how they will be shared.

Nothing to Report.

○ **Inventions, patent applications, and/or licenses**

Identify inventions, patent applications with date, and/or licenses that have resulted from the research. State whether an application is provisional or non-provisional and indicate the application number. Submission of this information as part of an interim research performance progress report is not a substitute for any other invention reporting required under the terms and conditions of an award.

Nothing to Report.

○ **Other Products**

Identify any other reportable outcomes that were developed under this project. Reportable outcomes are defined as a research result that is or relates to a product, scientific advance, or research tool that makes a meaningful contribution toward the understanding, prevention, diagnosis, prognosis, treatment, and/or rehabilitation of a disease, injury or condition, or to improve the quality of life. Examples include:

- *data or databases;*
- *biospecimen collections;*
- *audio or video products;*
- *software;*
- *models;*
- *educational aids or curricula;*
- *instruments or equipment;*
- *research material (e.g., Germplasm; cell lines, DNA probes, animal models);*
- *clinical interventions;*
- *new business creation; and*
- *other.*

Nothing to Report.

8. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

○ **What individuals have worked on the project?**

Name: Kevin Koch, PhD – no change

Name: Matthew Budde, PhD – no change

Name: Melissa Hollister – no change

Name: Mohammad Sherafati, PhD – no change

○ **Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?**

Koch, K.:

Previously active grants that are closed:

“The NCAA-DOD Grand Alliance: Concussion Assessment, Research & Education (CARE)”
(McAllister, Broglio, McCrea)

Indiana University/DOD Army Medical Research Acquisition

The Trustee of Indiana University

Office of Research Administration

980 Indiana Ave

Indianapolis, IN 46202

Performance Period: 9/15/2014-9/14/2019

Level of Effort: 8%

The goal of this project was to measure the natural history of physiologic recovery after sports-related concussion using modern MRI technologies coupled with other genetic, biomarker, and psycho-social metrics.

Specific Aims

Aim 1: Create a national multi-site consortium as a sustainable framework to achieve the clinical and scientific, priorities of the Concussion Research Initiative of the Grand Alliance

Aim 2: To conduct a prospective, longitudinal, multi-center, multi-sport investigation that delineates the natural history of concussion in both men and women by incorporating a multi-dimensional assessment of standardized clinical measures of post-concussive symptomatology, performance-based testing (cognitive function, postural stability), and psychological health.

Aim 3: Utilize the framework of Aim 2 to conduct advanced scientific studies which integrate biomechanical, clinical, neuroimaging, neurobiological and genetic markers of injury to advance our understanding of neurophysiological effects and recovery after SRC in college athletes.

“Comprehensive Study of Acute Effects and Recovery after Concussion” (McCrea)

DOD Army Medical Research Acquisition

USA Med Research ACQ Activity

820 Chandler St

Fort Detrick, MD 21702

Performance Period: 9/15/2014-9/29/2019

Level of Effort: 3%

The goal of this project was to measure the natural history of physiologic recovery after sports-related concussion using modern MRI technologies coupled with other genetic, biomarker, and psycho-social metrics.

Specific Aims: The overarching aim of this proposal is to investigate the predictive and correlative value of multiple diagnostic and prognostic markers of mTBI in a common injured sample and single study design, including:

- Advanced brain neuroimaging to study changes in brain structure and function
- Blood biomarkers to study changes in brain biochemistry and physiology
- Head impact sensor technologies to study the kinetics and kinematics of concussion and the effects of repetitive head impacts.

- Genetic testing to study the influence of genetics on risk of mTBI and post-concussive recovery.
- Clinical measures of postconcussive symptoms, neurocognition, balance, psychological health, and other functional capacities to correlate with neurobiological, neuroimaging, biomechanical and genetic markers of injury.

“Enabling Diffusion-Weighted MRI Near Metallic Implants” (Koch)

NIH Biomedical Imaging & Bioengineering

Holly Atherton

Office of Grants Management

6707 Democracy Boulevard

Bethesda, MD 20892-5469

Performance Period: 8/1/2017-5/31/2019

Level of Effort: 19%

The primary goal of this project is to explore and refine the technical alternatives for diffusion-weighted imaging in the near vicinity of metallic hardware.

Specific Aims:

Aim 1: Integrate diffusion-sensitized driven equilibrium technology into a conventional 3D Multi-Spectral Imaging platform.

Aim 2: Develop and integrate acceleration approaches for diffusion-weighted multi-spectral imaging near metal implants.

Aim 3: Perform signal to noise and contrast to noise assessments of diffusion prepared and diffusion sensitized MSI on a standardized diffusion phantom.

“Enhancing MAVRIC Metal Artifact Reduction Technology Phase II: Advanced Quantification and Image Repair” (Koch)

GE Healthcare

3200 N. Grandview Blvd.

Waukesha, WI 53188

Performance Period: 3/1/2017-7/30/2020

Level of Effort: 10%

This study’s proposed methods represent significantly enhanced technical and clinical additions to existing the existing MAVRIC5SL offering. As demonstrated by our phase I project deliverables and to facilitate rapid translation to clinical imaging evaluation, we propose to implement these technological advancements synergistically on top of the existing commercially available infrastructures (EPIC 3dfse.e psd and Orchestra MAVRIC reconstruction pipeline).

Specific Aims:

Aim 1: Develop and Evaluate Spectral Modelling and Bin Dilation for Reduction of Pileup Artifacts

Aim 2: Develop a Deployable Metallosis Detection and Characterization Toolkit

Aim 3: Explore, Develop, and Evaluate Joint Relaxation and Spectral Modelling Approach for Fat Saturation

Aim 4: Explore, Develop, and Evaluate Dynamic MAVRIC Scanning and Relaxometry Applications

“Connectome Technology Maintenance and Development Hub” (Koch/Nencka)

GE Healthcare

3200 N. Grandview Blvd.

Waukesha, WI 53188

Performance Period: 11/21/2017-11/20/2019

Level of Effort: 8%

This proposal outlines the creation of a GE-MCW connectome technology “hub”. Under this collaborative arrangement, MCW would manage, disseminate, and evolve research-dedicated connectome technology on the GE platform.

Specific Aims:

Aim 1: Construct advanced Connectome acquisition and reconstruction research prototype packages

Aim 2: Disseminate and support advanced Connectome acquisition and reconstruction research prototype packages

Aim 3: Develop enhancements to the existing Connectome acquisition and reconstruction technologies

Previously pending grants that are now active:

“Quantitative MRI of the Post-Injury Instrumented Spinal Cord” (Koch)

DOD Department of Defense (CDMRP, USAMRMC)

Lucinda F. Keeney

Grants Specialist

U.S. Army Medical Research Acquisition Activity

Performance Period: 10/1/2019-9/30/2022

Level of Effort: 15%

The long-term goals of this proposal are to advance MRI technology to limit the difficulties caused by metal implants, which could considerably improve post-operative medical care and improve clinical trial design and efficiency by enhancing patient stratification.

Specific Aims:

Aim 1: Relate spinal cord morphology at the site of injury in the instrumented spine to neurological outcomes by exploiting metal hardware artifact-reduction MRI.

Aim 2: Compare quantitative diffusion weighted imaging (DWI) of the instrumented spinal cord to atrophy-based biomarkers at the site of instrumented SCI.

“Enabling Kinematic Joint Profiling Using MRI” (Koch)

NIH Biomedical Imaging and Bioengineering

Office of Grants Management

6707 Democracy Boulevard

Bethesda, MD 20892-5469

Performance Period: 9/1/2019-8/31/2021

Level of Effort: 15%

The goal of this project is to establish and demonstrate methodological components required for MRI kinematic profiling. Data collection on a modest-sized cohort of 100 healthy control subjects is proposed for this purpose.

Specific Aims:

Aim 1: Develop acquisition and post-processing protocols that enable navigated 3D quantitative MRI kinematic profiling of the wrist.

Aim 2: Validate the proposed 3D MRI kinematic profiling approach utilizing motion analysis of the wrist and hand.

Aim 3: Develop a normative scaphoid-lunate kinematic profile template by applying the methods established in Aim 1 on a cohort of asymptomatic volunteers distributed across a wide range of ages.

Newly active grants:

“Clinical Integration of Quantitative Susceptibility Mapping into Routine Neuroimaging Using Deep Neural Networks” (Koch)

GE Healthcare

3200 N. Grandview Blvd.

Waukesha, WI 53188
Performance Period: 4/2/2019-4/1/2021
Level of Effort: 5%
The goal of this project is to develop and test for real time robust QSM inversion on standard VRE CPU hardware.
Specific Aims:
Aim 1: Integration of our deep learning QSM workflow as an online orchestra data plugin
Aim 2: Retrospective application and analysis of the QSM workflow on clinical SWAN datasets acquired on multiple scanner configurations at both 1.5T and 3.0T.
Aim 3: Application to detection of microbleed detection

“Improving the Efficiency of Advanced WARP 3D-MSI Metal Artifact Reduction for MRI”
(Koch/Nencka)

Siemens Medical Solutions

Maxine Tam
40 Liberty Blvd
Malvern, PA 19355

Performance Period: 7/15/2020-7/14/2021

Level of Effort: 5%

The goal of this project is to deploy 3D-MSI spectral calibration technology on the Siemens platform in order to improve the efficiency of the Advanced WARP 3D-MSI implementation.

Specific Aims:

Aim 1: Develop spectral calibration and “spectrally-oriented” 3D-MSI acquisition pulse-sequence technology.

Aim 2: Develop reconstruction algorithms to process spectral calibration data and spectrally-oriented 3D-MSI data acquired within Aim 1.

“The MCW Human Connectome Project Technology and Application Hub” (Koch/Nencka)
GE Healthcare

3200 N. Grandview Blvd.
Waukesha, WI 53188

Performance Period: 5/18/2020-5/17/2022

Level of Effort: 10%

The goal is to maintain the existing collaboration lines, while exploring increased levels of clinical translation using HCP technology.

Specific Aims:

Aim 1: Maintain and augment our disseminated HCP package with inclusion of new techniques such as AI based reconstruction and post-processing techniques for diffusion motion correction

Aim 2: Development and deployment of DL Hyperband

Aim 3: Quantitative analysis of DTI performance using Hyperband (AI and slice-ARC) and MUSE

Aim 4: Advanced QSM and morphological MRI assessment of TBI and dementia

“Advanced diagnostics of total hip replacements: usage of MAVRIC SL at 3T and automated anomaly detection” (Koch)

GE Healthcare

3200 N. Grandview Blvd.
Waukesha, WI 53188

Performance Period: 8/1/2020-7/31/2022

Level of Effort: 5%

The purpose of this research is to increase the utility and usability of the MAVRIC SL software application – particularly through its application to commonly assessed total hip replacements.

Specific Aims:

Aim 1: Utilize retrospectively collected data at MCW to develop an artifact “atlas” quantifying specific regions near total hip replacements where additional artifacts are expected to occur.
Aim 2: Utilize retrospectively collected data at MCW to develop “atlases” of soft tissues and bone pathology near total hip replacements.
Aim 3: Optimize MAVRIC SL protocols for application at 3T

“Service Academy Longitudinal TBI Outcomes Study (SALTOS)”

(McAllister/Pasquina/McCrea)

Indiana University/Uniformed Services University of the Health Sciences

Indiana University

IU Accounts Payable

400 E. 7th Street, Room 021

Bloomington, IN 47405

Performance Period: 7/1/2018-6/30/2022

Level of Effort: 1%

The overarching goal of the Concussion Assessment, Research and Education (CARE) – Service Academy Long Term Outcomes Study (SALTOS) Integrated Study (CSI) is to address five compelling public health questions with broad relevance to the sporting community and the general public in the United States and worldwide.

Budde, M.:

Previously active grants that are closed:

“The NCAA-DOD Grand Alliance: Concussion Assessment, Research and Education (CARE)”

DOD Army Medical Research Acquisition

USA Med Research ACQ Activity

820 Chandler St

Fort Detrick, MD 21702

Performance Period: 8/1/2014-9/14/2019

Level of Effort: Federal Time Commitments: 10%

The overarching goals of this proposal are (1) to create the mechanism and structure whereby the vision driving the Grand Alliance is realized and can be sustained; (2) to answer several fundamental questions about the natural history of injury and neural mechanisms underlying acute concussion and recovery; and (3) derive evidence-based approaches to concussion assessment, management and prevention

Specific Aims:

Aim 1: Create a national multi-site consortium as a sustainable framework to achieve the clinical and scientific priorities of the Concussion Research Initiative of the Grand Alliance

Aim 2: To conduct a prospective, longitudinal, multi-center, multi-sport investigation that delineates the natural history of concussion in both men and women by incorporating a multi-dimensional assessment of standardized clinical measures of post-concussive symptomatology, performance-based testing (cognitive function, postural stability), and psychological health.

Aim 3: Utilize the framework of Aim 2 to conduct advanced scientific studies which integrate biomechanical, clinical, neuroimaging, neurobiological and genetic markers of injury to advance our understanding of neurophysiological effects and recovery after SRC in college athletes.

“Concussive Injury: The Role of Sleep Restriction, Sleep Aids, Sedation, and Caffeine (Everson)

Department of Defense

Rebecca (Becky) Runyen

Medical Research Program Administrator

810 Schreider Street

Fort Detrick, MD 21702-5000

Performance Period: 6/15/2016-6/14/2020

Level of Effort: 5%

The goal of this proposal is to determine the relationship between traumatic brain injury and sleep using a rat model and behavioral and MRI outcomes.

Specific Aims:

Objective 1. Determine what will improve outcomes of mTBI.

Objective 2. Determine relationships between brain function, hormonal status, and behavioral changes long after repeated mTBIs are acquired.

Objective 3. Test the prediction that chronic exposure to sleep restriction, caffeine usage, or sleep aids modify long-term outcomes of mTBI.

“Advanced Diffusion MRI as a Prognostic Marker of Human Spinal Cord Injury” (Budde)

Craig H. Neilsen Foundation

Kim Cerise

Craig H. Neilsen Foundation

16830 Venture Boulevard, Suite 352

Encino, CA 91436

Performance Period: 7/31/2018-7/30/2020

Level of Effort: 12%

The goals of this project are to evaluate the potential of novel diffusion MRI techniques to predict outcome in acute spinal cord trauma patients.

Specific Aims:

Aim 1: DDE is a marker of acute spinal cord injury severity and prognostic of functional outcome.

Aim 2: DDE measures of axonal sparing are related to functional neurological status in chronic SCI.

Previously pending grant that is now active:

“Quantitative MRI of the Post-Injury Instrumented Spinal Cord” (Koch)

DOD Department of Defense (CDMRP, USAMRMC)

Lucinda F. Keeney

Grants Specialist

U.S. Army Medical Research Acquisition Activity

Performance Period: 10/1/2019-9/30/2022

Level of Effort: 10%

The long-term goals of this proposal are to advance MRI technology to limit the difficulties caused by metal implants, which could considerably improve post-operative medical care and improve clinical trial design and efficiency by enhancing patient stratification.

Specific Aims:

Aim 1: Relate spinal cord morphology at the site of injury in the instrumented spine to neurological outcomes by exploiting metal hardware artifact-reduction MRI.

Aim 2: Compare quantitative diffusion weighted imaging (DWI) of the instrumented spinal cord to atrophy-based biomarkers at the site of instrumented SCI.

Newly active grants:

“Determination of factors that influence addiction-related outcomes following brain injury”

Department of Veterans Affairs

Stuart Hoffman, PhD

Performance Period: 03/01/2020-02/29/2024

Level of Effort: 12%

To determine if ibudilast (an intervention that has improved TBI and addiction-related outcomes in pre-clinical studies) will mitigate the injury-associated increase in seeking, and will be

associated with a reduction in the mTBI-associated gliosis and mTBI-associated changes in structural and functional brain networks implicated in drug seeking behavior.

Specific Aims:

Aim 1: Measure oxycodone reinforcement after TBI.

Aim 2: Determine the chronicity of risk in the TBI-associated increase in addiction liability.

Aim 3: Measure the effects of ibudilast on addiction-related outcomes and reactive gliosis in comorbid TBI-addiction.

Aim 4: Determine the effects of ibudilast on brain networks implicated in drug seeking in comorbid TBI-addiction.

“Role of the pro-inflammatory cytokines IL-12 and IL-23 in secondary damage after spinal cord injury”

Department of Veterans Affairs

Audrey N. Kusiak, audrey.kusiak@va.gov

Performance Period: 04/01/2019-03/31/2023

Level of Effort: 5%

The goal of this study is to assess the influence of the pro-inflammatory cytokines IL-12 and IL-23 on inflammatory secondary damage after spinal cord injury (SCI) and to assess if the absence or inhibition of these cytokines will promote a better outcome in terms of reduced tissue damage and improved functional recovery.

Specific Aims:

Aim 1: Define the expression of IL-12, IL-23 and their receptors after spinal cord contusion injury in mice and correlate the amount of hemorrhage to expression levels of IL-12 and IL-23

Aim 2: Assess the functional role of IL-12 and IL-23 after SCI and define mediating mechanisms

Aim 3: Assess the effect of pharmacological inhibition of IL-12/IL-23

Klein, A.:

Previously pending grant that is now active:

“Quantitative MRI of the Post-Injury Instrumented Spinal Cord” (Koch)

DOD Department of Defense (CDMRP, USAMRMC)

Lucinda F. Keeney

Grants Specialist

U.S. Army Medical Research Acquisition Activity

Performance Period: 10/1/2019-9/30/2022

Level of Effort: 1%

The long-term goals of this proposal are to advance MRI technology to limit the difficulties caused by metal implants, which could considerably improve post-operative medical care and improve clinical trial design and efficiency by enhancing patient stratification.

Specific Aims:

Aim 1: Relate spinal cord morphology at the site of injury in the instrumented spine to neurological outcomes by exploiting metal hardware artifact-reduction MRI.

Aim 2: Compare quantitative diffusion weighted imaging (DWI) of the instrumented spinal cord to atrophy-based biomarkers at the site of instrumented SCI.

Kurpad, S.:

Previously active grant that is closed:

“Advanced Diffusion MRI as a Prognostic Marker of Human Spinal Cord Injury” (Budde)

Craig H. Neilsen Foundation Grant

Kim Cerise

Craig H. Neilsen Foundation

16830 Ventura Blvd, Suite 352

Encino, CA 91436

Performance Period: 7/31/2018-7/30/2020

Level of Effort: 1%

The goal of this study is to translate findings to acute humans SCI and evaluate the sensitivity and prognostic ability of DDE as a potential biomarker in clinical settings.

Specific Aims: Double diffusion encoding (DDE) is a marker of acute spinal cord injury severity and prognostic of functional outcome; DDE measures of axonal sparing are related to functional neurological status in chronic spinal cord injury.

Previously pending grant that are now active:

“Quantitative MRI of the Post-Injury Instrumented Spinal Cord” (Koch)

DOD Department of Defense (CDMRP, USAMRMC)

Lucinda F. Keeney

Grants Specialist

U.S. Army Medical Research Acquisition Activity

Lucinda.F.Keeney.civ@mail.mil

Performance Period: 10/1/2019-9/30/2022

Level of Effort: 1%

The long-term goals of this proposal are to advance MRI technology to limit the difficulties caused by metal implants, which could considerably improve post-operative medical care and improve clinical trial design and efficiency by enhancing patient stratification.

Specific Aims:

Aim 1: Relate spinal cord morphology at the site of injury in the instrumented spine to neurological outcomes by exploiting metal hardware artifact-reduction MRI.

Aim 2: Compare quantitative diffusion weighted imaging (DWI) of the instrumented spinal cord to atrophy-based biomarkers at the site of instrumented SCI.

Wang, M.:

Previously pending grant that are now active:

“Quantitative MRI of the Post-Injury Instrumented Spinal Cord” (Koch)

DOD Department of Defense (CDMRP, USAMRMC)

Lucinda F. Keeney

Grants Specialist

U.S. Army Medical Research Acquisition Activity

Lucinda.F.Keeney.civ@mail.mil

Performance Period: 10/1/2019-9/30/2022

Level of Effort: 1%

The long-term goals of this proposal are to advance MRI technology to limit the difficulties caused by metal implants, which could considerably improve post-operative medical care and improve clinical trial design and efficiency by enhancing patient stratification.

Specific Aims:

Aim 1: Relate spinal cord morphology at the site of injury in the instrumented spine to neurological outcomes by exploiting metal hardware artifact-reduction MRI.

Aim 2: Compare quantitative diffusion weighted imaging (DWI) of the instrumented spinal cord to atrophy-based biomarkers at the site of instrumented SCI.

○ **What other organizations were involved as partners?**

Nothing to Report

- *If there is nothing significant to report during this reporting period, state "Nothing to Report."*
- *Describe partner organizations - academic institutions, other nonprofits, industrial or commercial firms, state or local governments, schools or school systems, or other*

organizations (foreign or domestic) - that were involved with the project. Partner organizations may have provided financial or in-kind support, supplied facilities or equipment, collaborated in the research, exchanged personnel, or otherwise contributed. Provide the following information for each partnership:

- **Organization Name:**
- **Location of Organization:** *(if foreign location list country)*
- **Partner's contribution to the project** *(identify one or more)*
 - **Financial support;**
 - **In-kind support** *(e.g., partner makes software, computers, equipment, etc., available to project staff);*
 - **Facilities** *(e.g., project staff use the partner's facilities for project activities);*
 - **Collaboration** *(e.g., partner's staff work with project staff on the project);*
 - **Personnel exchanges** *(e.g., project staff and/or partner's staff use each other's facilities, work at each other's site); and*
 - **Other.**

9. SPECIAL REPORTING REQUIREMENTS

- **COLLABORATIVE AWARDS:** Nothing to Report
- **QUAD CHARTS:** Updated chart attached

10. APPENDICES:
