MRI Protocols Comparison of In-Vivo Spinal Cord Imaging of the Rats for Segmentation Purposes

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***Abstract*- We are developing a three-dimensional (3D) model of the rat spinal cord to act as a reliable tool for investigating mechanisms of spinal injury. Segmentation and meshing, by which the spinal geometry is extracted into a model, requires both considerably clear boundaries and high-contrast representation of the cord components: white matter, grey matter, meninges, CSF and IVD. Unfortunately, despite the advancement of MRI technology, obtaining high-resolution and high-contrast spinal cord of the rat is not an easy task; tedious protocols set up are required. This work comparedtwoprotocols that are commonly used for in-vivo MRI acquisitions; FLASH (T1 weighted) and TurboRare(T2 weighted). The software packages MicroDICOM and Mimics were used to assess the outcome of each protocol. As further comparison, we also examined ex-vivo datasets obtaining with MSME (T2 and proton density weighted) acquisition. The assessment was made based on the clarity of canny edgecontrast detection and the amount of unintended objects adjacent to the spinal cord components on the 3D model. We found that compared to TurboRare (T2 weighted), FLASH (T1 weighted) visually produced higher contrast between white and grey matter. This visual assessment was confirmed by the canny edge boundary detection on MicroDICOM. On Mimics, this difference was not detectable. Although the amount of unintended structures of the 3D modelof FLASH (T1 weighted) acquisitions less than that of the TurboRare (T2 weighted), it was more likely due to the signal uniformity rather than the effect of acquisition selection. Additionally, since this work only involved 3 datasets, whereby the statistical validation is not sufficient, we could not suggesta conclusive finding. However, this work is important as the basis further MRI protocol comparison studies.**

Keywords—MRI, T1 weighted, T2 weighted, spinal cord, grey matter, white matter.

I. INTRODUCTION

Spinal cord injury (SCI) mechanism is difficult to be understood solely by usingan experimental approach. Computation analysis is a well-accepted method to study the injury mechanism as it explains the event that could not be achieved experimentally[1]. Segmentation, the initial step of the computational analysis, is a process to extract geometry of the spinal cord to be used for further development steps; in case of our study, the mesh generation and the computational analysis. This step requires high quality image input, more importantly high contrast between the structures; in this case white matter, grey matter, cerebrospinal fluid (CSF) and other organs to be included in the model.

MRI is still by far prominent to image the spinal cord as it is non-invasive; its efficacy on the spinal cord imaging can be traced back since the correlation study between atrophy and disability study was commenced [2, 3]. Since then, both technique and MRI technology have been progressively discovered.

Despite of the advancement of current MRI technology, high-resolution in-vivo imaging of the rat spinal cord is so far difficult to achieve. There are at least two major constraints impinging the robustness of SC imaging; the first, associated with the image acquisition and the second, related to difficulties of segmenting the cord due to its anatomical complexity[4]. Common types of the segmentation challenges are low image resolution, low contrast ratio, subject with reduced CSF volume and above-average spinal curvature and artefacts due to motion – on in vivo imaging[4]. Many fully segmentations techniques have been built to handle these issues but none of them are yet thoroughlycope with the SC complexity imaging issues.

Having understood that the ultimate objective of such segmentation methods is to define boundaries as well as contrast ratioamong structures that need to be included in the model. These features are associated with MRI image acquisition during the scanning process. Therefore, selecting appropriate acquisition protocols is essential in ensuringhigh quality image suitable for segmentation purposes.

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In this work we compared MRI protocols for the in-vivo imaging protocols that are commonly used for spinal cord imaging: FLASH (T1 weighted) and TurboRARE (T2 weighted). The scope of this work is limited only to assess the protocols that are suitable for segmentation purposes. We used MicroDICOM and Mimics (Materialise) software to examine the protocols efficacy and develop the model. Noted that, this work is not 'standalone' study, instead it is a preliminary stage of the whole process of developing 3D model for the study entitled Correlation between Strain and Damage of Spinal Cord Injury in the Rats; a Finite Element Study. As such, further studies are required to generate conclusive findings.

II. MATERIALS AND METHODS

II.1 Materials

MRI datasets of four Fischer rats (180 – 200grams); 5 in vivo, 1 ex vivo, were acquired using 9.4T Nanoscope MRI (Bruker, Germany). We used FLASH (T1 weighted) and TurboRARE (T2 weighted) acquisitions for acquiring the in-vivo imagesand MSME (T2 and Proton Density weighted) for the ex vivo dataset. This work has been granted a permission to use animal by the Ethics Committee of The University of Western Australia. Scan time were varies in between 20 minutes to 1 hour for the in-vivo and up to 7 hours for ex-vivo scanning. All images were taken with optimum parameters setting resulting the best visual image representation in term of contrast, no visible artefacts, and low noise. The MRI images were exported into *dicom files.

Subjects	Sequence	TR	ETL	ST	Matrix	NA	FA	Comment
ID#1	T1_Flash	250		1	0.15x0.15	24		In-vivo
ID#1	T2_TurboRare	2500	8	1	0.15x0.15	32		In-vivo
ID#2	T1_Flash	250		1	0.125x.0125	160	335	In-vivo
ID#3	T1_Flash	250	1	1	0.15x0.15	32	35	In-vivo
ID#3	T2_Rare	2500	8	1	0.15x0.15	24	70	In-vivo
ID#4	PD_T2_MSME	5000	60	0.5	0.15x.15	32	90	Ex-vivo

Table 1. The dataset with its corresponding protocols set up. The 3D model without clean up

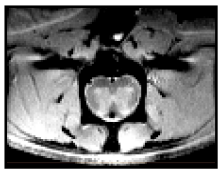
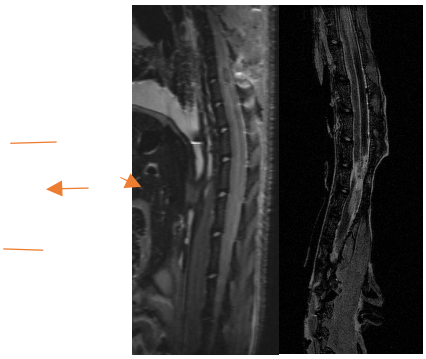


Fig. 1. Sagittal view of the in-vivo and ex vivodataset. Two slices were selected from the image dataset, one slice located on T8 and T12. The T9/10 is the injury site.



II.2 Methods

We used 2 software packages tobriefly analyse the image; MicroDICOM (Sofia, Bulgaria) and Mimics (Materialise, Belgium). MicroDiCOM is a free DICOM viewer was used to detect the canny edge of the grey and white matter. This canny edge detection was used to confirm the visual threshold among SC structures, more importantly white and grey matter. We segmented the dataset on Mimics; white and grey matter selectionswere made by thresholding the intensity distribution so that they were visually matched with their boundaries. To optimise the threshold, we selected two reference slices; one slice situated at T8 and the other at T11, which defined to the length of our 3D model.

II.3 Data Analysis

In order to assess the efficacy of each acquisition, we qualitatively highlighted two slices of the white and grey matter at T8 and T11.Using this techniques, we also assessed the signal uniformity between such slices; the more uniform the contrast the better Mimics able to coupe. The assessments were made based on the amount of structures beyond the region of interest; white and grey matter. The less structures outside the targeted areas (white and grey matter), the less manual intervention was involved. To visualise the 3D model, we generated the 3D using the "optimised" option.

III. RESULTS AND DISCUSSION

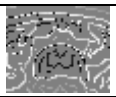
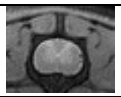
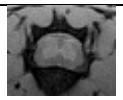
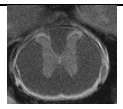
Acquisitions	Cany Egde	Axial View	Note
T1_Flash (R2)			Edge detection was sufficiently good, except on the edge
T2_Rare (R1)			Same as above

Fig. 2. The presentation of the canny edge detection performed by MicroDICOM and the spinal cord (white and grey matter)slices about T8.

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T1_Flash (R1)			Same as above
T2_Turbo Rare (uninjured_Ex-vivo)			Edge detection was sufficiently good, but not excellent on the edge.
T2_PD_MSME (injured-ex-xixo)			The boundaries between GM and WM was excellent, but the canny edge cannot be detected, which likely due to preservation.

Obtaining a high quality MRI dataset of the spinal cord of the living rat is not a straight forward task; it is not as simple as, for example brain. Nature complexity of the cord's structure in addition to the technical and ethical constraint of imaging a living rat, is the major challenge up to date. Since parameters setting is highly depending on the sample conditions, choosing appropriate acquisition is essential in order to generate high quality imaging outcomes. This high quality image is even more important from segmentation perspectives since it will be the initial foundation for further analysis.

In vivo spinal cord images were captured using T1_Flash and Turborare. The challenging in vivo image characteristic was that the spatial resolution was not quite high. It was constrained by short scan time as well motion artefacts.

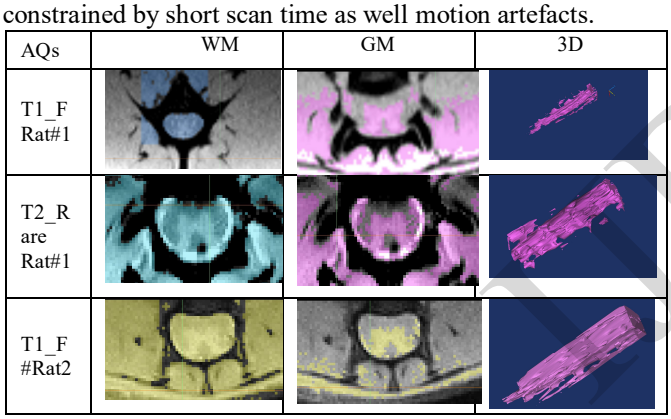


Fig. 3. The samples of Mimics representation of thresholding the white matter (WM) and grey matter (GM) and its associated 3D model.

From our qualitative assessment using the MicroDICom and Mimics, FLASH (T1 weighted) and TurboRARE (T2 weighted)produced fairly high quality images. Our results is visually much sharper than the image of the rats SC acquired using 9.4T MRI by [5]. The contrast ratio amongacquisitionswerevisually similar. When we applied the canny edge filter, we barely see the differences. However, after scrutinizing Fig. 3 that these two images were different; the separation line of that of the T1 is more than that of the T2_Turborare, which refer to a better contrast.

Mimics assessment also suggested that for both image acquisition able to deal very well to distinguish between white and the vertebrae, which appear dark on both images. However, once dealing with the contrast boundaries between white and grey matter, FLASH (T1 weighted) performed slightly better. Additionally, due to lack uniformity among slices more importantly which lies in between T8 – T11 (did not show up on the image), we used the slice at T11, which has low contrast ratio as a reference. This was due to the fact that, sincewe surely will involve manual segmentation, removing structures was much easier rather than creating new ones.

This visual assessment was confirmed by the canny edge boundary detection on MicroDICOM. On Mimics, this difference was not detectable. Although the amount of unintended structures of FLASH (T1 weighted) acquisitions less than that of the Turborare (T2 weighted), it was more likely due to the signal uniformity rather than aresult of the acquisition selection. Additionally, since this work only involved 3 datasets whereby the statistical validation was less strong to be performed, we could not suggest the conclusive finding. However, this work is important as the basis further MRI protocols comparison studies.

IV. CONCLUSION AND RECOMMENDATION

Many studies have compared the efficacy of various algorithms for serving fully segmentation purposes. Indeed, such idea is an interesting topic since there is yet no software to perform fully auto segmentation on the spinal cord. In 'less-sophisticated field', the issue on choosing the MRI image acquisition is real and need an urgent solution. In this work we examined the efficacy of twoMRI protocols for in-vivo imaging protocols; FLASH (T1 weighted) and TurboRare (T2 weighted) that were suited for segmentation. We involved MicroDICOM and Mimics (Materialise) software to qualitativelytest the protocols.

Since our work was not designed as a 'dedicated' study to solve this issue, we acknowledge that the data presented in this work were not sufficient to make a validated judgment. However, this work could be a basis for future studies in comparing the efficacy of various MRI acquisitions.

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V. REFERENCES

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