Study of Longitudinal Relaxation Time Multi Echo Multi Planar (T1 MEMP) and Diffusion Weighted Imaging (DWI) on Magnetic Resonance Imaging (MRI) Image

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Abstract. Magnetic Resonance Imaging (MRI) is an imaging technique for the human body cross-section, which utilizes electromagnetic radiations in the form of radio frequency. The MRI imaging technique is relatively complex, since the resulted images depend on many parameters, including Time Repetition (TR) and Time Echo (TE). This research is aimed to analyze the selection of TR and TE parameters, as well as to analyze the differences of signal intensity on White Matter (WM) tissue, Gray Matter (GM) tissue, and Cerebrospinal Fluid (CSF) of T1 MEMP and DWI images in the human brain. The obtained results showed that T1 MEMP images had short TR value (400–500 ms) and short TE value (13 ms), while DWI images had a b-value = 1,000 s/mm² with long TR value (7,000 ms) and long TE value (80–90 ms). The resulted signal intensity on WM tissue, GM tissue, and CSF was measured based on gray value distribution using RadiAnt DICOM Viewer version 2.2.9.10728 (64 bit) and ENVI version 4.5 software. The results showed that the average of gray value distribution on T1 MEMP images were 46.5–66.5 for GM tissue, 67.5–94 for WM tissue, and 18.9–45.5 for CSF, while the average of gray value distribution on DWI images were 178–255 for GM tissue, 92.1–177 for WM tissue, and 31.5–91.1 for CSF. Hence, the WM tissue appeared clearer by using T1 MEMP images and the GM tissue appeared clearer by using DWI images.

1. Introduction

Technological advances in the health field have a very significant impact on medical imaging techniques, particularly Magnetic Resonance Imaging (MRI). MRI is an imaging technique for human body cross-section, which utilizes the magnetic field gradient that fluctuates rapidly and electromagnetic radiations in the form of radio frequency (RF).

The human body cross-sectional images as the result of MRI system acquisition are affected by the Time Repetition (TR) and Time Echo (TE) parameters. Some of those images are: longitudinal relaxation time (T1) and Diffusion Weighted Imaging (DWI) [1]. The T1 images show a clear delineation of brain anatomical structures [2]. Meanwhile, the DWI images show the image contrast
based on water microscopic movement in tissue and can provide pathological information [3,4]. The resulted tissue signal intensity of T1 and DWI images are different for certain tissue parts, so it can be hyperintense or hypointense [2,5].

Hence, we conducted this research to analyze the selection of TR and TE parameters in order to produce the longitudinal relaxation time Multi Echo Multi Planar (T1 MEMP) and DWI images, as well as to analyze the differences of signal intensity on GM tissue, WM tissue, and CSF of T1 MEMP and DWI images in the human brain.

1.1. Longitudinal Relaxation Time Multi Echo Multi Planar (T1 MEMP)
The T1 MEMP images use a spin-echo pulse sequence with the Multi Echo Multi Planar (MEMP). MEMP is a sequence that uses the multi-slice and multi-echo acquisitions in one single TR (the time between applications of RF pulses). The T1 MEMP images should have a short TR to control the amount of T1 relaxation. Meanwhile, the T1 MEMP images should also have a short TE (the time between the RF pulse and spin echo) to reduce the transversal relaxation time (T2) weighting [1,6,7].

1.2. Diffusion Weighted Imaging (DWI)
The DWI or the proton density (PD) images also use the spin-echo pulse sequence. These images occur simultaneously with the mechanism of T1 and T2 weighted images. In this way, the increasing and decreasing processes of T1 and T2 relaxations allow to producing the dominant DWI images.

The DWI images show the limited diffusion area in water extracellular molecules of abnormality tissues. This area has a high signal. An increased sensitivity of diffusion is followed by an increased $b$-value of water extracellular molecules in tissue. The ranges of $b$-value in the DWI images usually from 500 to 1,000 s/mm$^2$ with long TR and short TE [1,4,8]. The $b$-value can be formulated as follows [9]:

$$b = γ^2 G^2 δ^2 (Δ−δ/3)$$

with $γ$ is the gyromagnetic ratio (MHz/T), $G$ is the diffusion gradient amplitude (mT/m), $δ$ is gradient pulse duration (s), and $Δ$ is time between pulses (s). The unit of $b$-value is s/mm$^2$.

2. Methodology
This study was conducted in the Radiology Installation room of a private hospital in Makassar, Indonesia, from October to December 2016. The used tools were a laptop with the Windows 8 operating system, RadiAnt DICOM Viewer software version 2.2.9.10728 (64-bit), and ENVI software version 4.5. The used materials were brain axial images of longitudinal relaxation time Multi Echo Multi Planar (T1 MEMP) and Diffusion Weighted Imaging (DWI).

![Figure 1. The flowchart of the study](image-url)
Figure 1 showed our study flowchart. The images were obtained randomly from MRI 1.5 T (GE Medical System) in DICOM extension (.dcm). Then, the DICOM images were converted into .jpg files by RadiAnt DICOM Viewer software version 2.2.9.10728 (64-bit). The converted images were classified into four age groups as in Bayat et al. [10]; the first group (0–18 years), the second group (18.1–40 years), the third group (40.1–65 years), and the fourth group (65.1–80 years). Next, Time Repetition (TR) and Time Echo (TE) values in the images were analyzed.

As for the ENVI software version 4.5 was used to analyze the gray value of Gray Matter (GM) tissue, White Matter (WM) tissue, and Cerebrospinal Fluid (CSF) with the cursor location. Furthermore, the images were segmented in order to clarify the areas of those three parts with different coloring. The image segmentation was based on the gray value distributions.

3. Result and discussion

3.1. Analysis of Time Repetition (TR) and Time Echo (TE) selection

The brain axial images of longitudinal relaxation time Multi Echo Multi Planar (T1 MEMP) and Diffusion Weighted Imaging (DWI) are classified into four age groups. Then, the value of the TR and TE parameters in images are selected, see table 1.

| Patient (years old) | Age Group | T1 MEMP | DWI |
|---------------------|-----------|---------|-----|
|                     |           | TR (ms) | TE (ms) | TR (ms) | TE (ms) |
| A (10)              | First Group | 420    | 13   | 7,000 | 90.5 |
| B (20)              | Second Group | 460    | 13   | 7,000 | 89.8 |
| C (21)              |            | 420    | 13   | 7,000 | 89.7 |
| D (34)              |            | 420    | 13   | 7,000 | 90.7 |
| E (34)              |            | 420    | 13   | 7,000 | 90.1 |
| F (36)              |            | 460    | 13   | 7,000 | 90.1 |
| G (52)              | Third Group | 420    | 13   | 7,000 | 92.1 |
| H (56)              |            | 420    | 13   | 7,000 | 90.1 |
| I (63)              |            | 420    | 13   | 7,000 | 90.3 |
| J (65)              |            | 500    | 13   | 7,000 | 91.2 |
| K (71)              | Fourth Group | 420    | 13   | 7,000 | 91.2 |

T1 MEMP brain axial images have various TR values in the 400–500 ms range. This range is included in short TR values (300–600 ms). Meanwhile, T1 MEMP brain axial images have the same TE values for all patients and classified as short TE values (a minimum to 30 ms). These results are consistent with the previous theory.

On the other hand, DWI brain axial images have the same TR values for all patients and classified as long TR values (more than 2,000 ms). As for DWI brain axial images have various TE values in the 80–90 ms range. This range is included in long TE values (more than 70 ms), contrary to the previous theory [1,4,8]. However, long TE values are linked to the high b-value (1,000 s/mm²) in images. This can improve the accuracy of early detection in tissue abnormalities [11].

Furthermore, TR and TE parameter selection has no correlation with the patient’s age. This is corresponding with Rauf et al. [12], with different image types (brain axial images of T2 PROPELLER and T2 FLAIR). The TR and TE parameters are linked with the amount of T1 and T2 relaxations [1].

3.2. Analysis of Signal Intensity Based on Gray Value Distribution

The signal intensity of each image type is depending on the image weighting. The signal intensity can be analyzed by the gray value distribution. This distribution gives the different coloring (segmentation) for WM tissue, GM tissue, and CSF of the T1 MEMP and DWI axial images, see table 2. Regarding the gray values of those three parts, they can be seen in table 3.

| Patient (years old) | Age Group | T1 MEMP | DWI |
|---------------------|-----------|---------|-----|
|                     |           | TR (ms) | TE (ms) | TR (ms) | TE (ms) |
| A (10)              | First Group | 420    | 13   | 7,000 | 90.5 |
| B (20)              | Second Group | 460    | 13   | 7,000 | 89.8 |
| C (21)              |            | 420    | 13   | 7,000 | 89.7 |
| D (34)              |            | 420    | 13   | 7,000 | 90.7 |
| E (34)              |            | 420    | 13   | 7,000 | 90.1 |
| F (36)              |            | 460    | 13   | 7,000 | 90.1 |
| G (52)              | Third Group | 420    | 13   | 7,000 | 92.1 |
| H (56)              |            | 420    | 13   | 7,000 | 90.1 |
| I (63)              |            | 420    | 13   | 7,000 | 90.3 |
| J (65)              |            | 500    | 13   | 7,000 | 91.2 |
| K (71)              | Fourth Group | 420    | 13   | 7,000 | 91.2 |

Based on the table 2, the red color indicates the GM tissue with gray value distribution ranges of 39–89 for the T1 MEMP axial images and 128–255 for the DWI axial images. Meanwhile, the green color indicates the CSF with gray value distribution ranges of 15–57 for the T1 MEMP axial images and 24–107 for the DWI axial images. As for the blue color indicates the WM tissue with gray value distribution ranges of 60–128 for the T1 MEMP axial images and 81–202 for the DWI axial images.
**Table 2.** The segmentation of T1 MEMP and DWI axial images

| Age Group | Patient | T1 MEMP Axial Image | Segmentation of T1 MEMP Axial Image | DWI Axial Image | Segmentation of DWI Axial Image |
|-----------|---------|---------------------|-------------------------------------|----------------|---------------------------------|
| First Group | A       | ![Image](image1)     | ![Image](image2)                    | ![Image](image3) | ![Image](image4)               |
|           |         | ![Image](image5)     | ![Image](image6)                    | ![Image](image7) | ![Image](image8)               |
|           | B       | ![Image](image9)     | ![Image](image10)                   | ![Image](image11) | ![Image](image12)              |
|           | C       | ![Image](image13)    | ![Image](image14)                   | ![Image](image15) | ![Image](image16)              |
|           | D       | ![Image](image17)    | ![Image](image18)                   | ![Image](image19) | ![Image](image20)              |
|           | E       | ![Image](image21)    | ![Image](image22)                   | ![Image](image23) | ![Image](image24)              |
|           | F       | ![Image](image25)    | ![Image](image26)                   | ![Image](image27) | ![Image](image28)              |
| Third Group | G       | ![Image](image29)    | ![Image](image30)                   | ![Image](image31) | ![Image](image32)              |
|           | H       | ![Image](image33)    | ![Image](image34)                   | ![Image](image35) | ![Image](image36)              |
Table 3. The gray value distributions of T1 MEMP and DWI axial images

| Patient | CSF Low | CSF High | GM Low | GM High | WM Low | WM High | CSF Low | CSF High | GM Low | GM High | WM Low | WM High |
|---------|---------|----------|--------|---------|--------|---------|---------|----------|--------|---------|--------|---------|
| A       | 20      | 45       | 46     | 65      | 66     | 90      | 35      | 97       | 184    | 255     | 98     | 183     |
| B       | 20      | 54       | 55     | 75      | 76     | 98      | 32      | 88       | 187    | 255     | 89     | 186     |
| C       | 20      | 48       | 49     | 68      | 69     | 93      | 39      | 107      | 185    | 255     | 108    | 184     |
| D       | 20      | 41       | 42     | 59      | 60     | 94      | 37      | 83       | 189    | 255     | 84     | 188     |
| E       | 20      | 46       | 47     | 62      | 63     | 85      | 33      | 99       | 203    | 255     | 100    | 202     |
| F       | 20      | 42       | 43     | 64      | 65     | 95      | 32      | 83       | 128    | 255     | 84     | 127     |
| G       | 18      | 42       | 43     | 62      | 63     | 85      | 32      | 97       | 190    | 255     | 98     | 189     |
| H       | 17      | 38       | 39     | 59      | 60     | 83      | 26      | 87       | 148    | 255     | 88     | 147     |
| I       | 22      | 57       | 58     | 89      | 90     | 128     | 32      | 91       | 183    | 255     | 92     | 182     |
| J       | 16      | 41       | 42     | 62      | 63     | 90      | 25      | 90       | 193    | 255     | 91     | 192     |
| K       | 15      | 47       | 48     | 67      | 68     | 93      | 24      | 80       | 168    | 255     | 81     | 167     |
| Average | 18.9    | 45.5     | 46.5   | 66.5    | 67.5   | 94      | 31.5    | 91.1     | 178    | 255     | 92.1   | 177     |

The gray value distribution averages of the T1 MEMP images range from 18.9 to 45.5 for CSF, from 46.5 to 66.5 for GM tissue, and from 67.5 to 94 for WM tissue. As for the gray value distribution average of the DWI images, they range from 31.5 to 91.1 for CSF, from 178 to 255 for GM tissue, and from 92.1 to 177 for WM tissue. These results show that the WM tissue has the highest signal intensity on the T1 MEMP images, while the GM tissue has the highest signal intensity on DWI images with the high b-value.

These results also correspond with the theories; the white substance appeared brighter than the gray substance on T1 images [3,6] and the gray substance appeared clearly on DWI images because of higher water content (it contains more proton) [6]. Tha et al. also showed in their study that the deep gray matter and pathological information (signal intensity abnormalities of the bilateral cerebral cortex) were more visible on the high b-value DWI images [11].
4. Conclusion

The T1 MEMP images had short TR values (from 400 to 500 ms), short TE value (13 ms), and gray value distribution averages that range from 18.9 to 45.5 for CSF, from 46.5 to 66.5 for GM tissue, and from 67.5 to 94 for WM tissue. The T1 MEMP images showed the WM tissue clearly. As for the DWI images had high $b$-value (1,000 s/mm$^2$), long TR value (7,000 ms), long TE values (from 80 to 90 ms), and gray value distribution averages that range from 31.5 to 91.1 for CSF, from 178 to 255 for GM tissue, and from 92.1 to 177 for WM tissue. The DWI images showed the GM tissue clearly.

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