Improve Image Quality of Transversal Relaxation Time PROPELLER and FLAIR on Magnetic Resonance Imaging

N Rauf, D Y Alam, M Jamaluddin and B A Samad
Department of Physics, FMIPA, University of Hasanuddin, Makassar, Indonesia

E-mail: n-rauf@fmipa.unhas.ac.id

Abstract. The Magnetic Resonance Imaging (MRI) is a medical imaging technique that uses the interaction between the magnetic field and the nuclear spins. MRI can be used to show disparity of pathology by transversal relaxation time (T2) weighted images. Some techniques for producing T2-weighted images are Periodically Rotated Overlapping Parallel Lines with Enhanced Reconstruction (PROPELLER) and Fluid Attenuated Inversion Recovery (FLAIR). A comparison of T2 PROPELLER and T2 FLAIR parameters in MRI image has been conducted. And improve Image Quality the image by using RadiAnt DICOM Viewer and ENVI software with method of image segmentation and Region of Interest (ROI). Brain images were randomly selected. The result of research showed that Time Repetition (TR) and Time Echo (TE) values in all types of images were not influenced by age. T2 FLAIR images had longer TR value (9000 ms), meanwhile T2 PROPELLER images had longer TE value (100.75 – 102.1 ms). Furthermore, areas with low and medium signal intensity appeared clearer by using T2 PROPELLER images (average coefficients of variation for low and medium signal intensity were 0.0431 and 0.0705, respectively). As for areas with high signal intensity appeared clearer by using T2 FLAIR images (average coefficient of variation was 0.0637).

1. Introduction
The Magnetic Resonance Imaging (MRI) is one of the most accurate diagnostic tools in the medical world [1]. The ability of MRI to be able to provide anatomical imaging of soft tissue with high resolution makes it a very important tool for imaging at the molecular and cell level [2]. The basic principle of MRI is based on nuclear magnetic resonance (NMR) along with the proton spin-spin relaxation process [1]. Relaxation process is divided into two parts, namely relaxation T1 and T2. Some techniques for generating T2 weighted images are Periodically Rotated Overlapping Parallel Lines with Enhanced Reconstruction (PROPELLER) and Fluid Attenuated Inversion Recovery (FLAIR).

Studies on PROPELLER and FLAIR have been widely practiced. Forbes et al. examined the measurements of the patient's head movements and their effect on image quality. The examination was done in the form of axial T2-W PROPELLER (P-CR corrected and uncorrected P-UNC) and conventional MRI (CONV) in five normal volunteers and thirty-five randomized patients. The results obtained are the PROPELLER MR sequence (P-CR and P-UNC) offering better image quality than the CONV sequences for all the cases studied [3]. Rathi and Palani also examined the weighting images of T1, T2, and FLAIR of twenty patients with glioma through distribution values using...
MATLAB software. Both of these studies concluded that the image with the FLAIR technique provides more information for pathological disorders than with T1 weighted images as well as ordinary T2 weighted images [4].

Based on the above studies, we conducted a study by comparing the parameters of transverse relaxation time of PROPELLER and the relaxation time of FLAIR in MRI image. This study focuses on brain images with variables Time Repetition (TR) and Time Echo (TE). Image comparison is clarified by using the ENVI software via image segmentation method by Roy and Bandyopadhyay [5] and Region of Interest (ROI).

1.1. Periodically Rotated Overlapping Parallel Lines with Enhanced Reconstruction (PROPELLER)
One significant problem in brain Magnetic Resonance Imaging is head movement. There is no data to measure movement, complexity, or influence on image quality. PROPELLER (Periodically Rotated Overlapping Parallel Lines with Enhanced Reconstruction) offers a new way of measuring and balancing head movements. The basic idea of PROPELLER is to try k-space in rotation using radial trellised strips.

![Patient movement artifacts (left) and motion artifacts substantially reduced with PROPELLER (right).](image)

1.2 Fluid Attenuated Inversion Recovery (FLAIR)
Although the imaging time is very long (usually 15 ± 20 min), the T2-FLAIR technique is proven to repeatedly show a variety of lesions, including cortical, periventricular, and meninges disease that are difficult to see in conventional imagery. In addition, the intensity of edema in the FLAIR image differs significantly from the intensity of Cerebra Spinal Fluid (CSF), unlike in T2 weighted images. CSF produces weaker signals than gray matter, tumors, or edema [6]. FLAIR is also substantially more sensitive to demyelinating diseases, such as multiple sclerosis.

1.3 Region Of Interest (ROI)
ROI can be drawn on top of MRI imagery by using any combination of polygons, dots, or vectors. In the ENVI software, the user can specify multiple ROI and describe it to either the Image, Scroll, or Zoom window. Additionally, users can develop an ROI to an adjacent pixel that is at a certain pixel value limit. When determining ROI, users assign pixels from imagery to enter or exit ROI [7].

2. Methodology
This research was conducted in Radiology Installation room, General Hospital in Makassar from October to December 2016. The tools used are laptop with Windows 7 operating system, RadiAnt DICOM Viewer software version 3.0.2.12209 (32-bit), and ENVI software version 4.5. The materials used are axial images of transversal relaxation Periodically Rotated Overlapping Parallel Lines with Enhanced Reconstruction (T2 PROPELLER) and axial images of transversal relaxation time Fluid Attenuated Inversion Recovery (T2 FLAIR). The first step in this research is randomly collecting
The patient data in the form of brain image with various parameter types in the form of DICOM extension (.dcm). The data are then grouped by age category. Once grouped, the selected image from the patient data is the axial image of T2 PROPELLER and the axial image of T2 FLAIR in the form of .jpg extension using RadiAnt DICOM Viewer software version 3.0.2.12209 (32-bit). Then, the Time Repetition and Time Echo values of the images are analyzed.

The next step is image processing with ENVI version 4.5. Image processing steps include axial imagery T2 PROPELLER and axial imagery T2 FLAIR, image conversion into gray-scale, high pass filter usage on gray-scale image, gray-scale image fusing and filtered image through histogram matching, and use of median filter in composite image. Then, the image is colored by using Region of Interest (ROI).

3. Result and discussion

The axial image of T2 PROPELLER and the axial image of T2 FLAIR are grouped. Then Time Repetition (TR) and Time Echo (TE) selected from the image, see table 1.

| Patient | T2 PROPELLER | T2 FLAIR |
|---------|--------------|----------|
| (year old) | TR (ms) | TE (ms) | TR (ms) | TE (ms) |
| A (10) | 4100.12 | 100.75 | 9000 | 91.26 |
| B (20) | 4592.62 | 102.10 | 9000 | 90.72 |
| C (21) | 4115.78 | 101.14 | 9000 | 91.70 |
| D (34) | 4147.40 | 101.90 | 9000 | 91.34 |
| E (34) | 4115.30 | 102.10 | 9000 | 91.08 |
| F (36) | 4588.33 | 102.00 | 9000 | 92.04 |
| G (52) | 4155.22 | 102.10 | 9000 | 91.96 |
| H (56) | 4155.22 | 102.10 | 9000 | 90.55 |
| I (63) | 4151.20 | 102.00 | 9000 | 91.70 |
| J (65) | 4811.40 | 102.10 | 9000 | 91.78 |
| K (71) | 4588.16 | 102.00 | 9000 | 92.92 |

The TR value of the axial image of T2 FLAIR is the same for all age groups. However, the value of each patient's TE varies 90.55 – 92.92 msec. This shows that there is no age effect on the TR and TE values of patients, but is influenced by the sequence type and the use of radio frequency inversion pulses 180° or reversal of gradient polarity at TE/2 [8].

The TR value of T2 PROPELLER and T2 FLAIR of each patient is long (greater than 1500 ms) [9]. The long TR makes the difference of T1 do not affect to the signal. The axial image of T2 FLAIR has a TR value longer than the axial image of T2 PROPELLER, thus allowing radio frequency excitation energy to be extended for longer by protons via spin relaxation. Thus, the axial image of T2 FLAIR has the smallest T1 weighting and the signal intensity difference between the tissues is not significant.

Furthermore, the TE values in the axial images of T2 PROPELLER and T2 FLAIR of each patient are also relatively long (more than 80 milliseconds) [9]. The long TE is required to produce a good T2 weighting image. The axial image of T2 PROPELLER has a TE longer than the axial image of T2 FLAIR, thus allowing the proton to dephasing or to have longer T2 relaxation and generate more signals from the tissue having a long T2 value. Thus, the axial image of T2 PROPELLER has the largest T2 weighting. However, the longer TE values will cause the total signal intensity to decrease and the image look rough.

3.1 Image Segmentation and Region of Interest (ROI)

The axial image of T2 PROPELLER and the axial image T2 FLAIR patient is processed by using segmentation method, which includes image conversion into gray-scale, high pass filter usage, image
integration through histogram matching, and median filter usage. Then, the image is colored by using ROI.

**Table 2.** Comparison of PROPELLER and FLAIR images of patient A.

| Image Processing      | T2 PROPELLER | T2 FLAIR |
|-----------------------|--------------|----------|
| **Original Image**    | ![Image](image1.png) | ![Image](image2.png) |
| **Grayscale Image**   | ![Image](image3.png) | ![Image](image4.png) |
| **High Pass Filter**  | ![Image](image5.png) | ![Image](image6.png) |
| **Histogram Matching**| ![Image](image7.png) | ![Image](image8.png) |
The red color indicates an area with a threshold range of 133 – 152
The green color indicates an area with a threshold range of 153 - 203
The blue color indicates an area with a threshold range of 204 - 255

Table 2 shows the brain image of one patient, namely patient A. The original image has dimensions of 512 x 512 pixels with three bands (Red, Green, and Blue). When the image is converted into gray scale, the bands are used only one (blue). Then, the gray scale image is filtered with a high pass filter to sharpen the image. The Kernel size selected on the filter is 3x3, and the image does not have significant blurring. Once filtered, the image is combined with gray scale image through a matching histogram. To reduce noise, the image is filtered again using the median filter. The Kernel size is 3x3. Then the image is colored using ROI. The selected colors are red, green, and blue.

In the axial image of T2 PROPELLER, the red color is the part (white matter and fat) that has a short T2 value, green color is gray matter, and blue color has a long T2 value or a lot of water content (CSF and high edema tissue) [8].

Whereas on the axial image of T2 FLAIR, the red color is CSF and the tissues, which have value T1 and T2 relative the same [10]. Weighting FLAIR with long T1 (in this case 2200 ms for all patients) reduced the intensity level of relative signals of CSF and the tissues, resulting in better assessment of the anatomy around. The blue color is a tissue that has a short T2 value [8]. Each patient image has its own threshold value range for staining. The value range data is shown in tables 3 and 4.

| Patient | Red Min | Max | Mean | Stdev | Green Min | Max | Mean | Stdev | Blue Min | Max | Mean | Stdev |
|---------|---------|-----|------|-------|-----------|-----|------|-------|---------|-----|------|-------|
| A (10)  | 133     | 152 | 141.2| 5.8   | 153       | 203 | 166.3| 119   | 204     | 255 | 241.2| 16.7  |
| B (20)  | 130     | 160 | 146.6| 7.4   | 161       | 208 | 173.7| 11.3  | 209     | 255 | 243.0| 15.1  |
| C (21)  | 130     | 153 | 141.9| 5.6   | 154       | 206 | 165.8| 11.6  | 207     | 255 | 243.3| 15.4  |
| D (34)  | 141     | 164 | 150.3| 6.3   | 165       | 210 | 178.2| 11.8  | 211     | 255 | 243.4| 14.4  |
The coefficient of variation is used to compare the data in table 3 and 4. The coefficient of variation (CV) is calculated from mean ($\mu$) and standard deviation ($\sigma$) of data. The average variation coefficient (CV) for T2 PROPELLER and T2 FLAIR is shown in table 5.

| Color | T2 PROPELLER | T2 FLAIR |
|-------|--------------|----------|
|       | $\bar{\mu}$ | $\bar{\sigma}$ | $\bar{CV}$ | $\bar{\mu}$ | $\bar{\sigma}$ | $\bar{CV}$ |
| Red   | 146.2        | 6.3       | 0.0431    | 144.4       | 7.0        | 0.0485 |
| Green | 173.0        | 12.2      | 0.0705    | 174.8       | 13.0       | 0.0744 |
| Blue  | 242.5        | 15.5      | 0.0639    | 241.7       | 15.4       | 0.0637 |

In table 5, the axial image of T2 PROPELLER has the smaller average variation coefficient value for red and green, while the axial image T2 FLAIR has the smaller average variation coefficient value for blue. If a data set has a small coefficient of variation, the data points are collected around the mean or in other words the data is uniform [11].

It means the axial image of T2 PROPELLER shows areas with low and medium intensity signals (red and green) better than axial image of T2 FLAIR, since axial image T2 PROPELLER has the larger T2 weighted value that makes a tissue with a short T1 appear dark due to the decay of signals. In addition, the axial image of T2 PROPELLER can overcome significant problems in brain magnetic resonance imaging, in this case the head motion artifact, through a series of concentric blades that
4. Conclusion

The conclusion of this study is no age influence on the selection of Time Repetition (TR) and Time Echo (TE) values for all types of images. In T2 FLAIR image, the TR value is longer than T2 PROPELLER image, so the T1 weighting value is the smallest and the signal intensity difference between the tissues is not significant. The T2 PROPELLER image has a TE value longer than the T2 FLAIR image, so the weighted value of T2 is greatest and generates more signals from the tissue with long T2. The T2 PROPELLER image is better used in areas with low and medium signal intensity, whereas areas with high signal intensity preferably use T2 FLAIR image.

References

[1] Brown M A, Semelka R C 2003 MRI: Basic Principles and Applications Third Edition (Hoboken, New Jersey: John Wiley and Sons, Inc.)

[2] Na H B, Song I C, Hyeon T 2009 Inorganic Nanoparticles for MRI Contrast Agents Adv. Mater. 21 2133–48

[3] Forbes K P, Pipe J G, Bird R and Heiserman J E 2001 PROPELLER MRI: Clinical Testing of a Novel Technique for Quantification and Compensation of Head Motion. Proc. Intl. Soc. Mag. Reson. Med 9

[4] Rathi V P, Palani S 2012 Brain Tumor MRI Image Classification with Feature Selection and Extraction using Linear Discriminant Analysis International Journal of Information Sciences and Techniques (IJIST) 2 4 131–146

[5] Roy S, Bandyopadhyay S K 2012 Detection and Quantification of Brain Tumor from MRI of Brain and its Symmetric Analysis Journal of Information and Communication Technology (JICT) 2 6 477–483

[6] Dvořák P, Bartušek K, Kropatsch W G and Směkal Z 2015 Automated Multi-Contrast Brain Pathological Area Extraction from 2D MR Images Journal of Applied Research and Technology (JART) 13 58–69

[7] Anonim. Region of Interest (ROI) Tool. http://www.harrisgeospatial.com/docs/RegionOfInterestTool.html. Access on 25 September 2016.

[8] Bushberg J T, Seibert J A, Leidholdt E M and Boone J M 2012 The Essential Physics of Medical Imaging: Third Edition (Philadelphia: Lippincott Williams & Wilkins)

[9] Schild HH 1990 MRI: Made Easy (Berlin: Schering AG)

[10] Damanik A M, Azam M and Nur M 2005 Pengaruh Parameter Teknis TR, TE, dan TI dalam Pembobotan T1, T2, dan FLAIR Pencitraan Magnetic Resonance Imaging (MRI) Berkala Fisika. 8 1 15–20

[11] Al-Saleh M F, Yousif A E 2009 Properties of the Standard Deviation that are Rarely Mentioned in Classrooms Austrian Journal of Statistics. 38 3 193–202