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OPTIMIZATION OF FAT SUPPRESSION TECHNIQUES USING DIXON AND APPLICATION IN MRI EXAMINATION

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ABSTRACT

Magnetic resonance imaging has been used to detect and assess the presence and extent of fat accumulation. Dixon technique has been used clinically to achieve fat suppression through different presession frequencies of fat and water protons. Dixon, allows the contribution of fat signals to be suppressed in post-processing rather than during acquisition, as well as providing a map of the distribution of water and fat. The aims of this study is to analyze the role of Dixon techniques on fat suppression or fat quantification. Evaluated its advantages in performing fat suppression, reducing artifacts, and describing Dixon's application on MRI examination. Literature review was conducted to analyze the effectiveness, role, and advantages of Dixon techniques in MRI examinations. Articles are selected based on inclusion criteria. Each article is qualitatively analyzed and explained descriptively. The results show that Dixon technique can be combined with several sequences, including gradient echo or fast spin echo. Scanning with Dixon sequences, namely 2-point Dixon, 3-point Dixon, 6-point Dixon and multi-point Dixon. Dixon technique used provides better fat suppression even in areas where other techniques fail for technical reasons. The uniformity of Dixon's technique in suppressing fat signals is significantly higher. Dixon technique plays an excellent role in MRI imaging of the head and neck, musculoskeletal, abdominal and breast. In conclusion, Dixon technique has been proven to be able perform fat suppression more effectively on MRI examination. In its application, Dixon can shorten the scanning time, thereby reducing the risk factor for sedation, especially for children.

Keywords: MRI examination; magnetic resonance imaging; fat saturation; fat suppression; Dixon

Introduction

Magnetic Resonance Imaging (MRI) is one of the most important and widely used imaging methods in modern examinations, to avoid ionizing radiation. MRI enables image acquisition in a variety of areas, and is volumetric for multiplanar and Three-Dimensional (3D) analysis. In MRI scans, most of the signals come from the nuclei of hydrogen atoms in water and lipid molecules because those molecules are abundant in the human body. A radiofrequency pulse is applied at the same Larmor frequency as the hydrogen nucleus, so that nuclear resonance can occur.[1]

MRI provides appropriate contrast sources and imaging techniques to enable non-invasive and accurate differentiation between adipose

tissue and lean tissue. MRI provides excellent contrast between soft tissues by harnessing the atomic properties of hydrogen and its molecules, most of which are water but to some extent lipids. It is known that fat stored in adipose tissue is an important part of the human body and can be used as a biomarker in many branches of medicine. However, fat can also hinder proper diagnostics or quantitative imagery by its interference with signals from the water.

Suppression of fat signals is a very useful diagnostic technique, possible due to the difference between water and fat in terms of resonant frequency and T1.[2] Fat tissue shows high signals in most MRI sequences because T1 is short, while water signals vary depending on the weighting. Precision frequencies and T1 can be used to generate sequences where fat signals can be suppressed assuming that the contribution of water signals remains constant.[1,3]

Fat signals on MRI can be suppressed using different techniques. Examples of fat suppression techniques include frequency-selective pulse sequences, inversion recovery and hybrid chemical shift techniques such as the Dixon technique.[1] Several fat suppression techniques have been developed and used widely: Chemical Shift-Selective Saturation (CHESS), Short-Tau Inversion Recovery (STIR) and Spectral Attenuated Inversion Recovery (SPAIR). CHESS and STIR have their advantages and disadvantages. Although CHESS has advantages of selectivity for fat and a high Signal to Noise Ratio (SNR), it is susceptible to magnetic field inhomogeneities. STIR is not sensitive to the inhomogeneity of the magnetic field. But it is not specific to fats. SPAIR is a hybrid technique that combines CHESS fat selectivity and STIR frequency inversion pulses. Thus, it has the advantages of high fat selectivity and low vulnerability to magnetic field inhomogeneity. Sequence Dixon is known as a class of chemical-shift-based water-fat separation methods.[2,4]

The Dixon technique has been used clinically for some time to achieve fat suppression through the exploitation of different presession frequencies of fat and water protons. This chemical shift-based method has the added advantage of providing fat only and water only images, as well as sequences of in-phase and out-of-phase images from a single acquisition. Variation in this method has recently led to the development of methods that can be routinely used in musculoskeletal Fast Spin Echo (FSE) applications.[3] The Dixon technique has the advantage of providing a high Signal-To-Noise Ratio (SNR) in a reasonable time, as well as homogeneous fat suppression. In addition, they can be combined with all types of sequences and provide, in a single acquisition, fat suppression and non-fat suppression images.[5]

The Dixon technique, unlike other fat suppression features, allows the contribution of fat signals to be suppressed in post-processing rather than during acquisition, as well as providing water and fat distribution maps. Several recent studies have demonstrated the application of the Dixon technique for quantitative assessment of Fat Fraction (FF), analysis of joint cartilage, bone marrow studies, and reduction of magnetic susceptibility artifacts in the presence of metal implants.[1] This sequence is available in most MRI equipment manufacturers with different acronyms: iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL; GE Healthcare, Waukesha, MI, USA); Dixon (Siemens Healthcare, Erlangen, Germany); DIXON (Philips Medical Systems, Best, the Netherlands); and FatSep.

Fat suppression and water fat separation techniques are widely used on MRI to improve image contrast, to avoid artifacts due to spectral differences between water and fat signals, Water and fat suppression/separation is very useful in the diagnosis of Fatty Liver Disease (FLD), and is also used in contrast enhanced imaging, in

cardiology, and clinical examination or other branches of medical science. For example, the amount of fat in tissues can be used as a biomarker in Non-Alcoholic Fatty Liver Disease (NAFLD) or cardiac steatosis, various muscle diseases such as muscular dystrophy and myopathy, and studies in metabolism, physical activity and obesity.[2,6]

There has been a lot of research regarding the use of the Dixon technique on MRI examination. Many studies have used Dixon in assessing and detecting metastases in bones/nodules in patients with prostate cancer.[7] Other studies have also shown the role of Dixon techniques in whole body MRI examinations, resulting in images with increased fat suppression, quantification of fat and iron. The Dixon technique also plays a role in musculoskeletal MRI examination, displaying tumors/lesions and being able to determine the degree of malignancy. This technique is also widely used in abdominal examination, especially the quantification of fat in liver, adrenal and pancreas.[6] Previous research has focused on the accuracy and application of the Dixon technique in displaying MRI images to improve diagnostic performance. The Dixon technique has been widely used in a wide variety of MRI examinations. Therefore, this study aims to analyze the effectiveness and role of Dixon techniques on fat suppression or fat quantification. It is necessary to review its advantages of suppressing fat, reducing artifacts as well as describing the application of the Dixon technique on MRI examination.

Methods

Systematic review is a type of secondary study that uses primary studies as a data source. This type of research is used to summarize evidence related to research questions, and it is very useful to integrate information from different studies on the same topic. The systematic review should follow a comprehensive and reproducible process, and is a good starting point to assist future research efforts.

Literature searches are systematically conducted on PubMed, ScienceDirect, google scholar, and ProQuest. Selecting journals based on their publication year, namely 2016-2021. The keywords used in the literature search include: fat suppression, Dixon, fat saturation, and fat quantification. The inclusion criteria are as follows: (a) abstract titles and keywords are evaluated, looking for studies that clearly address fat suppression, Dixon, fat saturation, and fat quantification. on musculoskeletal or abdominal MRI examination. (b) The results section and discussion section are fully listed to ensure that the fat suppression or quantification of the Dixon technique can be extracted from the text. Third, only articles written in English are used in this literature. The exclusion criteria are as follows: (a) articles written not in English, (b) articles are abstract only.

Results and Discussion

This section presents the results of article selection, techniques identified, the role of techniques and a discussion of the results.

Ten reviewed articles were published between 2016-2021. Regarding the evaluated MRI examination, 7 articles evaluating the Dixon sequence on musculoskeletal examination, 2 articles evaluating the Dixon sequence on abdominal examination, especially hepar, 1 article evaluating the Dixon sequence on the breast MRI examination. The article generally compares, evaluates, and assesses the quantification of fats in each organ examined. All 10 papers, 6 studies[4,8–12], conducted evaluations using a retrospective research design. The research conducted by Willemijn et.al[13] and Amber et.al[14] used prospective research designs in achieving research objectives. Nico et.al[15] study used a retrospective cross-sectional observational design. All papers have research objectives that focus on evaluating the use of Dixon techniques in efforts to suppress fat, uniformity of emphasis

produced, reduction of artifacts, image quality and assessment of the intensity of fat signals. All these mentioned studies were included because they evaluated the performance of the Dixon sequence in the determination of fat signals on MRI examination by means of experiments, described clearly and meaningfully.

All 10 papers, it uses analysis objectively and subjectively. Objective analysis is carried out by experienced radiologists. Subjective analysis conducts an assessment with a Likert scale, 3 points, 4 points and 5 scoring points. Some of the methods used in the study are as follows: analysis by a radiologist with 10 years of experience in head and neck MRI imaging. The radiologist will perform circular ROI on the axial plane in 2 regions (submandibular and subclavian). Radiologists were asked to evaluate the uniformity of fat suppression, the overall quality of the imagery, and assess the susceptibility of artifacts.[8] The ROI method for measuring the intensity of fat signals was also used by Shimizu et.al[9] which was applied to Dixon's in phase/out of phase sequence images. Analysis by radiologists is also carried out by other studies, with differences in their experience in radiology. The research by Ricardo et.al[10] was analyzed by radiologists with 6 years of experience. Yutaka et.al[16] was analyzed by 2 radiologists with 11 years and 30 years of experience. Radiologists were asked to assess artifacts due to breathing and artifacts due to incorrect separation of water and fat signals. Research Sangmin et.al4 with radiologists 20 years of experience, to assess the quality of fat suppression. Anastasia et.al[12] was analyzed by 2 radiologists of 5 years and 15 years of experience, for the evaluation of the quality of fat suppression specifically, the homogeneity of fat suppression, the definition of anatomical structures, and the pattern of improvement of lesions. Willemijn et.al[13] was also analyzed by 2 radiologists with 33 years and 15 years of experience. Amber et.al[14] was also analyzed by 2 radiologists with 14 years and 7 years of experience. Nico et.al[15] was analyzed by 3 radiologists, consultant neuroradiologists 9 years of experience, 7 years of radiology colleagues and third year residents in neuroradiology. Overall, these 10 studies obtained data from MRI examinations of patients who came to radiology. Scanning with Dixon sequences, namely 2-point Dixon, 3-point Dixon, 6-point Dixon and multi-point Dixon.

After reviewing 10 articles, Dixon's engineering abilities were found on musculoskeletal, abdominal and breast MRI examinations. This study aims to determine the effectiveness and role of Dixon on fat suppression or fat quantification as well as its ability to reduce artifacts. The results of the review found that MRI examinations generally use MRI scanners with a magnetic field strength of 1.5T – 3T, with Siemens, Philips, or GE vendors. The scanning protocol used adapts to the institution where the research is carried out. The Dixon technique can be combined with several sequences, including gradient echo or fast spin echo.

The results of the review found that the measurement of spinal cord signal intensity showed high image quality using the Dixon technique, compared to STIR and SPIR. The Dixon technique used provides better fat suppression even in areas where other techniques fail for technical reasons. The uniformity of Dixon's technique in suppressing fat signals is significantly higher. This Dixon technique requires a shorter acquisition time. This technique is relatively insensitive to the inhomogeneity of the B0 magnetic field, but sometimes the inhomogeneity is a phase error. The inhomogeneity of the B0 field and other system imperfections contribute to phase errors that result in signal contributions to water only and fat only images of pixels containing only fatty tissue.

Based on a review of the use of the Dixon technique on MRI imaging on hepar focused on

assessing the fat fraction of liver displayed using the Dixon 6-point sequence. This sequence can be used to assess rapid and reliable hepatic steatosis. Dixon's 6-point technique does not require a physicist to calculate the fat fraction. This Dixon 6-point sequence estimates the fat fraction in the range of 0-100%, is more comprehensive and displays value of tissue fat fraction. From the analysis of the article, it was found that the Dixon 6-point sequence allows estimating the iron content in liver with a value of T2*. Imaging of fat fractions with the Dixon 6-point method has shown excellent potency. Dixon's multi-echo sequences also have higher sensitivity and specificity for steatosis detection. Two-point Dixon allows for an effective screening tool for the detection of liver siderosis. Two-point dixon technique, or multi-echo Dixon is a more specific and quantitative technique with good diagnostic performance in evaluating fat fractions and liver iron.[9,11]

The results of the review also showed Dixon's technique in MRI lumbar vertebral analysis, especially evaluating fat fractions, determining the malnutrition of lesions in the lumbar. FF measurement with Dixon is superior and easy use. The Dixon technique provides valid results determining quantitative FF limits that allow discrimination between malignant and benign lesions. The Dixon technique shows that SNR and CNR are superior to STIR. Fat suppression with the Dixon technique successfully separates the lesion signals, water, and fat. This gives the SNR a high lesion and a lower SNR than the corpus of the normal lumbar vertebrae. This result is obtained with a shorter acquisition time. In the study it was found that the acquisition of Dixon for 2 minutes 20 seconds resulted in a 45% reduction in acquisition time compared to the SPAIR technique. Therefore, the Dixon technique is a fat suppression technique that is more suitable for lumbar vertebrae where there is a high susceptibility difference and it is difficult to obtain good magnetic field homogeneity.

From the analysis of the article the application of the Dixon sequence to the musculoskeletal proved to be significantly more homogeneous than the SPAIR technique. The application of Dixon to assess the spine, neck, elbow, shoulder, or mediastinum showed excellent performance. The Dixon technique has a reduced sensitivity to artifacts due to metal and is insensitive to the inhomogeneity of the B1 field. With the Dixon 2-point, 3-point, or 4-point technique can achieve a decrease in sensitivity to the inhomogeneity of the B0 field.

The use of sedation is often performed for pediatric MRI examinations, so that it can increase the risk for the patient. The Dixon technique is used to solve this problem, in children and adolescents. The application of Dixon provides strong fat suppression results in each case without the need for repetition. This advantage is inseparable from the placement of shimming volume.

Signal characteristics (isointense, hypointense or hyperintense signals) were assessed equally on fat only images of the Dixon T2 weighted sequence and in conventional T1 weighted. In detail, the collection of spinal fluid shows hyperintense signals in the fat only image of the T2 weighted Dixon sequence. The Dixon technique is used to detect spinal metastases displayed in fat only and water only images, providing diagnostic performance that may replace conventional weighted T1 imaging. The Dixon sequence has a high potential to assess spinal fluid clotting/bleeding. This evaluation of spinal fluid clotting/bleeding shows a comparable signal characteristic between fat only images and T1 weighted sequences. The Dixon sequence produces four sets of images obtained sequentially with different contrasts.

The results of the review found that using the Dixon was sensitive to the patient's movements, which was inseparable from the influence of the flexible echo used. The

magnetic field used on the scanner also tends to aggravate the artifacts that appear. Dixon combined with the Propeller technique makes it insensitive to the patient's movements. Most of the Dixon techniques observed for diagnosis appear to be errors in the unacceptable separation of water and fat. This error in the separation of fat and water signals is due to the large inhomogeneity of the magnetic field B0. In the MRI head and neck examination, there is often an error in the separation of water and fat signals, due to the low resolution in the direction of phase encoding. However, the error of unacceptable separation of water and fat signals can be overcome by making the inhomogeneity of the magnetic field B0 smaller, by simple methods, such as lowered the patient's chin. The application of the Dixon technique significantly decreases motion artifacts and improves overall image quality, demonstrating its potential in improving diagnostic performance.[16]

The study has some limitations, although the search is carefully formulated, there is still the possibility of some terms being lost Some studies may not be found by failures in the formulation of the search. For this study to be actual, it only contains papers from 2016-2022. Only academic articles were included in the study, so some nonacademic articles that provided relevant results may have been left out. First, the study selection is only one reviewer and then two more reviewers assess whether the article meets the criteria. Article selection can be done by more than one reviewer, to ensure no relevant articles are lost. Part of the classification is still subjective. Nevertheless, it is unlikely that these limitations are particularly detrimental to the findings of this study. The next limitation in the number of articles reviewed is a small number. This reflects little concern regarding Dixon's technique for fat suppression on MRI examinations that have been received in literacy. This research provides an important contribution in terms of pointing out the direction of research and reinforcing important implications for radiological design

Conclusion

This study conducted a qualitative analysis of the Dixon technique for fat suppression on MRI examination. The Dixon technique can be combined with several sequences, including sequence gradient echo and fast spin echo. Dixon techniques can be 2-point Dixon, 3-point Dixon, 6-point Dixon and multi-echo Dixon. This technique is proven to be able to suppress fat more effectively and more homogeneously on musculoskeletal, head and neck, breast, and abdominal MRI examinations. In its application, the Dixon technique can shorten the scanning time, thereby reducing the risk factor of sedation, especially for children. However, this technique is susceptible to metal artifacts and artifacts due to water and fat signal misconduct. This error often occurs due to an error in the direction of phase encoded. Despite these constraints, Dixon techniques promise to be developed in the future, one of which is for real-time fat valuation.

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