تصميم وتنفيذ نظام تبريد معدل لجهاز التصوير بالرنين المغناطيسي لتعزيز جودة الصورة

احمد بن حاتم ابوزناده

د. عبد الله محمد الدباعي

المستخلص

التصوير بالرنين المغناطيسي هو معدات تكنولوجيا عالية تعتمد على الاستقرار في درجة حرارة الجهاز لضمان جودة الصورة وخصوصا تسلسل ارتداد التدرج (Gradient Echo Sequences) إثناء الفحص . استخدام التصوير بالرنين المغناطيسي له دور هام في تشخيص العديد من الأمراض بما فيها السرطان. من الضروري تشخيص الحالات المرضية في مراحلها الأولى للحصول على علاج فعال من أي مرض . لتوضيح أكثر للمراحل الأولى لتشخيص المرض يجب أن تكون صور المرضى المستخدمة في التشخيص في أفضل نوعية من الحدة والوضوح لكي لا يترتب عليه أي تضليل إثناء وضع خطط العلاج والمتابعة للمرضى. هناك العديد من العوامل التي تعتمد على الحصول على صور عالية الجودة من أي جهاز ومن المعروف جيدا أن أصغر اختلاف في الظروف الحرارية تؤثر في جودة الصورة للرنين المغناطيسي.

أثناء دراستنا الأولية لتقييم إمدادات مياه التبريد المركزي للمستشفى، تبين أن إمدادات المياه الغير نظيفة وتجمع الرواسب بها تسبب في انسداد الإمدادات والتوقف المتكرر لجهاز التصوير بالرنين المغناطيسي. وحيث أن هذه الملاحظات تتطلب دراسة منهجية للأسباب المحتملة للتدهور في حدة الصورة والتي يمكن أن تكون مرتبطة مع تغيير طفيف في درجة حرارة أثناء تشغيل الجهاز.

درجة الحرارة الطبيعية (Magnet Shield Temperature) مابين٤٠ -٦٠ كلفن، ولكن مع ارتفاع درجات الحرارة (High Shield Temperature) يتم تلقائيا التسبب في اختلال التجانس للمجال المغناطيسي ، مما أدى إلى حدوث مشاكل (Shimming) مثل حدوث خلل أثناء الفحص كتشبع الدهون (Fat Saturation) وتسلسل ارتداد التدرج (Gradient Echo Sequences) أثناء التصوير بالرنين المغناطيسي. وفي هذا العمل سوف نقوم بتصميم وتشغيل نظام تبريد المياه باستخدام تكنولوجيا نظام المبادل حراري (Heat Exchanger System Technology) لتحسين جودة الصورة من خلال القضاء على مشاكل جودة الصورة مثل (Fat Saturation and Gradient Echo Sequences) من خلال تحسين مياه التبريد بالكفاءة المطلوبة لتجنب ارتفاع درجات الحرارة درع المغناطيس (Shield Temperature) من شأنها أن تؤثر على (gnet ColdMa Head) لجهاز الرنين المغناطيسي MRI وتسبب مشاكل في جودة الصورة.

Design and Implementation of a Modified Cooling System for MRI Scanner to enhance Image Quality

By

Ahmed Hatem Abuzinadah

Dr. Abdullah M. Dobaie

ABSTRACT

Magnetic Resonance Imaging (MRI) has progressed over 30 years from being a technique with great potential to one that has become the primary diagnostic investigation for many clinical problems. Recent advances in MRI technology are presented with emphasis on how this new technology impacts clinical operations (better image quality, faster exam times, and improved throughput).The image quality based on image contrast is affected by the amplitude and timing of the RF pulses used to excite the spin system. More advanced methods may use gradient pulses to modulate motion and alter tissue properties with exogenous contrast agents.

Image Quality Parameters are mainly divided into two categories; such as intrinsic and extrinsic parameters. The intrinsic parameters which are related to the tissue are depending on water density, longitudinal relaxation time (T1) and transverse relaxation time (T2) for magnetization transfer rate coefficients, chemical shift in water molecules corresponding to fat tissue, macroscopic and microscopic tissue motion and tissue susceptibility. The selectable parameters which are known as extrinsic parameters are considered as operational conditions which have direct impact on MRI scans. They depend on magnetic field-strength, shield temperature of the magnet, radio-frequency (RF) pulse timing, RF pulse amplitude, gradient amplitude and timing, RF pulse excitation frequency, its bandwidth and the receiver

bandwidth.[1] The capability of image temperature is a very attractive feature of MRI and has been actively exploited for guiding minimally invasive thermal therapies. Among many MR-based temperature-sensitive approaches, proton resonance frequency (PRF) thermometry provides the advantage of excellent linearity of signal with temperature over a large temperature range. Furthermore, the PRF shift has been shown to be fairly independent of tissue type and thermal history. For these reasons, PRF method has evolved into the most widely used MR-based thermometry method. In the present paper, the basic principles of PRF-based temperature mapping will be reviewed, along with associated pulse sequence designs. Technical advancements aimed at increasing the imaging speed and/or temperature accuracy of PRF-based thermometry sequences, such as image acceleration, fat suppression, gradient echo sequences, reduced field-of-view imaging, as well as motion tracking and correction.[2]

Magnetic Resonance Imaging is highly sophisticated equipment which relies on stable and tight temperature requirements in order to ensure image quality, especially gradient echo sequences. The potential use of MRI scans plays a greater role in the diagnosis of many diseases including cancer. For effective treatment of any disease it is required to diagnose the symptoms at their early stages. For clear distinction of early stages of the disease the diagnostic images should be sharper with higher qualities so that they should not mislead the treatment plans and follow up of patients. Obtaining high quality images from any modality depend on several factors. It is well known that the smallest variation of thermal conditions in the system degrade image quality.

From our preliminary studies, it is observed that in general, the central cooling water supply contain fine particles such as mud, dirt and sediments which could be the cause for blockages and frequent downtime of the MRI equipment. This observation would require systematic study of the possible cause of degradation in the sharpness of the image which could be linked with the small change in operating temperature of the scanner.

Acquiring medical devices, such as an MRI Machine, for the King Abdul Aziz University Hospital, requires a process which involves not only the hospital but also companies that will supply the medical devices to be acquired. In our case, the medical devices, with specifications indicated by the hospital, will be presented as a tender, which is the process of inviting companies and institutions to submit their formal offers. Each offer should have the supplier's requirements that include all necessary electrical, material, and safety details that would be needed during the delivery and installation of the medical equipment in the hospital. The MRI Symphony and Verio were installed using such a process, but both the hospital and the supplying company were not able to foresee the obstacles that would come from the unprocessed water supply.

In this work we proposed to design and operate a modified water cooling system for the diagnostic MRI scanner based on heat exchanger (HE) technology to achieve better quality images. We will implement the new cooling system on a 1.5T and 3T diagnostic scanner at our King Abdulaziz University Hospital (KAUH) and investigate the results of MRI scans obtained for fat saturation and gradient echo sequences. Also, we will demonstrate the effectiveness of the cooling water which is not only important for ecological considerations but also limit the high shield temperature that would affect the magnet cold head of the scanner in turn affecting the image quality.