

Single Breath-Hold Physiotherapy Technique

Effective tool for T2* magnetic resonance imaging in young patients with thalassaemia major

*Surekha T. Mevada,¹ Najma Al-Mahruqi,² Ismail El-Beshlawi,³ Mohamed El-Shinawy,^{1,4} Mathew Zachariah,¹ Abdul H. Al-Rawas,¹ Shahina Daar,⁵ Yasser Wali⁶

حبس النفس لمرة واحدة كتقنية علاج طبيعي أداة فعالة للتصوير بالرنين المغناطيسي (T2*) في المرضى الصغار جدا المصابين بالثلاسيميا الكبرى

سوريخا ميغادا، نجمة المحروقية، إسماعيل البشلاوي، محمد الشناوي، ماثيو زكريا، عبد الحكيم الرواس، شاهينا دار، ياسر والي

ABSTRACT: Magnetic resonance imaging using T2* (MRI T2*) is a highly sensitive and non-invasive technique for the detection of tissue iron load. Although the single breath-hold multi-echo T2* technique has been available at the Sultan Qaboos University Hospital (SQUH), Muscat, Oman, since 2006, it could not be performed on younger patients due to their inability to hold their breath after expiration. This study was carried out between May 2007 and May 2015 and assessed 50 SQUH thalassaemic patients aged 7–17 years old. Seven of these patients underwent baseline and one-year follow-up MRI T2* scans before receiving physiotherapy training. Subsequently, all patients were trained by a physiotherapist to hold their breath for approximately 15–20 seconds at the end of expiration before undergoing baseline and one-year follow-up MRI T2* scans. Failure rates for the pre- and post-training groups were 6.0% and 42.8%, respectively. These results indicate that the training of thalassaemic patients in breath-hold techniques is beneficial and increases rates of compliance for MRI T2* scans.

Keywords: Children; Iron Overload; Breath Holding; Physiotherapy; Thalassaemia Major; Oman.

المخلص: التصوير بالرنين المغناطيسي باستخدام T2* (MRI T2*) تقنية حساسة للغاية غيرخارقة للأنسجة للكشف عن زيادة الحديد في الأنسجة. بالرغم من أن تقنية حبس النفس المتعددة الصدى T2* متوفرة في مستشفى جامعة السلطان قابوس، مسقط، سلطنة عمان، منذ عام 2006، فإنه لا يمكن أن تستخدم للأطفال الصغار بسبب عدم قدرتهم على حبس أنفاسهم بعد الزفير. أجريت هذه الدراسة بين مايو 2007 ومايو 2015 حيث تم تقييم 50 من مرضى الثلاسيميا تتراوح أعمارهم 7-17 سنة. خضع سبعة من المرضى للتصوير بالرنين المغناطيسي الأساسي باستخدام (MRI T2*) ومتابعتهم لمدة سنة قبل التدريب على العلاج الطبيعي. بعد ذلك، تم تدريبهم من قبل أخصائي العلاج الطبيعي على حبس أنفاسهم لمدة 15-20 ثانية بعد نهاية الزفير قبل التصوير بالرنين المغناطيسي الأساسي. فشلت 6.0% و 42.8% من المرضى على حبس أنفاسهم لمدة سنة باستخدام MRI T2*. كانت نسبة الفشل لمجموعات ما قبل وما بعد التدريب 6.0% و 42.8% بالتوالي. تدل نتائج هذه الدراسة إلى أن تدريب الأطفال المرضى بالثلاسيميا على تقنيات حبس النفس مفيد ويزيد من معدلات الامتثال للتصوير بالرنين المغناطيسي (MRI T2*).

مفتاح الكلمات: الأطفال؛ الحديد الزائد؛ حبس النفس؛ العلاج الطبيعي؛ الثلاسيميا الكبرى؛ عمان.

HOMOZYGOUS BETA THALASSAEMIA IS AN inherited blood disorder characterised by deficient synthesis of the beta globin subunits of haemoglobin. Beta thalassaemia carriers comprise 1.5% of the worldwide population; an estimated 60,000 infants are born with this serious defect every year.¹ It is most commonly found in people of Mediterranean descent (Italians and Greeks), although it also affects people from other parts of the world such as Africa, the Middle East, the Indian subcontinent and Southeast Asia.² The Omani population is known to have a high prevalence of alpha thalassaemia and a substantial number of the population are carriers of either haemoglobin S or beta thalassaemia.³ The Genetic Blood Disorders

Survey in Oman revealed a prevalence of 9.5% for clinically significant haemoglobinopathy carriers. Beta thalassaemia was found to be the second most common haemoglobinopathy with a carrier rate of 2% in children under five years of age and a prevalence of 0.07% for homozygous beta thalassaemia.⁴

Patients with thalassaemia major require life-long red blood cell transfusion for survival. Senescence of transfused red cells results in iron deposition within the reticuloendothelial system with progressive deposition in the hepatic parenchyma, endocrine tissues and eventually the myocardium.⁵ Although serum ferritin is widely used to indirectly assess iron stores, several studies have shown that it does not accurately reflect hepatic or cardiac iron levels.^{6,7} Liver iron

Departments of ¹Child Health and ²Physiotherapy, Sultan Qaboos University Hospital, Muscat, Oman; ³Nottingham Children's Hospital, Nottingham University Hospital Trust, Nottingham, UK; ⁴Department of Paediatrics, Faculty of Medicine, University of Alexandria, Alexandria, Egypt; Departments of ⁵Haematology and ⁶Child Health, College of Medicine & Health Sciences, Sultan Qaboos University, Muscat, Oman

*Corresponding Author e-mail: tjmevada@yahoo.com

concentration can be determined by a liver biopsy, but this has high sampling variability. In addition, the procedure is invasive and complications requiring hospitalisation are not uncommon.^{8,9}

Magnetic resonance imaging using T2* (MRI T2*) is a highly sensitive, non-invasive and reproducible technique for the detection of tissue iron load.^{7,10,11} It is recommended that the first T2* cardiac magnetic resonance scan should be performed in thalassaemic patients as early as feasible without sedation to tailor the chelation treatment.^{12,13} In 2006, the MRI T2* liver and heart technique was introduced at the Sultan Qaboos University Hospital (SQUH), a tertiary care hospital in Muscat, Oman. Initially, only patients over 10 years of age were eligible for the procedure; however, most of the patients failed to complete the procedure due to either movement or an inability to hold their breath in expiration. This prompted hospital staff to implement a training programme designed by an SQUH physiotherapist to enable paediatric patients to successfully complete the procedure. This study therefore aimed to evaluate the effect of this training programme.

Methods

This study was carried out between May 2007 and May 2015 at SQUH. All patients between seven and 17 years old with thalassaemia major who were undergoing regular hypertransfusion at the SQUH Paediatric Thalassaemia Day Care Center were included in the study. Between May 2007 and May 2009, seven patients underwent a baseline MRI T2* scan using the single breath-hold multi-echo T2* technique. Between June 2009 and May 2015, all patients who fit the inclusion criteria, including the seven aforementioned patients, were individually reviewed by a physiotherapist during regular transfusion-related hospital visits (every 3–4 weeks). All patients subsequently underwent two or more training sessions designed to teach them to hold their breath at the end of expiration for approximately 15–20 seconds.

During the first training session, the required breath-hold procedure was demonstrated to each patient individually by the physiotherapist. The patients were shown how to take a deep breath and then exhale slowly, holding their breath at the end of expiration for approximately 15–20 seconds. The necessity of adequate breath-holding was emphasised as crucial for the procedure. The breath-hold at the end of expiration was timed with a stopwatch in order to achieve the required time for the procedure. Each patient was asked to repeat the breath-holding exercise until they could perform it correctly. The patients were

simultaneously instructed to remain still and avoid movement during breath-holding. They were also counselled to continue practicing breath-holding at home. In subsequent sessions, patients were reassessed by the physiotherapist. All patients who were able to hold their breath at the end of expiration for 15–20 seconds were scheduled for MRI T2* scans. Children who were still unable to hold their breath at the end of expiration were continuously reassessed at subsequent visits. Most of the patients were fully trained in less than three visits. During these sessions, the doctors and nurses also interacted with the patients in order to allay their anxieties regarding the procedure and to build their confidence. All of the patients received the physiotherapy training during scheduled transfusion appointments in order to minimise hospital visits and school absenteeism.

After the completion of the physiotherapy training, all patients underwent baseline cardiac MRI T2* scans using the single breath-hold multi-echo T2* protocol without general anaesthesia or sedation.^{14,15} Approximately a year later, the patients were given a follow-up MRI T2* scan. Failure was defined by an inability to complete the procedure either due to inadequate breath-holding or due to movement resulting in artefacts appearing on the scan. T2* values measured during the MRI were calculated using CMRtools (Cardiovascular Imaging Solutions Ltd., London, UK).

Continuous variables were presented as means, ranges and standard deviations. Categorical variables were presented as frequencies. A *t*-test was used to compare continuous variables in both groups. Fisher's exact test was used for 2 x 2 contingency tables. A *P* value of <0.050 was considered significant.

This study was approved by the Medical Research & Ethics Committee of the College of Medicine & Health Sciences at Sultan Qaboos University (MREC #980).

Results

Among the 50 patients who were included in the study, seven patients underwent MRI T2* scans before physiotherapy training. These patients were aged 10–16 years old (mean: 11.28 ± 2.13 years). Of these patients, three (42.9%) failed the procedure. A total of eight follow-up MRI T2* scans were performed one year later, as one patient had two follow-up MRI scans. At follow-up, three patients (37.5%) failed the procedure.

All 50 patients subsequently received physiotherapy training. These patients were aged 7–17 years old (mean: 10.45 ± 2.51 years). Of these patients, three

Table 1: Age and magnetic resonance T2* failure rates among young patients with thalassaemia major before and after physiotherapy breath-hold training (N = 50)

	Before training (n = 7)	After training (n = 50)	P value
Mean age in years ± SD (range)	11.28 ± 2.13 (10–16)	10.45 ± 2.51 (7–17)	0.372
Baseline MRI T2* failure, n (%)	3 (42.9)	3 (6.0)	0.021*
Follow-up MRI T2* failure, n (%)	3 (37.5) [†]	2 (2.9) [‡]	0.007*

SD = standard deviation; MRI = magnetic resonance imaging.

*Significant at $P < 0.050$. [†]There were eight total scans for this group as one patient had two follow-up MRI scans. [‡]There were 68 total scans for this group as 18 patients had two follow-up scans.

(6.0%) failed to complete the baseline MRI T2* scan. All three of these patients were nine years old. A total of 68 follow-up MRI T2* scans were performed one year later, as 18 patients underwent two follow-up MRI scans. Of these, two patients (2.9%) aged 13 and 15 years old failed the procedure [Table 1].

Discussion

Although breath-holding for MRI T2* scans is difficult for young children, the results of this study indicated that physiotherapy training among young patients with thalassaemia was effective in improving compliance to the MRI T2* procedure. Children as young as seven years of age were subsequently able to undergo MRI T2* scans without general anaesthesia or sedation, resulting in a reduced failure rate. In the group of patients who did not receive physiotherapy training, the results were suboptimal; it was this finding that prompted the researchers to adapt a uniform approach to train all patients aged >7 years old in a physiotherapy breath-holding technique to achieve optimal results.

The major limitations of cardiac MRIs in young children are the need to remain relatively still within the scanner and the need for breath-holding to acquire images without artefacts.¹⁶ Breath-holding problems are well documented in adults and it is likely they are more of an issue in children.¹⁷ These problems include an inability to understand and follow instructions for breath-holding, an inability to maintain the breath-hold for the whole scan (15–20 seconds) and fear of the procedure.¹⁶ Few studies have been reported on the use of MRI T2* in children and it appears that most centres either use sedation or general anaesthesia for the procedure.

Some of the alternative approaches used to obtain high-quality MRI scans include the use of a mock MRI

scanner or Cinemavision (Salvadorini Consulting LLC, Lexington, North Carolina, USA). A study by de Bie *et al.* evaluated the use of a mock scanner training protocol as an alternative for sedation and for preparing young children for MRI scans.¹⁸ In their cohort of 90 children aged 3.65–14.5 years old, 85 children passed the mock scanner training sessions.¹⁸ The mock scanner is a full-scale replica of an MRI system without magnets and requires the services of a doctor to conduct the training sessions for several days to a maximum of three weeks before the real MRI is carried out. The purpose of Cinemavision (Salvadorini Consulting LLC) is to allow patients to forget their surroundings while they watch a movie/television or listen to music/radio. Neither mock scans nor Cinemavision (Salvadorini Consulting LLC) are presently available at SQUH.

In the current study, severe cardiac iron overload (<10 ms) was observed in a 7-year-old child as a result of the physiotherapy training and subsequent successful completion of the MRI T2* scan. This had not previously been noted by serial serum ferritin monitoring or echocardiography. The patient underwent physiotherapy training prior to the initial MRI T2* scan. During this scan, he was detected to have a cardiac T2* value of 9.3 ms at a serum ferritin level of 2,605 ng/mL. Subsequently, he was put on chelation with desferrioxamine; however, he had sub-optimal compliance to the treatment. On follow-up, the patient was subsequently reassessed by the physiotherapist. Despite extensive counselling and chelator dose optimisation, a repeat MRI T2* scan performed after 18 months revealed a cardiac T2* value of 4.8 ms at a serum ferritin level of 2,796 ng/mL, indicating that the cardiac siderosis had worsened despite the fairly constant serum ferritin level. As a result, the patient was prescribed to combination chelation therapy with deferiprone and desferrioxamine. A repeat MRI after a further nine months revealed an improved cardiac T2* value of 8.1 ms at a serum ferritin level of 3,197 ng/mL. In the case of this patient, the physiotherapy training enabled the successful completion of the initial and follow-up MRI scans allowing the detection and subsequent treatment of the severe cardiac siderosis.

The use of physiotherapy training is advantageous to prepare paediatric patients with thalassaemia for MRI T2* scans using the single breath-hold, multi-echo T2* technique. Aside from the time-saving benefits, training also reduces the logistical issues of re-booking patients in busy hospital MRI departments and avoids the risks associated with general anaesthesia or sedation. Baseline and one-year follow-up MRI T2* scans, together with careful monitoring of iron overload progression, offers timely intervention for

optimal chelation and improved quality of life among young thalassaemic patients.

Conclusion

In this study, a high failure rate for MRI T2* scans was noted in a group of young thalassaemic patients who had not received physiotherapy training. However, among those who took part in a training programme that prepared patients to hold their breath for 15–20 seconds after expiration, the failure rate was significantly lower. This indicates that a training programme for paediatric thalassaemic patients is indeed beneficial and increases compliance. Breath-hold training also ensures paediatric patients avoid the complications of sedation or general anaesthesia.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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