Pulmonary regurgitation following total repair of Tetralogy of Fallot: Correlation of MR flow quantification with clinical ECG findings

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Abstract:
Tetralogy of Fallot is a collection of four congenital heart defects including ventricular septal defect and pulmonary stenosis. Current patient management usually involves early surgical intervention. However, patients are often left with a partly incompetent pulmonary valve and suffer from pulmonary regurgitation. In this work, patients underwent phase velocity cine MRI to quantify their pulmonary regurgitation. A good correlation ($r^2 = 0.69$) was found between regurgitation fraction and QRS duration which is known to lengthen when the ventricular volume increases. A strong correlation was also found between the age at scan and the regurgitation fraction ($r^2 > 0.9$).

Introduction

Tetralogy of Fallot (TOF) accounts for 5-6% of all congenital heart disease in the UK. Treatment usually involves the early surgical correction of the anatomical anomalies that make up TOF. However, this surgical correction can often leave the patient with an incompetent pulmonary valve and hence free pulmonary regurgitation, which can lead to dilatation of the right ventricle. Increased heart size is associated with a prolongation of the QRS complex, which can predispose the patient to ventricular arrhythmias and sudden death. MRI has been previously used to quantify regurgitation after TOF repair [1-3]. Other studies have found a causal relationship between right ventricular end diastolic volume and QRS duration [4-5]. This study investigates the correlation between QRS duration and regurgitation fraction measured by MRI.

Methods

This study was carried out between January 1999 and June 2001 at Guy's and St Thomas' hospitals.

Patients and volunteers:

Eight volunteers (mean age 22.3 years, range 21-24 years) were scanned in order to validate the MR protocol. Twenty-two patients (mean age 13.5 years, range 1.5-47.3 years) were initially selected from the current list of patients under the care of the Congenital Heart Disease Unit at Guy's Hospital, London. Twenty-one patients had a history of TOF repair with residual pulmonary regurgitation and one had a history of common ductus arteriosus repair, also with residual pulmonary regurgitation (patient four). **Table 1** summarises the investigations carried out on the patient group. Four patients (patients 1, 4, 6, 10) were scanned under general anaesthetics in the presence of an anaesthetist concordant with normal hospital procedures.

Patient	1	2	3-6	7	8-10	11-13	14	15	16	17-18	19-20	21	22
Ao Flow	+	-	+	-	+		+	-	+	-		+	-	-
PA Flow	+	+	+	+	+		+	+	+	+	+		+	+	+
Function	+	+	+	-	-		+	+	-	-	+		+	-	+

Table 1: Summary of MR examinations carried on the patients (Ao=Aortic, PA=Pulmonary Arteries).

ECG Measurements:

To obtain ECG data for the patient group patient records were accessed and the most recent ECG was used to measure the duration of the QRS complex. For the volunteers group, 12-lead ECG traces were obtained in order to assess the amount of variation in QRS duration within a small sample of the normal population.

MR Imaging:

MR imaging was carried out using a 1 Tesla Siemens, Impact Expert MRI scanner (St Thomas' hospital) or a 1.5T Philips Intera (Guy's Hospital). All volunteers and 10 patients (patient 1 to 10) were scanned St Thomas' hospital; the remaining patients were scanned at Guy's hospital. Flow in the aorta and the pulmonary artery were measured using phase velocity cine (PVC) MRI. The image parameters were optimized for each subject. However, echo time (TE) remains constant at 6.5 ms, as does slice thickness of 5 mm and a matrix size, which was 256x256. Retrospective gating was also used on the Philips scanner.

Flow quantification was performed using Medis flow software. Function data was obtained using a series of short axis images through the right ventricle (Gradient echo on Siemens, SSFP on Philips scanner). Image parameters and number of slices was optimized for each patient. Images were analyzed using software supplied by the manufacturers (Siemens: Argus, Philips: Easyvision cardiac package).

Results

The net pulmonary flow closely correlated with aortic flow ($r^2 > 0.9$, $p < 0.001$) and the forward pulmonary flow strongly correlated with the stroke volume ($r^2 > 0.9$, $p < 0.001$) thus indicating that MR is ideal for measuring regurgitation fraction.

Results also demonstrated a significant correlation between QRS duration and regurgitation fraction (**Fig. 1**) confirming that the increased ventricular sized due to the regurgitant valve is associated with a QRS widening. The QRS duration was similar in most of the volunteer (82.9 ± 4.9 ms, range 80-90 ms). However, one volunteer presented with an abnormal QRS duration of 140 ms due to suspected Wolf-Parkinson-White syndrome.
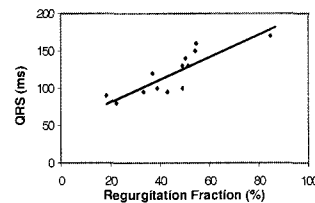
Fig. 1: Correlation between regurgitation fraction and QRS duration.
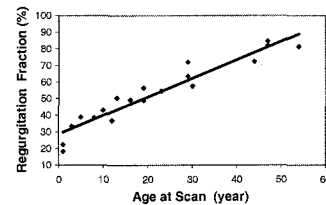
Fig. 2: Correlation between regurgitation fraction and age at scan. (three patients were excluded).

For most of the patients (19 out of 22), a strong correlation ($r^2 > 0.9$, $p < 0.001$) was also found between the age at scan and the regurgitation fraction (**Fig. 2**). This association may be due to the natural progression of the pulmonary regurgitation assuming that all the operation were carried in early childhood. However, a few patients did clearly not follow this trend, for example a 2.3 year old had a regurgitation superior to 50% and a 53 year old a regurgitation of less than 5%.

Conclusion

MR phase velocity mapping is a valid, accurate and repeatable technique for the measurement of flow (forward and regurgitant) in the pulmonary arteries of patients with TOF repair. Chronic pulmonary regurgitation is associated with an increase in QRS duration and routine ECG examination could be used in the follow-up of TOF repair patients. Changes in the QRS duration could be used as an indicator for further investigation. MRI flow data could then be used for selection of suitable patients for pulmonary valve replacement.

References

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