

Magnetic Resonance Imaging - Guided Cardiac Catheterization in Children and Patients with Congenital Heart Disease

Abstract

Background: Magnetic Resonance Imaging (MRI)-guided catheterization combines the benefit of cardiac catheterization with the advantages of cardiovascular magnetic resonance (CMR), allowing simultaneous haemodynamic assessment, detailed tissue characterization and anatomical evaluation without the use of ionising radiation. Real-time CMR guides catheter navigation through the heart chambers and vessels allowing haemodynamic and flow assessment under the same sedation or anaesthesia conditions. The drawback is the slightly increased procedural complexity due to the scarce availability of dedicated MRI-conditional catheters and wires. We retrospectively report our experience of MRI-guided catheterization in children and patients with congenital heart disease (CHD), comparing the cardiac output and indexed pulmonary vascular resistance measured using the traditional Fick method and CMR flows under the same haemodynamic conditions.

Methods: Children and young adults affected by CHD or cardiomyopathy referred for cardiac catheterization and MRI between May 2022 and October 2024 were invited to undergo MRI-guided heart catheterization. All MRI-guided catheterizations were performed in a suite equipped with a 1.5-Tesla MRI scanner adjacent to a preparation room at Ospedale Pediatrico Bambino Gesù in Rome. Baseline demographics, clinical characteristics, procedural data, invasive hemodynamic findings, CMR flows and procedural complications were recorded. Procedural success was defined as the completion of a full right heart catheterization. All procedures were performed by one of two paediatric interventional cardiologists with more than five years of experience in X-Ray-guided catheterization. Systemic and pulmonary blood flows were obtained by phase contrast CMR and compared to the Fick principle. QP:Qs and indexed pulmonary vascular resistance were also compared.

Results: Twenty-five patients underwent MRI-guided heart catheterization. The mean age was 12.3 ± 11.1 years old and the mean weight was 35.7 ± 22.5 Kg. Most of the patients had a cardiomyopathy and the indication for catheterization was surveillance and/or placement on the heart transplant list ($n = 13$; 52%), seven patients were univentricular heart palliated with Glenn ($n = 2$) and Fontan ($n = 5$), tricuspid valve anomalies ($n = 1$), total anomalous pulmonary venous return post-repair ($n = 1$), double outlet right ventricle post-repair ($n = 1$), Uhl's anomaly ($n = 1$) and congenitally corrected transposition of great arteries palliated with pulmonary artery banding ($n = 1$). A complete MRI-guided cardiac catheterization was performed successfully in 96% of patients. Most procedures were performed from a femoral access ($n = 23$; 92%). There were no procedural complications related to the procedure and no patient experienced hemodynamic instability or needed resuscitation. There was a moderate correlation between cardiac and pulmonary index measured by the Fick method and CMR flows ($R^2 0.59$, $p < .001$ and $R^2 0.42$; $p < .001$ respectively). There was a strong correlation between indexed pulmonary vascular resistance measured by the Fick method and CMR flows ($R^2 0.86$; $p < .001$) with a mean difference of -0.23 ± 0.51 WU*m², 95% CI -1.23 to 0.76 WU*m².

Conclusions: MRI-guided catheterization is feasible and safe in children and patients with CHD and can be performed with standard technology using existent CMR scans. MRI combines a better soft tissue visualisation with additional haemodynamic information obtained by catheterization, without the use of X-Ray. Flow measurements and pulmonary vascular resistance obtained by CMR flows and with the traditional Fick method have a good correlation at the baseline condition. Advancements in MRI technology with improved image quality, faster scanning times, and dedicated catheterization equipment may increase the role of MRI-guided catheterization in CHD and open more space for interventional procedures.