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► To cite this version:

Sarah Cohen, Anthony Dohan. Flow quantification in congenital heart disease with magnetic resonance imaging: A new tool in multimodality assessment of complex abnormalities. *Archives of cardiovascular diseases*, 2020, 113, pp.763 - 765. <10.1016/j.acvd.2020.11.001>. <hal-03492947>

HAL Id: hal-03492947

<https://hal.science/hal-03492947v1>

Submitted on 15 Dec 2022

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Flow quantification in congenital heart disease with magnetic resonance imaging: A new tool in multimodality assessment of complex abnormalities

Quantification des flux en imagerie par résonance magnétique chez les patients avec cardiopathie congénitale : un nouvel outil dans l'évaluation des anomalies complexes

Abbreviated title: Flow quantification in congenital heart disease with MRI

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KEYWORDS

Flow quantification;

Congenital heart disease;

Magnetic resonance imaging;

Cardiovascular magnetic resonance

MOTS-CLÉS

Quantification des flux

cardiopathie congénitale

imagerie par résonance magnétique

résonance magnétique cardiovasculaire

Abbreviations: 4D: four-dimensional; ACHD, adults with congenital heart disease; CHD, congenital heart disease; CMR, cardiovascular magnetic resonance.

Advances in medical and surgical therapy have increased the survival of patients with congenital heart disease (CHD). Currently, most children with CHD reach adulthood [1]. However, residual abnormalities in cardiac structure and function are common in adults with CHD (ACHD), specifically in more severe forms of CHD. Cardiovascular imaging is fundamental to the long-term care of this growing population. Imaging surveillance is essential to detect complications and haemodynamic changes before the onset of clinical signs [2]. ACHD require careful assessment of anatomy, flows, volumes and function. Echocardiography allows global non-invasive evaluation, and is readily available; thus, it is the first-line modality in daily practice. However, ultrasound examination may be limited, especially in terms of flow quantification: alignment of the Doppler beam may be inaccurate, and flow volume calculation requires the assumption of a cylindrical cross-sectional orifice area. In this population, cardiovascular magnetic resonance (CMR) has become an important tool for longitudinal follow-up, as it provides morphological and functional data without ionizing radiation [3-5].

Conventional CMR in CHD requires an increased number of sequences and an acquisition time of almost 1 hour to provide a comprehensive assessment of the disease. The presence of and supervision by an experienced operator are also often needed to adequately determine the orientation of slices in real time. More recently, four-dimensional (4D) sequences, such as 4D flow CMR, have emerged. In addition to providing visualization in real time of anatomical structure volumes, 4D flow CMR gives a motion visualization for assessment of blood flow velocities along any direction of space. The acquisition is performed in a single sequence of 7–10 minutes with free breathing. These technical improvements allow quantification of flows posteriorly to the whole-volume acquisition, whereas conventional two-dimensional flow CMR sequences require real-time adequate positioning of

acquisition boxes, and the measurements can only be done in the predefined position. In the context of CHD, where anatomy is usually unusual, the added value of conventional CMR may be impaired in case of non-optimal acquisition planes. Thus, a time-resolved whole-volume acquisition is especially interesting in this setting. The postprocessing work allows blood flow quantification, as well as flow visualization.

4D flow CMR has been applied in various clinical situations, mainly in research. Isorni et al. [6] investigated prospectively the usefulness of 4D flow CMR in the assessment of a large panel of CHD in adults and children. This study was conducted in a tertiary centre with a high volume of activity, and included a high proportion of patients with complex CHD, and a broad range of ages and body sizes. Although a time-resolved whole-volume acquisition is particularly useful in CHD, the assessment of flows remains challenging. In the study by Isorni et al., interobserver and intraobserver agreements were substantial for the assessments of flows. This finding is in line with a myriad of previous studies that have shown how important it is for complex CHD to be referred to tertiary centres [7]: imaging techniques (i.e. CMR, but also cardiac computed tomography) remain strongly operator dependent; in this regard, the multidisciplinary and multimodality approach is often the key to providing a comprehensive assessment of the disease. 4D flow CMR is always performed to complete the findings of an incomplete ultrasound examination, and the key clinical questions have to be well known by all the physicians who image the patient. The combination of anatomical and functional evaluations has to be assessed in the light of ultrasound results and clinical data, especially in adult patients, where important medical decisions depend on this multidisciplinary assessment (e.g. pregnancy, etc.)

Interestingly, 4D flow CMR is not yet used routinely, probably because assessment of flows in patients without CHD is usually needed in only a single plane to assess one heart valve [8]. In the context of patients with CHD, the need for this kind of sequence is more critical, as assessment of flows may be necessary in several directions in the same patient. Long scan duration, time-consuming postprocessing work, variations in imaging protocols across centres and limited availability of this technique remain major difficulties in terms of conducting a multicentre study. However, with the development of artificial intelligence and the refinement of postprocessing tools, we can assume that postprocessing will improve in reproducibility and standardization. Refinements in multidetector computed tomography technology over the past decade mean that it is now possible to acquire the

whole heart in one cycle, which dramatically decreases the rate of inconclusive cardiac computed tomography [9, 10]. We can assume that improvements in CMR sequences and magnets will follow the same evolution. Availability of magnetic resonance scanners will increase, and more and more 4D sequences will be available, which should simplify the assessment of complex diseases. The price will be an increase in the number of images and in the duration of the postprocessing process, which is already an important limitation in the development of CMR. Given that CMR is used extensively for follow-up of ACHD, adding a 4D flow MRI sequence to the routine examination may provide useful information for clinical and research purposes.

ACHD represent a heterogeneous population. Thus, a personalized approach, taking into account specific patient characteristics, should guide our choices in term of imaging modalities. The strengths and weaknesses of each modality should also be kept in mind. Medical imaging performance and quality are constantly improving, and it plays a growing role in the management of patients. However, any imaging modality – and especially CMR – aims to answer to a medical question that must be clearly stated to get a tailored answer with adequate sequences in complex diseases. 4D flow CMR is no exception to the rule, and despite a growing robustness, the medical question must remain relevant, to decide whether or not to add a 10-minute sequence to CMR, which is already a relatively long examination.

In conclusion, ACHD benefit from an appropriate combination of multiple imaging modalities, ideally performed by physicians with extensive ACHD expertise [11-14].

Sources of funding

None.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References

- [1] Marelli AJ, Ionescu-Ittu R, Mackie AS, Guo L, Dendukuri N, Kaouache M. Lifetime prevalence of congenital heart disease in the general population from 2000 to 2010. *Circulation* 2014;130:749-56.
- [2] Sizarov A, Raimondi F, Bonnet D, Boudjemline Y. Cardiovascular anatomy in children with bidirectional Glenn anastomosis, regarding the transcatheter Fontan completion. *Arch Cardiovasc Dis* 2018;111:257-69.
- [3] Biere L, Piriou N, Ernande L, Rouzet F, Lairez O. Imaging of myocarditis and inflammatory cardiomyopathies. *Arch Cardiovasc Dis* 2019;112:630-41.
- [4] Ederhy S, Mansencal N, Reant P, Piriou N, Barone-Rochette G. Role of multimodality imaging in the diagnosis and management of cardiomyopathies. *Arch Cardiovasc Dis* 2019;112:615-29.
- [5] Garot J. Four-dimensional flow cardiovascular magnetic resonance: Towards accurate flow quantification? *Arch Cardiovasc Dis* 2019;112:223-5.
- [6] Isorni MA, Moisson L, Moussa NB, et al. 4D flow cardiac magnetic resonance in children and adults with congenital heart disease: Clinical experience in a high volume center. *Int J Cardiol* 2020;320:168-77.
- [7] Mylotte D, Pilote L, Ionescu-Ittu R, et al. Specialized adult congenital heart disease care: the impact of policy on mortality. *Circulation* 2014;129:1804-12.
- [8] Guerin A, Dreyfus J, Le Tourneau T, et al. Secondary tricuspid regurgitation: Do we understand what we would like to treat? *Arch Cardiovasc Dis* 2019;112:642-51.
- [9] Krupickova S, Vazquez-Garcia L, Obeidat M, et al. Accuracy of computed tomography in detection of great vessel stenosis or hypoplasia before superior bidirectional cavopulmonary connection: Comparison with cardiac catheterization and surgical findings. *Arch Cardiovasc Dis* 2019;112:12-21.
- [10] Warin Fresse K, Isorni MA, Dacher JN, et al. Cardiac computed tomography angiography in the paediatric population: Expert consensus from the Filiale de cardiologie pediatrique et congenitale (FCPC) and the Societe francaise d'imagerie cardiaque et vasculaire diagnostique et interventionnelle (SFICV). *Arch Cardiovasc Dis* 2020;113:579-86.

- [11] Alacoque X, Cuttone F, Hadeed K, et al. Multimodal imaging and three-dimensional cardiac computational modelling in the management of congenital heart disease: The secret to getting ahead is to get started. Arch Cardiovasc Dis 2018;111:395-8.
- [12] Fresse-Warin K, Plessis J, Benelhadj H, Guerin P. Impact of fused computed tomography and fluoroscopy in the catheterization laboratory. Arch Cardiovasc Dis 2018;111:449-55.
- [13] Hadeed K, Hascoet S, Karsenty C, et al. Usefulness of echocardiographic-fluoroscopic fusion imaging in children with congenital heart disease. Arch Cardiovasc Dis 2018;111:399-410.
- [14] Hascoet S, Smolka G, Bagate F, et al. Multimodality imaging guidance for percutaneous paravalvular leak closure: Insights from the multi-centre FFPP register. Arch Cardiovasc Dis 2018;111:421-31.