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Clinical Research

Usefulness of Cardiovascular Magnetic Resonance Indices to Rule In or Rule Out Precapillary Pulmonary Hypertension

Nicolas Creuzé, MD,[a,*] Susana Hoette, MD,[b,*] David Montani, MD,[c] Sven Günther, MD,[c] Edmund Lau, MD,[c] Julien Ternacle, MD,[a] Laurent Savale, MD,[c] Xavier Jaïs, MD,[c] Florence Parent, MD,[c] Barbara Girerd, PhD,[c] Olivier Sitbon, MD,[c] Gérald Simonneau, MD,[c] Carlos E. Rochitte, MD,[b] Rogerio Souza, MD,[b] Marc Humbert, MD,[c] and Denis Chemla, MD[a]

[a] *Physiology and Radiology-EA4533, Faculté de Médecine Paris 11-APHP, Le Kremlin Bicêtre, France*

[b] *Cardiology and Pulmonary Division, University of Sao Paulo, Sao Paulo, Brazil*

[c] *Pneumology-APHP-Paris11, University-Inserm UMR_S999, Le Kremlin Bicêtre, France*

ABSTRACT

Background: Various cardiovascular magnetic resonance (CMR) imaging indices are used to assess pulmonary hypertension (PH; mean pulmonary artery pressure $\geq$ 25 mm Hg). We compared the value of CMR indices to diagnose precapillary PH in treatment-naive patients evaluated for the first time for known or suspected pulmonary vascular disease.

Methods: Right heart catheterization and CMR were performed within 48 hours of each other in 85 consecutive subjects. The tricuspid annular plane systolic excursion, right ventricular (RV) fractional area change (RVFAC), RV ejection fraction, systolic eccentricity index, and RV end-diastolic area over left ventricular end-diastolic area ratio were calculated. The pulmonary artery trunk diameter, main pulmonary artery relative area change, and mean flow velocity were also calculated.

Results: There were 20 non-PH subjects (14 women/6 men, 55 $\pm$ 14 years of age, mean pulmonary artery pressure [mPAP] = 20 $\pm$ 4 mm Hg) and 65 precapillary PH subjects (32 women/33 men, 60 $\pm$ 15

RÉSUMÉ

Introduction : De nombreux indices de l'imagerie cardiovasculaire par résonance magnétique (IRM cardiovasculaire) sont utilisés pour évaluer l'hypertension pulmonaire (HP; pression artérielle pulmonaire moyenne $\geq$ 25 mm Hg). Nous avons comparé la valeur des indices de l'IRM cardiovasculaire pour diagnostiquer l'HP précapillaire chez les patients vierges de tout traitement qui sont évalués pour la première fois pour une maladie vasculaire pulmonaire connue ou suspectée.

Méthodes : Le cathétérisme du cœur droit et l'IRM cardiovasculaire étaient réalisés à moins de 48 heures d'intervalle chez 85 patients consécutifs. La mesure de l'excursion systolique du plan de l'anneau systolique de l'anneau tricuspide, la fraction de raccourcissement de surface du ventricule droit (VD; FRSVD), la fraction d'éjection du VD, l'indice d'excentricité en systole et le ratio de la surface du VD en fin de diastole par rapport à la surface du VG en fin de diastole étaient calculés. Le diamètre du tronc de l'artère

Pulmonary hypertension (PH) is defined by a resting mean pulmonary artery (PA) pressure (mPAP) $\geq$ 25 mm Hg at rest during right heart catheterization (RHC).[1] PH can result from different aetiological factors but the common consequence is increased right ventricular (RV) afterload culminating in RV failure. Although RHC remains the gold standard test for confirming a diagnosis of PH, it is invasive and is normally reserved for when noninvasive investigations suggest probable PH. Doppler echocardiography is currently the most widely used noninvasive imaging method to detect PH, but its limitations include limited acoustic window, operator dependency, potential over/underestimation of PA pressure, and lack of tricuspid regurgitation jet in many patients.[2-4] Consequently, its accuracy for the diagnosis of PH has been challenged[2-4] and other noninvasive imaging tools are increasingly used.

Cardiovascular magnetic resonance (CMR) imaging is regarded as the gold standard noninvasive method for evaluation of RV structure and function in PH, which allows accurate and repeatable RV and PA analysis.[5-7] Various CMR-derived indices have been shown to correlate with pulmonary

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*These authors contributed equally to this work.

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Corresponding author: Dr Denis Chemla, Physiology and Radiology-EA4533, Faculté de Médecine Paris 11-APHP, Le Kremlin Bicêtre, France. Tel.: +33-1-45-21-79-90; fax: +33-1-45-21-35-51.

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years of age; P = not significant; mPAP = 46 ± 12 mm Hg; 54% with chronic thromboembolic PH). All CMR indices showed essentially the same (good) value to rule in precapillary PH. The RV end-diastolic area over left ventricular end-diastolic area ratio and RVFAC, which are relatively easy to measure, had a large area under the receiver operating characteristic curve (0.93, with optimal cut-off > 0.96, and 0.92, with optimal cut-off ≤ 35%, respectively), not significantly different from RV ejection fraction. In addition, RVFAC > 45% was documented in none of 65 PH and in 10 of 20 non-PH; thus, in a population similar to ours, RVFAC measurement could potentially have avoided unnecessary catheterization in 50% of non-PH subjects.

Conclusions: In treatment-naive subjects in whom pulmonary vascular disease is highly suspected, right-sided CMR indices distinguish between PH and non-PH patients. RVFAC might have particular value in excluding precapillary PH.

pulmonaire, la modification relative de la surface du tronc de l'artère pulmonaire et la vélocité moyenne du flux étaient également calculés.

Résultats : Il y avait 20 sujets non HP (14 femmes et 6 hommes, de 55 ± 14 ans, ayant une pression artérielle pulmonaire moyenne [PAPm] = 20 ± 4 mm Hg) et 65 sujets ayant une HP précapillaire (32 femmes et 33 hommes, de 60 ± 15 ans; P = non significatif; PAPm = 46 ± 12 mm Hg; 54 % souffrant d'HP chronique d'origine thromboembolique). Tous les indices de l'IRM cardiovasculaire montraient principalement la même (bonne) valeur pour confirmer l'HP précapillaire. Le ratio de la surface du VD en fin de diastole par rapport à la surface du VG en fin de diastole et la FRSVD, qui sont relativement faciles à mesurer, avaient une grande surface sous la courbe d'efficacité du récepteur (0,93 au seuil > 0,96 et 0,92 au seuil ≤ 35% respectivement), non significativement différente de la fraction d'éjection du VD. De plus, la FRSVD > 45 % n'était documentée chez aucun des 65 sujets HP, mais chez 10 des 20 sujets non HP. Ceci pourrait potentiellement avoir évité un cathétérisme inutile chez 50 % des sujets non HP.

Conclusions : Chez les sujets vierges de tout traitement chez qui la maladie vasculaire pulmonaire est très fortement suspectée, les indices de l'IRM cardiovasculaire du cœur droit se distinguent entre les patients HP et non HP. La FRSVD serait une valeur particulièrement utile pour exclure l'HP précapillaire.

hemodynamics and have been proposed to be of use for the detection of PH.[8-14] Right heart function is highly sensitive to increases in afterload; there is a progressive increase in RV mass and decline in indices of RV function, especially RV ejection fraction (RVEF), as PH evolves.[6,7,15-17] However, because of the complexity of the RV shape, many CMR-derived parameters (such as RV mass index and RVEF) are relatively labour-intensive and time-consuming.[17,18] Simple and reproducible functional measurements of the RV-PA unit with high diagnostic accuracy in excluding PH are desirable.

This study aimed to evaluate the diagnostic performance of a battery of cardiopulmonary CMR indices in consecutive patients who presented to a tertiary referral centre and were suspected to have precapillary PH.

Methods

This prospective study was conducted from January to December, 2010 at the French referral centre for severe PH. The a priori inclusion criteria were: (1) treatment-naive patients who were evaluated for the first time for known or suspected pulmonary vascular disease; (2) RHC showing either precapillary PH (mPAP ≥ 25 mmHg and PA occlusion pressure ≤ 15 mmHg; PH group) or normal mPAP and normal PA occlusion pressure (non-PH group); (3) CMR and RHC performed within 48 hours of each other; (4) no classic CMR contraindication; and (5) CMR imaging of good technical quality. A posteriori analysis indicated that no patient was excluded for classic CMR contraindication and all the CMR images were deemed of good technical quality. Chronic thromboembolic PH was diagnosed using positive ventilation-perfusion scintigraphy with vascular obstruction on pulmonary angiography. A reliable measurement of PA occlusion pressure could not be obtained in 4 PH patients in whom typical features of proximal chronic thromboembolism on computed tomography pulmonary angiography were documented. The study complied with the Declaration of Helsinki. The data collection was part of a standardized diagnostic approach registry set up in agreement with the Commission Nationale de l'Informatique et des Libertés (approval number 842063) and all patients provided informed consent.

RHC was performed with the patient in the supine resting position using a Swan-Ganz balloon catheter according to our routine protocol.[19,20] Thermodilution cardiac output was measured in triplicate and stroke volume was calculated. Pulmonary vascular resistance was calculated as the mean transpulmonary pressure gradient (mPAP − PA occlusion pressure) divided by cardiac output. Pulmonary capacitance was calculated as the stroke volume/PA pulse pressure.

All CMR imaging was performed using a 1.5-T magnet (Magnetom Avanto, Siemens Medical Solutions) with electrocardiogram gating during repeated breath-holds. The 4-chamber and short-axis cardiac views were obtained using cine imaging (balanced steady-state free-procession pulse sequences). A stack of short-axis cine imaging slices was acquired from RV base to apex. Up to 18 contiguous slices 6 mm thick were obtained in parallel to the plane of the tricuspid valve. For RVEF calculation, the end-systolic and end-diastolic areas were manually delineated in the short-axis including papillary muscles. The corresponding RV volumes were determined using ARGUS software (version VA 50C, Siemens Medical Solutions, Erlangen, Germany). The tricuspid annulus plane systolic excursion (TAPSE) was determined in the 4-chamber view as the distance travelled by the lateral tricuspid annulus from its most posterior to most anterior position. The corresponding RV end-diastolic area (RVEDA [cm^2]) and RV end-systolic area (cm^2) were determined in the 4-chamber view, including the papillary muscles (Fig. 1). The RV fractional area change (RVFAC) was calculated as RVFAC = 100 × (RVEDA − RV end-systolic area)/RVEDA. The RVEDA over left ventricular end-diastolic