Editorial

Fusion imaging in congenital heart disease: just a pretty picture or a new tool to improve patient management?

Imágenes de fusión en cardiopatías congénitas, ¿solo una imagen bonita o una nueva herramienta para mejorar el tratamiento de los pacientes?

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The use of fusion imaging in cardiology is rapidly emerging. The first application was proposed in 1992 with the fusion of single photon emission tomography images and computed tomography (CT) images to combine anatomical and functional information.[1] From then on, multiple approaches for fusion have been developed and have used different imaging modalities such as echocardiography, CT, nuclear imaging, and magnetic resonance imaging (MRI). In the setting of the catheterization laboratory, the combination of fluoroscopy and transesophageal echocardiography (TEE) or CT has also been used during structural heart disease interventions, and has shown additional value in terms of shorter fluoroscopy time and simplifying complex procedures.[2,3] However, in the field of congenital heart disease (CHD), fusion imaging has not been widely applied, even though it represents the ideal setting where combining multiple imaging modalities would significantly aid patient diagnosis and treatment decision-making. In particular, in complex patients such as those with a double outlet right ventricle with or without transposition of the great arteries, an (un)balanced atrioventricular septal defect or extreme cases of tetralogy of Fallot, an exact understanding of the anatomy and function becomes pivotal to design a therapeutic plan.

Two-dimensional transthoracic echocardiography (TTE) is currently the main tool used to diagnose a patient with CHD, providing sufficient anatomical information in most cases. Also, 3-dimensional (3D) TTE is increasingly applied in specialized centers, particularly in older children and adults, where, with dedicated probes fitted with a matrix array transducer, full volume 3D datasets can be easily obtained. When adequate training and experience was available, analysis of 3D TTE showed to further improve diagnosis of CHD.[4] TEE can be of additional value in the imaging of pulmonary venous return and to assess the anatomy and function of the atrioventricular valves. However, in children, TEE is not commonly performed due to discomfort and need for sedation, and its use is therefore limited during preoperative diagnostic catheterization or in the operating room, when more detailed anatomical information is needed prior to surgery.

As additional diagnostic tool, CT reveals new findings in almost 80% of CHD cases,[5] helping to define coronary anatomy, aortic arch anomalies, abnormal pulmonary venous connection, and the relationship between the great arteries and a ventricular septal defect.[6] Starting from a CT dataset, 3D printing has also shown an additional value in CHD patients, improving communication within multidisciplinary teams and therapeutic decision-making.[7] CT has, however, some limitations. The first is the use of radiation and contrast media and the need for the patient to lie still during breath-hold acquisition. In children, the "feed-and-wrap" technique and careful contrast injection by experienced personnel is therefore key to obtain diagnostic CT images. The second is that CT does not typically provide information on cardiac function, which can be relevant in some CHD.

As an important third diagnostic modality, MRI is gaining ground in the field of CHD, providing anatomical as well as functional data. However, MRI also has drawbacks, as it is time consuming and with long breath hold acquisitions, which are particularly challenging for young children and mentally retarded patients. In addition, patients with CHD often have epicardial pacemaker leads or abandoned pacemaker leads, which might preclude MRI.

With this imaging armamentarium, cardiologists and surgeons up until now had to "fuse" in their minds the images of TTE, CT and/ or MRI, in order to properly reconstruct the congenital defect anatomy as well as the function. This exercise requires training and experience and does not always leads to an accurate diagnosis. In a recent article published in *Revista Española de Cardiología*, Fournier et al.[8] propose a method to fuse 3D TTE and CT images to simplify the diagnostic process in CHD and gain maximal benefit from the 2 imaging techniques: anatomical information from the CT and functional information from the 3D TTE. Although fusion between CT and 3D TEE has been previously shown,[3] this study is the first to use the combination with 3D TTE, which is mostly used in CHD. The authors provide a step-by-step description on how to obtain such a fused image, with useful instructions on how to place landmarks and how to orient the dataset. Looking at their report, the first clinical question is whether this fusion technique is feasible, particularly in CHD. Fournier et al. show that a fusion image could be created in a variety of CHD patients from mild defects to complex cases.[8] The TTE views had to be reversed, before aligning

with the CT images and therefore proper identification of the anatomical landmarks was of pivotal importance. In the 14 cases they included (mainly children, median age 9.5 years), it took an average of 12 minutes to obtain the fused image, with no significant difference in time to complete the fusion process between simple and complex cases. Unfortunately, with this approach, the fusion images could not be stored to allow their subsequent recovery. This issue may therefore hamper their use during Heart Team discussion with the cardiac surgeon and/or interventional cardiologist.

The feasibility of this fusion technique in CHD patients therefore seems very promising but future innovations should certainly consider the following aspects: *a)* the need for a way to store the fusion image, allowing it to be recovered at any time; *b)* application from multiple echo and CT vendors; and *c)* improvement of workflow with a semiautomated approach, which is at this stage challenging considering the complexity and variety of CHD.

The second clinical question is whether 3D TTE-CT fusion is of real additional value when applied in clinical practice. This question was not the objective of the study by Fourier et al.[8] and future research is warranted to explore the additional role of 3D TTE-CT fused models in diagnosis and decision-making in CHD. Potentially, we believe this approach might particularly help in optimizing surgery or intervention planning, resulting in shorter procedural times, and optimal results and thereby faster patient recovery. Cases which might benefit from this technique are, for instance, patients with a misaligned ventricular septal defect to assess the ventriculoarterial connection and whether patch-closure is possible or might result in (dynamic) outflow tract obstruction. Similarly, in cases with double outlet right ventricle, the spatial relation between the ventricles and great arteries is crucial but sometimes difficult to assess using TTE. In all these patients, CT and 3D printing of a model already help the surgeon in deciding the surgical strategy, but still only provide a static assessment at one timepoint in the cardiac cycle. Having the dynamic information from 3D TTE in conjunction with the excellent anatomical information from the CT scan could further help the decision on therapeutic strategies.

Another potential application could be in patients with total or partial abnormal pulmonary venous connection and sinus venosus atrial septal defect. In these cases, a rerouting of the pulmonary veins and exclusion of the atrial septal communication is necessary and combining the images from CT and 3D TTE (or in adults 3D TEE) might help to determine the optimal surgical or percutaneous strategy.[9] Also, the assessment of the relationship between (aberrant) coronary arteries and adjacent structures, such as the right ventricular outflow tract and/or pulmonary valve, could be improved by having anatomical and function information. For instance, in patients with tetralogy of Fallot, a large conal branch or dual left anterior descending coronary artery might hamper the implantation of a percutaneous pulmonary valve with the risk of coronary artery obstruction. By combining CT and echocardiographic information, the relation between the coronary artery and the right ventricular outflow tract/pulmonary valve can be assessed throughout the cardiac cycle to predict whether pulmonary valve replacement can be achieved safely.

Finally, the use of fused images might be implemented in education and patient counseling to improve understanding of these complex diseases.[7] In fact, 3D images are more intuitive and might be easier to understand for patients and parents. In addition, if the fused images remain available after reconstruction, these can be used to teach junior physicians and fellows on the subject of complex congenital heart defects and to show the spectrum of disease severity.

In conclusion, when combining anatomical and functional data is crucial in clinical decision-making such as in CHD, the fusion of 3D echocardiography and CT could be of great value and the study by Fourier et al. paves the way for the application of this technique in clinical practice. Further development of more dedicated software to improve the fusion process (possibly semiautomated and implementing artificial intelligence) and the availability of the fusion images will hopefully stimulate its wide use in CHD with the objective of improving the care (from diagnosis to treatment) of these complex patients.

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