Archives of Cardiovascular Disease (2018) xxx, xxx–xxx

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REVIEW

Impact of fused computed tomography and fluoroscopy in the catheterization laboratory

Impact de la fusion scanner et fluoroscopie en salle de cathétérisme

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Received 3 February 2018; received in revised form 11 March 2018; accepted 12 March 2018

KEYWORDS
Heart disease;
Catheterization;
Fluoroscopy;
Tomography;
Multimodal imaging

Summary The development of structural interventional catheterization for acquired or congenital heart disease was made possible through concomitant advances in catheterization techniques/tools and imaging techniques (fluoroscopy, ultrasound, magnetic resonance imaging and computed tomography). Imaging should provide an accurate view of the lesions and the surrounding cardiac structures, as well as the medical devices and catheters used. Here, we address the subject of image fusion. The principle of image fusion is based on the superposition of several imaging techniques: real-time fluoroscopy and multislice imaging performed offline or ultrasound imaging performed simultaneously. The goals are to improve the overall visualization of the organ and the surrounding structures, and to help the interventional cardiologist to interpret fluoroscopy images.
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Abbreviations: 2D, two-dimensional; 3D, three-dimensional; CABG, coronary artery bypass graft; CT, computed tomography; CTO, chronic total occlusion; LAA, left atrial appendage; TOE, transoesophageal echocardiography.

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https://doi.org/10.1016/j.acvd.2018.03.001
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MOTS CLÉS
Cardiopathie ;
Cathétérisme ;
Fluoroscopie ;
Tomographie ;
Imagerie multimodale

Résumé Le développement du cathétérisme interventionnel structurel dans les cardiopathies congénitales ou acquises a été rendu possible grâce à l'évolution concomitante des techniques et du matériel de cathétérisme, et de l'imagerie cardiovasculaire: imagerie par rayonnements ionisants, échographie, imagerie par résonance magnétique et scanner. L'imagerie doit fournir une vue précise des lésions, des structures cardiaques environnantes, ainsi que des dispositifs médicaux et des outils utilisés. Nous abordons ici le domaine des images de fusion. Le principe de l'imagerie de fusion repose sur l'association en superposition de plusieurs techniques d'imagerie: fluoroscopie réalisée en direct et imagerie en coupe réalisée en différé ou imagerie échographique réalisée simultanément. Le but est d'améliorer la vue globale de l'organe et des structures avoisinantes, et d'aider le cardiologue interventionnel à s'orienter dans son image de fluoroscopie.
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Background

Computed tomography (CT)/X-ray image fusion is a new technology that allows the overlay of a three-dimensional (3D) CT model onto fluoroscopic images obtained in real time. CT scan systems provide a 3D reconstruction of a structure of interest, which can improve the two-dimensional (2D) spatial visualization of images obtained during a real-time medical intervention. This imaging technique has been described previously in interventional neuroradiology [1—4], in abdominal and vascular interventional radiology [5—8] and in cardiology, during atrial fibrillation ablation procedures [9—12]. In the context of congenital heart disease, image fusion has been reported to be helpful in complex haemodynamic procedures [13—15].

The advantages of CT image fusion are manifold. First, as a result of the full 3D registration between the CT volume and the X-ray system, the rotation of the CT volume is linked to the rotation of the X-ray system, enabling assessment of the best position for the X-ray system with respect to the anomaly, with no need for additional X-ray exposure. Second, during the procedure, image fusion facilitates optimal positioning of catheters, guides and balloons or devices, with minimum injection of radiocontrast agent. Third, because it is possible to visualize specific thoracic structures, the angiography before the interventional catheterization is simplified: for example, aortography of the coronary tree before pulmonary revalvulation is not mandatory because the coronary arteries can be localized on image fusion. Hence, using CT scans that are usually available from preoperative exploration, image fusion provides additional guidance during interventional catheterization, while limiting exposure to radiation and radiocontrast agents.

In this review we describe various procedures in acquired or congenital heart disease that could be facilitated by the use of image fusion.

Real-time 3D reconstruction and image fusion

Before CT scan/X-ray image fusion in the catheterization laboratory, an electrocardiogram-gated CT scan must be performed with contrast injection, allowing good opacification of the target structure. Before the examination, the first step is the segmentation of the CT scan, to delineate the structures of interest for fusion, using a dedicated workstation (Video A.1). Planning lines may also be added at this stage, and integrated into the segmented 3D model. During the intervention, the fusion software prepares a conic projection of the 3D model according to the C-arm geometrical configuration, which is then superimposed over the real-time fluoroscopy 2D images. The initial default registration is further refined manually, by sliding the superimposed model into alignment with remarkable landmarks, either from tableside or from the control room. This step may be performed from two different angulations at the operator's convenience.

The accuracy of the image overlay is then confirmed visually, through the use of contrast angiography. Finally, the CT overlay is available for live guidance, with no need for further operator interaction; C-arm angulations and table movements are synchronized with the 3D model. The model adapts continuously to system geometrical changes. This enables the optimal working view to be reached without X-ray exposure. This entire workflow takes 15 min per examination, including 10 min for the segmentation step at any time before the procedure and 5 min for registration during the examination. Because of the simplicity of the segmentation step, and the fact that it can be done on the workstation outside of an examination, training can be done within a few procedures. Because most complex congenital or acquired heart diseases usually require a CT scan for exploration, this technique does not lead to additional patient radiation exposure.

Image fusion and coronary artery disease

Locating a coronary artery bypass graft (CABG) that requires follow-up evaluation may be difficult with coronary angiography, especially for venous and radial artery grafts, which may involve variable proximal anastomosis locations. As a consequence, the procedure may be long, which can result in elevated radiation exposure [16] and increased nephrotoxic complications [17], particularly in high-risk patients (e.g. elderly or overweight patients and those with

Please cite this article in press as: Fresse-Warin K, et al. Impact of fused computed tomography and fluoroscopy in the catheterization laboratory. Arch Cardiovasc Dis (2018), https://doi.org/10.1016/j.acvd.2018.03.001

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