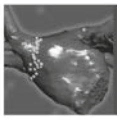

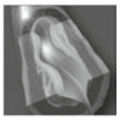

Catheter interventions for congenital heart disease with less and less radiation

"*Our innovative and imaginative use of alternative imaging techniques should allow us to reduce radiation exposure in our day-to-day practice.*"

KEYWORDS: catheter intervention ▪ congenital heart disease ▪ echocardiography ▪ radiation

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Percutaneous intervention for congenital heart disease (CHD) has been established as a core treatment modality since Rashkind pioneered balloon septostomy for neonates with transposition of the great arteries [1]. Since then, cardiac catheterization has progressed from mainly being a diagnostic procedure to interventions in the majority of cases, especially as a large amount of diagnostic information can be obtained with imaging modalities, such as echocardiography, computed tomography and MRI.

Catheter interventions for CHD (as well as for coronary disease) are traditionally performed under fluoroscopic guidance using radiation. Especially in pediatric practice, any use of radiation carries the potential risk of DNA damage and the development of malignancy years to decades after the procedure [2,3]. Hence, the 'as low as reasonably achievable' principle has been introduced, and efforts have been made to minimize the dose used for common interventions [4]. This can be facilitated by detailed visualization of complex anatomy with imaging modalities, such as MRI, prior to intervention. Such preprocedural planning allows preselection of the angulations needed for interventional angiography, hence decreasing procedure time and minimizing contrast and radiation load [5].

Echocardiography and angiography do not always correlate well, as shown for neonatal aortic valves [6]. Hence, in these cases, angiography as the gold standard to determine balloon size cannot be replaced by echocardiography.

Image fusion is a technique in which preexisting MRI or computed tomography images are overlaid on the live fluoroscopic images and are used as a 'road map' to guide catheter interventions (i.e., in coarctation of the aorta) [7].

Aging equipment

The use of older equipment in the catheter laboratory is associated with higher radiation as the image detectors, and even flat panels, detoriate over time; the x-ray doses needed for the same image quality increase 6–10% per year [4,8]. This means that after 10 years of use, the doses needed almost double. With modern fluoroscopic equipment, the average radiation needed for common interventions of CHD can be reduced by approximately 70%; however, even the latest equipment is subject to deterioration with age and, hence, radiation doses will continue to increase over time [8]. Windowing, adjustments of frame rate, energy use and contrast dose can all be preset for different body weights in modern catheter laboratories, and can always be fine-tuned further. Nevertheless, even the use of small doses of radiation can cause stochastic DNA damage. Therefore, other imaging techniques need to be applied whenever possible.

Imaging modalities other than fluoroscopy

Again, one of the first interventions carried out purely under echocardiographic guidance was the balloon atrial septostomy. The catheter can be visualized easily on subcostal views, and the intervention can be carried out safely and effectively [9,10]. Fluoroscopy guidance of balloon atrial septostomy is now reserved for complex atiral septal anatomy, such as in hypoplastic left heart syndrome where the left atrium is small, or where the use of a guidewire to achieve balloon stability seems beneficial [11]. The procedural risk is not increased with echocardiographic guidance compared with x-ray-guided techniques [12].

For some types of catheter intervention, namely closure of interatrial communications or left atrial appendage closure, a combination of

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fluoroscopy and echocardiography (either transthoracic, transesophageal or intracardiac) enables the interventionalist to visualize the important structures in far more detail than with fluoroscopy alone. In this setting, x-ray use helps with positioning of the guidewire and sheath in the pulmonary veins or left atrial appendage, and configuration of the device during delivery and release. It has, however, been shown that device closure of atrial septal defects can be performed without the use of any radiation under echocardiographic guidance only [13]. This has been further enhanced by the use of advanced echocardiographic techniques, such as 3D transesophageal echocardiography, which allows augmented visualization of all intracardiac structures, catheters and closure devices used. The sometimes complex anatomy of the patent foramen ovale is particularly well delineated using this modality. Recognition of a spiral separation between the primum and secundum septum may inform the operator that a defect will be challenging to close or is not closable; this information cannot be achieved using fluoroscopy or angiography [14].

> *“...stents in the right ventricular outflow tract ... have been performed almost entirely under echocardiographic guidance in neonates as small as 1.3 kg.”*

Valvoplasties have also been performed under echocardiographic guidance. It is a challenge for both the echocardiographer and the interventionalist to visualize the catheter traversing the different cardiac cavities, especially if guidewires are used. The tip of a guidewire in a pulmonary artery cannot be visualized echocardiographically and, hence, most interventionalists feel safer with fluoroscopy.

Bass and Wilson have developed techniques to close persistent arterial ducts in preterm neonates in the incubator under pure echocardiographic guidance [15]. Long-term follow-up will show whether the device or coil size used, based on echocardiographic measurements alone, was appropriate.

The use of coronary stents in the right ventricular outflow tract to temporize critically ill neonates with Tetralogy of Fallot is an exciting recent development. Extreme accuracy during stent placement in the dynamic outflow tact is required to allow complete relief of the outflow tact obstruction, while avoiding interference with the branch pulmonary arteries and right ventricular cavity. This accuracy is served well by the high temporal resolution provided by continuous echocardiographic monitoring. Such procedures have been performed almost entirely under echocardiographic guidance in neonates as small as 1.3 kg [16].

> *“The interventionalist has to know the limits and benefits of each modality in order to plan any intervention.”*

In many cases of CHD, MRI has replaced angiography as a diagnostic tool to delineate the anatomy. To use this imaging modality to guide catheter interventions, many hurdles need to be overcome. Standard cardiac catheters contain metal (for radio opacity) and, hence, cannot be used in the MRI scanner. Guidewires are a major problem as the interventionalist demands (for good reasons) certain mechanical properties. The first valvuloplasties in the MRI scanner have been carried out using fiber glass guidewires [17], but these have proven to be less robust and more pone to breakage than conventional metal wires. Although this approach may have major applications in the future, it remains in the early phases of clinical research.

Conclusion

Visualization of both the cardiac structures and catheter equipment varies with different imaging techniques. The interventionalist has to know the limits and benefits of each modality in order to plan any intervention. Frequently, more than one modality will have to be applied and one should not be limited to fluoroscopy for convenience only. Catheter interventions for CHD require proper planning and should include multiple imaging modalities, image overlay and the recognition of potential pitfalls in catheter or equipment visualization in order to minimize radiation exposure of the patients. More research is necessary to develop and evaluate MRI-guided interventions, and as echocardiography continues to evolve, we should consider its further routine integration for interventional guidance. Our innovative and imaginative use of alternative imaging techniques should allow us to reduce radiation exposure in our day-to-day practice.

Financial & competing interests disclosure

The authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

No writing assistance was utilized in the production of this manuscript.

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