Review

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Virtual Reality and Artificial Intelligence Paving the Future of Cardiac Interventions and Training, a Review of the Available Reviews

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Virtual Reality and Artificial Intelligence Paving the Future of Cardiac Interventions and Training, a Review of the Available Reviews

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Abstract: Several medical graduates, avoid surgical specialties especially those with complex and delicate anatomy due to their doubt in their visual spatial abilities. Many patients are deemed inoperable, particularly in the field of pediatric cardiology, due to the complexity of the anatomy. On a similar note, stratification of risk of cardiac interventions, and decision making, is a room of significant person-based and center-based bias. Two inter-related technologies, namely immersive virtual reality (VR) and artificial intelligence have made impossible things possible and can help to standardize decision making strategies. This review aimed at reviewing the main anatomical and lesion-based scopes of these advancements in the field of cardiac care, with a special focus on pediatric cardiology.

Keywords: cardiac care; cardiac interventions; artificial intelligence; virtual reality; visual spatial ability

Background

Virtual reality (VR) and artificial intelligence (AI) are increasingly important in the field of cardiac interventions [1]. These technologies can potentially enhance medical training, improve surgical planning, and enable more precise procedures. By leveraging virtual reality, medical professionals can simulate complex surgical scenarios and practice difficult procedures in a safe and controlled environment [2]. Artificial intelligence, on the other hand, can assist in interpreting medical images, predicting patient outcomes, and optimizing treatment strategies. As these technologies continue to advance, they are expected to play a significant role in advancing the field of cardiac interventions and improving patient care [3].

Virtual reality technology has the potential to effectively address interpersonal gaps in surgical skills by providing a realistic and immersive training environment. By simulating surgical procedures and scenarios, VR can help bridge the gap in skills and experience among surgeons, ultimately leading to improved patient outcomes [4].

Moreover, artificial intelligence plays a crucial role in predicting patients' outcomes through the analysis of vast amounts of medical data. By utilizing advanced algorithms, AI can identify patterns and trends that may not be apparent to human experts, enabling more accurate predictions of a patient's prognosis and response to treatment [5]. This has the potential to significantly enhance personalized healthcare and improve overall patient care.

In this literature review, we aim to highlight the most important anatomic scopes of virtual reality and artificial intelligence in guiding pediatric cardiac interventions via analysis of the most important reviews of literature tackling this matter.

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Main Body

Virtual Reality in Cardiology/Cardiac Surgery Training

The cognitive process of detecting targets in space, recognizing distance and directional relationships, and mentally altering their location is known as spatial skills. The ability to create, preserve, and work with mental pictures in space is known as visual spatial ability (VSA) [1].

Coming to the medical field, and while it is mandatory to evaluate the spatial ability for admission to undergraduate dental programs and aviation. surgical training programs do not require VSA testing before admission [6].

This might be one of the factors responsible for variations in outcomes of surgeries overall and pediatric cardiac surgeries.

An article by Kalun et al. suggested that "Measuring VSA in surgical trainees is important not only because the results suggest that individuals with higher VSA often demonstrate increased surgical performance, but also that those with higher VSA often require fewer training sessions to reach a certain performance point than their peers with lower VSA" [1].

The combination of virtual reality and artificial intelligence allows us to overcome the interpersonal variability of VSA. After traditional cross-sectional imaging is completed, a process called segmentation allows specialty engineers to convert 2D DICOM images to 3D VR Maker; which allows trainees and experienced surgeons to interact with those 3D models during pre-surgical planning and can theoretically improve the outcomes of cardiac surgeries and allow medical students with doubts over VSA to choose surgical specialties confidently.

One systematic review was found that discusses the results of VR training in tissue and non-tissue models, in cardiac surgical training [7].

We used this review to determine the number of studies involving immersive virtual reality training in cardiac interventions. We also analyzed the main fields where this technique is being implemented to improve the surgical skills of cardiothoracic residents.

The latter report depicted 27 studies and one catheter-based study was added during search [8–35]; most of these involved training on mitral valve specimens (28%), and coronary surgeries (25%). Other fields of training included mimicking cardiopulmonary bypass, cardiac transplantation, TEE, and cardiac catheterization.

Figure 1 displays the respective percentages of each anatomical field of training.

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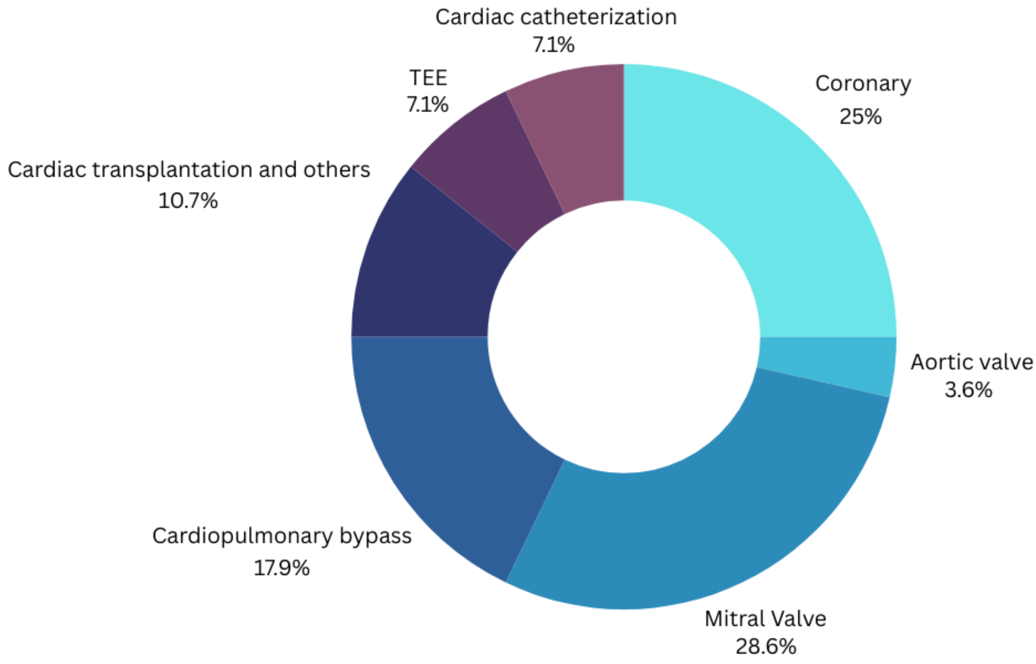

Figure 1. Percentages of scopes of VR-based cardiac surgery training. Abbreviations: TEE: transesophageal training.

Virtual Reality in Planning Cardiac Interventions

Current medical practice increasingly utilizes advanced 3D imaging modalities such as magnetic resonance imaging (MRI) and computed tomography (CT) to examine and assess complex congenital heart defects. These modalities enable comprehensive visualization of the cardiovascular anatomy and precise measurements of relevant intracardiac dimensions and volumes [36]. Nevertheless, the conventional representation of 3D anatomy through two-dimensional (2D) slices perpendicular to each other presents challenges in accurately assessing the intricate 3D structures and their spatial relationships. Overcoming these challenges involves reconstructing the patient-specific 3D anatomy using image processing techniques applied to CT or MRI data [37]. While various methods and software tools are available for this reconstruction, manual intervention is often necessary due to the intricate nature of the anatomy and the presence of imaging artifacts. The resulting 3D reconstructions can then be employed to enhance the comprehension of the complex anatomy [38].

Virtual reality has taken 3D reconstruction to a whole new level where reconstructed models are rendered interactable, with the aid of immersive virtual reality.

Steps include image acquisition and 3D modelling, then several programs are available, to import patient-specific models, and make them compatible with commercially available mounted headsets.

Our literature search identified a scoping review by Bakhuis et al. [39], which demonstrated that the number of case studies involving the use of VR in surgical planning for congenital heart disorders is lower than what is seen for education in training, with a total of ten studies, conotruncal anomalies, VSD open surgical closure, AV valve repair and pulmonary sequestration were the main field of the published reports (18%) (Figure 2) [40–50].

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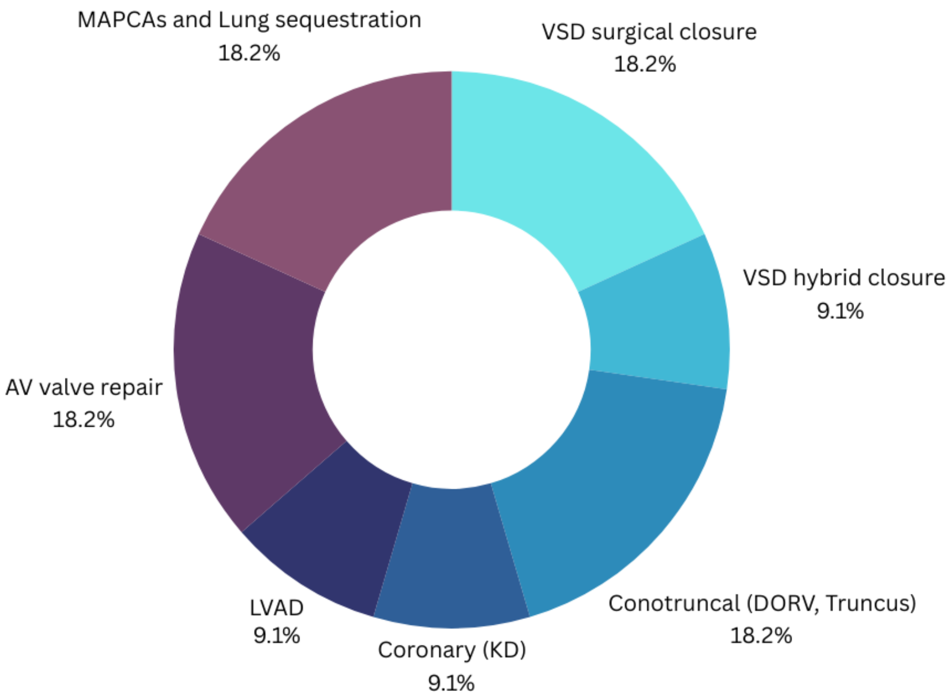

Figure 2. Percentages of distribution of immersive VR assisted cardiac surgeries. **Abbreviations:** AV: atrioventricular, DORV: double outlet right ventricle, KD: Kawasaki disease, LVAD: Left ventricular assisted device, MAPCAs: Main aortopulmonary connecting arteries, VSD: Ventricular septal defects.

Another aspect worth noting was the imaging modality used for 3D modelling, CT accounted for 60% of the reported studies, while CMR for 30%, and only one case report was performed using 3D echocardiography. (Figure 3)

This shows the drawback of reconstructive imaging, which relies on either high radiation or lengthy imaging modalities.

There is still a long way to go to develop echocardiographic software, and 3D modalities in this bedside technique to be adaptable to immersive virtual reality and to spare the patients from lengthy, inconvenient procedures and from radiation.

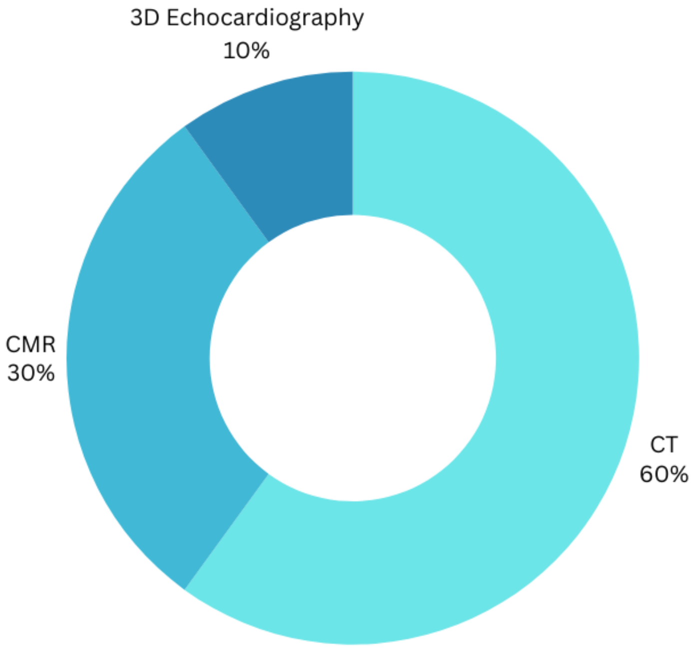

Figure 3. Percentages of distribution of imaging modalities used for VR reconstruction. Abbreviations: CMR: Cardiac magnetic resonance, CT: computed tomography.

Expertise also is another barrier to the generalization of VR reconstructive software, Figure 4 illustrates a VR-based reconstruction of a case of partial anomalous pulmonary venous return performed by non-trained individuals, by a user-friendly software [51].

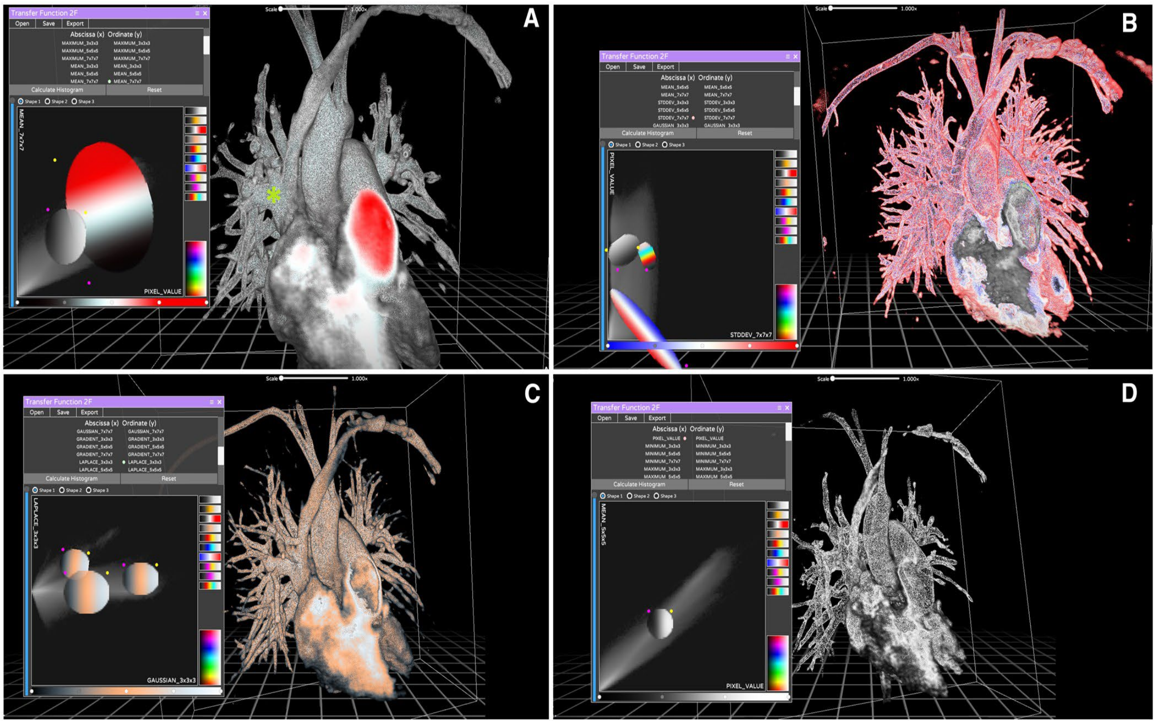

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Figure 4. Reconstructions of case 2 generated by the participants. The diagnosis was partial anomalous pulmonary venous [51].

Big Data, Is Artificial Intelligence, Substituting the Multidisciplinary Approach in Cardiac Surgery?

The development of advanced deep-learning technology now provides the chance to identify risk indicators that were not previously measurable. This technology can also evaluate intricate, interconnected patterns using easily accessible clinical data for predicting risks.

Sulague and colleagues [52], have published recently their preprint which served as a basis for identifying relevant AI-based studies in the field of cardiac interventions.

This review included 33 studies [53–85], that explored how machine learning can predict certain events such as major bleeding or mortality after different types of cardiac surgeries.

Regarding the specific fields tackled by the predictive model of machine learning, coronary surgeries, and heart transplantation were the most important point of focus, accounting for 39% of the studies tackling the role of AI in risk prediction (Figure 5).

A new software developed in Sinai Medical Center, aimed at using 12-lead ECG in risk prediction in non-cardiac surgeries. The newly manufactured software, PreOpnet was superior to the routinely used Revised Cardiac score index, in anticipating adverse events after non-cardiac surgeries [85].

Another recent review, published during the drafting of this manuscript, showed that >672 AI-based devices have already been approved by the FDA and might have an impact on the outcomes of cardiac patients, from planning to risk assessment.

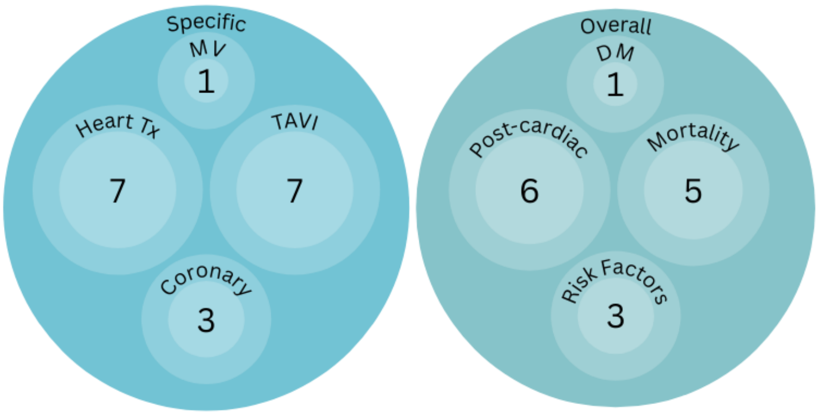

Figure 5. Number of studies employing machine-learning and artificial intelligence in decision making in cardiac surgery, categorized by scope. Abbreviations: DM: decision-making, MV: mitral valve, TAVI: Transcatheter aortic valve implantation. Tx: Transplantation.

Figure 6 is a flowchart illustrating the study selection process

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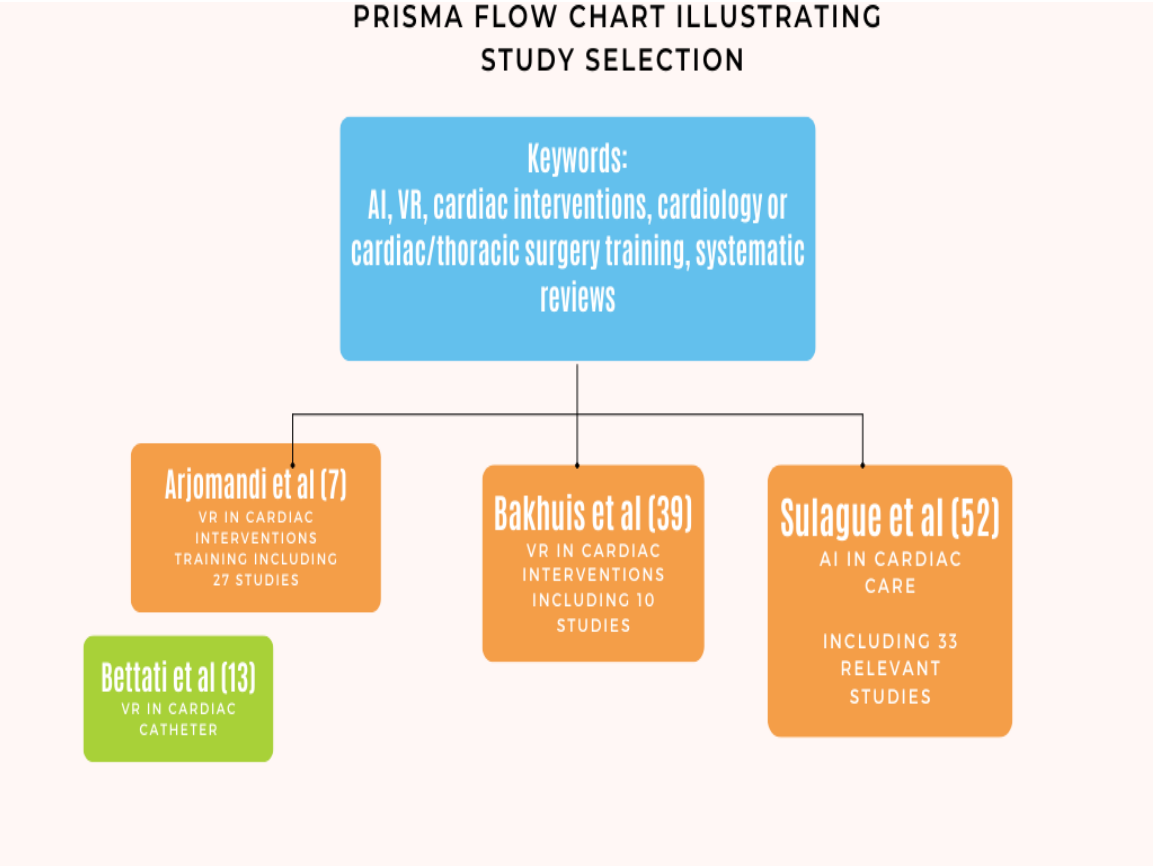

Figure 6. Flow chart of the studies selection process.

Figure 7 is a flowchart illustrating the potential future uses of AI in cardiac care, many features are still under implementation.

Figure 7. Future uses of AI in cardiac care, a promising journey.

Conclusion

AI and VR might be part of the present but the whole future. It is increasingly said in the small indoor chats of physicians that these emerging technologies will gradually reduce their jobs. But from another perspective, it is very unlikely that this would happen.

VR will help improve medical and surgical training. Nevertheless, it will allow better interaction with reconstructed models and will therefore improve surgical outcomes.

AI in the field of machine learning will help in better diagnosis and will shorten by its algorithm the interpretation time of images and other acquired data, which will not only improve risk prediction but will also give more time for healthcare personnel to develop their knowledge and get exposed to a larger number of patients.

Changing the perspective, from being replaced to absorbing the change and getting the advantages from it, is what physicians in all specialties need to start doing.

It is also wort mentioning that by the time this review was complete and written, many other VR and AI-based reports have been added to literature, which would not be included by the time this manuscript will be reviewed and published.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org. Supplementary Table 1: Studies involving VR based training in cardiac surgery categorized by the anatomical scope. Supplementary Table 2: Studies involving immersive VR in pediatric cardiac surgery categorized by the type of treated lesion. Supplementary Table 3: Table 3: Studies involving use of AI in cardiac care classified by scope of interest.

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Conflicts of Interest: The authors declare no conflict of interest.

List of Abbreviations

AI	Artificial intelligence
AV	Atrioventricular
CMR	Cardiac magnetic resonance
CT	computed tomography
DM	Decision making
DORV	Double outlet right ventricle
KD	Kawasaki disease
LVAD	Left ventricular assist device
MAPCAs	Main aorto-pulmonary connecting arteries
MV	Mitral valve
TAVI	Transcatheter aortic valve implantation
TEE	Transesophageal echocardiography
Tx	Transplantation

VR	Virtual reality
VSA	Visual spatial ability
VSD	Ventricular septal defect
VSD	Ventricular septal defect

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