Virtual reality in cardiac interventions – New tools or new toys?

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Abstract

Improvements in medical imaging and a steady increase in computing power are leading to new possibilities in the field of cardiovascular interventions. Interventions can be planned in advance in greater detail, even to the point of simulating procedures. Nevertheless, all techniques are at an early stage of development. It is of utmost importance that tools, especially if they can be used as decision support are intensively validated and their accuracy is demonstrated. In our commentary, we summarize current techniques for guiding improvement planning, but also critically discuss the downsides of these techniques. Following the work of Kenichi and colleagues, we also discuss necessary steps in advancing new tools and techniques, particularly as they are used in routine clinical practice. We also discuss the role of artificial intelligence, which could play a crucial role in this context in the future.

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In the study by Kenichi and colleagues published in this issue of the Journal of Cardiac Surgery, a pig's heart was filled with silicone, subjected to a CT scan and the images imported into special software to display it as a virtual 3D model and measure the relevant anatomical structures. What sounds a little strange at first glance makes perfect sense for a few reasons: Cardiac imaging has become an important part of procedure planning in cardiovascular medicine, especially for structural heart but also coronary artery disease[1,2]. Image modalities that play a crucial role in this context are cardiac computed tomography (CCT)[3] , echocardiography[4–6]and cardiac magnetic resonance imaging (CMRI)[7]. Each modality has its own advantages and disadvantages. While CCT has a very high spatial resolution, echocardiography and CMR can be used to perform functional examinations of the heart. To take advantage of different modalities simultaneously, fusion of imaging modalities has been proposed, e.g. fusion of echocardiography and fluoroscopy for mitral interventions[8]or fusion of invasive coronary angiography and myocardial perfusion imaging[9]and others. With the increasing computing power of computers, the use of medical images is now reaching new possibilities: The available data is used to segment cardiac structures or even whole hearts[10–12]. These geometric models can then be used for further applications, such as simulating cardiac interventions[13–15]or 3D printing to better understand complex anatomies. The latter became popular before interventions involving congenital heart defects[16], as these are highly individualised from patient to patient. Using a 3D-printed model, surgical planning can be done "hands-on". But the use of 3D models can also be very helpful in adult cardiac surgery, e.g. mitral valve repair, where the anatomy on the arrested heart can be very complex to assess[17]. In addition to sophisticated modelling of the anatomical structures of the heart and therapy simulation, a third application of the use of high-quality cardiac images can be seen in education and training. Here, too, virtual visualisations of three-dimensional images, but also 3D-printed models can be used. For example, training ventricular septal defect repair on a silicone model of a heart is described as a useful method for training[18]. In adult cardiac procedures, 3D-printed models can help in planning access, for example in surgical minimally invasive aortic valve replacement[19] or to avoid complications in transcatheter aortic valve implantation[20]. The very recent trend is to integrate 3D models into virtual reality applications, as described in the paper by Kenichi and colleagues presented in this issue. Advantages of such tools are the possibilities to interact with 3D images with little effort. Models can be rotated in all directions, zoomed in and out and measurements can be taken. In addition, 3D models can be used in augmented reality scenarios, e.g. for decision support in complex surgical procedures[21].

Despite numerous achievements in this field, there are still some limitations to this advanced technology: First of all, the availability of such tools is limited. Cost can play a role. However, another important factor is the "unfriendly" user interface of many applications and the complicated integration into the clinical environment. Development is sometimes done without sufficient communication with the clinician, who is the end user. However, this problem arises on both sides of the street. Clinicians often have limited interest in new tools that could help facilitate procedures in the future, but are not yet finally developed. The applications are at an early stage and still have many flaws and drawbacks. Very few are available as ready-to-use tools. Paradoxically, much input from clinicians would be important on the way to a ready-to-use solution, but this is often lacking. Another fact that could lead to mistrust of the new tools is the very small number of patients that are often included in studies to validate the tools. A very important feature of applications used in a medical context is of course the accuracy of the models and measurements. In many studies, the validation of the models is not convincing precisely because of the small number of patients and images that are used to develop and validate the models which may be enough to produce nice pictures and prove the feasibility of certain applications or when the model is used for training purposes. However, as soon as it becomes clinically relevant, the accuracy of the models must be close to one hundred percent. The method described in this paper is an interesting concept for an alternative method to validate the accuracy of a particular tool, in this case virtual reality modelling. The model was compared with other standard measures like 3D-MPR assessment and with manual measurements made possible by using the silicon cast of the original anatomy. Unfortunately, only the feasibility on one model was shown and the measurements were not repeated with multiple hearts or with multiple investigators performing the measurements. However, such a method has the potential to be useful for validation purposes, as the silicon model is naturally more available and consistent than patient data. The development of methods that do not require patient involvement and produce the same results is highly desirable. A big step has already been taken with the advent of machine learning algorithms used in cardiovascular modelling. Several entities are currently being studied, for example, aortic aneurysm. Liang et al. used datasets from twenty-five patients to sample 729 representative aortic shapes from all shape distributions described by a statistical shape model. Rupture risk was calculated using finite element analysis and the backward displacement method[22]. They could show that their approach is much faster than other methods and had a high risk classification accuracy. Currently, modelling heart structures and simulating therapies is already possible. Many concepts are on the way and developing rapidly. To be convincing and relevant in daily clinical routine, comprehensible validation to prove accuracy is essential. Otherwise, it is dangerous for clinicians to rely on virtual models. The path is already paved, but currently cardiac modelling, simulation and virtual reality are still in development and need to be considered as additional tools for planning and decision-making in cardiac interventions. In the near future, the incredible opportunities presented by such techniques are likely to play a major role in cardiovascular care. Small steps and studies like the one by Kenichi and colleagues are very important to continue on this path, so that virtual reality arrives in medicine and is not reserved for video game lovers.

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