Congenital Heart Disease

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EDITORIAL

Innovations in Pediatric and Congenital Cardiac Surgery

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Cardiac surgery is one of the youngest surgical disciplines. Only a century ago the heart and great vessels were not surgically approachable, and any pathology affecting these structures that needed surgery inevitably led to a poor prognosis [1]. The turning point came with the introduction of modern anesthesia and, above all, with the invention of extracorporeal cardiopulmonary circulation.

After nearly 70 years, technological progress has not stopped. Notions of biomedical engineering are an integral part of any modern surgeon's curriculum. Nowadays, the potential game changers in cardiac surgery are mainly related to imaging techniques and tissue engineering.

The Use of 3D Printing and Virtual Reality

Cardiologists and cardiac surgeons were among the first to take an interest in and adopt three-dimensional (3D) reconstruction techniques in order to improve clinical outcomes and patient care. Twenty years after the first attempts, at the present time many large centers have already engineers dedicated to the reconstruction and printing of complex clinical cases. This allows for a personalized approach leading to preoperative planning and counseling that has been shown to improve clinical outcomes and even mortality [2,3]. A digital 3D reconstruction includes simple but powerful algorithms to create a virtual accurate rendering of the patient's anatomy. This can then be examined, archived, or even used in the operating room to allow for real-time navigation.

As mentioned, one of the most important applications of 3D anatomical models is preoperative planning. This is particularly true for complex interventions and, when it comes to congenital heart disease, for particular anatomical variations or in case of reinterventions [4]. 3D printed models have proven their usefulness in a wide range of diseases [5]. Similarly, 3D models have been useful for the demonstration of the feasibility of complex operations such as biventricular conversions in patients who would otherwise have been candidates for palliative techniques and a univentricular physiology [6,7].

Another interesting recent application is the use of this technology for preoperative counseling [8,9]. This has proved particularly useful in the pediatric world to explain and raise awareness among parents about the diseases affecting their children. A recent application in this regard is the use of 3D printed hearts derived from fetal imaging, a very promising application of 3D printing.

More recently, virtual reality entered the medical field as a simulated experience that can be similar or completely different from the real world. In this way, it is possible to transform the real environment into a virtual one, maintaining the correct spatial references so that the experience can be as realistic and immersive as possible.

Over the years, a huge number of applications have been made in the medical field such as surgical simulation, which has been shown to significantly improve surgical performance [10,11]. However, the most important application for congenital heart disease is the unique ability to allow surgeons to carefully explore a patient's heart prior to surgery, familiarize themselves with the procedures they intend to perform, and evaluate the different possible approaches, all without the slightest risk for the patient.

From Biological Materials to Tissue Engineering

Due to their inherent nature, congenital heart disease predominantly afflicts children. Surgical outcomes have dramatically improved in recent years. However, the main problem is still represented by the fact that pediatric patients grow rapidly, while each foreign body or implanted device remains do not and therefore becomes undersized. This fundamental issue has been addressed in various ways, but above all with a restructure of the fundamental philosophy of the surgical approach: "trying to repair rather than replace". Yet, this is not always possible, especially when the affected structures are too damaged or completely absent.

Cardiovascular prostheses have always been essential in pediatric and congenital cardiac surgery. In this sense, the ideal prosthesis should have the following characteristics: mechanical strength and long-term ability to withstand continuous hemodynamic stress, little or no toxicity, little or no immunogenicity, biocompatibility, availability for emergency use, resistance to thrombosis *in vivo*, ability to resist infection, ability to integrate and grow with host tissues and, finally, a reasonable cost [12]. None of the currently available solutions have all these characteristics, so the surgeon is obliged to choose the most suitable material, which is usually a biological material.

Currently, available materials can be classified according to the origin of the implanted tissue. This can come directly from the patient such is the case of autografts (e.g., pulmonary root in the Ross operation), from a donor of the same species as for homograft (e.g., donation of valves or even entire organs), or from a donor of different species as for xenografts (the use of bovine pericardium for heart valves is widespread). Each solution has its own disadvantages, including shortage of available tissues, immune-mediated rejection, the need for permanent anticoagulant therapy, limited duration, and, ultimately, the inability of many of these to grow and integrate fully into the guest [13].

Recently, tissue engineering emerged as a branch of biomedical engineering whose purpose is to develop solutions of repair or replacement with biological tissue using cells, scaffolds, and conditioning techniques. Most of the approaches currently under development are based on the use of biodegradable scaffolds which, once implanted in the host, are gradually colonized by the host cells, degraded, and remodeled, achieving complete integration.

The processes used in tissue engineering can be divided into three main strands: *in vitro*, *in vivo*, and *in situ*. *In vitro* techniques use seeded scaffolds which are then grown in bioreactors and surgically implanted to complete the process. *In vivo* techniques, on the other hand, use the host organism as a bioreactor. The scaffolds are then implanted in temporary sites, so that the host directly colonizes the scaffold and creates a fibrous matrix which can then be removed and implanted in the final site. Finally, *in situ* approaches rely on the host's ability to directly colonize a scaffold implanted in the final location, making the final product completely integrated.

In conclusion, the future of pediatric and congenital heart surgery will increasingly depend on preoperative surgical planning and the development of prosthetic substitutes for a fully personalized approach. Hopefully, this will lead to enormous changes in the prognosis and treatment of our patients. The future is now, and we need to be ready.

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