Since its inception in 1896, cardiac surgery has evolved into a very successful specialty with the creation of new treatment options for previously untreatable diseases. The establishment of these new treatments drove the invention and development of new technology (e.g. the heart-lung machine), novel surgical materials and devices (e.g. suture material, grafts, mechanical and biological valves), as well as the introduction of new medications (e.g. heparin and cyclosporine), and the development of new surgical techniques by pioneering surgeons (e.g. cross-circulation, aortic surgery and heart transplantation). Beginning with the first successful suture of a laceration of the heart in 1896, further advances followed, encompassing many fields and providing management solutions for hitherto unmanageable cardiovascular diseases. Landmark innovations include:

(i) Suture for a stab wound of the heart (Ludwig Rehn, Frankfurt/Main, Germany, 1896).
(ii) Ligature of the patent ductus Botalli (Robert Gross, Boston, MA, USA, 1938).
(iii) Resection of a coarctation of the aorta (Clarence Crafoord, Stockholm, Sweden, 1944).
(iv) Palliative oxygenation in ‘blue babies’ (Blalock-Taussig shunt, Alfred Blalock, Baltimore, MD, USA, 1944).
(v) First use of the heart-lung machine (John Gibbon, Philadelphia, PA, USA, 1953).
(vii) Valve replacement (Alfred Starr, Portland, OR, USA, 1960).
(viii) Coronary artery bypass grafting (Vasilii Kolesov, St. Petersburg, Russia, 1964; Rene Favaloro, Cleveland Clinic, Cleveland, OH, USA, 1967).
(ix) Left heart assist device (Michael DeBakey, Houston, TX, USA, 1966).
(xi) Total artificial heart (Denton Cooley, Houston, TX, USA, 1969).

The speed with which technological developments have evolved has increased rapidly in recent years, facilitated in part by the growth of the Internet and its impact on global communications. Medicine, in general, and cardiac surgery, in particular, have benefitted from these new technologies: stem cell research, e.g. growth of a brain (Fig. 1) [1-2], tissue engineering and advances in mechanical circulatory support systems being some examples.

One very impressive new development is the 3D printer. The term ‘printer’ is misleading in the sense that objects are not being truly printed. The origin of this description for such machines originates from the fact that their mode of function is reminiscent of an ink-jet printer. However, instead of ink, synthetic material (e.g. polylactate) is being used.

3D print technology (also termed rapid prototyping, additive manufacturing) was developed in the 1980s and for some time was used only in industry. These industrial printers are still very expensive (several hundred thousand Euros) and are used mainly for product development in the aviation, car manufacturing and film industries (Fig. 2). Currently, these printers produce not only prototypes, but also industrial components, e.g. a Tornado of the British Royal Airforce has flown with replacement parts produced by a 3D printer. Researchers are also working to produce food from a 3D printer, e.g. ‘real’ meat using stem cells from a biopsy of beef from a cow. In addition, some researchers are also working on printing a house by using cement instead of cells or plastic materials.

These very expensive industrial printers are not yet in routine use in medicine. The concept of a 3D printer that could be available for every household in the future is seen as a real
possibility. Currently, several companies have developed much cheaper 3D printers for everyday use (e.g. German RepRap GmbH; Stratasys, Eden Prairie, MN, USA; MakerBot, New York, NY, USA; 3DS Systems, Rock Hill, SC, USA). However, 3D printers with a price tag of less than US$ 5000 (e.g. Cube, Builder 3D, Ultimaker and Witbox 2X) represent only 6.5% of the total turnover of 3D printers worldwide. In addition, they are still very slow: for example, it takes approximately 1 h to print a 15-mm artery. In New York, there is already a 3D printer store, where you can buy your own 3D printer.

Without doubt, 3D printers are slowly entering our daily life. This will also open the door for the use of 3D bioprinters in medicine (Fig. 3). Even though the emergence of this technology in hospitals is taking place very slowly, and has so far only been applied in animals, several prostheses and implants have already been produced with 3D printing. For example, researchers just recently ‘printed’ a moveable hand (Fig. 4). In addition, ears, noses, finger bones and skin can also be bioprinted (Wake Forest Institute for Regenerative Medicine, USA).
In Washington’s Childrens’ National Medical Center, 3D prints of a patient’s heart are being produced to better plan procedures in congenital cardiac surgery. These models reveal important information preoperatively. At the Stanford University Department of Cardiothoracic Surgery, groups are also working on producing 3D models from computed tomography data to better prepare for a complex operation the following day.

At the visionary end of this spectrum is the idea of investigating biological materials (stem cells, etc.), in the hope of one day 3D-printing cells, valves, vessels or even organs, e.g. the entire heart. There would no longer be any organ shortage and patients with terminal heart failure would get their new hearts from their own cells without the need for postoperative medications! Bypass materials would be made out of your own cells. Your new heart valve would come out of the bioprinter! Even though this may still be science fiction today, just dare to think about the new treatments in fields for which there are no treatment options yet available. In China, mini-kidneys are already produced. However, there is no doubt this cutting edge technology could also be used for ethically questionable purposes, e.g. to print embryos, weapons, etc.

Please look out for more on this topic in EJCTS. In the next three issues, we will have Reviews about this new technology. Yoo and colleagues will give an overview of ‘Bioprinting technology and its application’ [3]. Schwandt and his colleagues [4] will present their application to human heart valves (Fig. 5) and Tovar and co-workers [5] will show the potential of this new technique for the production of vessels (Fig. 6). In addition, there are regular manuscript submissions dealing with the possibilities of 3D printing in cardiothoracic surgery [6].

REFERENCES


