Editorial

The use of 3D printing in cardiac surgery

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In this issue, Chen *et al.* present a case report where a patient with a right-sided aortic arch, Kommerell's diverticulum (KD) and an aberrant left subclavian artery underwent surgical repair, and the surgeons printed a patient-specific three-dimensional (3D) model before surgery to serve as a surgical guide. Using the 3D printed model, they managed to select the size of the frozen elephant trunk for implantation (32 mm) and visualize the aorta and its branches pre-operatively, to decide on the section to resect, reducing operative time. The patient made an uneventful recovery and postoperative computed tomography (CT) scan of the aortic arch demonstrated graft shape, position and patency.

In many fields, such as the aeronautical industry and global navigation industry, the use of computers, virtual simulation and various technological advances have greatly improved the efficiency, accuracy and precision of tasks previously manually performed by humans. Surgery itself has increasingly become complex and miniaturized with the advent of laparoscopic surgery, robotic surgery and other forms of minimally invasive surgery, in order to create smaller wounds, reduce post-operative pain and decrease wound healing time. At the same time, computer assisted surgery has been implemented in various surgical disciplines, such as orthopedic surgery (1), stereotactic neurosurgery (2), virtual reality and augmented reality in plastic surgery (3) and surgical navigation in oral and maxillofacial surgery (4,5). There is also increasing discussion regarding the use of artificial intelligence in medicine (6).

Pre-surgical planning has also improved with technology, with preoperative 3D reconstruction of radiographic CT images, virtual simulation of surgery (7), and preparation for surgery using stereolithographic or 3D printed models (8), custom made surgical instruments (9) and patient-specific surgical implants (10). There are a number of surgical specialties where surgical planning, 3D printing and computer aided design are particularly relevant, namely specialties that involves reconstruction (11), such as craniofacial reconstruction surgery, orthopedic surgery, where the patient suffers from a defect usually due to congenital malformation, trauma or malignancy. Congenital heart surgery (12,13) is another field where the reconstructed anatomy is of paramount importance as the resultant blood flow and patient hemodynamics are directly affected by the surgeon's reconstruction. This is especially difficult as no two patients have identical anatomy, not only the intracardiac anatomy, but also the extracardiac anatomy (14), such as the chest wall and the relation of the heart to the chest wall. Taking patient specificity into account using 3D printing technology is thus very relevant and recent papers have reported useful applications (13-16). Chen *et al.* should be congratulated for their valuable use of 3D printing technology to aid in the surgical treatment of complex aortic disease with a good outcome.

Recent increased availability of 3D printing technology has led to extensive use in emerging industries, which has produced a variety of interesting legal implications. The

Food and Drug Administration (FDA) is currently working to develop a plan for regulating not only 3D printed devices and drugs, but also how to treat the 3D printers and software for patient safety. In December 2016, the FDA explained in a Consumer Update that they view their role in medical applications of 3D printing and the review of 3D printed devices as Regulate, Research, Resource (3Rs) (17), in order to protect public health. For example, in March 2017, Materialise recently obtained FDA approval to 3D print patient-specific radius and ulna osteotomy orthopedic surgery guides for use in children with fractures of the upper limb (18). As 3D printing technology continues to develop, it will be important to follow the relevant regulatory agencies, going forward.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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