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Physical models of the foetus created using magnetic resonance imaging, computed tomography, and ultrasound data: history, description, and potential uses

Modelos físicos de fetos criados por meio de dados da ressonância magnética, tomografia computadorizada e ultrassonografia: histórico, descrição e potenciais aplicações

Editorial

Improvements in the technology for non-invasive acquisition and visualization of images have brought about great advances in medicine, particularly in the diagnostic and prognostic assessments of foetal anomalies[1]. In general, ultrasound (US) and magnetic resonance imaging (MRI) are two techniques that are used to acquire images of the foetus and uterus during pregnancy. The computed tomography (CT) also provides detailed foetal images, especially those of the foetal skeleton from the 30th week; however, its application is limited to the diagnosis of complex skeletal disorders because of the effects of ionizing radiation[2].

The earliest attempts to graphically represent the foetus date back to the 15th century A.D. Artistic renderings from that period onwards can be found in museums and private collections worldwide. Leonardo da Vinci is among the artists who refined the quality of the foetus visual representation. By means of several anatomical studies, da Vinci illustrated the entire process of foetal development.

The usage of physical models in medical teaching began in Italy during the Renaissance. At that time, highly realistic wax models began to be employed to accurately represent different parts of the human body, including changes in the bodies of pregnant women. The Florentine school also used models to teach anatomy, with the aim of dissemination of morphological and anatomical information without the need of the direct observation of a cadaver. Various models can still be observed in the permanent exhibition at La Specola, in the Museum of Zoology and Natural History in Florence, Italy, which was founded in 1775. Until the early 19th century, it was the only scientific museum specifically created for the general public[3]. Another significant initiative occurred in France around 1778, when Madame Du Coudray designed and produced a set of teaching models made of different types of fabric and materials known as "La Machine". These realistic examples of the mother-foetus couple were used in many villages for teaching and spreading information about the birth process[3,4].

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US has given us a means to study the foetus, and it has been used in obstetrics for more than 30 years. At present, it is the predominant method for the routine screening of foetal malformations due to its relative simplicity and safety for the mother-foetus couple. MRI is a non-invasive diagnostic technique that provides sharp images of the human body and is complementary to US[4].

Today, many companies are dedicated to producing physical teaching models that represent all stages of pregnancy. These models, with some of them being of pathological cases, are used in medical schools and related fields of study for inspection and palpation sessions[3,5,6]. Virtual three-dimensional (3D) modelling has gained great momentum in recent years because of the development of high-performance software used in the areas of engineering, architecture, and design. It has also become increasingly easier to use, facilitating the visualization of 3D images, which can be generated from data obtained from conventional imaging techniques (e.g. US, CT and MRI) or from other techniques like laser scanning. The post-processing of medical imaging data may provide new applications for 3D representation, facilitated by technological advances in virtual 3D modelling software.

Only two studies using US data to construct 3D models have been conducted. Blaas et al.[7] calculated the volume of embryos and foetuses in the first trimester of pregnancy, transforming such area into a virtual model. The second study, conducted by Nelson and Bailey[2], converted 3D data from US into a body surface/shape represented in the form of polygons, which is then transposed onto physical models using various types of rapid prototyping devices, allowing the creation of solid 3D objects. This was considered the first attempt to change US data into 3D physical models.

The segmentation and reconstruction techniques created for foetal modelling can be applied to the construction of both virtual and physical models constructed using US, MRI, and CT data[1,8-11]. 3D printing technologies allow the conversion of 3D virtual models into physical ones rapidly, easily, and precisely. In the construction process, a 3D data file is moved to a rapid prototyping machine that builds physical models by overlaying thin layers of raw materials[6,12,13] (Figure 1).

Werner et al.[9] described the use of physical models in foetal research, an area in which there are few studies of 3D digital modelling. Their preliminary research suggests possible uses in representing interactions between parents and foetus during the prenatal period, physically recreating uterine cavity at pregnancy and recreating scale anatomical models of the foetus. A major concern of the study was the difficulty to obtain high-quality images that could be manipulated using 3D modelling software without a loss of accuracy. Foetal movements through image acquisition were a major difficulty, especially in MRI studies. This problem is less significant in US because images are acquired at real time and may be frozen during movement. However, limitations of grey scale images decrease the lower contrast resolution of US in some cases. The quality of the process is directly associated with the accuracy of the mathematical data that will be used to generate physical models. The pictures are achieved in layers, which are overlapped to create models[9].

Figure 1. Virtual and physical model of a 32-week-old foetus obtained using ultrasound and magnetic resonance imaging scan data and printed using a ZCorp 3D printer and plaster-based powder

This study sought to demonstrate the advantages of 3D visualization in comparison with traditional visualization techniques. Using such modality, the region of interest can be evaluated and manipulated by the observer to clearly appreciate the physical characteristics of anatomical structures and their spatial relationships. In this respect, rapid prototyping served as a 3D visualization method, forming a powerful tool for the visualization of various anatomical structures. The resulting models represent an important palpable model for teaching and helped conveying more comprehensible information to pregnant women[9].

It is believed that physical models will assist in the palpatory and interactive study of complex abnormalities in various disciplines in the near future. In addition, these techniques allow the creation of 3D models with the physical characteristics of the foetus, which may be useful for providing a more direct emotional connection of prospective parents to their unborn children.

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