The Fetal Heart

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Chapter 10

Summary

Chapter 1 During the last decade prenatal sonographic assessment has become an integral part of obstetric care. Fast technological advances over the last years have made it possible to assess the human fetus in three dimensions. The clinical use of cardiac three-dimensional (3D) ultrasound, however, is still unclear.

The detection rates of congenital heart disease in conventional ultrasound screening programs are suboptimal. The examination of the fetal heart is a technically difficult part of a fetal ultrasound scan. 3D ultrasound might offer a solution to this problem. The acquisition of digital 3D volumes might make the screening less dependent on the skills of the sonographer. Moreover, with a digital data volume available, automated cardiac screening becomes a possibility.

Additionally, 3D ultrasound offers a new way to obtain measurements of the fetal heart. There are different conventional methods to evaluate the fetal cardiac function. These methods, however, are known to be limited in accuracy and reliability. An accurate and reliable method to assess the fetal cardiac function could be very useful in the management of a number of fetal conditions. Using 3D ultrasound and spatiotemporal image correlation (STIC) it is possible to measure the volumes of fetal heart chambers on different moments during the cardiac cycle. These measurements could provide estimates of parameters of the fetal cardiac function.

In **Chapter 2** we evaluate the feasibility of an automated 3D software tool for the extended basic cardiac screening in routine ultrasound practice (SonoVCAD). In this study we have shown that 3D ultrasound can be introduced into routine ultrasound practice without much difficulties. All four sonographers acquired images of sufficient to good quality in more than two-thirds of the cases. Automated retrieval of all cardiac planes necessary for an extended basic cardiac examination was successful in less than half of the cases. Currently, SonoVCAD still lacks the consistency to be clinically feasible for cardiac screening purposes.

In **Chapter 3** the feasibility of four-dimensional (4D) ultrasound using STIC in routine fetal echocardiography was systematically analyzed. STIC creates a virtual 3D cardiac cycle displayed in a cineloop. In three-fourths of the examined women successful STIC volumes could be acquired. Around two-thirds of the acquired volumes was of sufficient to high quality. Our results showed that sonographers do not have to be specifically experienced in 3D/4D ultrasound imaging to acquire high-quality STIC volumes. 4D ultrasound using STIC is feasible in clinical practice. Our result further stress the importance of training and experience of the sonographers in the successful application of 4D ultrasound.

The results in **Chapter 4** show that it is possible to perform valid volumetric measurements using 4D ultrasound and STIC. Using a customized miniature balloon model, volumes comparable to fetal cardiac chambers were measured. Three different methods to obtain volumetric measurements were compared. 3D volumetric measurements were found to be accurate from 0.5 mL onward although all methods underestimated the actual volumes to a certain extent. A method of manual tracing and summation of multiple slices (3D slice method) proved most useful when applied to in-vivo investigations.

The reliability of volumetric measurements obtained from 4D volumes acquired using STIC was evaluated in **Chapter 5**. We collected volume datasets from two sources: fetuses over a range of gestational ages and also from a miniature balloon model. Volume calculations were obtained by the 3D slice method. The datasets were analysed by three observers repeatedly. Measurement errors of balloon volumes were small and reliability was good. In the fetus, measurement errors shown to decrease with operator experience and reliability were better for stroke volume than for ejection fraction.

In **Chapter 6** image reconstruction artefacts during the use of 4D ultrasound and STIC are presented. These artefacts were encountered during the validation study presented in chapter 4. The distorted shape, the thickened wall and the blurred speckles observed in the spatiotemporal rearranged volumes, in our opinion, were the result of gating artefacts. These observations can be important for the understanding of the methodology of STIC and thus for the analysis of STIC volumes in daily practice.

Reference values for left and right ventricle volumes, and for indices of fetal cardiac function are presented in **Chapter 7**. In this prospective longitudinal study, STIC volumes were acquired periodically from 12 weeks of gestation onwards. This study establishes reference values from 12 to 30 weeks of gestation. STIC seems to overcome many of the pitfalls of conventional ultrasound methods and has the potential to become the method of choice for cardiac volumetric assessments.

Different non-invasive techniques have been evaluated over the years, almost exclusively by echocardiography. The fast development of new imaging modalities has added an enormous amount of knowledge to this field of research. New non-invasive techniques, some adopted from adult cardiology have been studied in the fetus. **Chapter 8** presents an overview of the current state of the field of non-invasive assessment of fetal cardiac function.

Chapter 9 provides a general discussion of the results of this thesis and suggests future research strategies to further explore the many possibilities of 3D ultrasound of the fetal heart.