CHAPTER 18

Conclusions and Future Developments

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Abstract Despite the dramatic improvement in the quality of diagnostic ultrasound Congenital Heart Disease (CHD) are the most common and less frequently diagnosed prenatally anomalies. This is mainly secondary to the difficulties in training expert and dedicated sonographer in the study of fetal heart. Four dimensional (4D) sonography may overcome operator dependency allowing offline 4D examination of the fetal heart. This approach opens the possibility of performing a virtual echocardiography in fetuses at high risk or suspected to be affected by a CHD through networking capabilities. As a consequence virtual echocardiography may allow to extend the benefit of advanced of cardiac examination in patients followed in peripheral centers thus reducing the number of unnecessary referral to tertiary centers.

Key Words: Congenital Heart Disease, Screening, 4D Echocardiography, Spatiotemporal Image Correlation (stic), virtual Echocardiography. Virtual Reality.

Congenital heart disease (CHD) are the most common structural anomalies, commonly estimated to be 8/1000 live births (chapter 1). Despite their high prevalence and the clinical importance of their identification during pregnancy, thus allowing to evidence associated structural and genetic and to improve the perinatal outcome, the results of the screening programs up to now reported are far from to reach acceptable levels of diagnostic efficiency (chapter 2).

A detailed study of fetal cardiac anatomy (chapter 3) improve the possibility of diagnosing CHD, but the degree of experience of the sonographer has a significant impact on the quality of the examination of the fetal heart and as a consequence of the rate of detection of major CHD. Indeed, it has been shown that the learning curve of a sonographer already confident in obtaining the four chamber view to properly visualize also the outflow tracts requires a training time of up to 3 years [1].

The revolution in diagnostic ultrasound occurred with the advent of four dimensional (4D) applications may overcome these problems of operator dependency allowing offline 4D examination of the fetal heart. The use of the SpatioTemporal Image Correlation (STIC) algorithm allows examination of the fetal heart within a real-time 4D volume, displaying the cardiac cycle in a cineloop. With this technique it is possible to acquire a volume starting from the standard four chamber view of the fetal heart and then off line navigating inside the volume in a multiplanar way obtaining all the diagnostic planes necessary. We recently described a technique of analysis , the "3 steps technique" (Fig. **1**), that makes it possible to obtain in less than 1 minute the four chambers view and the outflow tract views. (2).

In video 1 the three simple steps of scrolling and rotation on Y axis are shown (in this example the total amount necessary to complete the heart study was 25 seconds)

In this way every examiner able to obtain a four chamber view of the fetal heart may acquire a volume cardiac datasets. Once acquired, the "digital heart" can be examined by searching the conventional planes (e.g. outflow tracts) or to obtain offline any other virtual cardiac plane (e.g. en face view of the ventricular septum), views of the fetal heart that are difficult or impossible to obtain with conventional 2D ultrasound.

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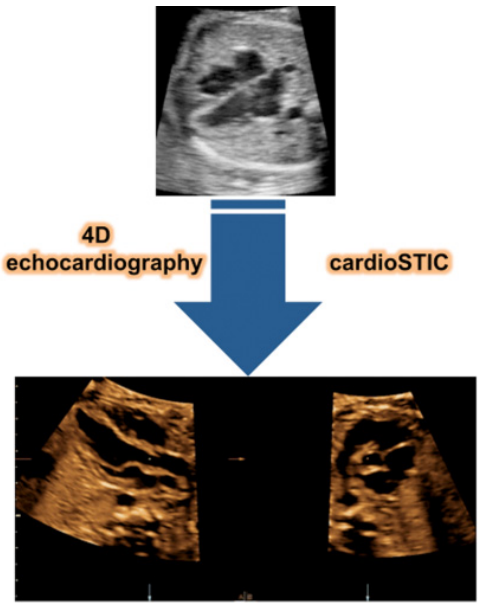

Figure 1: (video 1) Possibility of obtaining the outflow tracts from the 4 chamber view using the "3 steps technique" [2] from acquired 4D cardioSTIC volume data sets.

This approach can be also used to avoid unnecessary referrals for echocardiography to tertiary centers. Indeed the prevalence of CHD in pregnant women with traditional risk factors is extremely low and as shown in Fig. **2**.

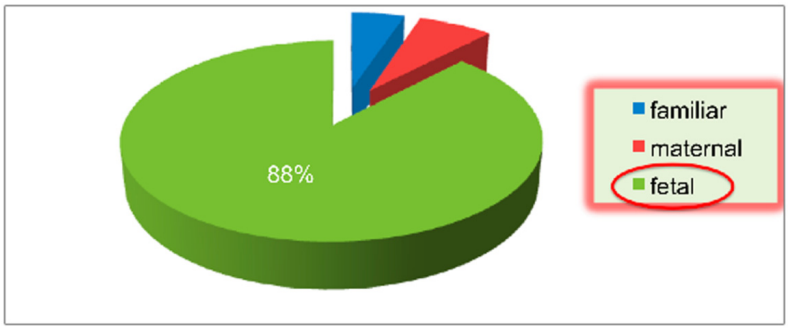

Figure 2: Prevalence of CHD in the population referred to the Department of Obstetrics and Gynecology Università di Roma Tor Vergata according to the risk factor

In our experience 88% of CHD diagnosed were found when a fetal risk factor was present while the prevalence is extremely low when maternal or familiar risk factors are the indication of referral. Of interest is that among fetal risk factor the two most effective risk subcategories were the abnormalities in second and first trimester (nuchal translucency NT) screenings (Fig. **3**).

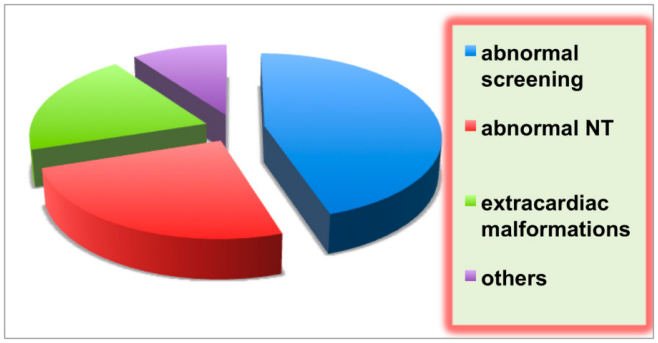

Figure 3: Prevalence of CHD in the population referred to the Department of Obstetrics and Gynecology Università di Roma Tor Vergata among fetal risk factors. The most frequent subgroups were abnormal second trimester screening (blue) and increased nuchal translucency (red)

The availability of a cardiac volume datasets acquired properly may allow to perform a virtual echocardiography. This may be performed off-line after the end of the examination of the patents directly by the sonographer or supervised by an observer with more detailed experience. In fetuses suspected to be affected by a CHD or with "classical" risk factor (i.e. familiar, maternal) the cardiac volume can be sent using internet networking capabilities to a referral center [3]. This approach has been already proved particularly efficient in countries in which patients are screened far from referral centers [4, 5].

Virtual echocardiography allows to extend the possibility of having an advanced cardiac examination to pregnancies followed in peripheral unit and avoid unnecessary referral. This approach allows also the identification of patients in which the referral is indicated for performing a conventional echocardiography in tertiary unit. (Fig. **4**).

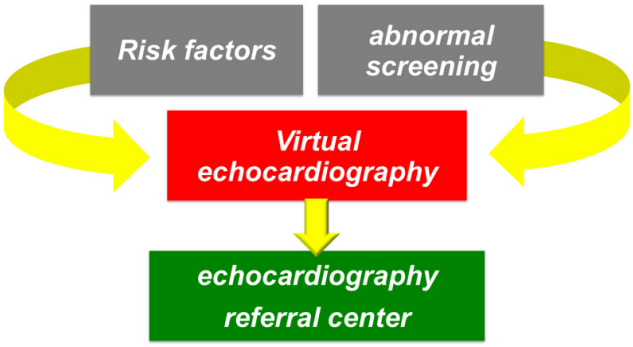

Figure 4: Flow chart of the admission criteria to conventional echocardiography in presence of the possibility of performing a virtual fetal heart examination using internet networking capabilities to a referral center.

In the near future, by using the new diagnostic advances allowed by 4D ultrasonography, it will become possible to refer only selected patients to experts team in fetal cardiology where a detailed antenatal diagnosis can be obtained and a multidisciplinar discussion done with the parents regarding the risks, surgical intervention required and long-term outcome (Fig. **5**).

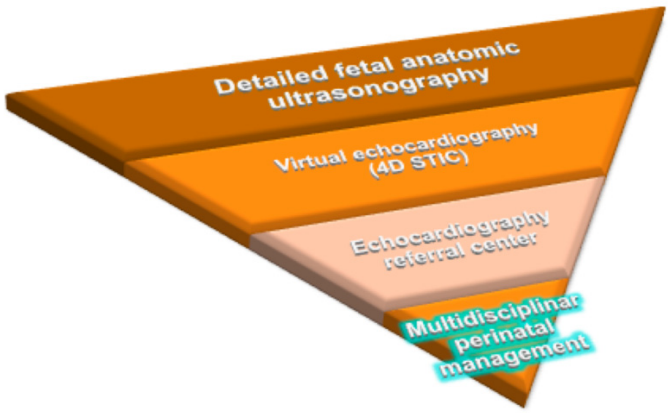

Figure 5: Diagnostic steps to be followed in the management of a fetus with CHD

Further future developments will be dependent by the technology available but there are already some evidences of the possibility to generate non-linear virtual reality object movies of volume images acquired prenatally [6]. Virtual

reality have been currently applied to assist in complex surgical procedure in medical imaging and education and there is no doubt that will be applied in the near future also to the study of the fetal heart.

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