Current Experience and Prospect of Internet Consultation in Fetal Cardiac Ultrasound

Fernando Viñals

Clínica Sanatorio Alemán, Centro AGB Ultrasonografía, Concepción, Chile

Key Words

Congenital heart defect • Fetal echocardiography • Fetal heart • Internet • Prenatal diagnosis • STIC • Telemedicine • Three-dimensional ultrasound

Abstract

Objective: Internet consultation with volume ultrasound is one of the strategies studied to attempt to improve prenatal detection of congenital heart defects (CHD). **Methods:** This methodology is a form of telemedicine in which a volume block of the fetal heart (either static 3D or STIC volume dataset) is acquired by an operator (non-expert) and transmitted via internet for remote consultation. Naturally, this methodology is suitable for remote locations or those with less access to specialists able to confirm or rule out a prenatal diagnosis of CHD. **Results:** The use of internet consultation demonstrates that some intracardiac anomalies can be ruled out and others confirmed, thus enabling the parents to prepare for the likely outcome of the pregnancy and to modify the perinatal management. **Conclusion:** Internet consultation offers a good alternative for fetuses from more isolated locations with a high risk of CHD. Moreover, this methodology could become an interesting tool for distance learning and training.

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Introduction

For over a decade, attempts have been made to improve prenatal detection of congenital heart defects (CHD). Alongside advances made in ultrasound technology, the standards for ultrasound screening of the fetal heart have been revised and agreed upon by the different medical associations, who have also made efforts to offer training and further qualifications to ultrasound professionals [1, 2]. The detection of CHD during routine scanning is also improving, although perhaps rather more slowly and irregularly, requiring considerable effort from educators and ultrasonographers in terms of training and capacitation [3]. In spite of this, a recent study among three major tertiary pediatric centers in northern California once again brought to the fore the question of why we manage to diagnose so few cases of CHD [4]. Friedberg et al. [4] reported a prenatal detection rate of 28% of major CHD, despite 99% access to screening ultrasound. There was a significant difference in the diagnostic skills in university centers versus community-based ultrasound centers.

Internet consultation with volume ultrasound is one of the strategies studied to attempt to improve prenatal detection of CHD [5, 6]. We can define this methodology

as a form of telemedicine in which a volume block of the fetal heart (either static 3D or STIC volume dataset) is acquired by an operator (non-expert) and transmitted via internet for remote consultation. Naturally, this methodology is suitable for remote locations or those with less access to specialists able to confirm or rule out a prenatal diagnosis of CHD. It must be remembered that although termination of pregnancy is legal in many countries, attitudes towards termination due to fetal heart disease vary with regard to judgment of the severity of the problem or the influence of associated anomalies [7]. On the other hand, in most of Latin America, termination of pregnancy is illegal or only legal under certain conditions. In these cases, the main objective of cardiac screening is to optimize perinatal management, particularly for ductal dependent lesions [7]. This includes preparing parents for a likely outcome and planning the timing, mode and site of birth in order to deliver an infant in the best possible hemodynamic condition [8]. As the outcome of congenital heart surgery has improved, it has become increasingly important to focus not only on surgical survival, but on the overall outcome, thus reaffirming the need to reduce perinatal acidosis, hypoxemia, and shock [9–12]. These conditions all require opportune and competent neonatal medical attention which may only be possible through timely and accurate prenatal diagnosis.

Several questions must be answered before considering remote consultation with volume ultrasound.

Is It Feasible for a Remote Sonographer to Acquire Good Volumes?

An adequate acquisition is an essential step towards achieving an adequate volume display and subsequent analysis. Various factors influence the success of a protocol for volume acquisition of the fetal heart: firstly, if consecutive patients will be examined or just selected cases; secondly, if extra time can be allowed for unfavorable fetal positions, and thirdly, if there is a standardized acquisition technique with feedback regarding technical errors. If the acquisition protocol includes more than one volume, there is a greater chance the relevant information can be obtained than if only one volume is analyzed. There are also a number of technical factors that influence the quality of the volume acquired [13, 14]. A good-quality STIC volume is usually the result of appropriate settings for the ultrasound system and an acquisition time of at least 10 s. Even if the technique is adequate, fetal movement may create artifacts that influence the vol-

ume quality, even when the acquisition is carried out by experts. If the acquisition is made according to protocol and using static 3D, a fast acquisition with good resolution and minor exposure to artifacts can generally be achieved, but at the cost of losing the functional information included in the heart movement and cine [15]. Some reports address the question of the ability of non-expert operators to acquire good-quality volume datasets of the fetal heart [16–18]. It would be logical to assume that with practice and experience, combined with ongoing improvements in image resolution and an expected reduction in the time required to achieve acquisitions, this first essential step in volume ultrasound should become increasingly straightforward.

How Feasible Is the Transfer of Volumes?

Today, the development of the internet, ever-increasing connection speeds, ever-greater webmail storage and transfer capacities, and the possibility of using a dedicated server have considerably reduced the limitations experienced only a few years ago, and this trend will probably continue into the future [5]. Alongside this, the volume datasets can be subjected to wavelet compression, thus reducing their size and further facilitating internet transfer. A recent collaborative study demonstrated that the average time required to upload or download STIC volume datasets into a dedicated server was 2 min (range: 1–3 min) [19].

Once a Volume Has Been Acquired and Transmitted via the Internet, Can It Be Adequately Interpreted Remotely?

Specialist centers have reported an acquisition success rate of 95% for STIC volumes, achieving adequate visualization of the fetal heart in 70–90% of cases [20, 21]. However, few studies have assessed the diagnostic success rate when the 3D/4D acquisitions of the fetal heart were carried out by non-expert operators [5, 6, 18]. In my opinion, two different factors must be taken into consideration prior to any critical analysis of the accuracy of the method. Firstly, operators who are motivated and enthusiastic to learn the acquisition method and correct their technique over time based on feedback from a remote reviewer will produce the good-quality volume datasets so essential for any subsequent successful analysis [5, 6, 16, 17]. Almost 2 decades ago, Sharland and Allan [22] already

demonstrated that the enthusiasm and attitude of the physicians involved in fetal heart screening was often reflected in the results. The figures produced with local STIC acquisition by a general obstetrician performing antenatal ultrasound and subsequent remote analysis by an expert are similar to those from specialized centers when examining fetuses from 12 weeks to near term [23, 24]. The second point to consider is this: should the cardiac structures/views included in the volume datasets for remote analysis provide enough information to carry out an extended cardiac examination or is it also necessary to generate diagnostic rendering views of the fetal heart or attempt to accomplish a complete fetal echocardiography [17]? A recently reported study helps to keep our feet on the ground. Seven international centers with expertise in STIC ultrasonography uploaded normal and abnormal heart volumes for blind analysis. Ten percent of volume datasets studied had limited clinical value due to poor image quality, insufficient anatomical information or artifacts [19]. Some physicians only requested internet consultation to reconfirm normal cardiac anatomy, while others would confirm a suspected structural defect. Data available to date suggests that at least 3 out of 4 times, a trained and motivated non-expert operator can achieve an adequate and sometimes more than adequate acquisition, to enable subsequent remote analysis of the volume dataset to reach accurate conclusions regarding the fetal heart. The fact that the volume display and analysis is also potentially operator dependent should also be taken into consideration. It has been shown that standardized analysis could be reproducible and that there is a learning curve for manipulation and analysis of the volume datasets [25–27]. The increasingly wide-spread use of post-process software along with more uniform standards amongst experts can probably explain the recently reported excellent intra-observer, inter-observer, and inter-center agreement in the identification of fetal cardiac structures and final cardiac diagnosis [19].

Is There Any Practical Benefit for the Patient?

One of the most important aspects of prenatal diagnosis is the preparation of the parents for the implications of a diagnosis [8]. Certain circumstances are shared by many developing countries: a geographical situation with isolated localities, scarce or centralized (in the capital city) resources and few fetal and/or pediatric cardiologists. The use of internet consultation demonstrates that some intracardiac anomalies can be ruled out and others

confirmed, thus enabling the parents to prepare for the likely outcome of the pregnancy and to modify the perinatal management [5]. Naturally, an accurate diagnosis is necessary to provide a clear picture of the prognosis and outline the perinatal management. Again, an adequate volume acquisition is essential for an effective volume analysis in order to achieve an accurate and conclusive diagnosis, an essential step to helping parents obtain access to the best form of management available to them.

How Many Experts Are Ready and Willing to Carry Out Remote Diagnosis?

Internet consultation for fetal cardiac ultrasound is time consuming. Although the median time required to analyze a volume acquired at a tertiary level was 6 min (range: 2–15 min) [19], naturally, longer time spans may be necessary to reconstruct poorer-quality volume datasets. Such reconstruction and analysis takes longer than regular screening of the fetal heart by extended examination [2]. Furthermore, dedicated software is needed, which obviously has a cost, while the consultation itself is free of charge. Another important aspect for experts concerns the degree of certainty that can be placed on a diagnosis based on images generated by a distant operator, since several limitations, including the lack of information regarding an eventual extracardiac lesion, could affect the analysis. This last point leads us to ask ourselves who should or could ultimately take on the medical-legal responsibility for the diagnosis. In current circumstances, I do not believe there is wide-spread enthusiasm from experts to offer their services for a formal program of remote diagnosis, with all the time demands and dedication that such a program implies. However, I do believe the need to seek a second opinion from an expert is often unaddressed, and internet consultation offers a simple way to provide this if volume ultrasound technology is available. Approximately 10% of the pregnant population shows in their anamnesis a condition that increases their risk of giving birth to a newborn with heart defects (family history, maternal diabetes, teratogens exposure, etc.). Other fetuses prove to be at risk of carrying CHD due to nuchal translucency of over 3.5 mm or reversed flow in the ductus venosus or tricuspid regurgitation. In others, a suspicion of CHD may arise after routine screening. Lastly, some extracardiac anomalies indicate an elevated risk of CHD [28]. All the aforementioned cases are an indication to perform a fetal echocardiography but, within the context of what was mentioned in the previous para-

graph, internet consultation could be a good alternative for more isolated areas or those without access to experts.

There is no space at this point to consider the implementation of a massive fetal cardiac screening program with volume ultrasound [23]. On the other hand, if only those cases that proved more difficult to interpret or displayed possible abnormalities were referred for remote analysis, we would run the risk that if the local cardiac screening was inaccurate, underdiagnosis would continue to occur. In prenatal diagnosis, a self-critical attitude is healthy, and retrospective review of the number of CHD cases detected in a determined period of time is advisable. In view of the major CHD incidence rate, one would expect to suspect or diagnose a defect with these characteristics in approximately 3–4 of every 1,000 fetuses assessed. If detection rates do not reach this level or a major and/or critical heart defect has remained undiagnosed, one alternative could be to participate in a volume ultrasound and internet consultation program. Theoretical and technical training would be required, but this could be carried out remotely, even via e-mail. Local physicians would need STIC-capable ultrasound systems.

Patient recruitment deserves special comment. A critical analysis of diagnostic performance would require consecutively qualifying patients to be included in the program, irrespective of how busy the clinics were at the time. This would avoid the problem of acquiring or transmitting only 'nice' volumes, while avoiding more complex or difficult cases. Furthermore, if this methodology were to be used only for sporadic cases, the local operator involved in the volume acquisition would lack the expertise to acquire volumes of sufficient quality to identify the structures and views of the fetal heart and thus confirm or rule out CHD. The volume datasets must be reviewed remotely and all comments, favorable or otherwise, must be sent as feedback to local physicians. Close contact between the remote experts and the ultrasound units is es-

sential in order to ensure adequate training [3, 28, 29]. A good-quality volume dataset is only achieved when the operator has carefully chosen the settings in order to obtain a high-quality 2D image, searched for the best acoustic window to avoid shadowing artifacts, and competently handled the settings for 3D/4D acquisition. If the aforementioned points are fulfilled and the operator obtains a transverse view of the thorax at the level of the four-chamber view, it is very likely that the volume information would be complete enough for remote analysis. The volume acquired can also be reviewed locally offline, even with the ultrasound system itself. The training for such a procedure appears to be short and allows an operator, without any experience in insonating the outflow tract, to detect anomalies at this level [30]. It is very likely that this methodology would not only improve the quality of volume acquisitions, but also facilitate the understanding of the information contained in the transverse section views and the spatial orientation of the great arteries. It is our impression that the physicians involved in our studies were at the lower end of mid average ultrasound capabilities. However, over the last few years, ultrasound operators have become much more highly qualified and able to evaluate the fetal heart with greater precision and detail.

It is difficult to draw any conclusions in the absence of large-scale prospective studies. However, internet consultation offers a good alternative for fetuses from more isolated locations with a high risk of CHD. Moreover, this methodology could become an interesting tool for distance learning and training. Today, volume ultrasound is experiencing an increasingly generalized usage alongside enormous developments in internet technology. Seen from this perspective, the methodology offers benefits for both the patients and the doctors involved in one of the most challenging areas of prenatal diagnosis.

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