

SPATIO-TEMPORAL IMAGE CORRELATION (STIC): A NEW TECHNIQUE FOR FETAL HEART EVALUATION*

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Abstract Although congenital heart defect is the most frequent anomaly in newborns, its antenatal detection rate through conventional ultrasound remains low. 3D and 4D ultrasound technology was developed early in the nineties, bringing great benefits in obstetrics, especially in cases of dubious diagnosis at 2D ultrasound. The spatio-temporal image correlation (STIC) is a significant development in the field of 4D ultrasound. A software coupled with a Voluson 730 Expert equipment allows a volumetric acquisition of the fetal heart and its vascular connections. Volumetric analyses are performed in multiplanar and surface rendering modes or, alternatively in association with color Doppler. Major advantages are fast images acquisition and the possibility of a later analysis by fetal echocardiography specialists. Differently from 2D ultrasound, this technique may be applied for evaluating any congenital cardiopathy because of the increased number of frames acquired from a specific anatomical region. Main disadvantage is related to the necessity of fetal immobility. The higher diffusion of this method may improve prenatal detection of heart malformations since volumes data captured by a sonographer may be sent through the Internet for analysis by fetal echocardiography specialists.

Keywords: Congenital heart defect; Prenatal diagnosis; STIC.

Resumo *Spatio-temporal image correlation (STIC): nova técnica para avaliação do coração fetal.*

As malformações cardíacas são as mais frequentes anomalias congênitas ao nascimento, entretanto, a sua detecção pré-natal pela ultra-sonografia convencional permanece baixa. As ultra-sonografias de terceira e quarta dimensões surgiram no início da década de 90, apresentando grandes aplicações em obstetrícia, principalmente nos casos de diagnósticos duvidosos à ultra-sonografia bidimensional. O *spatio-temporal image correlation* (STIC) representa grande avanço na área de ultra-som de quarta dimensão; constitui-se em um *software* acoplado ao aparelho Voluson 730 Expert, que permite a aquisição volumétrica do coração fetal e suas conexões vasculares. As análises volumétricas são realizadas nos modos multiplanar e de renderização, podendo-se também utilizar o Doppler. Apresenta, como grandes vantagens, a aquisição rápida e a possibilidade de análise posterior por especialistas em ecocardiografia fetal. Pode ser aplicada para a pesquisa de quaisquer cardiopatias congênitas, pois permite a aquisição de qualquer plano, diferentemente do ultra-som bidimensional. Sua principal desvantagem está relacionada aos movimentos fetais. A maior difusão do método pode permitir um aumento na detecção de malformações cardíacas, pois possibilita ao ultra-sonografista geral encaminhar, via Internet, os volumes para a análise por especialistas em ecocardiografia fetal.

Unitermos: Doença cardíaca fetal; Diagnóstico pré-natal; STIC.

INTRODUCTION

Congenital heart defects (CHD) are the most frequent congenital malformation in

neonates. Incidence ranges from 4 to 11 in 1,000 live births. About 50% percent of cases present major malformations responsible for about 20% of deaths in the neonatal period and more than 50% of deaths in the first infancy⁽¹⁾. The prenatal diagnosis may improve neonatal outcomes in some presentations of CHD⁽²⁾.

Two-dimensional ultrasound is the technique of choice for prenatal diagnosis of CHD, in spite of presenting the following limitations: the size of the heart varies as a function of gestational age; the fetal positioning may vary during examination, making imaging of structures more difficult; fetal movements during examination may affect acquisition of the necessary diagnostic images; oligohydramnios may compli-

cate images acquisition; images interpretation must be done in real time, either during examination or later, in a videotape review; and acquiring images of the heart can be time consuming⁽³⁾.

In the last few years, great efforts have been made in an attempt to improve intrauterine detection of CHD, including the introduction of a concept, by American Institute of Ultrasound in Medicine (AIUM), recommending examination of a view of great vessels' outflow tract from the basis to the four-chamber view for this purpose⁽⁴⁾.

Recently, with the introduction of 3D and 4D ultrasound in the obstetric practice, volume data acquisition has been tried as a way to improve CHD detection. This

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method advantages are: lower dependence on the acquisition angle, fetal positioning and the examiner experience and, also, the possibility of the dataset storage for later evaluation by an expert in fetal echocardiography^(5,6). Main disadvantages are artifacts resulting from fetal movements and maternal respiratory movements.

The spatio-temporal image correlation (STIC) is a technological development of the 4D ultrasound for acquisition of volume data from the fetal heart and connections, allowing multiplanar and surface reconstruction of the heart anatomy, besides allowing the assessment by means of the cine loop feature⁽⁷⁻⁹⁾. Presently, as a result of the technological development, there is the possibility of using color Doppler and gray scale amplitude, allowing new diagnoses^(10,11). Also, the STIC allows heart volume data transmission through the Internet (tele-STIC), for analysis by other specialists⁽¹²⁾.

The purpose of this paper is to describe the STIC technique, its limitations, advantages and potential applications, besides reviewing the most update literature about this technology.

DESCRIPTION OF THE TECHNIQUE

STIC is a software integrated with the Voluson 730 Expert (General Electric Medical Systems; Kretztechnik, Zipf, Austria) and a real-time convex transducer for automatic scanning (RAB 4–8 MHz).

The sweepings are transversely performed, along the chest and abdomen, up to visualization of the four-chamber view. Whenever possible, acquisition should be done with an anteriorly oriented cardiac apex with a 10°–45° angle between the intraventricular septum and the US beam. The volumetric acquisition time is between 7.5 and 12.5 seconds and, whenever possible, it should be done in the absence of fetal movements and the patient must momentarily hold her breath. After volumetric acquisition, the necessary adjustments can be made to improve contrast resolution.

The volume data set obtained through the sweeping is processed both in the multiplanar and surface modes. In both

modes the image assessment can be performed in a static way or in motion by means of cine loop. In multiplanar mode, the heart image is displayed in three (axial, sagittal and coronal) planes. The A plane (upper left) includes the four-chamber view (axial), while B (upper right) and C (lower left) planes include heart views in sagittal and coronal planes (Figure 1). Images from outflow tracts, aortic arch and ductal arch may be obtained by rotating the heart images along the three orthogonal axes (*x*, *y* and *z*) and moving the reference point. The surface mode represents the rendered car-

diac volume, presenting a cine loop sequence that, on its turn, allows an evaluation of the cardiac movement through a complete cardiac cycle (Figure 2). The cine loop may also be played in slow motion or stopped for a more detailed analysis of any cardiac structure, for example, an assessment of valves (Figure 3).

Color Doppler and gray scale amplitude may be associated, provided 2D ultrasound frame rate is maintained above 17 Hz in order to allow acquisition of a higher number of images, consequently improving images quality (Figures 4 and 5).

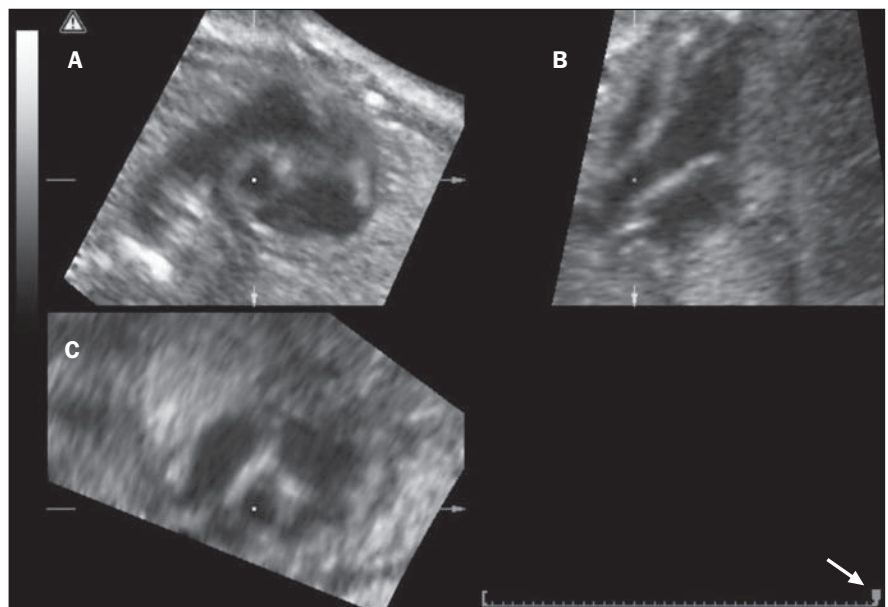


Figure 1. STIC – multiplanar mode. (A) Sagittal plane of pulmonary artery outflow tract (acquisition plane), (B) sagittal plane and (C) coronal plane. Cine loop is observed on the lower left corner of the image (white arrow), allowing real-time evaluation of a complete cardiac cycle.

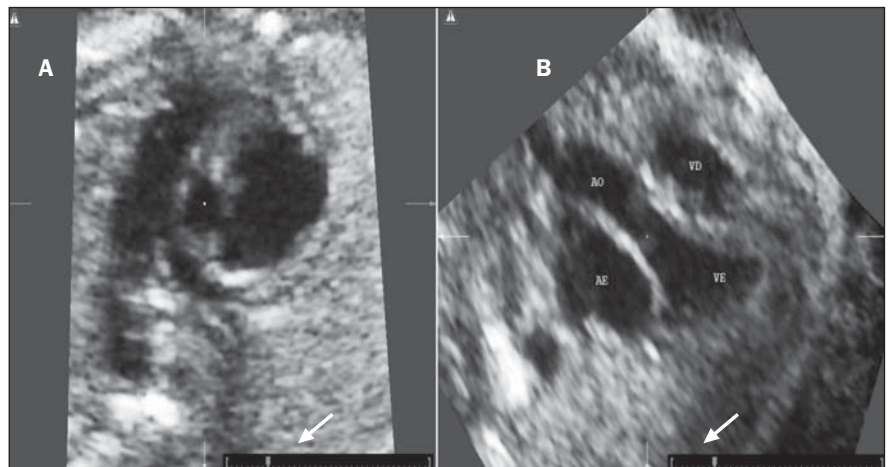


Figure 2. STIC – surface mode showing pulmonary artery (A) and aorta artery outflow tracts (B). Cine loop is observed on the lower corners of both images (white arrows).

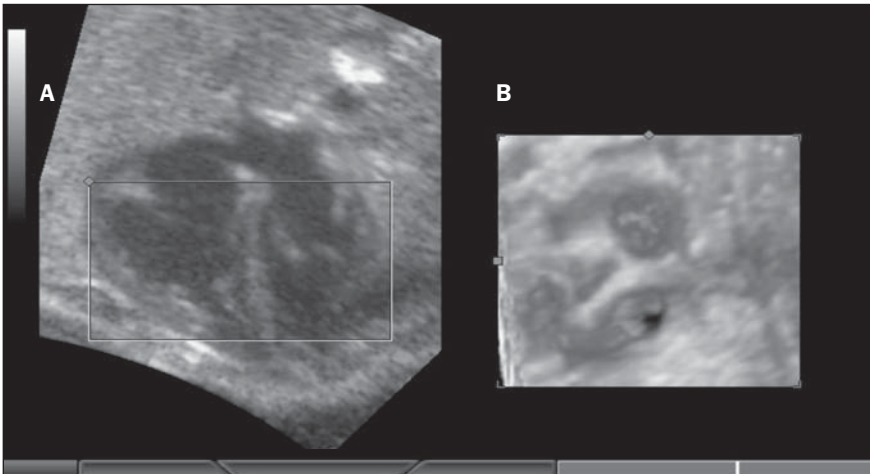


Figure 3. (A) Coronal plane at the level of the four cardiac chambers (acquisition plane); (B) STIC – surface rendering mode showing cardiac valves.

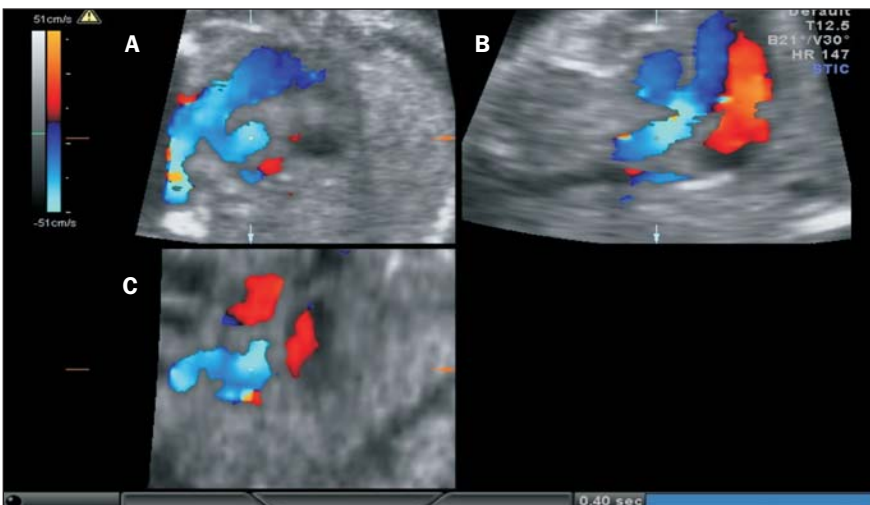


Figure 4. STIC – multiplanar mode associated with color Doppler. (A) Axial plane at the level of pulmonary artery outflow tract (acquisition plane), (B) sagittal plane and (C) coronal plane.

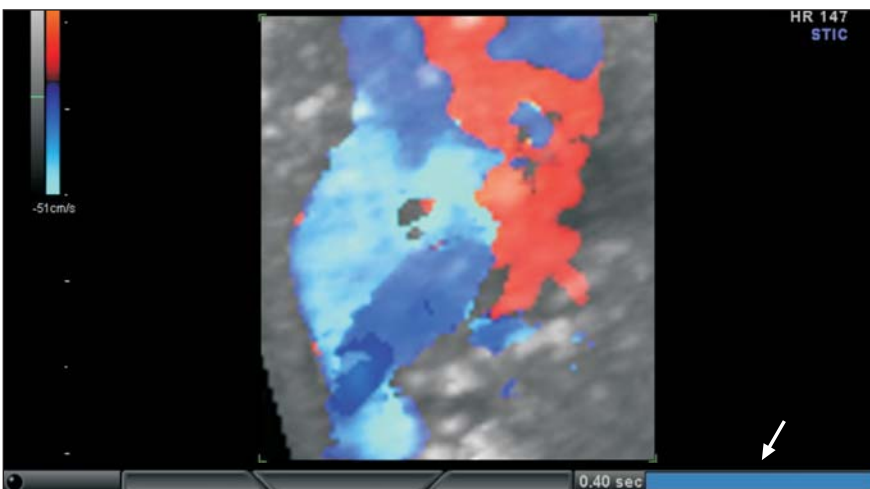


Figure 5. STIC – surface model associated with color Doppler. Cine loop is observed on the lower left corner of the image (white arrow).

Once volumetric acquisition is completed, the data set is stored in a computer hard disk drive for later analysis. The analysis may be performed in the workstation itself or the data set may be transferred to a CD and processed by a specific software - the 4D Views (2.1 version, Luminary, General Electric Medical Systems; Krestztechnik, Zipf, Austria).

LIMITATIONS

Potential limitations of this technique such as: early gestational age (less than 13 weeks), fetal positioning (acoustic shadows caused by ribs), maternal obesity and previous abdominal surgeries, may affect the images quality, however these factors also affect the conventional ultrasound and cannot be considered as affecting specifically the STIC method.

Fetal movements, sudden changes in the fetal heart rate during volumetric acquisition, besides maternal respiratory movements, also will alter images in the B (sagittal) and C (coronal) planes; the A (axial) plane image is not altered for being the original acquisition plane.

In cases where there is an association of color Doppler with gray scale amplitude, main limitation is related to the angle of insonation and perpendicular incidence must be avoided.

ADVANTAGES

STIC technique advantages are the following:

1. The technique delivers a temporal resolution corresponding to a 2D mode frame-rate of approximately 80 frames/s, when the image is seen in cine loop.
2. An unlimited number of images planes can be examined (through rotation on the orthogonal axes or reference point rotation in the multiplanar mode).
3. Specific cardiac structure can be visualized in the surface mode with cine loop and in zoom, allowing assessment of the heart morphology and function.
4. Shorter evaluation time, mainly in cases of suspected complex heart defects.
5. Acquired data can be digitally stored for a later analysis by a fetal echocardiography expert; so the sonographer may per-

form the volumes acquisition, transferring data files for analysis by specialists in tertiary centers by means of telemedicine via an Internet link (tele-STIC).

6. Higher CHD detection rate, since there is no necessity of specific training in fetal echocardiography, making this method accessible to any medical sonographer.

7. In the surface mode, the method allows an easy understanding of the heart anatomy by parents, mainly in cases of suspected congenital cardiopathy.

APPLICATIONS

The STIC technique allows spatial evaluation of the relationship between heart and basic great vessels.

With the multiplanar mode, intraventricular septum, atrioventricular valves, great vessels outflow tracts, aorta and ductal arch may be evaluated in detail.

The surface mode with cine loop evaluates the cardiac movements and is of great significance for assessment of alterations in morphology and function.

The association of color Doppler with gray-scale allows the evaluation of the blood flow in basic great vessels and cardiac chambers, providing a more easy visualization of the great vessel outflow tracts, site and extent of interventricular septum defects.

LITERATURE REVIEW

Gonçalves *et al.*⁽⁸⁾ have first described the STIC applications for fetal heart evaluation. Their study has included 69 fetuses and identified 35 normal fetuses, 16 presenting congenital anomalies without cardiovascular system involvement, and 18 with congenital anomalies. Transverse and sagittal sweeps of chest were performed. Analyses were performed both in multiplanar and surface modes. They have concluded that this novel method may complement another diagnostic imaging modality for diagnosis of CHD. Potential advantage is the feasibility of analysis in the absence of the patient, constituting a new modality for medical teaching.

Gonçalves *et al.* also have described STIC applications associating color Doppler with gray scale. Seven fetuses have

been evaluated: four of them have not presented any abnormality, one has presented extracardiac malformation and two, heart anomalies detected by echocardiography. They have observed that the association of the multiplanar mode with color Doppler has allowed evaluation of septal defects site and extent. The surface mode associated with color Doppler has allowed an appropriate evaluation of great vessels outflow tracts (both in fetuses presenting normal heart anatomy and fetuses with double outflow tract of the right ventricle), regurgitation stream in case of tricuspid failure and visualization of venous flow at the level of the foramen ovale⁽¹¹⁾.

In a study similar to the above mentioned of Gonçalves *et al.*, Chaoui *et al.*⁽¹⁰⁾ have evaluated 35 normal fetuses and 27 fetuses presenting CHD with gestational age between 18 and 35 weeks, with sweeps performed at the level of the four cardiac chambers. They have concluded that STIC in association with color Doppler is a promising technique for heart evaluation both in multiplanar and surface rendering modes. Limitations of this technique occur late in the gestational period because of the larger heart dimensions and early in the gestational period as a result of low discrimination of signals. In addition, insonation perpendicular to the structure of interest does not image color Doppler signals and should be avoided during acquisition.

Viñals *et al.*⁽¹²⁾ have evaluated fetal heart volume acquisition performed by general gynecologists with STIC, with later analysis by a fetal echocardiography expert aiming at confirming or excluding a heart anomaly. Fifty pregnant women at gestational ages between 20 and 36 weeks were prospectively evaluated and volumetric data were analyzed by two general gynecologists living in Chilean remote areas. Heart structures were individually classified as: non-identified; identified but inadequate for diagnosis purposes; and adequate for diagnosis purposes. Three of 50 fetuses had post-natally confirmed CHD, two has extracardiac anomalies and one had a suspect for CHD not confirmed by the specialist using the tele-STIC resource. The fetuses presenting CHD were referred to a tertiary center, receiving specialized

neonatal care. The study demonstrates that in Chile, like in other countries where there are few fetal echocardiography experts and, at the same time, a poor access to skilled neonatal assistance, the STIC may improve the prenatal CHD detection and, consequently, offer an appropriate assistance to these neonates.

CONCLUSIONS

The STIC technique is a significant development in the fetal heart evaluation with 3D/4D ultrasound, allowing the acquisition of any image planes and leading to the diagnosis of a high number of non-septal cardiac pathologies. Also, there are the advantages of short acquisition time, non-dependency on specific training and possibility of a later analysis by fetal echocardiography specialist.

Considering the low number of reference centers in pediatric cardiology and the poor access to a skilled neonatal assistance, a higher diffusion of this method may lead to an increase in the congenital heart defects detection rates. As a result, pregnant women carrying fetuses with cardiopathies would be referred to reference centers to receive an adequate neonatal support, decisively contributing to the decrease in infantile mortality rate due congenital cardiopathies.

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