Ultrasound Technology Update: 4D Fetal Echocardiography
Spatio-Temporal Image Correlation (STIC) for Fetal Heart Acquisition

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Abstract

Spatio-Temporal Image Correlation (STIC) is a new approach for clinical assessment of the fetal heart. This feature offers an easy to use technique to acquire data from the fetal heart and its visualization in a 4D cine sequence. The acquisition is performed in two steps: First, data is acquired by a single, automatic volume sweep. In the second step the system analyzes the data according to their spatial and temporal domain and processes a 4D cine sequence. This sequence presents the heart beating in real-time in a multi-planar display. The examiner can navigate within the heart, re-slice, and produce all of the standard planes necessary for comprehensive diagnosis.

Keywords: Spatio-Temporal Image Correlation, fetal heart, visualization, 4D

Özet

Ultrason Teknolojisinde Yenilikler: 4D Fetal Ekokardiografi

Fetal kalp görüntülemesinde Spatio-Temporal Image Correlation (STIC)

Spatio-Temporal Image Correlation (STIC) fetal kalp değerlendirmesi için yeni bir yaklaşımdır. Bu özellik sayesinde fetal kalpten data daha kolay teknikle elde edilmekte ve kalbin 4D sine sekanslı görüntülenmesi daha rahat yapılabilmektedir. Bunlar iki basamakta yapılmaktadır: İlk olarak data tek ve otomatik bir hacim taraması ile toplanır. İkinci basamakta sistem eldeki bilgileri zamansal ve uzaysal pozisyonuna göre analiz eder ve 4D sine sekansını oluşturur. Bu sekans kalp atımının multiplanda canlı olarak görüntülenmesini sağlar. Bu sayede incelemeyi yapan kişi kalbin içerisinde dolaşabilir, tekrar kesitler alabilir ve geniş kapsamlı teşhis araştırması için gerekli bütün standart planları oluşturabilir.

Anahtar sözcükler: uzaysal-zamansal görüntü korelasyonu, fetal kalp, görüntüleme, 4D

Introduction

The fetal heart, which represents the majority of all fetal malformations, is one of the most important organs studied during the pregnancy (1).

Unfortunately, the heart is a very complex structure so anomalies are difficult to detect, especially for a less-experienced ultrasound professional. As a result, heart diseases are often undetected and show an unsatisfactory detection rate during routine obstetrical exams (2) and result in poor prognoses for the postnatal infant.

It is not mandatory for the obstetrician to deliver a specific diagnosis but to discover that "there is something wrong", and consecutively to refer the patient to a specialist for further clarification (3).

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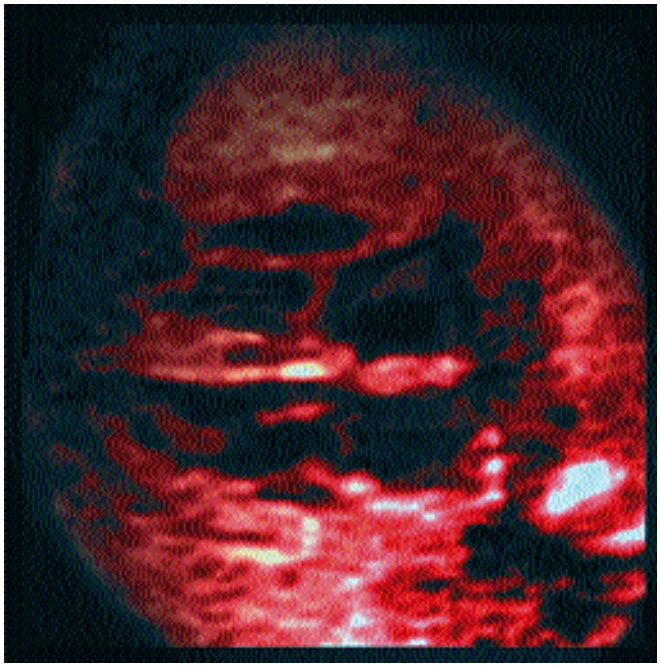
The aim for the development of the STIC technique was to create a useful screening tool that is easy to use and facilitates the detection of fetal heart anomalies during routine obstetrical exams. In several studies 4D fetal echocardiography proves to offer a more comprehensive assessment of the fetal heart morphology and relationship of the great vessels (4, 5), even if the fetus is in an unfavourable scanning position (6).

The dedicated STIC acquisition stores complete volume data sets containing the fetal heart. Once accustomed to the handling of 3D/4D the user can take great advantage of all the information provided. STIC reduces dependency on the examiner's experience in scanning the fetal heart. Not only 2D frames of the region of interest are recorded, but all of the information adjacent to it. In consequence, the user can digitally store the acquired data, re-optimize and re-slice them at any time, even when the patient has already left. Additionally, data files may be transferred to or from remote sites to seek a second opinion or expertise.

Materials and Methods

The ultrasound system used is the commercially available VOLUSON 730 Expert series (GE Medical Systems Kretz



This image illustrates a rendered view of a fetal heart. It clearly demonstrates the atria and the insertion of the inferior vena cava, the AV-valves, the ventricles and the tendons.

Ultrasound, Zipf, Austria). The transducer capable of the STIC technique is the real-time 4D probe for obstetrical/gynecological and abdominal application. STIC is an entirely integrated part of the system's 3D/4D basic software option. Any other external accessory is not necessary.

Technology

Acquisition

The STIC data acquisition is an automatic volume acquisition, which means the array inside the transducer housing performs a slow, single sweep, recording one single 3D data set. This volume consists of a high number of 2D frames, one behind the other. Due to the small region of interest necessary for the fetal heart, the B-mode frame rate during the volume scan is very high, in the range of approximately 150 frames per second. Assuming a volume acquisition time of 10 seconds and sweeping over an area of 25 degrees (both parameters can be adjusted), there are 1500 B-mode images in the volume memory. During this acquisition time the fetal heart beats 20 to 25 times, which means there are 20 to 25 images showing a systolic peak contained within these 1500 B-mode frames (see Figure 1).

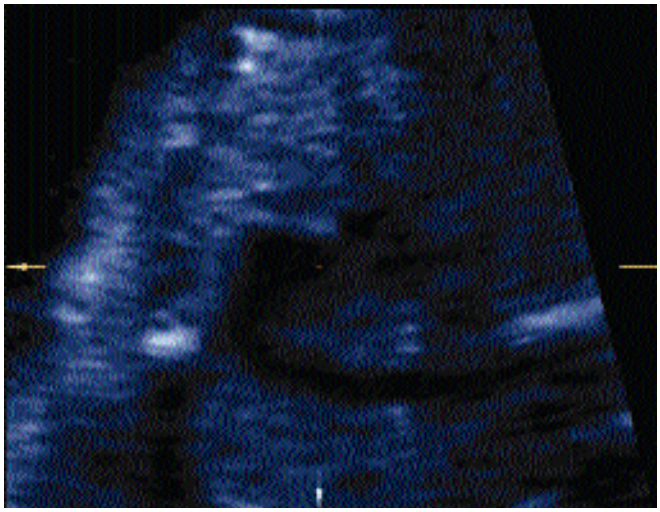


Figure 2. Two orthogonal planes showing the right and left ventricle and the left ventricular outflow tract (left) and the descending aorta (right).

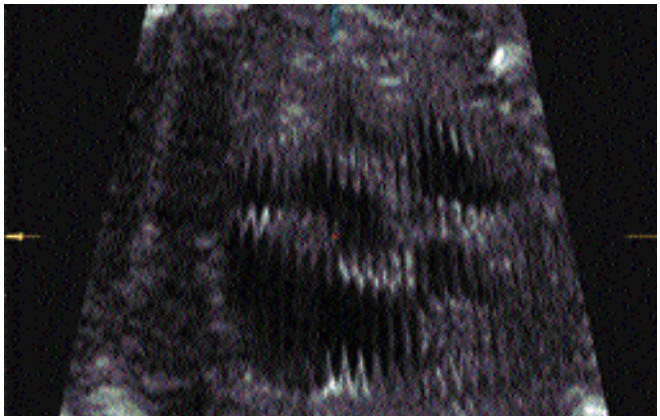


Figure 1. Raw data volume showing a beating fetal heart during a slow 3D sweep. This information is used to calculate the fetal heart rate. This image illustrates a rendered view of a fetal heart. It clearly demonstrates the atria and the insertion of the inferior vena cava, the AV-valves, the ventricles and the tendons.

Postprocessing

Immediately after the volume scan is finished the system runs a spatial and temporal correlation of the data and detects the earlier mentioned systolic peaks and consecutively calculates the heart rate.

Based on the exact timing of the systolic peaks and the time fraction between one systole and the next, the system processes an internal trigger. Now the system rearranges the B-mode frames in a new order according their spatial and temporal domain. This results in 40 volumes, each one representing a "snapshot" of the heart during a complete heart cycle. Example: volume #1 shows the heart exactly at the systolic peak, volume #2 shows the heart 10 milliseconds later, volume #3 another 10 milliseconds later and so forth…. volume #40 shows the heart 10 milliseconds right before the systolic peak. Now there are 40 consecutive volumes presenting one complete heart cycle.

Visualization

These volumes are displayed in an endless cineloop and show the beating heart. The loop may also be played in slow motion or stopped at any time for detailed analysis at a certain stage during the cycle. Because there is three-dimensional information behind each frame scan planes can be moved and rotated. Thus, the four-chamber view, long axis, short axis, great vessels and all the other views can be displayed, both in a frozen state and with the heart in motion. Different display formats are availab-

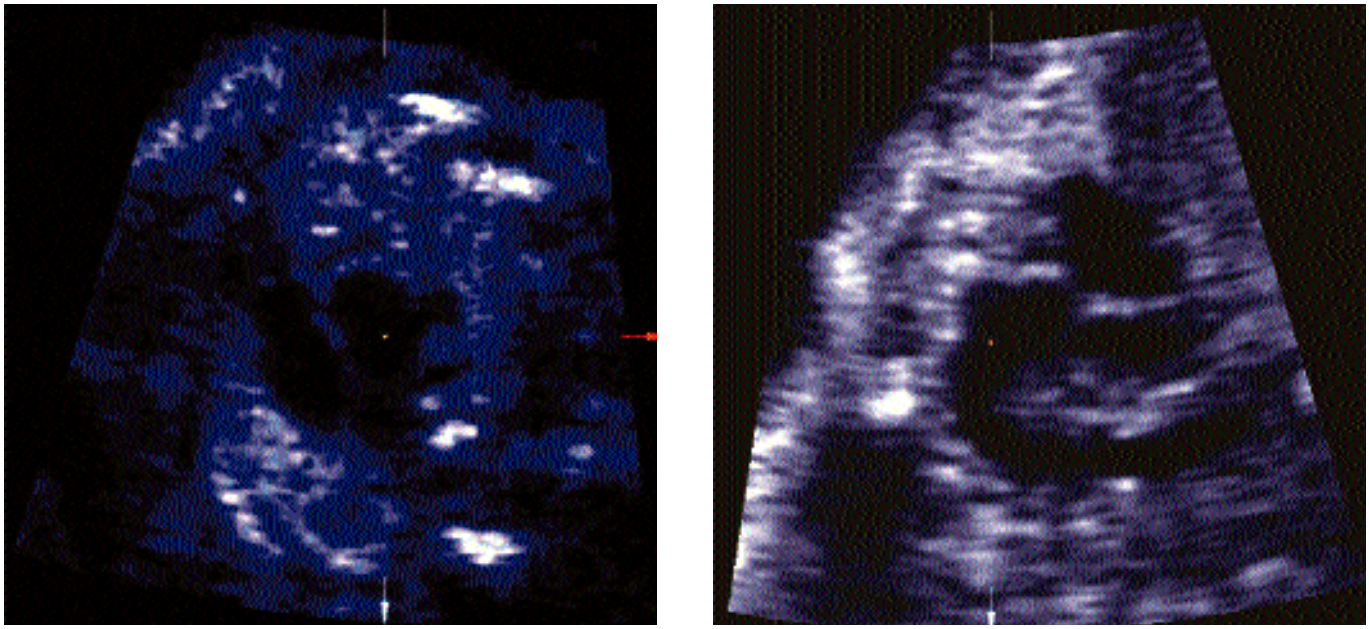


Figure 3. Two orthogonal planes showing the aorta and pulmonal artery (left), and the aortic arch and descending aorta (right).

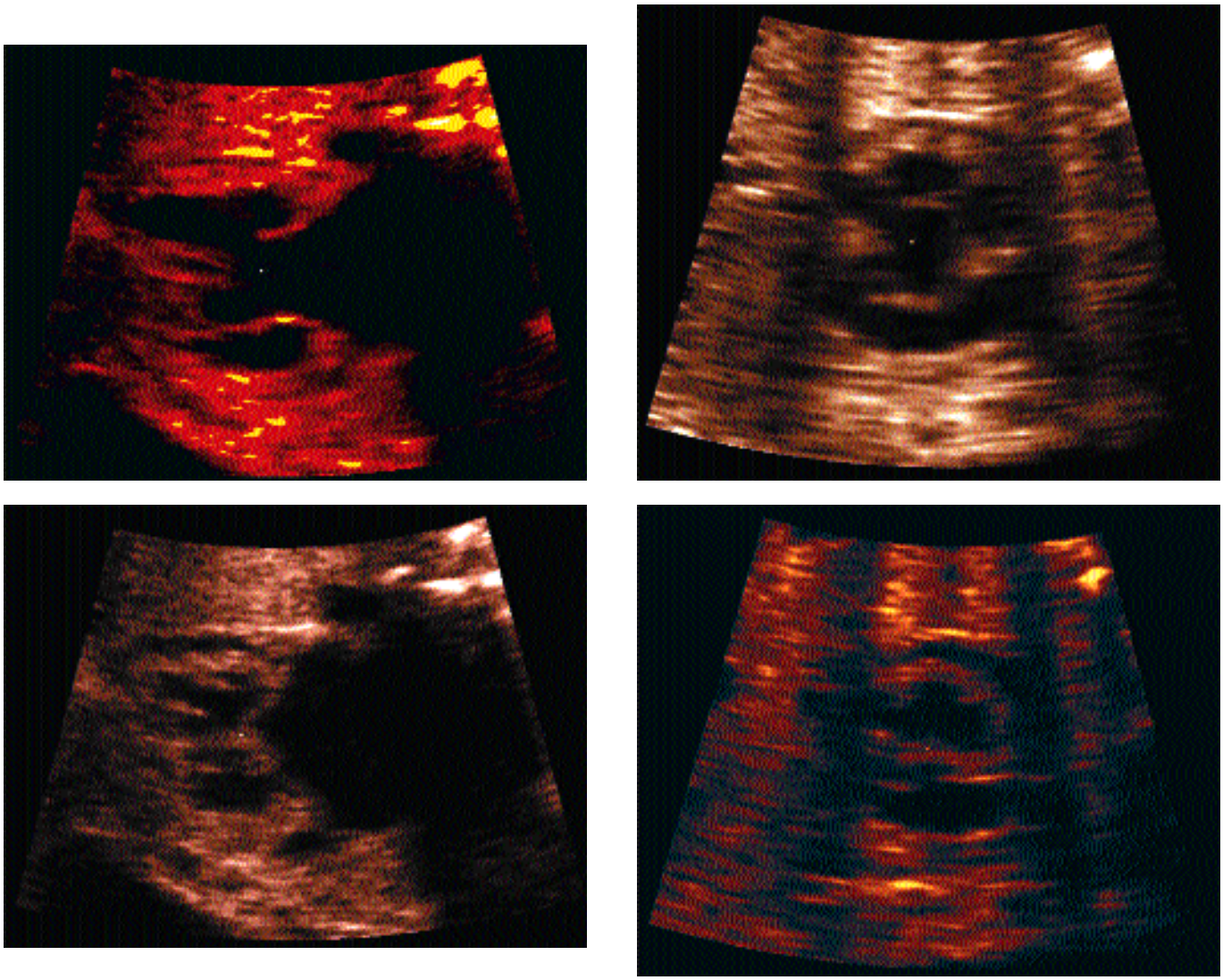


Figure 4. Orthogonal planes demonstrating an AV-canal during diastole (top) and systole (bottom).

le: multi-planar view (three planes perpendicular to each other), single plane and volume rendering is possible as well.

Clinical Benefit

STIC is easy to use and offers completely new possibilities in clinical assessment of the fetal heart. Up to now it was only possible to visualize the heart on a 2D ultrasound image.

Examining the fetal heart in 2D is often rather difficult, especially if the fetus is very lively. Frequently the fetus can move away while desired structures are displayed and thus make it necessary to readjust the scan plane. With STIC, only a short period of time without fetal movement is necessary to acquire the entire dataset. After the acquisition the heart can be assessed offline, without being dependent on fetal cooperation. This can significantly accelerate the examination of the fetal heart.

Another disadvantage of 2D ultrasound is that only findings detected and scanned by the first examiner are documented. Any structure missed in the 2D scan or improper image slices (not standard orientations) make it impossible to accurately re-analyze the data. Whenever any uncertainty arises the patient must return for another exam. A STIC data set offers information of the entire fetal heart including surrounding structures with the heart in motion. There is no external equipment necessary. The technique delivers a temporal resolution which corresponds to a B-mode frame rate of approximately 80 frames per second. STIC data can be stored and transferred digitally to be analyzed at any time at any site. This opens up entirely new aspects of offline expertise to clinicians for remote areas with less experience in fetal echo.

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