L'ECOCONTRASTOGRAFIA PER LA VALUTAZIONE DELLA CINETICA E DEI VOLUMI VENTRICOLARI. QUALI VANTAGGI?

CONTRAST ENHANCED LEFT VENTRICULAR OPACIFICATION FOR WALL MOTION AND VENTRICULAR VOLUMES EVALUATION: WHICH ADVANTAGES

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Echocardiography is the recognized technique for detect left ventricular wall motion. In almost all the echocardiographic exams the cavity end-systolic and end-diastolic dimensions are calculated to have an estimate of the global ventricular function. Despite the many improvements in the echocardiographic technique there is still a small percentage of patients in which, because of the bad ultrasound penetration, it is very difficult an accurate estimate of the ventricular dimension and sometimes of the wall motion.

1 Contrast enhanced left ventricular opacification to detect wall motion and endocardial border

1.1 Usage of contrast media to enhance bidimensional black and white ventricular opacification

The dropout of the endocardial border in apical views is common and may preclude assessment of left ventricular function even in patients with adequate acoustic windows ([1]). The ability to adequately define the endocardial borders by using a transpulmonary contrast agent is an important clinical goal in echocardiography. Since the original observation of Gramiak ad Shah ([2]) that the injection of indocyanine green causes opacification of blood flow, the need and possibility to visualize intracavitary and parenchymal blood flow has been recognized and has stimulated worldwide research to develop biocompatible and efficacious contrast agents ([3]). The value of contrast echocardiography to improve volume determination for the right ventricle has been proven ([4]).

For this reason several studies have been attempted ; in these studies sonicated human albumin demonstrated a good opacification of the left ventricle and a satisfactory improvement in the delineation of the endocardial border to determine ventricular volumes ([5]).

The improvement of the contrast enhanced echocardiographic assessments of left ventricular volumes and ejection fraction has produced a very good correlation with the obtained with those calculated with contrast ventriculography ([5]) or magnetic resonance imaging ([6]). Moreover it has been demonstrated that the improved left ventricular endocardial border definition after contrast translates into more accurate measurements of global and regional left ventricular systolic function([6]). This is also because structures that are parallel to the ultrasound beam, such as the endocardial border in the apical views, are difficult to resolve with echocardiography. Conversely, spherical microbubbles in the left ventricular cavity provide a surface that is perpendicular to the ultrasound beam, have a large scattering cross section ([10]) and therefore facilitate endocardial visualization and tracing of its contour. The advantage of contrast echocardiography is most striking in the subjects with two or more non visualized segments on the baseline echocardiogram.

1.2 Limitations of bidimensional black and white ventricular opacification

The destruction of microbubbles caused by the strong acoustic emission power delivered continuously against the fragile microbubbles injected intravenously can reduce this method reliability ([7]). For this reason has been developed a new method of “intermittent emission of ultrasound” (ECG triggering at 1 or more frame/cycle) ([8]), which destroys much less microbubbles than the continuous acoustic emission power (see following paragraph) and the “second harmonic imaging” which improves the visualization of contrast in the left ventricular cavity.

Besides to these echocardiographic technical improvements, several studies demonstrated the prolonged duration of contrast effects using second generation contrast agents. Also the usage of perfluorcarbons filled microbubbles can improve the visualization because of the low diffusivity and blood solubility of perfluorcarbons ([9]). In addition it has been noted that air-filled microbubbles demonstrate a decrease in contrast intensity during systole attributed to microbubble destruction by intracavitary pressure.

Improved visualization of the left ventricular cavity after contrast agent administration may not translate into improved measures of global and regional left ventricular systolic function. Contrast induced attenuation artifacts may obscure the endocardial surface ([3,9]). In addition, accumulation of contrast agent simultaneously in the left ventricular myocardium and cavity may reduce visualization of the border between the blood pool and the endocardium. Perhaps more important, microbubbles may slow the velocity of ultrasound transmission through the cavity, resulting in spatial misregistation of the true endocardial surface ([10]).

1.3 Second harmonic color Doppler to enhance the left ventricular cavity filling

Some studies demonstrated that the contrast effect in opacifying the left ventricular cavity can be magnified with the usage of echo color Doppler. This is due to the fact that the movement of the blood in the cavity gives a signal which is at a high velocity, even though at a low intensity, and can be very well visualized with a filter setting similar to that used for the color Doppler detection of transvalvular flows. Moreover it is very easy and quick to delineate the cavity contour when you see the difference between the colors of the blood (red and blue in the traditional color map or different intensity of orange for the non-directional color map) and the gray (or the black if you reduce the receiving gain) of the myocardial wall.

However, the conventional color Doppler coding can very often produce artifacts. The most common is the “Blooming effect” : in the image you see an excess of color blooming out of the area were the signal is really detect. This problem is almost completely solved by the second harmonic modality ; the same image seen with the second harmonic shows a cavity contour that almost never exceeds in the myocardial wall.

1.4 Systo-diastolic triggering on time markers

The microbubbles are destroyed by the excess of power output emission. It is necessary to preserve the microbubbles especially when you are looking for perfusion, since the bubbles flow into the arterioles and the capillary very slow ; therefore the capillary bed needs 3-5 seconds to refill after the ultrasound caused microbubbles destruction. This phenomenon is much less evident when the contrast echocardiography is performed to detect the left ventricular cavity opacification.

An other utility of the triggering on the ECG markers is the time accuracy of the ultrasound image. When the color (or power) Doppler is used with a big scanning window the frame rate of the continuous imaging can go down to 8 Hz or less. This low frame rate can give a color Doppler image that is up to 150 msec distant from the real end systolic or end diastolic position of the heart. To solve this limitation it is possible to set the time interval on the ECG, in order to obtain a fixed and time accurate image, always corresponding to the real end systole and end diastole.

2 Automatic edge detection

Although echocardiography is extremely useful for qualitative and quantitative assessment of left ventricular dimensions and function, the time-consuming and tedious manual procedures needed to measure dimensional and functional parameters by traditional off-line analysis systems, make their use unpopular in routine clinical settings.

To overcome this problem has been developed an echocardiographic system, Automatic Boundary Detection, that provides automatic on-line identification of acoustic blood-tissue interfaces and quantification of left ventricular cavity volumes on frame-by-frame base. Several studies showed a potential in a clinical setting, but only in patient with a good image quality this method gives reliable results [1, 11].

Some limitations affect this automatic analysis and suggested the usage of intravenous contrast injection to obtain more information from this automatism : 1) the echo-dropout affecting the endocardial border that results in subendocardial misplacement of the detected automatic border in comparison with the true border; 2) the region of interest on the left ventricle enbodies a small segment of left atrial area (atrial contamination effect); 3) intracavitary structures (such as papillary muscles, chordae and mitral leaflets) are excluded by the automatic software. In addition the control settings (power gain control and time-gain compensation level) are operator-dependent and their adjustment can affect the volume determination. Finally, the image quality is a somewhat more stringent need for automatic echocardiography than for traditional two-dimensional imaging for the impossibility to integrate visually the echocardiographic images.

2.1 Usage of contrast and matematic tools to detect automatically the color borders

When the intravenous contrast injection is used in conjunction with color Doppler and systo-diastolic triggering modality a precise imaging of left ventricular cavity at end systole and diastole is obtained. Preliminary analysis on this images have been done by our and other groups using matematic software packages that analyze a particular region of interest[1]. This software give the value of end systolic and diastolic volume for each cardiac cycle and of an average of several cardiac cycle.

One big limitation that affects this preliminary method is the fact that has to be performed off line. This limitation make the analysis time consuming and the results cannot be compared with the visual analysis of wall motion ; however this limitation can be easily overcome with the technical improvements.

3 Clinical implications

The contrast enhanced automatic edge detection can be considered a new reliable tool for quantitative assessment of left ventricular dimensions and function. This new technique can also be capable of monitoring stress-induced acute changes of left ventricular size and function[1].

The contrast enhanced edge detection echocardiography has a great potential in different clinical settings. Its capabilities, in real time beat-to-beat monitoring of left ventricle, may be usefully applied when studying acute changes of the left ventricular function. This potential can be extended to follow-up of left ventricular function in patients affected by various cardiac diseases, such as myocardial infarction (left ventricular remodelling and aneurysm), valvular heart diseases, cardiomyopathies, congenital heart disease. Lastly, it could be applied also for quantitative functional assessment in other cardiac chambers.

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