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Free-Hand Four-Dimensional Echocardiography:

A Diagnostic Tool in Coronary Artery Disease

Alexander P. Bock, M.S., Angela Genov, M.D., and Rainer J. Zotz, M.D.

Department of Internal Medicine/Cardiology, Leipzig University Heart Center, Leipzig, Germany

Direct echocardiographic visualization of coronary arteries has been difficult due to the inherent problems involved in obtaining ultrasound access. We used freehand four-dimensional echocardiography in a 79-year-old patient with a trifurcational stenosis. We were able to identify a 6 × 11 mm possibly subintimal atheromathous plaque and to measure the diameters of the left descending coronary artery before, in, and behind the stenosis. There was good agreement with the angiographic measurements. This successful approach may be an argument to motivate further research in this area. (ECHOCARDIOGRAPHY, Volume 19, February 2002)

freehand, 4-D, diagnostic tool

Conventional angiography images coronary arteries by roentgenographic visualization of an internally applied contrast agent. Thus, only the inner lumen of the coronary artery is displayed, not its wall or surrounding structures. Because ultrasound has the ability to image noninvasively[1] not only the inner lumen but also the surrounding structures of a vessel,[2] we postulated that it would be possible to image coronary artery piques in four dimensions.

Freehand[3] four-dimensional (4-D) echocardiography[4-6] allows acquisition of cardiac scans during one breath (10 sec to 20 sec). When the raw data are processed, the reconstruction error can be reduced to a degree in the range of ultrasound beam resolution.

Case Report

A 79-year-old woman with suspected coronary heart disease was referred for invasive cardiologic diagnosis. She presented with a history of hypertension and exercise-induced dyspnea as well as chest pain within the last 6 months. Her pulse rate was 50 beats/min and the basal blood pressure was 180/100 mmHg. The electrocardiogram (ECG) under resting conditions showed a normal sinus rhythm. Exercise testing performed at 75 W showed typical electrocardiographic signs of stress coronary insufficiency. Routine laboratory tests were all normal. Conventional transthoracic echocardiography (TTE) showed a good left ventricular function (ejection fraction 75%) without regional dyskinesia. Aortic and mitral valves were slightly sclerotic, resulting in a grade 1 mitral regurgitation. Angiography (Figs. 2A, 3) confirmed a good global ejection fraction (81%) and identified a severe trifurcational stenosis (main stem 75%, left anterior descending coronary artery 90%, and left circumflex coronary artery 75%).

Methods

All transthoracic ultrasound investigations were ECG-triggered and breath gated. In order to acquire 4-D datasets, a conventional scanhead (S4-HP 21330A, Hewlett-Packard, Andover, MA, USA) was connected with a flock-of-birds receiver (6DFOB, Ascension Technology Corp., Burlington, VT, USA) as part of a magnetic field position sensing system.[3]

No rotation was required with this freehand technique. It was not necessary to obtain volumes of the entire heart. In advance, specific areas containing interesting structures could be defined. To visualize one of them, we developed a two-step modified scanning procedure. Figure 1 demonstrates the procedure. From the standard left lateral decubitus position (left),

Address for correspondence and reprint requests: Rainer J. Zotz, M.D., Klinikum Schwalmstadt, Krankenhausstr. 27, 34613 Schwalmstadt, Germany. E-mail: rzo@schwalm-eder-kliniken.de

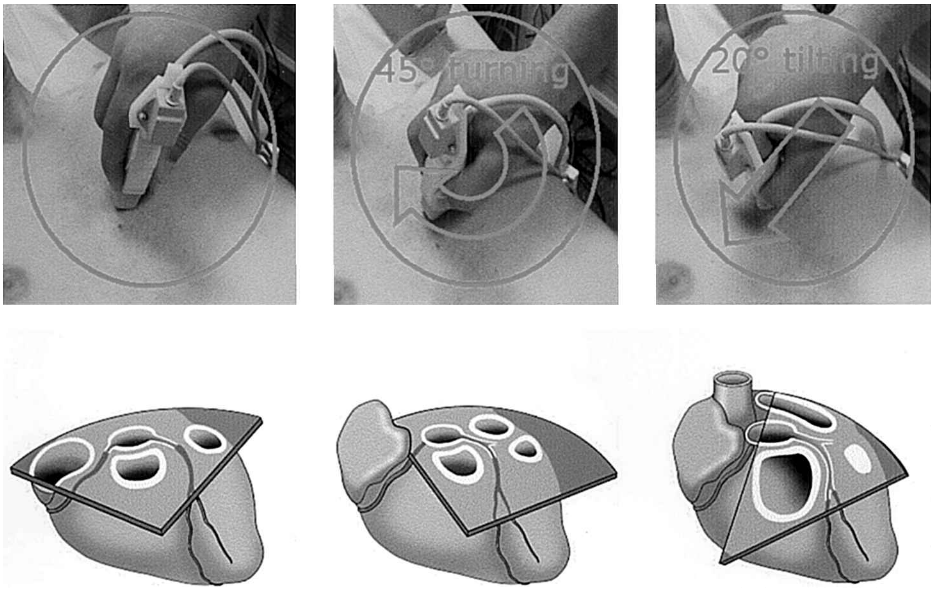

Figure 1. *Ultrasound transducer position for four-dimensional data acquisition.*

the scanhead was turned clockwise approximately 45° (middle). Then, a shifted movement of approximately 15° towards the right foot (right) allowed new views of the left coronary artery. This was the starting point for the 4-D scans. Therefore, the scanhead was tilted carefully to about 30° in a vertical direction within 10 seconds to 20 seconds in end-expiration. The result was a volume segment that contained the left coronary artery from its aortic origin up to more than 8 cm continuous length. With InViVo Software (Medcom GmbH, Darmstadt, Germany), the data were processed and volume-rendered.

A freehand 4-D echocardiographic (Figs. 1C, 3, and 4) investigation detected the stenosis and showed good agreement with the angiographic findings (prestenosis 4.5 mm, intrastenosis 1.4 mm, and poststenosis 3.3 mm). Ultrasound and angiographic measurements were

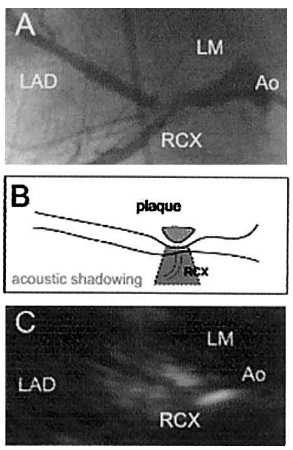

Figure 2. *Three different preparations of the same region of interest (ROI).* **A.** *Angio frame acquired in the right anterior oblique (RAO) position.* **B.** *Outline drawing with acoustic shadowing window.* **C.** *Slice of a three-dimensional echocardiographic volume dataset. LAD = left anterior descending artery; LM = left main coronary artery; RCX = ramus circumflexus; Ao = aorta.*

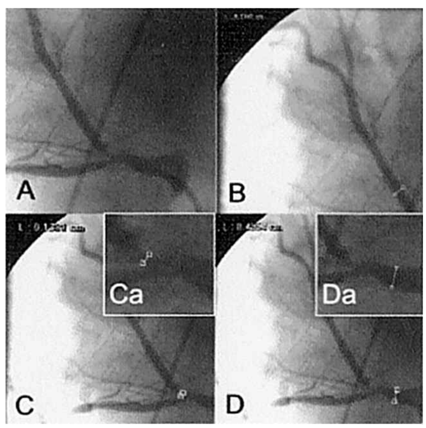

Figure 3. *Different diameter measurements in angio frame (Fig. 2).* **A.** *Original.* **B.** *Poststenotic part in the LAD 3.3 mm,* **C.** *Intrastenotic 1.3 mm;* **Ca.** *zoom of ROI.* **D.** *Prestenotic part in the LM 4.5 mm;* **Da.** *zoom of ROI. LAD = left anterior descending artery; ROI = region of interest; LM = left main coronary artery.*

performed with the identical software. Ultrasound diameters were 0.45 cm prestenotic (Figs. 3D and 4B), 1.3 mm intrastenotic (Figs. 2C and 3D), and 3.3 mm poststenosis (Figs. 3B and 4B). A 6 × 11 mm solid structure, most likely an atheromatous plaque (Fig. 5), was detected. It produced a clearly visible acoustic shadowing.

Discussion

The ability to image noninvasively at least small parts of the epicardial coronary tree would obviously be of great advantage. In our patient we were able to identify coronary artery disease in the left coronary trifurcation using freehand 4-D ultrasound. It was possible to identify the reason for the stenosis using ultrasound (i.e., a plaque producing a typical acoustic shadow). Hence, we were unable to provide any information on the left circumflex coronary artery laying in this shadow (Figs. 2B, 4C, and 5). The degree of ultrasound stenosis agreed well with angiographic measurements.

Using freehand 4-D ultrasound data acquisition, it was not necessary to image the coronary artery directly. However, a 4-D dataset of the region of the anticipated coronary artery was acquired. Postprocessing required less than 2 minutes and produced a steady volume. To reduce the amount of data, a region of interest (ROI) was identified in this volume. Optional 2-, 3-, and 4-dimensional views can be obtained by browsing this volume dataset, and they can be displayed as a cine loop. This permits the visualization of interesting coronary arteries from different angles within this dataset.

This ultrasound method has the advantage of not only visualizing the artery lumen but also the surroundings of a vessel that can contain plaques protruding into the vessel lumen. It also complements findings of intravascular ultrasound.[7,8]

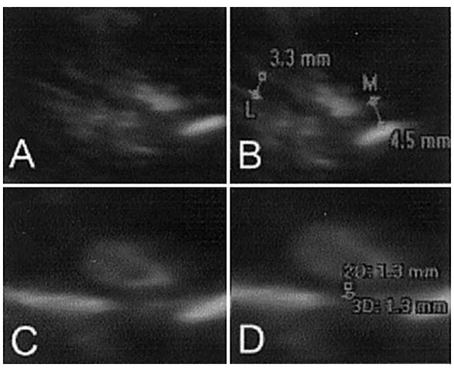

Figure 4. *Different diameter measurements in 4-D volume dataset (Fig. 2).* **A.** *Original.* **B.** *Prestenosis 4.5 mm and poststenosis 3.3 mm.* **C.** *Browsed frame.* **D.** *Intrastenosis 1.3 mm.*

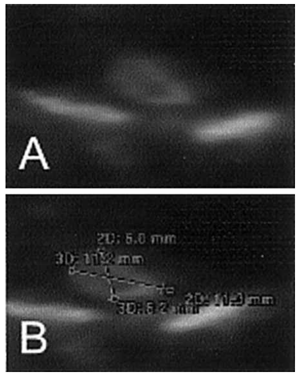

Figure 5. *View similar to Figure 4C.* **A.** *Acoustic shadowing of the posterior wall.* **B.** *Plaque dimensions 6.2 × 11.2 mm.*

Conclusion

Freehand 4-D echocardiography may have potential as a useful tool in coronary artery diagnostics. Further studies are necessary to confirm these preliminary perceptions.

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