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Computer real time detection of intravascular bubbles

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EGENVALGTE

COMPUTER REAL TIME DETECTION OF INTRAVASCULAR BUBBLES

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SUMMARY

We have developed a system for real time detection and quantification of intravascular gas bubbles. The system is based on computer processing of video signals of echo cardiographic images. Images from any ultrasound scanner can be used, provided a standard PAL video signal is available. The detection programme is a stand-alone application for Macintosh computers, and the only additional hardware requirement is a commercially available video frame grabber card for digitisation of the video signal. The system is best suited for transesophageal echocardiography (TEE) which gives images of good quality. It is thus well suited for use in animal decompression experiments. Other areas of application include surveillance in connection with open heart and laparoscopic surgery.

INTRODUCTION

Intravascular gas bubbles are considered a measure of decompression stress, thus methods for detecting and quantifying such bubbles are important for development and verification of decompression procedures. We have earlier described a computer programme, EchoBubble, for quantification of intravascular gas bubbles in 2-dimensional (2D) ultrasonic images (Eftedal and Brubakk 1991, Eftedal and Brubakk 1993). The bubbles appear as spots of high intensity, easily discriminated from the weak reflections of the surrounding blood, as can be seen in fig. 1. A specially designed pattern recognition algorithm in EchoBubble performs the identification of the bubble reflections.

We now suggest a new computer programme for bubble detection in 2D images. ArdiBubble is based mainly on the same algorithms for bubble identification as EchoBubble, but it has been designed to process video signals in real time. The programme searches through all images in the video signal acquired by a frame grabber. This gives continuous information about the number of

bubbles present, whereas EchoBubble, which is based on post processing of digitised raw data, in practice is limited to quantification of bubbles in 1 heart cycle every 5 minutes.

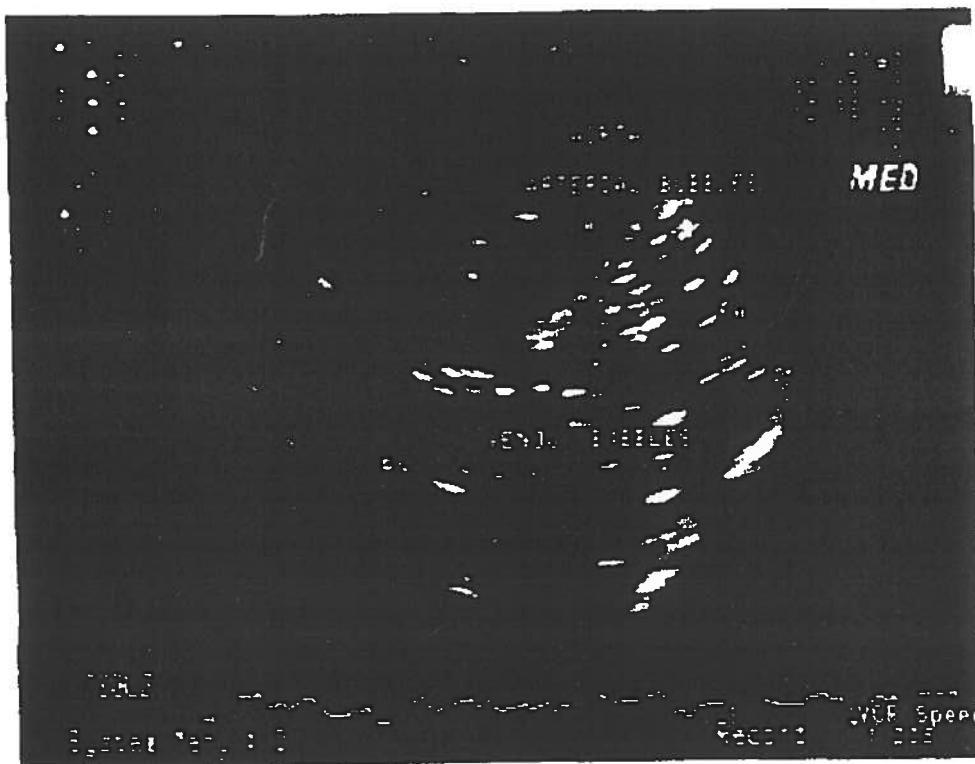


Fig 1. Ultrasound image from decompressed pig, showing venous and arterial gas bubbles. PA = pulmonary artery, RV = right ventricle.

SYSTEM DESCRIPTION

The video signal is transferred from the ultrasound scanner to a video frame grabber card, type ML 200122, mounted in a Macintosh computer. Any ultrasound scanner can be used, provided it has a PAL standard video output. ArdiBubble displays the video signal in a separate window on the computer screen (fig. 2, "Video display" window). For each image frame digitised, the programme detects bubbles within a defined search area. The number of detections per cm^2 for each image is shown in the "Bubble Detection" window. For each minute, the programme calculates average number of detections per cm^2 and shows the result graphically in the "Real time display" window. The results can also be presented numerically for further processing in a

spreadsheet, and all results are optionally saved to a file. A number of parameters can be manipulated to optimise the detection algorithm depending on the image quality.

Once the programme is started and the search area is positioned in the image, the system is fully automatic. The results come out in real time, and no personnel intervention is required. In the design and implementation of the programme a simple, user-friendly interface has been emphasised. The system therefore requires little previous computer knowledge by the user.

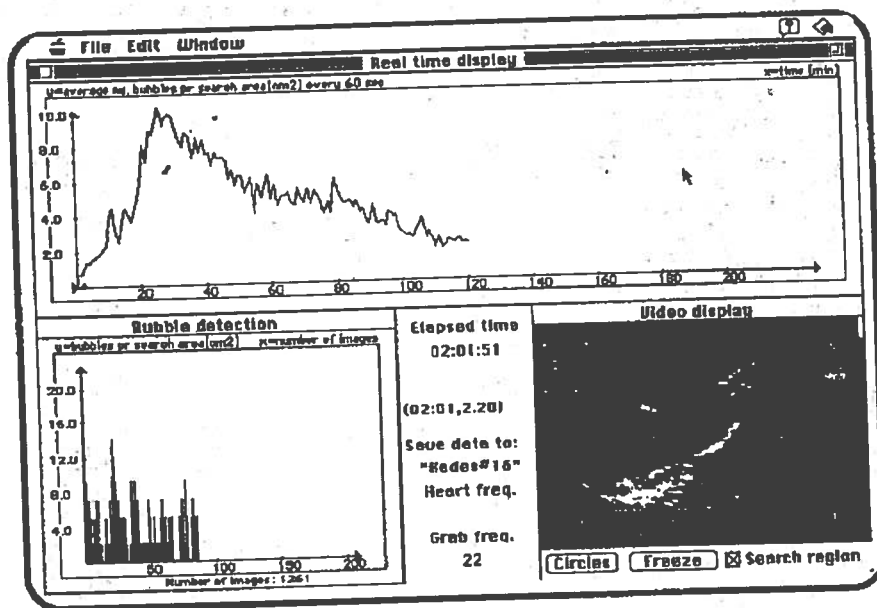


Fig. 3 Windows shown on the desktop when running ArdiBubble. Real time display shows number of detections per cm² for each minute since the programme was started. Bubble detection window shows number of detections per cm² in the last images processed. Video display shows the video images digitised by the frame grabber card.

RESULTS AND DISCUSSION

To verify ArdiBubble we compared the results obtained by ArdiBubble and EchoBubble from a decompression experiment with a pig. The pig had undergone a 2 minute decompression after being exposed to a pressure equivalent to 20 msw for 180 minutes. Ultrasound imaging was done with a Vingmed Sound CFM 750 scanner and a 6.5 MHz TEE probe giving a view as shown in fig. 1. EchoBubble analyses were performed every 5 minutes for the first 30 minutes after the decompression, subsequently every 15 minutes until 120 minutes post decompression. ArdiBubble analyses were performed continuously. The results are shown in figure 3.

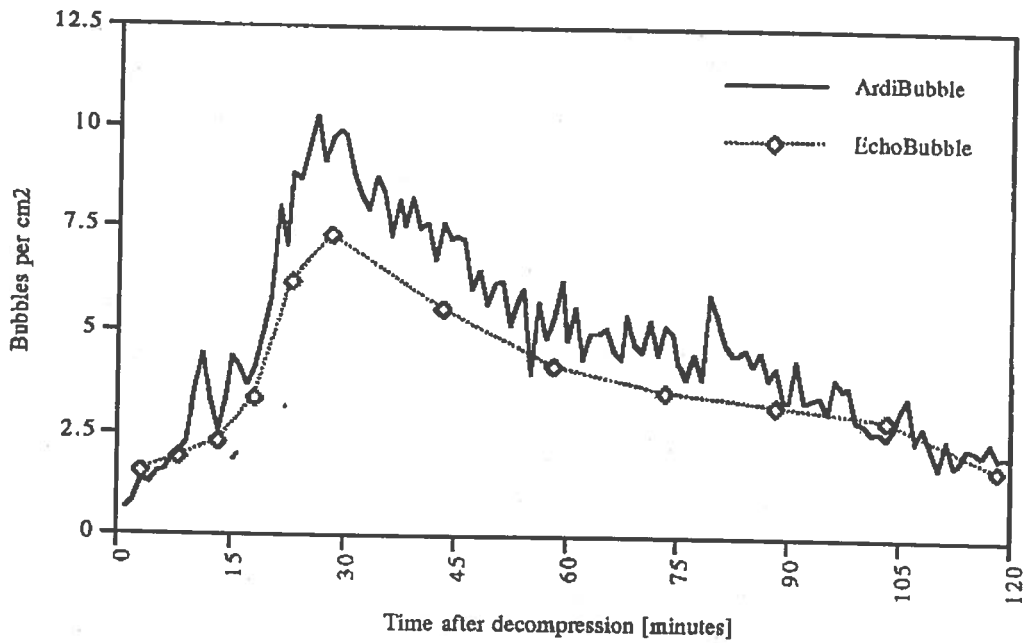


Figure 3. Comparing bubble detections in the pulmonary artery of a decompressed pig using ArdiBubble and EchoBubble.

The shape of the two curves are quite similar. The main difference is that ArdiBubble tends to give a somewhat higher output. A probable reason for this is that the intensity threshold for detection, which is an adjustable parameter, has been set lower for ArdiBubble than EchoBubble. The images analysed by EchoBubble are raw data from the scanner, while the images analysed by ArdiBubble are video signals. Contrast, gain and other properties related to the image quality will not be equal for the 2 signals, and this may impose differences on the number of detections. Despite of the differences we conclude that the 2 systems in this experiment give equivalent results.

The ArdiBubble graph consists of 120 data points compared to the 12 points on the EchoBubble graph. Each sample on the ArdiBubble graph is acquired by averaging over a search area of approximately 0.3 cm² for 1 minute with a frame rate of 25 images per second. This gives a total area per sample of about 450 cm². Each EchoBubble sample is based on images from 1 heart cycle (typically 25 images) with 10 cm² of search area in each, giving a total of 250 cm² per sample. ArdiBubble will therefore in general probably give a better estimate of the amount of gas bubbles present in the pulmonary artery during an experiment.

Compared to EchoBubble, the new system is simpler to use, quicker and requires less human intervention. Whereas EchoBubble typically requires 12 to 15 MB of data storage for the digitised images, ArdiBubble can perform post experimental bubble detection from videotape recordings. Furthermore, ArdiBubble can be applied to PAL video signals from any ultrasound scanner.

The limitations connected to the use of ArdiBubble are essentially the same as when using EchoBubble. A fairly constant view of the intravascular area is required, the method is thus best suited for TEE imaging. The possibilities for use in decompressions involving humans are therefore limited. Use of an ultrasound scanner also makes the method more expensive and less portable than Doppler detection of bubbles. However, the system has given us insight into the relationship between actual bubble numbers and bubble grades as used in Doppler ratings.

Although the method has been developed for the study of decompression bubbles, it is also well suited for monitoring during operations with a risk of vascular gas emboli. Such operations include laparoscopic and open heart surgery.

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