DETECTION OF CIRCULATING BUBBLES WITH 2D ECHOCARDIOGRAPHY AND PULSED DOPPLER

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Formation of venous gas emboli as a result of decompression from hyperbaric pressures is well recognized. Such bubbles may be "silent" or may induce symptoms of decompression sickness. Since 70s' circulating bubbles can be detected by ultrasonic methods (1, 2). Detection of circulating bubbles can be used as an indicator of the safety of a dive and his decompression procedure (3, 4). Continuous wave Doppler is the more widely used but the analysis of the signals obtained involve a degree of subjectivity. Then, the inter-rater agreement on the grading of intravascular bubble signals can be important and statistics of studies with a few records can be falsed (5). Others ultrasonic methods for detecting bubbles have been evaluated. Echocardiography (two dimensionnal (2D) image or M-mode) can visualised circulating bubbles in right cavities (6, 7). Transesophageal echocardiography is semi invasive and only used during experimental animal studies (8). Ideal detection method in sport diving is not defined. No element exists to compare 2D echocardiography and pulsed Doppler in sport divers. We assessed the interest of these two methods. Then we defined the methodology of an exam with these two technics and proposed a grade to quantify circulating bubbles.

METHODS

Divers

Twenty one sport divers (20 men-1 woman) age 35 +/-12 years (19-54) performed 46 SCUBA dives (mean depth 35 +/-8 msw. mean duration 30 +/-6 minutes). No order as for the duration and to the profile of the dive was given by the cardiologist. All gave informed consent. Decompression procedures were conducted in respect of decompression table in France (Marine Nationale 90 or Table du ministère du travail 92).

2D Echocardiography and Pulsed Doppler

Bubble detection was performed 1 hour after diving. The ultrasonic apparatus was a Vingmed CFM 750/A (Diasonics) with a 2,5 MHz probe. The ultrasonics examinations were done in the supine position both at rest and during periodic isometric contraction of the quadriceps. Images were obtained in parasternal view (long axe and short axe) and four apical chamber view. A quantitative evaluation of circulating bubbles was performed using 2D images. Circulating bubbles were also detected with pulsed Doppler. The sample volume was placed in the outflow area of the right ventricle just below (1-2 cms) the pulmonary valve. Each exam was registered in video tape and analysed by two independent investigators. To quantitate circulating bubbles in the venous circulation bubble scores were calculated using the Spencer Doppler code (2) and a 2D echocardiographic grade built by Powell (7). Respective interest of these two methods was studied in analysis of the results. Then a 2D echocardiographic and Doppler grade was proposed. Four apical chambers view and aortic blood flow doppler study were systematically made to detect circulating bubbles in the left cavities.

RESULTS

No circulating bubble was observed in the left cavities of the heart (2D images and aortic blood flow study).

The **2D images** were mediocre or average quality in 30% of cases in our population. Circulating bubbles were observed in right cavities of the heart in 26 cases (Table 1). Short axes parasternal view and right cavities long axe view were the best incidences to detect circulating bubbles.

Pulsed Doppler confirmed the results of 2D Echocardiography in 26 cases and detected circulating bubbles in 5 others cases (Table 1). Circulating bubbles are listened in the pulmonary blood flow and are visualised in the flow spectrum like anechogene elements.

GRADE	0	1	2	3	4
Powell (2D Echocardiography)	15	4	20	2	-
Spencer (Pulsed Doppler)	15	9	7	14	1
2D Echocardio. and pulsed Doppler	15	9	7	13	2

Table 1 : Results of circulating bubble detection

The level of circulating bubble was higher during **isometric contraction of quadriceps** in 10 cases. Bubble detection was then positive after isometric contraction of the extremities in 2 cases although it was negative before contraction.

A 2D Echocardiography/Pulsed Doppler grade was built with combination of Spencer and Powell grades (Table 2). Table 1 give the bubble grade according to the 2D Echocardiography and pulsed Doppler grade.

Grade 0	Complete lack of bubble signal (2D Echocardiography an pulsed Doppler)
Grade 1	Occasional bubbles, the great majority of cardiac periods are free of bubbles (2D Echocardiography and Pulsed Doppler
Grade 2	Steady flow of bubbles (2D Echocardiography), many but less than half of the cardiac periods contain bubble signals singularly or in group (pulsed Doppler)
Grade 3	Steady flow of bubbles (2D Echocardiography), majority of the cardiac periods contain bubble signals singularly or in group (pulsed Doppler)
Grade 4	Bubbles fill cardiac chambers (2D Echocardiography), all the cardiac periods contain bubble signals in group (pulsed Doppler)

Table 2 : 2D Echocardiography and pulsed Doppler grade

DISCUSSION

In our study 2D echocardiography seems to be less sensitive than pulsed Doppler. Indeed pulsed Doppler detect circulating bubbles in 5 cases in which 2D echocardiography detection seems to be negative. This difference seems to be principally secondary to the poor quality of 2D images in certain divers. An Echodoppler grade can be built with combination of bubble grades of Powell and Spencer. The examination by the pulsed Doppler allows to supply the 2D imagery in case of poor echogenicity (30% of cases in our study). Furthermore, pulsed Doppler determines with more precision, the quantification of the degrees of bubbles, when using classifications more precise than those used for the 2D imagery. Then for moderate quantities of bubbles (grade 2 of Powell and grade 2 and 3 of Spencer), pulsed Doppler brings the precision that makes defect in the 2D imagery. In case of high density of bubbles, 2D echocardiography could improved the accuracy of Doppler detection. Then a decrease of the subjectivity of the count of circulating bubbles can result of the combination of 2D echocardiography and pulsed Doppler. Complementary studies are needed to demonstrate these observations. As suggested

by precedent studies an increase in the circulating bubbles can be observed during isometric muscle contraction of the extremities (6). The origin is the brutal release of the stationnary bubbles in vessels in the inferior cava system. This manoeuvre can be of interest when bubbles are rare.

CONCLUSION

Visualisation of circulating bubbles with 2D echocardiography is possible, however this method is limited by diver echogenicity. Pulsed Doppler method guided by 2D imagery is the more sensitive for this detection. Then combination of 2D echocardiography and pulsed Doppler can be proposed to increase the accuracy of Doppler detection used only. The count of the bubbles may be improved by 2D echocardiography and pulsed Doppler when using a combination of Spencer's and Powell's grading. Further studies are needed to compare continuous Doppler to pulsed Doppler guided by 2D echocardiography.

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