The Effect of Respiratory Motion on the Echocardiogram

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The effects of respiratory movements on the ultrasonic echoes of the cardiac structures were recorded and analyzed in 50 consecutive patients. Deep inspiration in cooperative patients resulted in a considerable increase of dense anterior echoes, with blotting out of any distal or posterior echoes in 12 of 44 patients (group A). In the second or larger series (32 of 44 patients; group B), a posterior displacement of most of the identifiable intrinsic cardiac echoes was seen with deep inspiration, particularly those of the posterior wall of the left ventricle. Forced expiration produced an opposite or anterior displacement of the cardiac echoes. Normal respirations showed similar but smaller excursions.

While recording the ultrasonic echoes of the heart, particularly those of the posterior wall of the left ventricle, we frequently observed an undulating, distorting, and blocking effect accompanying even normal respiration. It was sometimes necessary to request the patient to hold his breath in order to obtain clear echoes. On instructing our patients to inhale deeply, we found that a fairly consistent relation existed between the respiratory excursion and the resultant displacement of the recorded echoes. In many instances, we were soon able to predict these changes provoked by breathing.

Although it is generally known by experienced echocardiographers that respiration can materially alter and even interfere with the recording of the intrinsic cardiac echoes, an analysis of the resultant changes has not been previously reported. Respiratory modifications have been vaguely noted by several observers; however, no systematic study has been reported. Feigenbaum¹ and many others have given constructive advice on obtaining improved echocardiograms by empirical rotation of the patient in order to avoid the pulmonary interference. Weyman et al² have noted the influence of respiration on the pulmonary arterial pressure and its pulmonary valvular echoes. This report represents a study of the specific effects of respiratory movements on the recorded echocardiogram.

Materials and Methods

The echocardiograms of 50 consecutive male patients were obtained in the usual routine manner with the patient lying supine or tilted toward the left lateral position and with the transducer placed in the left third or fourth interspace lateral to the sternal border. No attempt was made to classify or arrange the patient according to his clinical diagnosis. Usually the aortic root was first visualized; and after its successful recording, the patient was instructed to inhale deeply, then to exhale deeply, and finally to withhold his breathing. A similar procedure was then followed for the mitral valve area and for the posterior wall of the left ventricle. Unless the patient was quite dyspneic or ill, these orders could easily be followed. Echoes were obtained with an ultrasonic scope (Ekoline 20A) and were viewed and recorded on a strip chart recorder (Electronics for Medicine), usually at 25 mm/second. Both focused and nonfocused 2.25-MHz transducers with diameters of five-eighths inch were used. The depth was usually calibrated to 13 cm (in 1-cm gradations in all cases), and in some instances the total distance was increased to 18 cm in order to reach the full inspiratory displacement of the posterior wall of the left ventricle. The distances of all excitations of the cardiac echoes were measured wherever possible.

With inspiration the anteroposterior diameter of the chest increases, and the lungs inflate and expand particularly anteriorly, partly filling the space previously occupied by the heart and the adjacent contiguous ribs and sternum.³,⁴ This movement produces a posterior displacement and rotation of the heart and its contained structures. The sequence of events can readily be seen upon fluoroscopic examination of a patient lying supine on a flat table with the x-ray tube and viewing screen placed on either side of the patient and utilizing a horizontal beam.

Cardiac displacement was also verified by roentgenograms taken in a normal patient lying on the table in a left lateral position and employing a vertical x-ray beam. Figure 1A and 1B shows roentgenograms taken during deep expiration and
Group A

In another 12 (27 percent) of the remaining 44 patients, deep inspiration produced a marked increase in anterior echoes confluent with those of the chest wall that completely blotted out any distal or posterior echoes so that only a blank space remained (Fig 2). This was primarily due to the anterior interposition of the lung absorbing and reflecting completely all emitted ultrasonic waves. Edler6 was the first to note this high reflection and absorption by the interspaces of the air-filled alveoli. A change in the angle of incidence of the transducer might be another factor in the production of these anterior echoes. Rotation of the heart might also cause a variance in the echoes.

Group B

The remaining 32 patients, a larger series of 73 percent of the 44 patients, all demonstrated a posterior displacement of the intrinsic recognizable cardiac echoes on deep inspiration. In these instances the lung expansion only partly blocked transmission of the distal echoes. The most pronounced effect occurred with the echoes of the posterior wall of the left ventricle, which were often displaced 2 cm posteriorly (Fig 3). An opposite anterior excursion of 1 cm with forced expiration frequently occurred, so that a total deviation of 3 cm was seen with the combined deep respiratory movements. The interventricular septum usually paralleled this displacement of the posterior wall of the left ventricle, the internal diameter of the left ventricle remaining constant. Similarly, the echoes of the mitral leaflets were displaced posteriorly with

Figure 1A (upper). Normal patient's roentgenogram during forced expiration, taken with vertical beam with subject lying in left lateral position. Curved trace is anterior cardiac border which is in contact with inner sternal border, and straight line is diagonal axis of heart. 1B (lower). Roentgenogram of same patient taken during deep inspiration and in same position. Here, air space anterior to heart has expanded to 12 mm, and anteroposterior diameter has increased 30 mm (as measured from inner sternal margin to anterior thoracic spine in unreduced film). Diagonal line has become more vertical.

deep inspiration, respectively. It is evident that the air space anterior to the heart has increased considerably during the inspiratory phase, resulting in a posterior displacement of the heart together with a more vertical diagonal axis. During the inspiratory phase, the anteroposterior diameter of the thorax, measured from the inner sternal margin to the anterior border of the thoracic spine, increased from 13.3 to 16.3 cm (on the original unreduced x-ray film).

RESULTS

In our series of 50 consecutive patients with various clinical conditions, only six were unable to cooperate and perform the requested respiratory motions and, thus, were eliminated from the study. Such failure to follow orders was due to dyspnea, severe illness, or poor comprehension.
3. Posterior wall of left ventricle is displaced 2 cm posteriorly with deep inspiration and 1 cm anteriorly with deep expiration; thus, it has total excursion of 3 cm. Septum moves parallel to posterior wall of left ventricle, diameter of left ventricle remaining constant at 2.5 cm in systole and 4 cm in diastole.

depth inspiration (Fig 4), but their opening and closing slopes remained unchanged. The systolic anterior motion of the posterior wall of the left ventricle was often blunted, and its pulsations were diminished by the inspiratory maneuver but still could be identified. As in group A, the anterior echoes were frequently increased in thickness and density during the inspiratory phase. Often, only moderate inspiration demonstrated the posterior deviation of the cardiac structures, while deep inspiration increased the anterior echoes enough to eliminate all distal signals.

The anterior and posterior aortic root and the semilunar valves displayed a similar posterior inspiratory deviation, usually of 1 cm (Fig 5). The
posterior wall of the left atrium also paralleled this deviation to the same extent.

The tricuspid valve could also be seen to be displaced posteriorly during deep inspiration (Fig 6). The influence of normal quiet respiration could sometimes be detected by viewing the undulations of the posterior walls of the left atrium or of the left ventricle, and the respiratory rate per minute could then be determined.

**DISCUSSION**

This study demonstrates that respiratory movements produce a displacement of echoes of the intrinsic structures of the heart. With deep inspiration a smaller group (A) of the patients show a considerable increase in the anterior echoes, which completely block any distal signals. This primarily results from the anterior interposition of the lungs between the heart and the inner surface of the chest. Yet in a larger group (B) of patients, while the anterior echoes are only moderately augmented, the distal signals can still be identified. Here inspiration produces a uniform posterior excursion of the intrinsic cardiac structures resulting mainly from the posterior displacement of the heart. Forced expiration, in contrast, results in an anterior excursion of the cardiac structures but does not reveal any diminution of the usual anterior or chest wall echoes. Normal respiration produces excursions similar to those occurring with deep respiration but to a lesser extent.

Both normal and deep respiratory movements usually produce parallel excursions of the echoes of the intrinsic structures, so that the observed diameter of the left ventricle or the left atrium remains constant and the size of the cardiac chambers remains essentially unchanged; however, the right ventricular diameter could not be assessed because of the great increase of the anterior echoes camouflaging the right ventricular wall and chamber. As already noted, the valvular and septal configurations are not altered by the respiratory movements.

Blunting or decreased anterior systolic movement of the posterior wall of the left ventricle on inspiration is an interesting finding frequently seen during this study and occurs together with the posterior deviation of the wall. It is possible that it may be due to a diminished left ventricular filling pressure occurring with forced inspiration. While no change could be detected in the diameter of that chamber, a small decrease in size might not be measurable by the echocardiographic methods employed. Other possible explanations for the blunting are a variation in the angle of incidence of the transducer beam or the influence of longitudinal rotation of the heart.

These changes induced by respiration are not meant to represent a new artificial method of recording echocardiograms but rather are intended to eliminate some of the pitfalls in obtaining clear signals. Inspiratory movements not only increase the blocking anterior echoes through anterior pulmonary expansion but may also change the angle of incidence of the transducer ray relative to the heart. There is no evidence that respiratory motion sets up any unusual reverberations which affect the recorded signals other than those mentioned. In a practical way, requesting the patient to hold his breath may enable the examiner to secure clear echoes not otherwise obtainable. A knowledge of the influence of respiratory movements will also help the echocardiographer interpret many distortions and artifacts. The cyclic undulations of the posterior walls of the left ventricle or of the left atrium which are occa-

**FIGURE 6.** Tricuspid valve descends 7 mm during deep inspiration and is partly obscured by increase in anterior echoes. Posterior wall of left atrium (PWLA) is displaced 18 mm posteriorly at same time. Note that during quiet respiration, PWLA undulates at 2.2-second intervals or respiratory rate of 28/sec (each vertical time line represents one second). This patient had severe combined heart failure with marked right ventricular and left atrial dilatation. This may account for simultaneous appearance of tricuspid valve with PWLA.
sionally observed are due to normal respiratory movements and provide a graphic record of the respiratory rate.

REFERENCES


Detergents

Soap, a chemical compound of fatty acids and alkali, mainly caustic soda and caustic potash, as a detergent served the test of times since ancient Roman days. In the latter era, when sacrificial animals were burnt on the altars of Sapo Hill near Rome, fat soaked down through wood ashes into the clay below; the soapy clay was found to be a cleansing agent. Etymologists assert that Sapo is the origin of the word soap. According to Schwartz, AM (Encyclopedia Americana, New York, Encycl Am Corp, 1974), Soap is a detergent; however, in common usage the term “detergent” is not applied to soap but only to synthetic non-soap substances. Synthetic detergents are not made from fats and oils; they are more efficient cleansing agents than soap, and in hard water clean better than soap. The molecules of detergents emulsify fatty substances and render them removable from their sites. The first synthetic detergent was developed in Germany in 1916. Because it was too harsh, it was used by industry only. Household detergent was produced first in the United States in 1933. Enzyme additives greatly improve the efficacy of detergents. It is estimated that 50 million households in the United States are using enzyme-containing laundry products. The great majority of laundry detergents contain proteolytic enzymes. Of this category, subtilins are derived by fermentation from strains of Bacillus subtilis which is ubiquitous in soil. Spores of this microbe are less than 5 microns in size and can readily reach the alveoli. Subtilins constitute 0.1 to 1 percent of the enzyme material in common laundry detergents. Inhalational exposure to this enzyme resulted in sensitization and asthma-like symptoms in 20 to 50 percent of detergent-manufacturing and soap factory workers. Sporadic instances of similar manifestations have been observed in subjects doing household laundry chores, washing walls with enzyme-containing soaps in their homes, or engaged in odd cleaning jobs. Early reports on the industrial occurrence of this condition were made by Pepys, J (J Royal

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