

# Determination of right ventricular wall thickness in systole and diastole

## *Echocardiographic and necropsy correlation in 32 patients*

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**SUMMARY** To show that right ventricular wall thickness (RVWT) measurements can be made with precision by echocardiography, we correlated these measurements with those obtained at necropsy in 32 terminal patients. The correlation between the echocardiographic diastolic right ventricular wall thickness (mean  $4.0 \pm 1.62$  mm) and the necropsy measurement (mean  $4.3 \pm 1.52$  mm) was good ( $r = 0.83$ ) in all 32 patients with normal or increased right ventricular wall thickness at necropsy. In 19 patients without necropsy evidence of right ventricular hypertrophy (RVWT  $\leq 4$  mm), the mean diastolic and systolic right ventricular wall thicknesses were  $3.0 \pm 0.92$  mm and  $5.1 \pm 1.64$  mm, respectively. In 13 patients with necropsy evidence of right ventricular hypertrophy (RVWT  $\geq 5$  mm), the mean diastolic and systolic right ventricular wall thicknesses were  $5.3 \pm 1.56$  mm and  $8.2 \pm 1.88$  mm, respectively. We conclude that technically satisfactory echocardiograms of the right ventricular wall can be obtained in adults and that these allow measurement of systolic and diastolic right ventricular wall thicknesses. Echocardiography can reliably estimate the diastolic wall thickness and may be helpful in the evaluation of right ventricular hypertrophy.

Visualisation of the wall of the right ventricle is difficult in man. The right ventricular free wall is not traceable from cine-angiograms (Arcilla *et al.*, 1976), and can only be measured at necropsy (Sokolow and Lyon, 1949; Allenstein and Mori, 1960; Selzer *et al.*, 1960; Flowers and Horan, 1972). The right ventricular cavity dimension can be estimated by echocardiography by measuring from an assumed location of the anterior border of the right ventricle 5 mm from the chest wall echoes (Popp *et al.*, 1969; Feigenbaum, 1976) to the right side of the interventricular septum.

Recently, right ventricular wall thickness has been measured in children by echocardiography (Hagan *et al.*, 1973; Solinger *et al.*, 1973; Epstein *et al.*, 1975; Goldberg *et al.*, 1975). These echocardiographic measurements have not been validated with necropsy findings, though the diastolic measurements correlate well with the wall thickness measured using callipers at the time of open heart surgery (Arcilla *et al.*, 1976). Right ventricular wall thickness and motion have not been evaluated in adults and no measurements are available (Joyner,

1974; Gramiak and Waag, 1975; Chang, 1976; Feigenbaum, 1976). To show that measurements of right ventricular wall thickness can be made with precision in adults by echocardiography we correlated these measurements with those obtained at necropsy in 32 male patients. This paper reports the results of this study.

### **Subjects and methods**

All terminal patients known to us were studied by echocardiography. Thirty-two of these patients died within one month of echocardiography and necropsy measurements of right ventricular wall thickness were made (Table).

#### **ECHOCARDIOGRAPHIC TECHNIQUE FOR OBTAINING RIGHT VENTRICULAR WALL ECHOES**

The echocardiographic recordings were made using a strip chart recorder with the patient in the supine position. A 2.25 MHz transducer was used to record the right ventricular wall echoes in all patients. As the chest wall gives strong echoes, this can result in poor resolution of the anterior right ventricular

Table Correlation of echocardiographic and necropsy measurements of right ventricular wall thickness in all patients

Patient number	Age (y)	Diagnosis	Necropsy (mm)	Echocardiogram (mm)	
				diastole	systole
1	56	Coronary heart disease	6	6	10
2	71	Coronary heart disease	7	6	10
3	59	Cardiomyopathy	6	5	7
4	63	Coronary heart disease	6	5	7
5	87	Cardiomyopathy	6	7	9
6	57	Coronary heart disease	5	6	9
7	38	Coronary heart disease	5	5	8
8	39	Coronary heart disease	5	5	8
9	48	Coronary heart disease	5	5	7
10	78	Coronary heart disease	3-5	4	6
11	54	Coronary heart disease	3	2	5
12	76	Coronary heart disease	3	3	4
13	55	Coronary heart disease	3	3	4
14	59	Coronary heart disease	2	2	3
15	61	Cardiomyopathy	4	3	5
16	56	Cardiomyopathy	3	3	4
17	84	Coronary heart disease	3	4	8
18	62	Cardiomyopathy	3	3	5
19	60	Coronary heart disease	4	2	5
20	66	Coronary heart disease	4	2	5
21	56	Coronary heart disease	3	2	6
22	62	Coronary heart disease	3	3	5
23	45	Coronary heart disease	3	3	5
24	56	Coronary heart disease	3	2	2
25	50	Cardiomyopathy	4	2	5
26	64	Cardiomyopathy	7	6	10
27	48	Coronary heart disease	6	5	9
28	60	Cardiomyopathy	6	6	10
29	56	Coronary heart disease	6	6	10
30	81	Coronary heart disease	4	5	9
31	54	Coronary heart disease	3	3	5
32	40	Cardiomyopathy	4	4	6

wall. It was necessary to adjust carefully the coarse gain, near gain, and depth compensation controls to record right ventricular wall echoes adequate for measurement of wall thickness. Placement of the depth compensation ramp and its angle of slope are not fixed for recording the right ventricular wall. This control is used to suppress echoes close to the transducer and to increase the intensity of echoes farther away from the transducer. The depth compensation settings recommended for echocardiographic examination of the left ventricle (Chang, 1976) are not appropriate for obtaining echograms of the right ventricular wall.

In our experience, right ventricular wall echoes were clearly seen only when we specifically looked for them. On a routine echocardiogram for a left ventricular study, the right ventricular wall was not well defined (Fig. 1A, left panel). On reducing the near gain, the right ventricular wall echoes were better seen (Fig. 1A, right panel). In the last two beats the right ventricular wall echoes are reasonably clear, though the right ventricular wall could not be completely separated from the chest wall. In Fig. 1B, separation of right ventricular wall from

the chest wall was achieved by decreasing the near gain and increasing the coarse gain. Though the right ventricular wall is well seen in both panels of Fig. 1B, the left panel is better suited for assessing the right ventricular wall thickness and motion than the right panel, as it has higher gain and darker colour. The right ventricular wall shows a posterior motion away from the chest wall during systole, and is thicker in systole than in diastole (Figs 2 and 3). The anterior echo-free space seen in Fig. 1B is not the result of the pericardial effusion. No posterior echo-free space was present in any patient though we specifically looked for pericardial effusion by standard techniques (Horowitz *et al.*, 1974). The right ventricular wall thickness was measured from the pericardium to the endocardial surface of the right ventricle at a level where the interventricular septum, mitral valve, and posterior left ventricular wall were well seen; end-diastolic measurements were made at the beginning of QRS, and systolic measurements when right ventricular wall thickness was greatest.

#### NECROPSY TECHNIQUES

At necropsy the hearts were dissected in a uniform manner and the right ventricular wall thickness measurements were made without knowledge of the echocardiographic measurements. The right ventricular wall thickness was measured in millimetres with a ruler, in the mid-portion of the free wall of the right ventricle (between the base and the apex). Sections were carefully made to avoid the valleys between the trabeculations. The normal right ventricular wall thickness at necropsy is 2 mm, and right ventricular hypertrophy is usually considered to be present if the wall thickness is 5 mm or more.

#### Results

The diastolic and systolic measurements of right ventricular wall thickness were correlated with the necropsy measurements. The correlation between diastolic wall thickness measured by echocardiography (mean  $4.0 \pm 1.62$  mm) and at necropsy ( $4.3 \pm 1.52$  mm) was good ( $r = 0.83$ ) in all 32 patients (Fig. 4). The correlation between the systolic wall thickness measured by echocardiography ( $6.4 \pm 2.42$  mm) and at necropsy was less good ( $r = 0.59$ ).

There were 19 patients without right ventricular hypertrophy, having a wall thickness 4 mm or less at necropsy. The mean diastolic right ventricular wall thickness measured at echocardiography was  $3.0 \pm 0.92$  mm (range 2-5 mm) and the mean systolic measurement was  $5.1 \pm 1.64$  mm (range 2-9 mm).

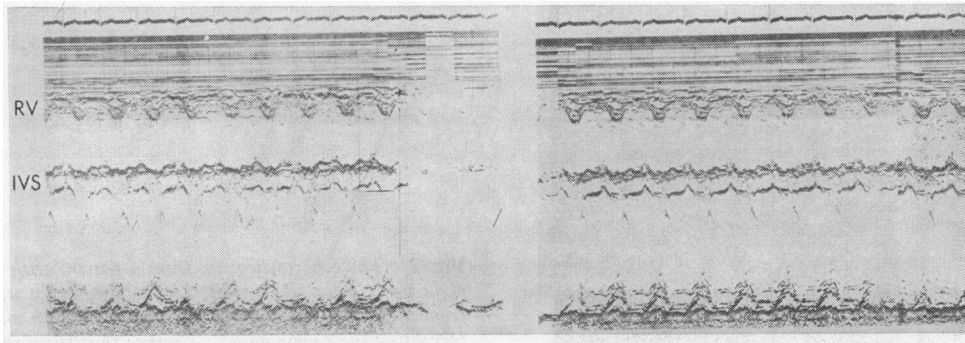


Fig. 1(A)

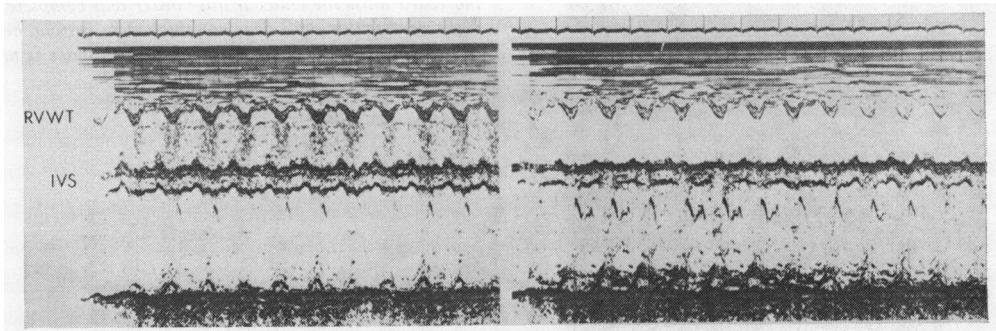


Fig. 1(B)

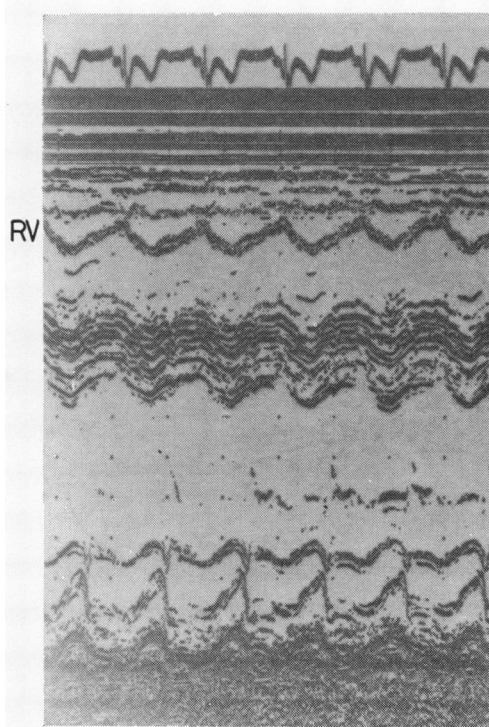
Fig. 1(A) (left panel) Right ventricular (RV) wall seen on a routine study is not separate from the chest wall echoes. This is because of a high near gain. On the right side of left panel the gain is decreased abruptly with the right ventricular wall almost disappearing. (right panel) The right ventricular wall is seen better. The endocardial margins are more distinct, but the right ventricular wall and chest wall echoes are still close to each other. Though this echo is not optimal for right ventricular wall thickness measurement, the right ventricular dimension can be accurately measured from the endocardium of the right ventricular wall to the right side of septum. Thus, one would not have to use the customary approximation of about 0.5 cm from the chest wall echoes as to the location of the anterior border of the right ventricle. The last two beats of the tracing show a clear right ventricular wall. (B) An optimal right ventricular wall recording from the same patient. The chest wall echoes have been suppressed by manipulation of the near gain, coarse gain, and the depth compensation controls. The right ventricular wall is separated from the chest wall by an anterior echo-free space not caused by a pericardial effusion. The thickness and motion of the right ventricular wall can be evaluated from this echocardiogram. During systole the right ventricular wall thickens and moves away from the chest wall in a posterior direction. The right panel shows a reduction in gain with virtual disappearance of the right ventricular wall echoes in the last few beats.

There were 13 patients with right ventricular hypertrophy as evidenced by right ventricular wall thickness 5 mm or more at necropsy. The mean diastolic wall thickness measurement by echocardiography was  $5.3 \pm 1.56$  mm (range 5-6 mm) and the mean systolic thickness measurement was  $8.2 \pm 1.88$  mm (range 6-10 mm).

### Discussion

Our data show that echocardiographic measurements of diastolic right ventricular wall thickness correlate

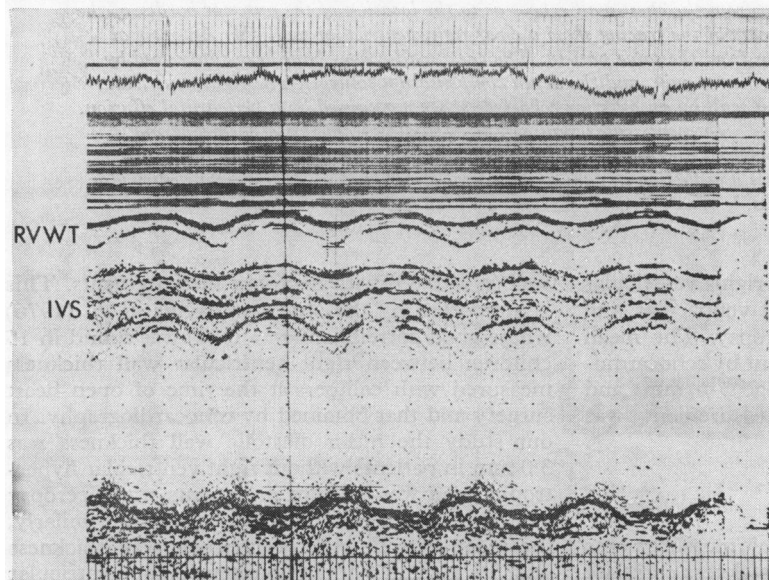
well ( $r = 0.83$ ) with necropsy measurements. This is supported by the study of Arcilla *et al.* (1976) where good correlation ( $r = 0.87$ ) was found in 15 children between right ventricular wall thickness measured with callipers at the time of open heart surgery and that obtained by echocardiography. In our study the mean diastolic wall thickness was 3.0 mm in patients without right ventricular hypertrophy, and was 5.3 mm in patients with necropsy evidence of right ventricular hypertrophy. Similarly, the mean systolic right ventricular wall thickness was 5.1 mm in patients without right ventricular



**Fig. 2** The echocardiogram from a patient with a thin right ventricular (RV) wall. This is completely separated from the chest wall by decreasing the near gain and increasing the coarse gain. To ensure that the right ventricular wall thickness was seen in full, the gain was increased until the endocardial border was complete. The right ventricular wall does not thicken in systole, but has very good motion. The anterior echo-free space is not the result of a pericardial effusion.

hypertrophy, and was 8.2 mm in patients with necropsy evidence of right ventricular hypertrophy. These measurements of right ventricular wall thick-

ness in adults may be helpful in evaluating right ventricular hypertrophy and right ventricular mass (Arcilla *et al.*, 1976).



**Fig. 3** A distinct right ventricular wall completely separated from the chest wall by an echo-free space (not due to pericardial effusion) is shown here. Both margins of the right ventricular wall are distinct, and the diastolic and systolic measurements of its thickness can be accurately made. The right ventricular wall thickens during systole, has good motion, and displays a posterior motion away from the chest wall.

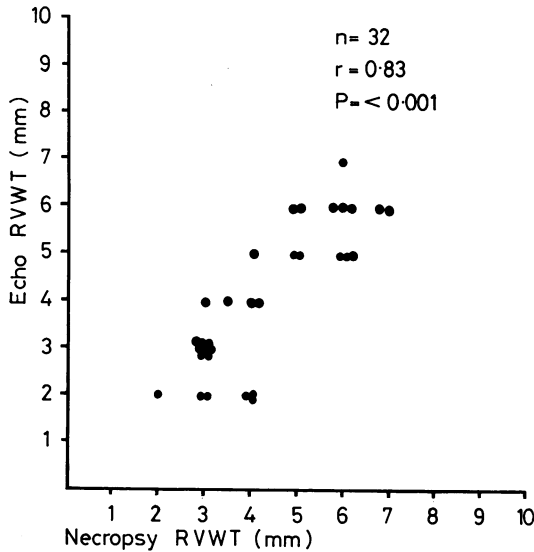


Fig. 4 Correlation between the echocardiographic measurements of right ventricular wall thickness (RVWT) and the necropsy measurements was good ( $r = 0.83$ ) in 32 patients. The diastolic RVWT for all patients ranged between 2 and 6 mm (mean  $4.0 \pm 1.62$  mm), the systolic RVWT ranged between 2 and 10 mm (mean  $6.4 \pm 2.42$  mm), and the necropsy RVWT ranged between 2 and 7 mm (mean  $4.3 \pm 1.52$  mm).

It has been said that the anterior right ventricular wall is difficult to record in the absence of significant anterior pericardial effusion and is clearer in the presence of exaggerated motion, as seen in hypertrophic subaortic stenosis (Feigenbaum, 1976). In our study, the recording of clear right ventricular wall echoes was unrelated to the magnitude of right ventricular wall excursion. Furthermore an anterior echo-free space could be seen in the absence of pericardial effusion, as has been described before (Solinger *et al.*, 1973; Horowitz *et al.*, 1974; Epstein *et al.*, 1975). Our success in obtaining satisfactory right ventricular wall echoes is in large part the result of our interest in measuring wall thickness and not because of new technical advances. Good quality echograms appropriate for right ventricular wall thickness measurement were obtained in nearly 90 per cent of subjects up to 18 years of age by Arcilla *et al.* (1976), and in 73 of 77 children by Allen *et al.* (1977).

We conclude that technically satisfactory echocardiograms of the right ventricular wall can be obtained in men which allow measurements of systolic and diastolic wall thickness. Measurements of diastolic right ventricular wall thickness by

echocardiography correlate well with necropsy measurements, and may be useful in the non-invasive evaluation of right ventricular hypertrophy and mass in man.

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