An Anatomical Study of the Healty Human Heart by Echocardiography with Special Reference to Physiological Valvular Regurgitation

ANNALS OF ANATOMY

An anatomical study of the healthy human heart by echocardiography with special reference to physiological valvular regurgitation*

Claudio Macchi[1], Sandra Zecchi Orlandini[2] and Giovanni E. Orlandini[2]

[1]Institute of Gerontology and Geriatric Medicine
[2]Department of Human Anatomy and Histology, University of Florence,
Viale Morgagni 85, I-50134 Florence, Italy

Summary. 110 healthy subjects (45 men and 65 women ranging in age between 24 and 60 years) were studied by 2-dimensional echocardiography. In each subject the diameters of the cardiac chambers, the thickness of the intraventricular septum and posterior wall of the left ventricle in diastole, as well as the diameters and circumferences of the aortic and mitral rings were measured. Moreover, in each subject color doppler echocardiography was performed. Pulmonary valve regurgitation was observed in 47 subjects (42.7 %). This finding was not correlated in a statistically significant manner to either age, sex, body weight, or height. The incidence of pulmonary regurgitation, however, tended to decrease with age. In 37 subjects (33.6 %), tricuspid regurgitation was detected without any correlation to the above parameters. In 11 cases (10 %), mitral regurgitation was observed; its correlation to age was statistically significant ($p < 0.05$). Aortic regurgitation was noted in 9 (8.2 %) cases; its incidence was directly correlated to age ($p < 0.01$). The observed regurgitations were defined as "physiological" and precise characteristics were choosen so as to distinguish such "physiological" from "pathological" regurgitations.

Introduction

Until a few years ago, it was taken for granted that if an echocardiogram demonstrated a normal cardiac pattern (including chamber size, wall thickness and valve structure), apposition of the valvular leaflets was also normal, expecially in subjects who had no abnormal auscultatory findings (i. e., murmurs).

The use of doppler and color doppler techniques in diagnostic cardiology has proved to be extremely useful not only for determining "in vivo" the size of the heart chambers and the thickness of their walls during the different phases of cardiac activity, but also for the dynamic study of the atrioventricular and arterial valves. Thus, valvular regurgitation can be easily detected (Abbasi et al. 1980; Curtius et al. 1985). Recent studies have demonstrated that it is possible to detect a high percentage of regurgitation in otherwise normal valves in healthy subjects with no cardiac pathology (Kostucki et al. 1986; Feigenbaum 1986; Takao et al. 1988).

The aim of this study was to examine the incidence of valvular regurgitation in a random population of healthy subjects, and then to determine the presence of possible correlations with cardiac and extracardiac parameters in order to establish the characteristics of "physiological" regurgitations that distinguish them from pathological ones. It is essential to avoid treating a normal condition as though it were pathological. Healthy patients would otherwise be considered ill. Furthermore, in the field of sport medicine, it is necessary to have confidence in one's assessment that a subject is healthy and does not have pathological regurgitation.

Material and methods

110 subjects (45 men and 65 women, aged between 24 and 60 years) were studied. All were healthy and asymptomatic and

* Dedicated to Prof. Dr. Wolfgang Kühnel on the occasion of his 60th birthday.

Correspondence to: G. E. Orlandini

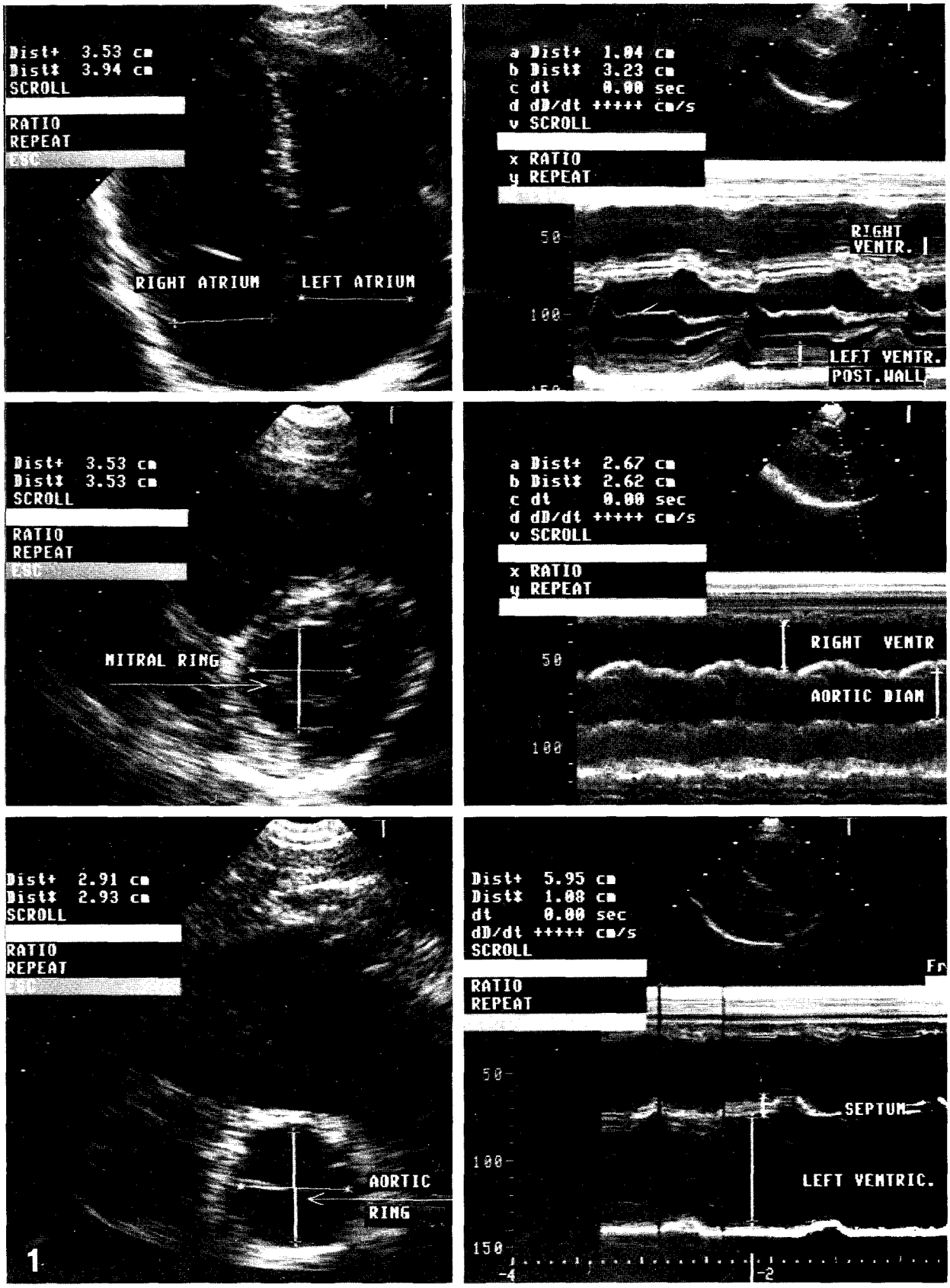

Fig. 1. 2-D echocardiograms illustrating the method of measurement for chamber diameters, thickness of the interventricular septum and posterior wall of the left ventricle as well as the diameters and circumferences of the aortic and mitral rings.

without any detectable valvular abnormality. A 2-D echocardiogram was performed on each subject, and the following parameters measured (Fig. 1):

1) maximal diameters of chambers in cross section,
2) thickness of interventricular septum in diastole,
3) thickness of posterior wall of left ventricle in diastole,
4) aortic and mitral ring diameters and circumferences

Furthermore, color doppler echocardiography was performed in each subject. For the 2-D and color doppler echocardiograms, an Acuson model 128, with a 3.00 MHz probe was used. Valvular regurgitant flow was calculated (taking as a point of reference the distance from the valvular plane and the area of the regurgitant jet as demonstrated by color coding, in mm and mm^2, respectively); its duration (msec), and its velocity (m/sec) were measured (Fig. 2).

Results

In Table 1 the mean values of each measurement, for all subjects and then separately for the two sexes are reported. The mean diameters of the right chambers and left atria did not appear to be statistically correlated to age, sex, body weight, or height, even though, as a general trend, these values tended to increase with age.

The mean diameter of the left ventricle as well as the thickness of the interventricular septum and the posterior wall of the left ventricle, however, were significantly greater in the male sex ($p < 0.02$). Moreover a significant direct correlation existed to body weight ($p < 0.01$),

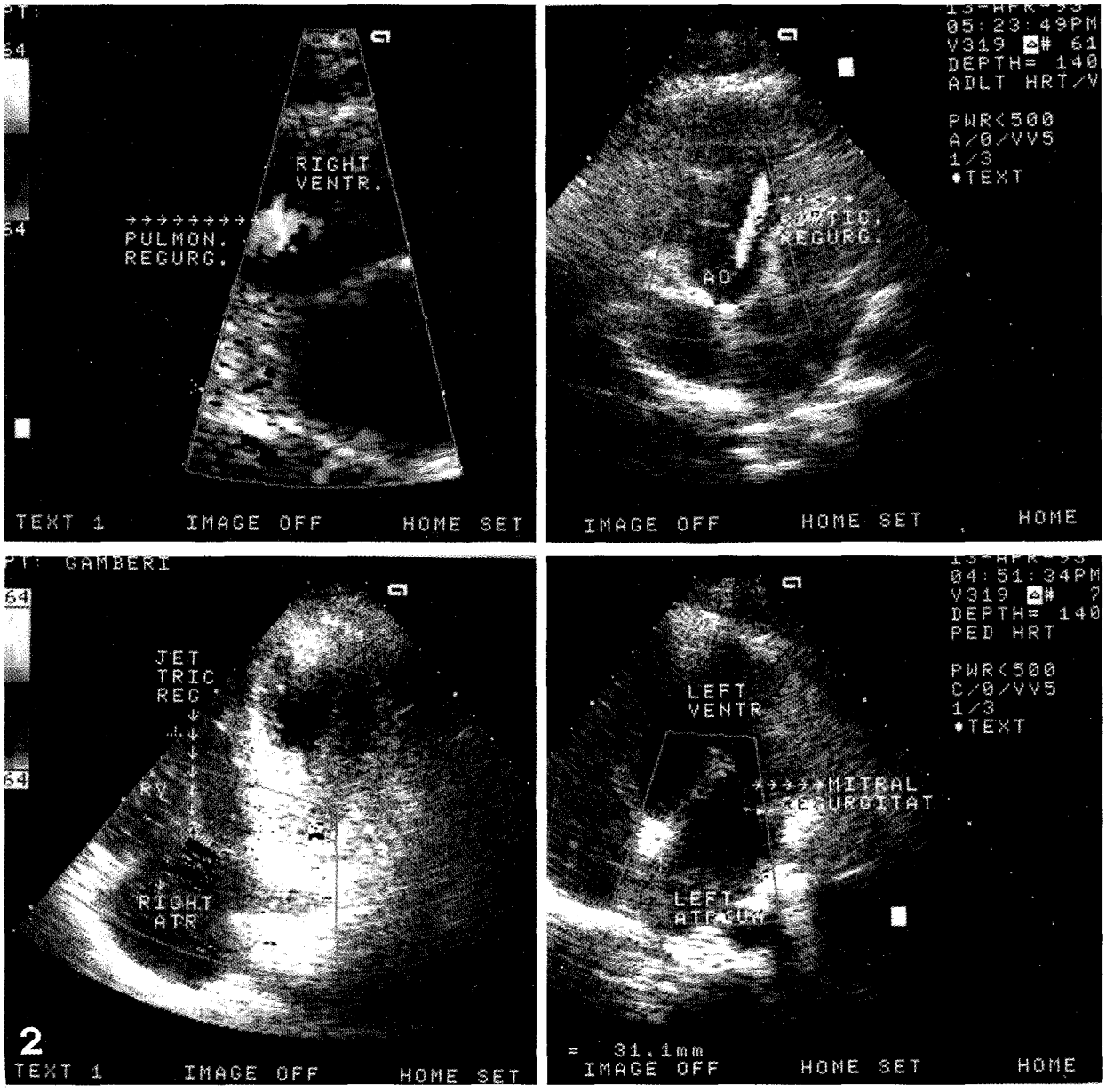

Fig. 2. Echo color-doppler of four subjects with valvular regurgitation.

Table 1. Mean values (mm ± sd) of the cardiac chamber diameters, thickness of the interventricular septum and posterior left ventricular wall and diameters of the aortic and mitral rings in total of cases

	Totality	Males	females	Pt
RVDd	18.3 ± 1.2	18.3 ± 1.2	18.2 ± 1.3	ns
LVIDd	47.1 ± 3.3	48.0 ± 3.8	46.2 ± 2.9	< 0.02
RAD	23.5 ± 1.9	23.6 ± 1.9	23.4 ± 1.9	ns
LAD	32.2 ± 2.6	32.5 ± 2.8	31.8 ± 2.5	ns
IVSd	7.9 ± 1.2	8.7 ± 1.1	7.2 ± 1.2	< 0.02
PLVWd	7.4 ± 1.2	7.9 ± 1.3	6.9 ± 1.0	< 0.02
AOD	24.8 ± 1.6	25.8 ± 1.7	23.8 ± 1.6	< 0.01
MD	30.3 ± 1.6	32.2 ± 1.8	28.4 ± 1.4	< 0.01

Abbreviations:
RVDd = dimension of right ventricle
LVIDd = internal dimension of left ventricle
RAD = dimension of right atrium
LAD = dimension of left atrium
IVSd = thickness of interventricular septum
PLVWd = thickness of posterior wall of left ventricle
AOD = diameter of aortic ring
MD = diameter of mitral ring
Lower case d indicates measurements at the end of diastole.

whereas the direct correlation to age and height did not reach the confidence level.

As concerns the mean diameters of aortic and mitral rings, which were larger in males ($p < 0.01$), a significant direct correlation existend only to body weight and height ($p < 0.01$). As regards the continence of each valve assessed by color doppler echocardiography, the following results were obtained.

Physiological regurgitation through the *pulmonary valve* was observed in 47 cases (42.7 %) in mid- to late diastole. The mean maximal velocity was less than 1 m/sec; the mean duration, which was measured no more than 8 mm from the valvular plane, was less than 160 msec; and the mean area of the regurgitant jet was less than 35 mm^2. There were not statistically significant correlations between age, sex, body weight, or height and valvular regurgitation. Nevertheless, the incidence of pulmonary valvular regurgitation tended to decrease with age.

In 37 cases (33.6 %) *tricuspid* regurgitation was observed, primarily in early to mid-systole (29 cases), but also throughout systole (8 cases). The mean maximal velocity was less than 1.8 m/sec, and the mean duration was less than 150 msec. These findings were observed on average no more than 8 mm from the valvular plane. The mean area of the color-coded jet was less than 34 mm^2. There were no correlations between regurgitation and age, sex, body weight, or height.

Mitral regurgitation was demonstrated in 11 cases (10 %). It was holosystolic, with a mean maximal velocity less than 3.5 m/sec, a mean duration of less than 160 msec, a mean distance from the valvular plane of less than 10 mm, and a mean regurgitant jet area of less than 30 mm^2. No correlations were observed between the degree of regurgitation and sex, body weight, or height. However, there was a statistically significant correlation between the presence of mitral regurgitation and age ($p < 0.05$).

Aortic regurgitation was observed in 9 subjects (8.2 %) all of them older than 46 years, thus giving significance to the factor age ($p < 0.01$). There were no correlations to sex, body weight, or height. Regurgitation occurred in early diastole and had a mean maximal velocity of less than 3 m/sec, a mean duration of less than 180 msec, a mean distance from the valvular plane of less than 10 mm, and a mean regurgitant jet area of less than 40 mm^2.

Table 2 lists the mean diameter of the cardiac chambers, the mean thicknesses of the interventricular septum and posterior wall of the left ventricle and the mean diamters of the aortic and mitral rings in subjects without (A) and with (B) "physiological" regurgitation. In both sexes there were no significant differences in the mean values of these measurements between the subjects with and without valvular regurgitation.

Table 2. Mean values (mm ± sd) of the cardiac chamber diameters, of the interventricular septum and posterior left ventricular wall thickness and of the aortic and mitral ring diameters in subjects without (A) and with regurgitations (B)

	A		B	
	Males	Females	Males	Females
RVDd	18.3 ± 1.3	18.4 ± 1.4	17.9 ± 1.2	18.3 ± 1.3
LVIDd	47.8 ± 4.8	47.3 ± 2.8	48.3 ± 2.8	48.1 ± 3.1
RAD	24.4 ± 1.9	23.3 ± 1.8	23.8 ± 1.9	23.5 ± 2.1
LAD	32.1 ± 3.1	31.3 ± 2.6	32.9 ± 2.6	31.2 ± 2.4
IVSd	8.5 ± 0.9	7.8 ± 1.2	8.9 ± 1.2	7.6 ± 1.3
PLVWd	8.0 ± 1.3	7.2 ± 1.2	7.9 ± 1.4	7.6 ± 0.8
AOD	25.7 ± 1.8	23.9 ± 1.7	25.9 ± 1.6	23.7 ± 1.4
MD	32.2 ± 1.7	28.5 ± 1.3	32.3 ± 1.9	28.4 ± 1.5

Abbreviations: see Table 1

Discussion

Our morphometric data, with the exception of those on the aortic ring, are in agreement with those reported by most other authors (Feigenbaum 1986; Braunwald 1989). Leguerrier et al. (1982) also observed that the diameter of the aortic ring is greater than reported in older studies and suggested that this is due to the general increase in body weight and height in the population during the past half century (Pineau 1970). Most of the original morphometric studies date back to the early 1900s.

Our results show that a remarkably large proportion of the cardiologically healthy, non-elderly population does have "physiological" regurgitation. The study also affirms the sensitivity of color doppler echocardiography for detecting regurgitation. The percentage of valvular

regurgitation is lower than that reported in studies on young athletes (Merlino et al. 1989; Mori et al. 1990). This is particularly true for pulmonary regurgitation. In athletes, as in other subjects during conditions of high cardiac output, the pulmonry valve may be insufficient in its center of apposition due to an increase in the caliber of the pulmonary artery (Scarpini and Nassiacos 1990). Merlino et al. (1989) claim that physiological pulmonary insufficiency is the rule in highly-trained athletes, such as marathon runners. The fact that physiological pulmonary regurgitation tends to decrease with age, also reported by Yoshida et al. (1988), may be attributed to a worsening of the acoustic window (secondary to emphysema or obesity), which makes the visualization of the pulmonary valve and color coding difficult. Alternately, it may be attributed to a different pathogenetic mechanism, such as a structural alteration of the valvular apparatus. Our data regarding the pulmonary valve are intermediate between those reported by Choong et al. (1989), who described physiological regurgitation in 5 % of their subjects, and those of Takao et al. (1988), who reported holodiastolic regurgitation to be present in 39 out of 50 subjects.

With respect to "physiological" tricuspid regurgitation, our data are intermediate between those obtained by Berger et al. (1989), who described "physiological" regurgitation in 17 % of their cases, and those of Yoch et al. (1984) who reported a figure of 95 %. Scarpini et al. (1990) hypothesized that physiological regurgitation through the tricuspid valve is due to an imperfection in the valvular apparatus, whereby uneven contractions of the papillary muscles and the morphological inhomogeneity of the three leaflets combine to interfere with the synchrony of the entire apparatus. Even the incidence of "physiological" regurgitation through the tricuspid valve becomes reduced with advancing age, as does pulmonary regurgitation.

With respect to "physiological" mitral regurgitation, our data agree with those of Yoch et al. (1984). Choong et al. (1989) suggested that the statistically significant correlation between mitral regurgitation and age is brought about by a modest degeneration of the leaflets, which can alter the homogeneity of their surfaces, or by an increase in intracardiac pressure.

With regard to "physiological" aortic regurgitation, our data agree with those of Akasaka et al. (1987). In our subjects aortic regurgitation was present in 9 cases, all of whom were older than 46 years of age. This signifies that there is probably an age related thickening of the aortic valve cusps, possibly associated with sclerosis of the arterial walls and ectasia of the aortic root, so much so that it should not be considered entirely physiological. The differences among the data reported by various investigators regarding the percentage of physiological regurgitation are most probably related to many factors: the age of the subjects examined and the quality of the acoustic window, the method used, the sensitivity and settings of the apparatus used, and the criteria adopted in defining regurgitation. Yoshida et al. (1988) defined regurgitation to be present when the flow lasts for at least 100 msec, as assessed by color time motion.

On the basis of our data, it may be stated that regurgitation is physiological when it meets the following criteria: it is found no more than 1 cm from the valvular plane, it is less than 3 mm in width, its area is less than 50 mm^2 of measured color-coded surface, it lasts only between 100 and 200 msec, and has a maximal velocity of less than 2 m/sec in the right heart and 3.5 m/sec in the left heart. It may be concluded that mild "physiological" valvular regurgitation is a frequent finding, but caution is nevertheless warranted when making a prognosis on the possible progression of a condition of regurgitation. Pathological progression may eventually occur in some valves, in particular the aortic and the mitral.

References

Abbasi AS, Allen MV, De Cristofaro D, Ungar I (1980) Detection and estimation of the degree of mitral regurgitation by range gated pulsed doppler echocardiography. Circulation 61: 143 – 147

Akasaka T, Yoshikawa J, Yoshida K, Okumachi F, Koizumi K, Shiratori K, Takao S, Shakudo M, Kato H (1987) Age-related valvular regurgitation: a study by pulsed doppler echocardiography. Circulation 76: 262 – 265

Berger M, Hecht SR, Van Tosh A, Lingam U (1989) Pulsed and continuous wave doppler echocardiography assessment of valvular regurgitation in normal subjects. J Am Coll Cardiol 13: 1540 – 1545

Braunwald E (1984) Heart disease, 2nd edn. WB Saunders, Philadelphia

Choong CY, Abascal VM, Weyman J, Levine RA, Gentile F, Thomas JD, Weiman AE (1989) Prevalence of valvular regurgitation by doppler echocardiography in patients with structurally normal hearts by two-dimensional echocardiography. Am Heart J 117: 636 – 642

Curtius JM, Thyssen M, Breuer HW, Loogen F (1985) Doppler versus contrast echocardiography for diagnosis of tricuspid regurgitation. Am J Cardiol 56: 333 – 336

Feigenbaum H (1986) Echocardiography, 4th edn. Lea & Febiger, Philadelphia

Kostucki W, Vandenbossche JL, Friart A, Englert M (1986) Pulsed doppler regurgitant flow patterns of normal valves. Am J Cardiol 58: 309 – 313

Leguerrier A, Leguerrier AM, Logeais Y, Rioux C, Cabrol C, Lanchou C (1982) Dimensions of the aortic ring: An anatomical (84 cases) and surgical (439 cases) study. Anat Clin 3: 325 – 328

Merlino B, Santini C, Vannicelli R, La Rosa Gangi M, Palmieri V, Zeppilli P (1989) L'ecocardiografia doppler e color doppler nella valutazione del cuore d'atleta. Rassegna Intern Med Sport 19: 1 – 6

Mori F, Zuppiroli A, Favilli S, Minneci C, Cupelli V (1990) L'ecocardiografia intergrata nella valutatione morfologica e funzionale del cuore d'atleta. Ecocardiografia 3: 207 – 212

Pineau H (1970) Relation entre les moyennes de la stature des deux sexes pour quelques populations contemporaines ou très anciennes. Arch Anat Pathol 418: 325 – 328

Sacarpini S, Nassiacos D (1990) Rigurgito valvolare fisiologico: una problematica nuova dell'ecocardiografia doppler. Ecocardiografia 3: 133 – 138

Takao S, Miyatake K, Izumi S, Okamoto M, Kinoshita N, Sakakibara Hn, Nakagawa H, Yamamoto K, Sakakibara H, Nimura Y (1988) Clinical implications of pulmonary regurgitation in healthy individuals. Detection by cross-sectional pulsed doppler echocardiography. Br Heart J 59: 542 – 550

Yoch PG, Naasz C, Schnittger I, Popp RL (1984) Doppler tricuspid regurgitation in normals: Is it real? Circulation 70: (suppl II) 11 – 40

Yoshida K, Yoshikawa J, Shakudo M, Akasaka T, Jyo Y, Takao S, Shiratori K, Koizumi K, Okumachi F, Kato H, Fukaya T (1988) Color doppler evaluation of valvular regurgitation in normal subjects. Circulation 78: 840 – 847

Accepted July 22, 1993