Estimated right ventricular systolic pressure during exercise stress echocardiography in patients with suspected coronary artery disease

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OBJECTIVE: To determine the normal range of estimated right ventricular systolic pressure (RVSP) at peak exercise during exercise stress echocardiography (ExECHO) in a series of consecutive patients referred for the investigation of coronary artery disease.

METHODS: Of 1057 ExECHO examinations over a span of 11 months, 807 met the study criteria. A total of 250 patients were excluded, 188 for missing rest or peak RVSP measurements, 16 for a resting RVSP above 50 mmHg, 16 for nondiagnostic echocardiographic images and the remaining 30 for missing data. The maximal tricuspid regurgitant jet was recorded at rest and following acquisition of the stress images (mean $\pm$ SD) time 103.1 ± 35.2 s). A mean right atrial pressure of 10 mmHg was used in the calculation of RVSP. All data were entered into a cardiology database (CARDIOfile; Registered trademark, Kingston Heart Clinic) for later retrieval and analysis.

RESULTS: There were 206 male (58.9 ± 12.0 years of age) and 601 female patients (57.4 ± 12.0 years of age). Patient age ranged from 18 to 90 years. The mean resting and peak exercise RVSP was 27.8 ± 7.8 mmHg and 34.8 ± 11.3 mmHg in men, and 27.8 ± 7.7 mmHg and 34.6 ± 11.7 mmHg in women, respectively. The mean increase in RVSP was 7.0 ± 8.8 mmHg in men and 6.7 ± 8.9 mmHg in women. The 95% CI for peak RVSP was 12.2 mmHg to 57.4 mmHg in men, and 11.2 mmHg to 58.0 mmHg in women. There was no significant difference in peak RVSP for a normal ExECHO compared with an abnormal ExECHO. RVSP at rest and at peak exercise increased with both age and left atrial size.

CONCLUSIONS: In individual patients, the RVSP should not increase above the resting value by more than 24.6 mmHg in men and 24.5 mmHg in women. This value was calculated as the increase in RVSP plus $2 \times$ SD of the RVSP. Peak RVSP should not exceed 57.4 mmHg in men and 58.0 mmHg in women. If either of these criteria is exceeded, the response of RVSP to exercise should be considered abnormal.

Key Words: Coronary artery disease; Right ventricular systolic pressure; Stress echocardiography

La tension systolique estimative du ventricule droit pendant l'échocardiographie d'effort de patients chez qui on présume une coronaropathie

OBJECTIF : Déterminer la plage normale de la tension systolique du ventricule droit (TSVD) estimative pendant l'effort de pointe d'une échocardiographie d'effort (ECHOef) chez une série de patients consécutifs aiguillés afin d'explorer la possibilité de coronaropathie.

MÉTHODOLOGIE : Des 1 057 examens d'ECHOef effectués sur une période de 11 mois, 807 respectaient les critères de l'étude. Au total, 250 patients ont été exclus, 188 pour avoir raté les mesures de TSVD pendant l'effort de pointe ou au repos, 16 parce que leur TSVD au repos était supérieure à 50 mmHg, 16 parce que les images échocardiographiques n'étaient pas diagnostiques et les 30 autres parce que les données étaient incomplètes. Le flux de régurgitation tricuspiddienne maximal était enregistré au repos et après l'acquisition des images d'effort (durée moyenne $\pm$ ÉT) de $103,1 \pm 35,2$ s). Les auteurs ont utilisé une tension auriculaire droite moyenne de 10 mmHg pour calculer la TSVD. Ils ont inclus toutes les données dans une base de données cardiologiques (CARDIOfile; marque déposée, Kingston Heart Clinic) en vue de leur extraction et de leur analyse ultérieures.

RÉSULTATS : On dénombrait 206 patients de sexe masculin (de $58,9 \pm 12,0$ ans) et 601 de sexe féminin (de $57,4 \pm 12,0$ ans). Les patients avaient de 18 à 90 ans. La TSVD moyenne au repos et pendant l'effort de pointe était de $27,8 \pm 7,8$ mmHg et de $34,8 \pm 11,3$ mmHg chez les hommes, et de $27,8 \pm 7,7$ mmHg et de $34,6 \pm 11,7$ mmHg chez les femmes, respectivement. L'augmentation moyenne de la TSVD était de $7,0 \pm 8,8$ mmHg chez les hommes et de $6,7 \pm 8,9$ mmHg chez les femmes. L'IC de 95 % pour la TSVD oscillait entre 12,2 mmHg et 57,4 mmHg chez les hommes, et entre 11,2 mmHg et 58,0 mmHg chez les femmes. On ne constatait aucune différence significative entre la TSVD pendant l'effort de pointe d'une ECHOef normale et d'une ECHOef anormale. La TSVD au repos et pendant l'effort de pointe augmentait à la fois avec l'âge et la dimension de l'auriculaire gauche.

CONCLUSIONS : Chez chaque patient, la TSVD ne devrait pas dépasser la valeur au repos de plus de 24,6 mmHg chez les hommes et 24,5 mmHg chez les femmes. Cette valeur était calculée comme l'augmentation de la TSVD, majorée de deux fois l'écart-type de la TSVD. La TSVD pendant l'effort de pointe ne devrait pas dépasser 57,4 mmHg chez les hommes et 58,0 mmHg chez les femmes. Si le patient dépasse l'un ou l'autre de ces critères, il faut considérer la réponse de sa TSVD à l'effort comme anormale.

METHODS

Patient population

All patients referred to the Kingston Heart Clinic for ExECHO studies since May 26, 1999, had their ExECHO data entered into a comprehensive cardiology database, CARDIOfile (Registered trademark, Kingston Heart Clinic). At the time the data were extracted, there were 9340 ExECHOs in CARDIOfile. The clinic has had extensive experience with ExECHO since 1994, with more than 12,000 studies. Since January 2008, data entry has included both resting and postexercise RVSP measurements. From January 5, 2008, to November 28,

Data defining the normal increase in right ventricular systolic pressure (RVSP) during exercise stress echocardiography (ExECHO) are lacking, especially in patients suspected of having coronary artery disease (1,2). Similarly, there is a definite lack of exercise RVSP data over a wide range of ages (2-5). Our objective was to define the increase in RVSP in patients with a normal or abnormal ExECHO, the normal range of RVSP in both male and female patients and the normal increase in RVSP for different age groups. All studies were performed at the Kingston Heart Clinic, an outpatient cardiology referral centre in Kingston, Ontario.

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TABLE 1
M-mode echocardiographic findings in male and female patients at rest

Patients	Age, years	LA size, mm	IVS, mm	PW, mm	LVDD, mm	LVSD, mm	EF (Teich), %	LV mass, g
Male (n=206)	58.9±12.0	39.2±5.8	10.3±2.0	9.9±1.8	51.2±5.9	33.1±5.6	57.7±10.0	194.5±54.6
Female (n=601)	57.4±12.0	34.8±4.8*	8.8±1.6*	8.5±1.5*	47.3±4.9*	29.2±4.6*	61.6±8.0*	138.1±39.6*

Data presented as mean $\pm$ SD. * $P<0.0001$ versus male individuals using unpaired t test. EF Ejection fraction; IVS Interventricular septum; LA Left atrium; LV Left ventricular; LVDD LV end-diastolic diameter; LVSD LV end-systolic diameter; PW Posterior wall

TABLE 2
Exercise stress testing data for male and female patients, and patients with normal and abnormal studies during exercise stress echocardiography

Patients	Exercise duration, s	Metabolic work, METs	Target heart rate, beats/min	Heart rate achieved, beats/min	Rest SBP, mmHg	Rate pressure product, $\times 10^3$	Peak SBP, mmHg
Male (n=206)	436.1±155.0	8.8±2.6	137.0±10.2	140.3±16.1	134.2±17.6	24.9±4.9	176.7±24.6
Female (n=601)	354.9±145.3**	7.5±2.3**	138.2±10.1*	146.5±16.5**	128.5±17.6**	24.4±4.0	166.5±20.0**
Normal (n=667)	386.1±151.3	8.0±2.5	138.8±10.1	148.9±13.2	129.2±17.0	25.3±3.7	170.2±20.9
Abnormal (n=140)	326.2±140.0**	7.0±2.2**	133.7±9.3**	125.6±17.5**	133.7±20.5**	20.1±4.8**	163.8±24.5*

* $P<0.05$; ** $P<0.0001$ using unpaired t test for male versus female, and normal versus abnormal individuals. MET Metabolic equivalents of task; SBP Systolic blood pressure

TABLE 3
Right ventricular systolic pressure (RVSP) data for exercise stress echocardiography in male and female patients, normal and abnormal studies and RVSP response according to age groups

Patients	RVSP, mmHg			
	Rest	Peak	Increase	Peak exercise normal, 95% CI
Male (n=206)	27.8±7.8	34.8±11.3*	7.0±8.8	12.2–57.4
Female (n=601)	27.8±7.7	34.6±11.7*	6.7±8.9	11.2–58.0
Normal (n=667)	27.4±7.4	35.7±12.8*	6.7±9.7	10.1–61.3
Abnormal (n=140)	29.8±8.7†	36.6±12.7*	6.8±10.0	11.2–62.0
Age, years				
<50 (n=189)	26.4±7.0	32.1±10.2*	5.7±8.0	11.7–52.5
50–75 (n=571)	28.0±7.8	35.0±11.8*	7.0±9.1	11.4–58.6
>75 (n=47)	31.7±7.8	39.9±12.3	8.2±8.7	15.3–64.5

Data presented as mean $\pm$ SD unless otherwise indicated. * $P<0.0001$ rest RVSP versus peak RVSP, except for age >75 years ($P<0.0005$); † $P<0.05$ rest RVSP, normal versus abnormal

2008, 1057 patients underwent ExECHO. Patients whose resting RVSP was greater than 50 mmHg were excluded from the analysis (n=16). Only patients with all relevant data points, as indicated in Tables 1 to 4, were included. RVSP data (either rest or peak, or both) were missing for 188 patients and another 30 patients had other data points missing. A further 16 patients had nondiagnostic echocardiographic images. This left 807 patients for analysis. Approximately 80% of patients are referred by other physicians, primarily family doctors. Baseline information is collected, including the reason for the test, coronary risk factors and current drugs. Patients were examined before exercising and any patients with congestive heart failure were excluded.

Exercise echocardiography

Treadmill ExECHO was performed in the standard manner. All echocardiographic imaging was performed using GE VIVID 7 Dimension systems (GE Healthcare, USA). M-mode measurements were performed at rest in the parasternal long-axis view. When measuring the left ventricular (LV) dimensions using the GE VIVID 7 Dimension system, the sample can be aligned perpendicular to both the septum and inferolateral walls. DEFINITY (Lantheus Medical Imaging Inc, USA) echocardiographic contrast has been used in patients who had uninterpretable

TABLE 4
Right ventricular systolic pressure (RVSP) data for exercise stress echocardiography in various subgroups

	n	RVSP rest, mmHg	RVSP peak, mmHg
Hypertension	357	28.1±8.1	35.4±12.5
No hypertension	450	27.6±7.3	34.0±10.9
FH of CAD	291	27.9±7.6	34.8±12.1
No FH of CAD	516	27.8±7.7	34.5±11.3
Dyslipidemia	289	28.0±7.7	34.8±11.8
No dyslipidemia	518	27.7±7.7	34.5±11.5
Obese	284	26.8±8.0	33.3±12.2
Not obese	523	28.4±7.5	35.3±11.3
Smoker	149	26.2±7.3	32.7±10.7
Nonsmoker	658	28.2±7.7	35.0±11.8
Diabetes	87	27.7±7.8	35.0±12.6
No diabetes	720	27.8±7.7	34.5±11.5
Previous MI	52	28.1±8.7	36.7±13.3
No previous MI	755	27.8±7.6	34.5±11.5
Previous stroke	32	27.8±7.9	34.4±11.0
No previous stroke	775	27.8±7.7	34.6±11.6
COPD	74	29.0±7.6	37.2±11.4
No COPD	733	27.7±7.7	34.3±11.6
ANOVA		$P=0.3048$	$P=0.3004$
Bartlett's test		$P=0.9488$	$P=0.4105$

Data presented as mean $\pm$ SD. Using one-way ANOVA and the Bartlett's test for homogeneity of variances, there were no significant differences between subgroups at rest or peak exercise. CAD Coronary artery disease; COPD Chronic obstructive pulmonary disease; FH Family history; MI Myocardial infarction

baseline echocardiographic images. Images were then transferred to a GE ECHOPac workstation (GE Healthcare) for offline analysis. Exercise treadmill tests were performed using the standard Bruce protocol. RVSP was measured if tricuspid regurgitation (TR) was present in the right ventricular inflow view, apical four-chamber view or the subcostal view. Post stress RVSP was measured immediately following acquisition of the stress images. Saline bubbles were not injected in any patient to enhance the tricuspid velocity envelope. Every 10th study was re-examined for the time to measurement of the RVSP and the mean ($\pm$ SD) delay was 103.1±35.2 s following completion of the exercise test. The view with the maximal TR jet velocity (V) was used to calculate

Figure 1) Relationship between peak systolic blood pressure (SBP) and peak right ventricular systolic pressure (RVSP). There was no significant correlation using linear regression analysis (n=807)

the RVSP using the modified Bernoulli equation ($RVSP = 4V^2 + RAP$) (6,7). The mean right atrial pressure (RAP) was assumed to be 10 mmHg. Patients were categorized as normal or abnormal based on their resting and post exercise wall motion.

Statistical analysis

The normal ranges of rest and peak stress RVSP were based on 95% CIs ($CI = \text{mean} \pm 2SD$). The normal increase in RVSP for an individual patient was calculated as $2 \times SD$ of the increase in RVSP ($\Delta RVSP$) plus the mean $\Delta RVSP$. Data were analyzed using linear regression, Student's unpaired *t* test or one-way ANOVA, where appropriate. $P < 0.05$ was considered to be statistically significant. The Bartlett's test was used to test for homogeneity of variances across subgroups when performing one-way ANOVA. Data were analyzed using Prism 3.0 Software (GraphPad Software Inc, USA).

RESULTS

Resting echocardiogram for men and women

Data concerning the baseline echocardiography findings are shown in Table 1. There were 206 (26%) men and 601 (74%) women. The mean patient age was 58.9 ± 12.0 years for men, and 57.4 ± 12.0 years for women (*P*-value nonsignificant); patient age ranged from 18 to 90 years for men, and 19 to 88 years for women. In general, as expected, men had significantly larger echocardiographic dimensions than women. The resting ejection fraction, calculated from the M-mode measurements, was significantly lower in men than in women ($57.7 \pm 10.0\%$ versus $61.6 \pm 8.0\%$; $P < 0.0001$).

Exercise performance for men and women

Exercise treadmill data are shown in Table 2. Exercise duration was significantly longer in men than in women (436.1 ± 155.0 s versus 354.9 ± 145.3 s; $P < 0.0001$). As expected, metabolic work was also significantly higher in men than in women (8.8 ± 2.6 METs versus 7.5 ± 2.3 METs; $P < 0.0001$). However, rate-pressure product was similar in men and women ($24.9 \times 10^3 \pm 4.9 \times 10^3$ versus $24.4 \times 10^3 \pm 4.0 \times 10^3$, respectively; *P*-value nonsignificant). The target heart rate was significantly lower in men than in women (137.0 ± 10.2 beats/min versus 138.2 ± 10.1 beats/min; $P < 0.05$) and the heart rate achieved was significantly lower in men than in women (140.3 ± 16.1 beats/min versus 146.5 ± 16.5 beats/min; $P < 0.0001$).

Relationship among RVSP, systolic blood pressure and age

There was no statistically significant relationship between resting systolic blood pressure (SBP) and resting RVSP using linear regression analysis. There was no significant difference between peak SBP and

Figure 2) Relationship between age and rest right ventricular systolic pressure (RVSP). Rest RVSP increased significantly with age. $P < 0.0001$ using linear regression analysis (n=807)

Figure 3) Relationship between age and peak right ventricular systolic pressure (RVSP). Peak RVSP increased significantly with age. $P < 0.0001$ using linear regression analysis (n=807)

peak exercise RVSP using linear regression analysis (Figure 1). Both rest and peak exercise RVSP increased significantly with age (Figures 2 and 3; $P < 0.0001$). Men had a higher resting SBP than women (134.2 ± 17.6 mmHg versus 128.5 ± 17.6 mmHg; $P < 0.0001$, see Table 2). Men also had a significantly higher peak exercise SBP than women (176.7 ± 24.6 mmHg versus 166.5 ± 20.0 mmHg; $P < 0.0001$, see Table 2).

The normal range of RVSP in ExECHO for men and women

RVSP data at rest and peak exercise are presented in Table 3. Peak RVSP was significantly higher than resting RVSP in both men and women ($P < 0.0001$). There was no significant difference in peak RVSP in men compared with women (34.8 ± 11.3 mmHg versus 34.6 ± 11.7 mmHg, respectively). Similarly, there was no significant difference in $\Delta RVSP$ in men compared with women (7.0 ± 8.8 mmHg versus 6.7 ± 8.9 mmHg, respectively). The normal allowable increase in RVSP above the resting value for an individual male or female patient was 24.6 mmHg and 24.5 mmHg, respectively. The peak RVSP range (95% CI) for male and female patients was 12.2 mmHg to 57.4 mmHg, and 11.2 mmHg to 58.0 mmHg, respectively.

Exercise performance for normal and abnormal ExECHOs

Exercise treadmill data for normal and abnormal ExECHOs are shown in Table 2. As expected, there were significant differences for all measured parameters.

The normal range of RVSP in normal and abnormal ExECHOs

RVSP data in abnormal and normal ExECHO responses are presented in Table 3. Age was significantly higher in abnormal than in normal ExECHOs (62.8 ± 11.0 years versus 56.7 ± 11.9 years; $P < 0.0001$). The resting RVSP was significantly higher in abnormal than in normal ExECHOs (29.8 ± 8.7 mmHg versus 27.4 ± 7.4 mmHg; $P < 0.05$). However, there was no significant difference between abnormal and normal ExECHOs with respect to the peak RVSP (36.6 ± 12.7 mmHg versus 35.7 ± 12.8 mmHg; P -value nonsignificant). Similarly, there was no significant difference in Δ RVSP in abnormal compared with normal ExECHOs (6.8 ± 10.0 mmHg versus 6.7 ± 9.7 mmHg, respectively). The peak RVSP range (95% CI) for abnormal and normal studies was 11.2 mmHg to 62.0 mmHg and 10.1 mmHg to 61.3 mmHg, respectively.

The normal range of RVSP according to age groups

RVSP data in all patients were analyzed according to the following age groups: younger than 50 years, 50 to 75 years, and older than 75 years (Table 3). One-way ANOVA testing revealed a significant difference in both resting and peak RVSP among all three age groups. The peak RVSP range (95% CI) for these groups was 11.7 mmHg to 52.5 mmHg, 11.4 mmHg to 58.6 mmHg, and 15.3 mmHg to 64.5 mmHg, respectively.

The normal range of RVSP according to left atrial size

RVSP data in all patients were analyzed according to left atrial (LA) size. LA size was divided into 40 mm or less ($n=677$), or greater than 40 mm ($n=130$). Using the unpaired Student's t test, there was a significant difference between the two groups at rest (27.4 ± 7.4 mmHg versus 29.8 ± 8.6 mmHg, respectively; $P < 0.001$) and at peak exercise (34.0 ± 11.1 mmHg versus 38.0 ± 13.6 mmHg, respectively; $P < 0.0005$).

The RVSP response according to subgroups including homogeneity

RVSP data were analyzed according to various subgroups as seen in Table 4. There were no significant differences in mean RVSP between the subgroups using ANOVA at rest or at peak exercise. The Bartlett's test for equal variances showed no significant difference indicating homogeneity of variances across all subgroups.

DISCUSSION

We have defined the increase and normal ranges for RVSP during ExECHO in male and female patients, normal and abnormal ExECHO responses, and for different age groups. These patients are predominantly referred to our facility for investigation of symptoms to rule in or rule out myocardial ischemia. To our knowledge, our paper is the first to report such data in this population. The study by Bossone et al (3) is the only previous study to investigate RVSP during ExECHO but only in normal subjects, whereas numerous studies have investigated the response of RVSP to exercise in patients after cardiac transplantation (8), congenital heart disease (9) and atrial septal defect (10). The population in the Bossone et al study did not include any female individuals, and consisted of highly conditioned male athletes ($n=26$, mean age 20 years) and young, healthy male controls ($n=14$, mean age 19 years). The present study has shown, and previous studies have also suggested, that resting RVSP increases progressively and normally with age (11-13). Therefore, we believed it was necessary to define the normal range of RVSP with ExECHO across a much wider range of ages. Our population more accurately reflects the range in age of patients seen in the typical outpatient cardiology clinical setting.

Overall, there was no significant difference between men and women for age, resting RVSP, peak exercise RVSP and Δ RVSP (Table 3). In elderly patients, our data indicate that RVSP may approach 65 mmHg at peak exercise. Bossone et al also found that RVSP could approach this value in highly conditioned male athletes (3). Others have shown that in normal controls ($n=12$; 11 men), the mean RVSP increased from 22 mmHg at rest to 31 mmHg at peak

exercise, whereas in patients with chronic pulmonary disease, RVSP increased from 46 mmHg at rest to 83 mmHg at peak exercise (14). Similarly, in patients with congestive heart failure, RVSP increased from 45 mmHg at rest to 73 mmHg at peak exercise (15). We believe these data underscore the necessity of considering the clinical presentation of symptomatic patients with cardiopulmonary disease when assessing the response of RVSP to exercise as normal or abnormal.

We found that both resting and peak exercise RVSP increased significantly with age. There was no significant relationship using linear regression analysis between RVSP and SBP, either at rest or peak exercise. Furthermore, men and women had similar resting and peak exercise RVSPs, despite the fact that men had significantly higher resting and peak exercise SBPs than women. Contrary to previous work investigating SBP and RVSP (16), our data indicate that SBP does not accurately predict the response of RVSP to exercise. However, when we differentiated the normal ExECHOs from the abnormal ExECHOs, a nonsignificant trend was found for a negative correlation between peak RVSP and peak SBP in patients with an abnormal ExECHO. This is an interesting finding that suggests that a lower SBP response to exercise may be a reflection of impaired LV systolic or diastolic function or indeed both. More abnormal ExECHO data are required to confirm this finding.

We observed that men had significantly lower ejection fractions than women ($57.7 \pm 10.0\%$ versus $61.6 \pm 8.0\%$; $P < 0.0001$). This may simply be a reflection of the fact that a greater proportion of male patients had an abnormal ExECHO than the female patients (28.6% versus 13.5%).

In our laboratory, if a patient exceeds the accepted range for peak exercise RVSP, a bubble study is performed to exclude intracardiac shunting, specifically at the atrial level. If there is any such evidence, a transesophageal echocardiogram may be required. If the bubble study is normal, patients may need a workup for pulmonary hypertension, such as a ventilation/perfusion scan to exclude pulmonary embolism and pulmonary function studies. If appropriate on clinical grounds, a sleep study may be required.

Limitations of our study deserve attention. The TR jet was measured both at rest, and slightly after peak exercise, due to the time required for acquisition of the stress images. Therefore, the increase and normal ranges of peak exercise RVSP may have been underestimated. The selection of 10 mmHg as an appropriate RAP surrogate in this population is also questionable. The range of normal pressures would be 5 mmHg lower if 5 mmHg had been chosen.

Having shown here that RVSP increases with age, both at rest and peak exercise, and previous studies showing that resting RVSP increases with body mass index (16), further studies will be required to define the normal range of peak exercise RVSP according to body mass index. The relative lack of male compared with female patients reflects a local bias in performing routine exercise treadmill testing in male patients and exercise echocardiography in female patients. We do not have pre-exercise or postexercise Doppler information concerning concomitant valvular heart disease, specifically mitral valve disease. We examined our data with respect to LA size, and there was a significant difference in RVSP between patients with an LA size of 40 mm or less, and those with a size greater than 40 mm. It is possible that the patients with increased LA size had other echocardiographic abnormalities such as significant mitral regurgitation or abnormal LV diastolic function. A full Doppler examination was not part of our routine ExECHO protocol. Finally, the Kingston Heart Clinic is an outpatient cardiac facility and approximately 80% of our referrals come from family physicians. This referred population likely has a relatively low prevalence of coronary artery disease. This is reflected in the observation that only 17% of our ExECHOs were abnormal.

CONCLUSIONS

During ExECHO, the peak exercise RVSP was 34.8 ± 11.3 mmHg in men, and 34.6 ± 11.7 mmHg in women (P -value nonsignificant). The normal range (95% CI) of peak exercise RVSP is 12.2 mmHg to

57.4 mmHg in men, and 11.2 mmHg to 58.0 mmHg in women. The normal range for patients younger than 50 years, 50 to 75 years, and older than 75 years of age was 11.7 mmHg to 52.5 mmHg, 11.4 mmHg to 58.6 mmHg, and 15.3 mmHg to 64.5 mmHg, respectively. In an individual patient, RVSP should not increase by more than 24.6 mmHg above the resting value in men, and 24.5 mmHg in women. If these criteria are met, the response of RVSP to exercise should be considered normal. These data should be taken into account when using rest and peak exercise estimates of RVSP in the investigation of patients with suspected coronary artery disease.

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