Factors influencing the echocardiographic estimate of right ventricular systolic pressure in normal patients and clinically relevant ranges according to age

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BACKGROUND: Previous studies have shown that in the absence of underlying cardiac pathology, the echocardiographic estimate of right ventricular systolic pressure (RVSP) increases progressively and normally with age. There are limited data in patients older than 60 years of age.

OBJECTIVE: To define the ranges of RVSP according to age and to include more elderly patients than have previously been reported.

METHODS: All patients undergoing echocardiography since May 26, 1999, at the Kingston Heart Clinic (Kingston, Ontario) have had their data entered into a locally designed cardiology database (CARDIOfile; Registered trademark, Kingston Heart Clinic). RVSP was calculated from the peak tricuspid regurgitant jet velocity (V) using the modified Bernoulli equation ($RVSP = 4V^2 + RAP$), with the mean right atrial pressure (RAP) estimated to be 10 mmHg. Of the 22,628 patients who had undergone echocardiography, 10,905 had RVSP measured. All abnormal echocardiograms were excluded, leaving 1559 echocardiograms for analysis.

RESULTS: Patient age ranged from 15 to 93 years. The mean age was 49 years. RVSP increased significantly only after the age of 50 years. The mean ($\pm$ SD) RVSP for those younger than 50 years, 50 to 75 years, and older than 75 years of age was 27.3 ± 5.7 mmHg, 30.2 ± 7.6 mmHg and 34.8 ± 8.7 mmHg, respectively ($P < 0.0001$ among all age groups). The normal range (95% CI) of RVSP in those younger than 50 years, 50 to 75 years, and older than 75 years of age was 16 mmHg to 39 mmHg, 15 mmHg to 45 mmHg, and 17 mmHg to 52 mmHg, respectively. Multivariate analysis indicated that age, mitral diastolic early-to-late filling velocity ratio, ejection fraction, aortic size and early mitral filling velocity/early diastolic mitral annular velocity were the only significant independent variables. There were significant changes in diastolic function with increasing age, which may have been responsible for the changes in RVSP.

CONCLUSIONS: RVSP remains stable in both men and women until the age of 50 years. Thereafter, RVSP increases progressively in a linear manner with age and is significantly higher in patients older than 75 years of age. The changes may relate to changes in diastolic function. These ranges should be taken into account when using echocardiogram-derived RVSP for the diagnosis of pulmonary hypertension in the absence of cardiovascular disease.

Key Words: Echocardiography; Pulmonary hypertension

Les facteurs influant sur l'évaluation échocardiographique de la tension systolique du ventricule droit chez des patients normaux et les plages cliniquement pertinentes selon l'âge

HISTORIQUE : Des études antérieures ont démontré qu'en l'absence de pathologie cardiaque sous-jacente, l'évaluation échocardiographique de la tension systolique du ventricule droit (TSVD) augmente avec l'âge, de manière progressive et normale. Les données sur les patients de plus de 60 ans sont limitées.

OBJECTIF : Définir les plages de TSVD selon l'âge et inclure les patients plus âgés déclarés auparavant.

MÉTHODOLOGIE : Les données de tous les patients qui ont subi une échocardiographie à la Kingston Heart Clinic de Kingston, en Ontario, depuis le 26 mai 1999, sont saisies dans une base de données cliniques locale (CARDIOfile; marque déposée, Kingston Heart Clinic). La TSVD était calculée d'après la vitesse (V) du flux de régurgitation tricuspide au moyen de l'équation de Bernoulli modifiée ($TSVD = 4V^2 + TAD$), la tension auriculaire droite (TAD) moyenne étant estimée à 10 mmHg. Des 22 628 patients qui avaient subi une échocardiographie, 10 905 avaient fait mesurer leur TSVD. Tous les échocardiogrammes anormaux étaient exclus, laissant 1 559 échocardiogrammes à l'analyse.

RÉSULTATS : Les patients, de 15 à 93 ans, avaient un âge moyen de 49 ans. Ce n'est qu'après l'âge de 50 ans que la TSVD augmentait de manière significative. La TSVD moyenne ($\pm$ ÉT) pour les moins de 50 ans, les 50 à 75 ans et les plus de 75 ans correspondait à $27,3 \pm 5,7$ mmHg, $30,2 \pm 7,6$ mmHg et $34,8 \pm 8,7$ mmHg, respectivement ($P < 0,0001$ dans tous les groupes d'âge). La plage normale (95 % IC) de TSVD chez les moins de 50 ans, les 50 à 75 ans et les plus de 75 ans oscillait entre 16 mmHg et 39 mmHg, 15 mmHg et 45 mmHg, et 17 mmHg et 52 mmHg, respectivement. Selon l'analyse multivariée, l'âge, le ratio précoce-tardif de la vitesse de remplissage diastolique mitral, la fraction d'éjection, la dimension de l'aorte et la vitesse de remplissage mitral précoce par rapport à la vitesse annulaire mitrale diastolique précoce étaient les seules variables indépendantes significatives. La fonction diastolique changeait considérablement avec l'âge, ce qui peut expliquer les variations de la TSVD.

CONCLUSIONS : La TSVD demeure stable jusqu'à l'âge de 50 ans, chez les hommes et chez les femmes. Ensuite, elle augmente progressivement de manière linéaire avec l'âge, et elle est considérablement plus élevée chez les patients de plus de 75 ans. Ces modifications peuvent être liées aux changements de la fonction diastolique. Il faudrait tenir compte de ces plages lorsqu'on utilise la TSVD dérivée de l'échocardiogramme pour diagnostiquer une hypertension pulmonaire en l'absence d'une maladie cardiovasculaire.

Echocardiography has become a useful noninvasive screening tool for assessing pulmonary hypertension (1,2). In the absence of right ventricular (RV) outflow tract obstruction, RV systolic pressure (RVSP) is equal to pulmonary artery systolic pressure (PASP) (3-5). RVSP can be estimated from the tricuspid regurgitant (TR) jet velocity using the modified Bernoulli equation (6) ($RVSP = 4V^2 + RAP$),

with right atrial pressure (RAP) assumed to be constant at 10 mmHg in patients with normal hearts (5). RVSP measurement has become the standard for estimating PASP (7).

Currently, the normal range of PASP and surrogate RVSP is poorly defined, especially in patients older than 60 years of age. RVSP is dependent on age (8-11), body mass index (BMI) (8,12) and sex (8).

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TABLE 1
Population characteristics and echocardiographic parameters in patients with normal echocardiograms (n=1559)*

Echocardiographic variable	Mean $\pm$ SD	95% CI
Age, years	48.9 $\pm$ 18.4	12.1–85.7
Height, cm	167.1 $\pm$ 9.8	147.5–186.7
Weight, kg	74.2 $\pm$ 17.1	40.0–108.4
Body mass index, kg/m ²	26.5 $\pm$ 5.5	15.6–36.5
Aorta, mm	29.9 $\pm$ 4.1	21.7–38.1
Left atrium, mm	34.0 $\pm$ 4.4	25.3–42.8
Left atrial volume index, mL/m ²	18.3 $\pm$ 5.1	8.1–28.5
LVDD, mm	48.0 $\pm$ 4.7	38.6–57.4
LVSD, mm	29.9 $\pm$ 4.3	21.3–38.5
IVS, mm	8.7 $\pm$ 1.4	5.9–11.5
Posterior wall, mm	8.4 $\pm$ 1.3	5.8–11.0
Ejection fraction, %	66.0 $\pm$ 5.5	55.0–77.0
E/A ratio	1.39 $\pm$ 0.57	0.25–2.53
E/e' ratio	8.6 $\pm$ 2.4	3.8–13.4
Left ventricular mass index, g/m ²	78.3 $\pm$ 17.3	43.7–112.9

*Women comprised 66.9% of the population. E/A Mitral diastolic early-to-late filling velocity; E/e' Early mitral filling velocity/early diastolic mitral annular velocity; IVS Interventricular septum; LVDD Left ventricular diastolic dimension; LVSD Left ventricular systolic dimension

We attempted to define the range of RVSP in subjects with normal echocardiograms over a much wider range of age groups, with more elderly subjects than have previously been reported.

METHODS

Patient population

All patients referred for echocardiography studies since May 26, 1999, at the Kingston Heart Clinic (Kingston, Ontario) have had all their data, including echocardiographic data, entered into a comprehensive cardiology database, CARDIOfile (Registered trademark, Kingston Heart Clinic). CARDIOfile contained 50,394 patients at the time of the present analysis. A total of 22,628 echocardiograms had been performed; RVSP was measured in 10,905 (48.2%) of those echocardiograms. Since January 5, 2005, when the clinic's equipment was updated and tissue Doppler imaging became available, 11,023 echocardiograms were performed; RVSP was measured in 7466 (67.7%). Abnormal echocardiograms were excluded. Echocardiograms were excluded if the biplane ejection fraction (EF) was lower than 50%. Echocardiograms were also excluded for the following M-mode abnormalities: left ventricular (LV) diastolic dimension greater than 58 mm, LV systolic dimension greater than 39 mm and a left atrium (LA) of greater than 40 mm. Patients were also excluded with an early mitral filling velocity/early diastolic mitral annular velocity (E/e') ratio of greater than 14 and an E/e' of 9 to 14 if their LA volume index was greater than 33 mL/m². This test was performed to exclude patients with diastolic dysfunction (13). All echocardiograms with a peak aortic gradient of greater than 16 mmHg were excluded, as were those with aortic regurgitation if the aortic jet width/LV outflow tract ratio was greater than 0.20. Patients with mitral regurgitation and a mitral effective regurgitant orifice area of greater than 0.20 cm² or a mitral mean gradient of greater than 4 mmHg were also excluded. The clinic's database had fields for RV size and systolic function, cardiomyopathy, congenital heart disease, tumours/masses and abnormal pericardium. Any abnormal entry in any of these fields was also excluded. Finally, there were five fields for M-mode abnormalities; any echocardiogram with any M-mode abnormality was also excluded. This left 1559 normal echocardiograms in which RVSP was measured. The parameters of normal echocardiograms are shown in Table 1.

TABLE 2
Clinical indication in 1559 patients with normal echocardiograms who had right ventricular systolic pressure measured

Clinical indication	n (%)
Left ventricular systolic function	706 (45.5)
Murmur	457 (29.2)
Arrhythmia	194 (12.3)
Suspected cardioembolic stroke	66 (4.2)
Syncope/presyncope	64 (4.1)
Congenital heart disease	16 (1.1)
Pericardial disease	5 (0.3)
Suspected familial disease	21 (1.3)
Suspected pulmonary hypertension	9 (0.6)
Diastolic function	9 (0.6)
Other	12 (0.8)

Echocardiography

Two-dimensional echocardiography was performed in the standard manner using American Society of Echocardiography (ASE) recommendations (7). RVSP was measured if TR was present in the RV inflow view, the apical four-chamber view or the subcostal view. The view with the maximal tricuspid jet velocity was used to calculate RVSP using the modified Bernoulli equation. The mean right atrial (RA) pressure was assumed to be 10 mmHg in all patients.

Diastolic function comparison

Tissue Doppler was measured in the apical four-chamber view in the basal septum. The estimations of filling pressures in patients with normal EF were performed using ASE guidelines (13). The 1559 echocardiograms making up the study population were divided into two groups:

1. Echocardiograms with an E/e' ratio of lower than 9; and
2. Echocardiograms with an E/e' ratio of 9 to 14 with an LA volume index of lower than 34 mL/m².

These two groups were then compared with echocardiograms with worsening diastolic function:

1. Those with echocardiogram findings identical to groups 1 and 2 (see above), except the E/e' ratio was greater than 14;
2. Echocardiograms with an EF of lower than 50% and nonrestrictive physiology (mitral diastolic early-to-late filling velocity [E/A] ratio of 1.0 to 1.99 and E/e' ratio of greater than 14); and
3. Echocardiograms with an EF of lower than 50% and restrictive physiology (E/A ratio of greater than 1.99 with a mitral inflow deceleration time of less than 151 ms).

Statistical analysis

Bivariate linear regression analysis was used to determine any linear association between RVSP and age, BMI, EF, LV diastolic dimension, LV systolic dimension, E/A ratio, E/e' ratio, LA size and LV mass index. Multivariate analysis via multiple regression analysis and stepwise linear regression was used to determine whether any of the same variables were independent predictors of RVSP. Data segregated into deciles of age were analyzed using one-way ANOVA with the Tukey-Kramer comparisons test. The two-tailed Student's *t* test was used to compare means where appropriate. The normal ranges of RVSP were based on means $\pm$ 2 SDs (95% CIs). *P* < 0.05 was considered to be statistically significant. Data were analyzed using JMP 8.0 software (SAS Institute Inc, USA).

RESULTS

Indication for echocardiography

The indications for echocardiography are shown in Table 2. The most common indications were assessment of LV systolic function, cardiac murmur and arrhythmia. These three indications accounted for 87.0%

TABLE 3
Echocardiographic parameters of male and female patients with normal echocardiograms who had right ventricular systolic pressure (RVSP) measured

Variable	Male patients	Female patients	P
n (%)	516 (33.1)	1043 (66.9)	
Age, years	48.2±18.8	49.2±18.2	0.31
RVSP, mmHg	28.9±7.1	29.2±7.1	0.43
Height, cm	176.5±7.6	162.5±7.1	<0.0001
Weight, kg	82.8±15.7	69.9±16.1	<0.0001
Body mass index, kg/m ²	26.6±4.6	26.5±5.9	0.74
Aorta, mm	32.8±3.9	28.5±3.4	<0.0001
LA, mm	35.5±4.2	33.3±4.3	<0.0001
LA volume index, mL/m ²	18.4±5.0	18.3±5.2	0.72
LVDD, mm	50.1±4.6	46.9±4.5	<0.0001
LVSD, mm	31.8±4.1	29.0±4.1	<0.0001
IVS, mm	9.2±1.3	8.4±1.3	<0.0001
Posterior wall, mm	9.0±1.2	8.2±1.3	<0.0001
Ejection fraction, %	64.9±5.6	66.5±5.3	<0.0001
E/A ratio	1.40±0.56	1.39±0.57	0.74
E/e' ratio	8.0±2.3	9.0±2.4	<0.0001
LV mass index, g/m ²	84.0±17.0	75.5±16.7	<0.0001

Data presented as mean ± SD unless otherwise indicated. E/A Mitral diastolic early-to-late filling velocity; E/e' Early mitral filling velocity/early diastolic mitral annular velocity; IVS Interventricular septum; LA Left atrium; LV Left ventricular; LVDD Left ventricular diastolic dimension; LVSD Left ventricular systolic dimension

TABLE 4
Statistical analysis of independent variables that affect right ventricular systolic pressure in male and female patients with normal echocardiograms

Independent variable	Bivariate analysis P	Multivariate analysis P
Age, years	<0.0001	<0.0001
E/A ratio	<0.0001	<0.001
Ejection fraction, %	<0.005	<0.005
Aorta, mm	NS	<0.005
E/e' ratio	<0.0001	<0.05
LA, mm	<0.0005	NS
LA volume index, mL/m ²	NS	NS
Posterior wall, mm	NS	NS
LVSD, mm	NS	NS
LVDD, mm	NS	NS
IVS, mm	NS	NS
Body mass index, kg/m ²	NS	NS
LV mass index, g/m ²	NS	NS

E/A Mitral diastolic early-to-late filling velocity; E/e' Early mitral filling velocity/early diastolic mitral annular velocity; IVS Interventricular septum; LA Left atrium; LV Left ventricular; LVDD Left ventricular diastolic dimension; LVSD Left ventricular systolic dimension; NS Nonsignificant

of all echocardiograms. As expected, there were significant differences between male and female patients in many echocardiographic parameters; however, there was no statistically significant difference in RVSP between men and women (Table 3). Given this information, the male and female results were combined when performing linear regression and multiple linear regression, and when determining the normal ranges for RVSP in the absence of cardiovascular disease.

Bivariate and multivariate analysis

The results of bivariate and multivariate analysis for all patients are shown in Table 4. The only significant independent variables using multivariate analysis were age, E/A ratio, EF, aortic root measurement

Figure 1 Right ventricular systolic pressure (RVSP) in men and women with normal echocardiograms according to deciles of age. Using one-way ANOVA, $P<0.0001$. RVSP significantly increased only after the age of 49 years (Tukey-Kramer comparison test, $P<0.001$). Data are presented as mean ± SEM (n=1559)

Figure 2 Right ventricular systolic pressure (RVSP) according to diastolic function. The first two groups are the current normal echocardiograms. The third group (early mitral filling velocity/early diastolic mitral annular velocity [E/e'] >14) are patients with the same echocardiographic findings but abnormal diastolic function. The final two groups are abnormal nonrestrictive diastolic function (AbNR) and abnormal restrictive diastolic function (AbR). Using one-way ANOVA, $P<0.0001$. Tukey-Kramer comparisons are $P<0.001$ for all except E/e' 9 to 14 versus E/e' >14 ($P<0.05$). Data are presented as mean ± SEM

and E/e' ratio. The results of changes in RVSP with age according to deciles are shown in Figure 1. Overall, there was a highly significant difference using ANOVA ($P<0.0001$). Tukey-Kramer comparison testing revealed no significant difference in mean RVSP between deciles for subjects younger than 50 years of age. The mean RVSP only increased significantly after 49 years of age. For deciles above 49 years, there were significant differences between all other deciles ($P<0.001$).

RVSP according to diastolic function

RVSP increased progressively with worsening diastolic function. For the two normal diastolic function groups (E/e' lower than 9 and E/e' 9 to 14 with an LA volume index lower than 34 mL/m²), the mean (± SD) RVSP was 28.9±6.4 mmHg and 30.1±7.6 mmHg, respectively. For the three abnormal diastolic function groups (EF greater than 50% and E/e' greater than 14; EF lower than 50% with E/A 1.0 to 1.99 and E/e' greater than 14; and EF lower than 50% with E/A greater than 1.99 and a deceleration time of less than 150 ms), the mean RVSP was 32.6±8.2 mmHg, 38.9±11.6 mmHg and 45.6±14.7 mmHg, respectively (Figure 2).

Figure 3) Right ventricular systolic pressure (RVSP) according to clinically relevant age groups in patients with normal echocardiograms. Using one-way ANOVA, $P < 0.0001$. Using Tukey-Kramer comparisons, $P < 0.001$. Data are presented as mean $\pm$ SEM ($n = 1559$)

TABLE 5
Right ventricular systolic pressure (RVSP) according to clinically relevant age groups

Age group	n	RVSP, mmHg	
		mean $\pm$ SD	95% CI
<50 years	765	27.3 $\pm$ 5.7	15.9–38.7
50–75 years	688	30.2 $\pm$ 7.6	15.0–45.4
>75 years	106	34.8 $\pm$ 8.7	17.4–52.2

Using one-way ANOVA, $P < 0.0001$. Using Tukey-Kramer, $P < 0.001$ between all groups

RVSP according to clinically relevant age groups

Patients were separated into three age groups: younger than 50 years ($n = 765$), 50 to 75 years ($n = 688$), and older than 75 years ($n = 106$). The mean RVSP for each group was 27.3 ± 5.7 mmHg, 30.2 ± 7.6 mmHg and 34.8 ± 8.7 mmHg, respectively ($P < 0.0001$ using one-way ANOVA). Using Tukey-Kramer comparisons, the significance was $P < 0.001$ between groups (Figure 3). The normal reference 95% CIs for RVSP for patients younger than 50 years, 50 to 75 years, and older than 75 years were 15.9 mmHg to 38.7 mmHg, 15.0 mmHg to 45.4 mmHg, and 17.4 mmHg to 52.2 mmHg, respectively (Table 5). Although diastolic function was strictly normal within the entire study population, diastolic function is a continuous variable. There were clearly changes within the normal range with advancing age that indicated a gradual deterioration in LV diastolic function with age that was highly statistically significant for all diastolic measurements (Table 6).

DISCUSSION

Our analysis of echocardiogram-derived RVSP over a 10-year period revealed that RVSP increased significantly with age. To our knowledge, the present study was the first to observe that RVSP increases significantly only after 49 years of age. Previous studies have defined the normal ranges of RVSP across deciles of age. However, they have not compared RVSP values in deciles above 60 years of age. We observed a significantly higher mean RVSP in patients older than 75 years of age. With these findings, we believe it is far more useful to define the normal ranges of RVSP in the following age groups: younger than 50 years, 50 to 75 years, and older than 75 years. We also believe our study was the first to show how RVSP increases with worsening diastolic function. Using multivariate analysis, we found the following independent variables to be statistically significant predictors of RVSP: age, E/A ratio, EF, aortic root size and E/e' ratio.

TABLE 6
Diastolic function parameters according to clinically relevant age groups

Age group	n	E/A	E/e'	e' (m/s)
<50 years	765	1.72 $\pm$ 0.58	7.65 $\pm$ 1.95	0.12 $\pm$ 0.03
50–75 years	688	1.11 $\pm$ 0.34	9.40 $\pm$ 2.31	0.08 $\pm$ 0.02
>75 years	106	0.91 $\pm$ 0.32	10.84 $\pm$ 2.17	0.06 $\pm$ 0.01

Data presented as mean $\pm$ SD. Using one-way ANOVA, $P < 0.0001$. Using Tukey-Kramer, $P < 0.001$ between all groups. e' Early diastolic mitral annular velocity; E/A Mitral diastolic early-to-late filling velocity; E/e' Early mitral filling velocity/early diastolic mitral annular velocity

Previous population studies have demonstrated that RVSP increases with age (8–11), BMI (8,12) and sex (8). Unlike other studies, ours did not find sex, BMI or any LV dimension to be significant using multivariate analysis, although most were significant using bivariate analysis. The overall mean RVSP in our study ($n = 1559$) was 29.1 ± 7.1 mmHg, and the mean age was 48.9 ± 18.4 years. Previous studies, such as one by McQuillan et al (8), found a lower mean RVSP of 28.3 ± 4.9 mmHg ($n = 3790$), but the mean age of the population was considerably lower (at 33 years) and their population included patients with an age range of one to 89 years, whereas our patient range was 15 to 93 years. The McQuillan et al study had only 199 patients older than 60 years of age, whereas the present study had 513 patients older than 60 years of age. These two differences, namely mean age and age distribution, may account for the higher mean RVSP in our population and therefore, the different reference ranges we recommend for our adult population.

One issue that arose was whether we truly had a population with normal echocardiograms. For systolic function, we only selected patients with an EF of greater than 50%. With respect to diastolic function, we only selected patients with normal diastolic function. We excluded all patients with significant left-sided valvular regurgitation or stenosis. Although no right-sided measurements were made, we had fields in our database for two-dimensional comments on the RV and the atria. We chose only patients with an RV comment of "Right ventricular size and systolic function is normal" and an atria comment of "Both atria are normal". We believe we did everything possible to select only normal echocardiograms.

Limitations

Shortcomings of our study should be addressed. It is important to note that estimates of RVSP using echocardiography require a detectable TR jet. Echocardiography may overestimate RVSP in populations by undersampling normal patients who lack a detectable TR jet, given that patients with no TR are more likely to have lower pulmonary pressure (4). By applying the same exclusion criteria to our database but selecting the RVSP field as "Is Null" (not recorded), we found 741 normal echocardiograms where the RVSP was not measured. This indicates a 68% success rate for detecting and recording the RVSP, and emphasizes the problem of undersampling. Previous data have also shown that 'unexplained' elevated RVSP is associated with systemic hypertension (10). Unfortunately, we do not measure blood pressure during routine echocardiography. However, we did analyze resting and peak systolic blood pressure in patients undergoing exercise echocardiography ($n = 807$), and found no relationship using either bivariate or multivariate analysis. This work is published in *The Canadian Journal of Cardiology* (14). Another issue was the marked under-representation of men in our study population; there was almost twice as many women ($n = 1043$) as men ($n = 516$). We also had virtually no clinical information on the majority of these patients. The Kingston Heart Clinic is an outpatient cardiac facility. Over 80% of the patients referred to our clinic for all forms of cardiac testing, including echocardiography, come from outside referring physicians. We do have an American College of Cardiology/American Heart Association

guideline-driven referral form for all cardiac procedures performed at the clinic, so we know the indication for the echocardiogram but not the patient's medical history. The final issue is estimating the mean RA pressure at 10 mmHg. It is common practice in many echocardiography laboratories to make this assumption for RA pressure and therein lies our explanation. It is not our practice to perform the 'sniff test' while imaging the inferior vena cava.

CONCLUSIONS

In the present patient population, RVSP remained stable in both men and women until the age of 50 years. Thereafter, RVSP increased progressively in a linear manner. RVSP was significantly higher in patients older than 75 years of age. The RVSP range in those younger than 50 years, 50 to 75 years, and older than 75 years of age was 15.9 mmHg

to 38.7 mmHg, 15.0 mmHg to 45.4 mmHg, and 17.4 mmHg to 52.2 mmHg, respectively. These changes in RVSP were both statistically significant and clinically relevant. These changes with age should be taken into account when using RVSP in the diagnosis of pulmonary hypertension. Within our patient population, there was a gradual deterioration of diastolic function with age, but it remained within the 'normal' range of the ASE recommendations (13). This may explain the increase in RVSP in our patients over the age of 75 years. For these elderly patients with RVSP in the upper quartile (44 mmHg to 52 mmHg), further investigation (including close examination of RV function) may be required when all other parameters, including those of diastolic function, are normal. Finally, in patients with clearly abnormal diastolic function, we noted a progressive increase in RVSP with worsening degrees of diastolic function.

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