Original article

Kardiologia Polska
2011; 69, 1: 9–15
ISSN 0022–9032

# Usefulness of echocardiography in the identification of an excessive increase in pulmonary arterial pressure in patients with systemic sclerosis

Michał Ciurzyński[1], Piotr Bienias[1], Katarzyna Irzyk[1], Zuzanna Rymarczyk[1], Maciej Kostrubiec[1], Agnieszka Szewczyk[2], Maria Glińska-Wielochowska[2], Joanna Żyłkowska[3], Marcin Kurzyna[3], Piotr Pruszczyk[1]

[1]Department of Internal Medicine and Cardiology, Medical University, Warsaw, Poland
[2]Department of Dermatology, Medical University, Warsaw, Poland
[3]Department of Chest Medicine, National Institute of Tuberculosis and Lung Diseases, Warsaw, Poland

## Abstract

**Background:** In systemic sclerosis (SSc), changes in the lungs and pulmonary hypertension (PH) are complications most adversely affecting the prognosis. Given the availability of specific treatment, early diagnosis of PH is very important. Exercise echocardiography, by increasing the patient's cardiac output, makes it possible to identify patients with elevated pulmonary artery pressure (PAP) during exercise. The diagnostic role of exercise echocardiography is still unclear, mainly because of the lack of prospective studies.

**Aim:** To identify SSc patients with abnormally elevated PAP at rest or with a significant increase PAP during exercise, subsequently verified by right heart catheterisation (RHC).

**Methods:** A total of 71 consecutive patients (67 females and 4 males, mean age 56.9 ± 17.1 years) with SSc diagnosed according to the American College of Rheumatology criteria were enrolled in this prospective study. The patients underwent transthoracic echocardiography (Philips iE33) with the measurement of tricuspid regurgitation peak gradient (TRPG) and an exercise test involving the standard treadmill exercise according to the Bruce protocol with the evaluation of TRPG at 1 min following the completion of exercise. The PH was suspected when TRPG at rest was > 31 mm Hg ($V_{max}$ > 2.8 m/s) or increased by at least 20 mm Hg from baseline following exercise. Patients with suspected PH were referred for resting and exercise RHC.

**Results:** The exercise testing was performed in 67 patients revealing normal left ventricular (LV) systolic function in all of them. The mean LV ejection fraction was 66.1% ± 3.9%. The TRPG at rest could be recorded in 65 (97%) patients with the mean value of 26.9 ± ± 7.6 mm Hg (range 17–57 mm Hg). A resting TRPG of > 31 mm Hg, suggestive of possible PH, was demonstrated in 14 (21%) patients. During exercise test 56 (84%) patients achieved the maximum heart rate. A Doppler spectrum enabling the measurement of TRPG following the exercise was obtained in 66 (98.5%) patients. The gradient following the exercise could not be measured in one patient with a resting TRPG of 30 mm Hg. The mean post-exercise TRPG was 40.3 ± 4.1 mm Hg (range 17–70) and the mean post-exercise increase in TRPG was 12.9 ± 8.5 mm Hg (range 2–38). A TRPG increase of > 20 mm Hg was found in 11 (16%) patients (including 4 patients with resting values exceeding 31 mm Hg and 7 patients with normal resting values). Twenty-one (31%) patients with echocardiographic suspicion of PH (TRPG > 31 mm Hg at rest and/or a post-exercise increase in TRPG of more than 20 mm Hg) were referred for RHC with 16 patients actually undergoing the procedure. Four out of these 16 patients were qualified because of the "positive" exercise echocardiography in the presence of normal TRPG values. During catheterisation arterial PH was found in 2 patients, and an excessive precapillary PAP elevation in 2 further patients. Resting venous PH was found in 1 patient and an excessive postcapillary PAP elevation at rest was demonstrated in 11 patients.

**Conclusions:** Exercise echocardiography is a safe and useful screening tool for PH diagnosis in patients with SSc. It enables to identify patients with normal systolic PAP at rest but a significant increase during exercise. The final confirmation of PH and differentiation between precapillary arterial and postcapillary venous PH requires RHC.

**Key words:** systemic sclerosis, connective tissue diseases, pulmonary hypertension, echocardiography

Kardiol Pol 2011; 69, 1: 9–15

**Address for correspondence:**
Michał Ciurzyński, MD, PhD, Department of Internal Medicine and Cardiology, Medical University of Warsaw, ul. Lindleya 4, 02–005 Warszawa, Poland, e-mail: michal.ciurzynski@wum.edu.pl

**Received:** 28.06.2010 **Accepted:** 20.10.2010

## INTRODUCTION

In systemic sclerosis (SSc) changes in the lung parenchyma and pulmonary hypertension (PH) are complications that most adversely affect prognosis [1, 2]. Various pathophysiological mechanisms lead to the development of PH in this group of patients. Some patients develop pulmonary arterial hypertension (PAH) as a result of isolated pulmonary arteriopathy, while others develop PH secondary to interstitial lung disease. Patients may also develop pulmonary venous hypertension (PVH) associated with left ventricular (LV) diastolic dysfunction or PH due to thromboembolic disease. When evaluating the patient with PH the predominant underlying mechanism should be identified, as it determines further management.

According to the current guidelines, right heart catheterisation (RHC) is the reference diagnostic method in PH [3, 4]. The diagnosis of PH is confirmed when mean pulmonary artery pressure (mPAP) during RHC exceeds 25 mm Hg. Unfortunately, the diagnosis is often delayed until the disease is advanced, as the initial clinical manifestations are usually uncharacteristic. In symptomatic PAH, the proliferative changes in the pulmonary vessels are already severe. Early detection of PH, when it is still asymptomatic or oligosymptomatic, is therefore very important for further prognosis.

Echocardiography, as a non-invasive method, is a widely available screening diagnostic tool. The guidelines suggest considering annual echocardiographic assessments of patients with SSc, even if they remain asymptomatic [3]. Exercise echocardiography, by increasing cardiac output, makes it possible to identify patients with elevations in PAP during exercise. The current European Society of Cardiology (ESC) guidelines consider exercise echocardiography a class III recommendation with the level of evidence C, which means that this diagnostic modality is of no practical use in patients with suspected PH [3]. However, the authors emphasise that one of the main limitations of this method is the insufficient number of prospective studies and the lack of a commonly accepted methodology for such studies.

The aim of our study was to attempt to identify, using echocardiography, SSc patients with abnormal PAP at rest or a significant elevation of PAP during exercise, verified by RHC.

## METHODS

### *Patients*

A total of 71 consecutive patients (67 females and 4 males, mean age 56.9 ± 17.1 years) with the diagnosis of SSc (mean duration of the disease 9.0 ± 12.4 years, range 1–45 years, median 6 years) were enrolled in this prospective study. The diagnosis of SSc was based on the American College of Rheumatology criteria [5]. Diffuse disease was demonstrated in 43 (61%) patients and limited disease in the remaining 28 (39%) patients.

We did not include patients with manifestations of coronary artery disease, severe hypertension, LV hypertrophy and significant valvular heart disease. We excluded patients with significant pulmonary dysfunction defined as forced vital capacity (FVC) and total lung capacity values < 60% predicted and/or the forced expiratory volume in one second to vital capacity ratio (FEV1/VC) < 70% predicted. We also did not include patients with significant fibrotic changes in the lung by high-resolution computed tomography. One of the exclusion criteria was renal impairment with serum creatinine exceeding 1.2 mg/dL.

During the study, due to exacerbation of SSc, 11 (5%) patients received glucocorticosteroids and 4 (6%) immunosuppressant agents. Most patients with SSc additionally received drugs recommended by their dermatologists, mainly vitamin A and/or vitamin E and drugs with a potentially beneficial effect on the microcirculation, such as pentoxifylline, bencyclane and buflomedil (68 [96%] and 61 [86%] patients, respectively). Angiotensin converting enzyme inhibitors or angiotensin II receptor (AT1 receptor) blockers were taken by 36 (51%) and calcium antagonists by 27 (38%) patients.

All the patients gave informed consent and the study protocol was approved by the local bioethics committee.

### *Assessment of the severity of systemic sclerosis and its target-organ complications*

Before the study a detailed assessment of the severity of SSc and its target-organ complications was performed. All the patients underwent an interview and a physical examination for signs and symptoms suggestive of PH. The severity of cutaneous manifestations was rated using the Rodnan skin score. Mild disease (0–6) was present in 29 (41%) patients, moderate disease (9–16) in 24 (34%) patients and severe disease (over 16) in 18 (25%) patients. In order to detect pulmonary involvement, if any, each of the patients underwent a chest X-ray, a lung HRCT scan, and pulmonary function testing with an assessment of carbon monoxide diffusing capacity.

### *Echocardiography*

Echocardiography was performed with the Philips iE33 system (Andover, Massachusetts, USA) using a 2.5–3.5 MHz transducer. The views were obtained and the measurements made in accordance with the Polish Society of Cardiology Echocardiography Section Standards [6]. The scans were recorded digitally. Measurements from three consecutive cardiac evolutions during expiration were used for calculations. In the apical four-chamber view, the tricuspid regurgitant jet was identified using colour-coded Doppler. Then, using continuous-wave Doppler, the maximum velocity of the regurgitant jet ($V_{max}$) was recorded. Using the simplified Bernoulli equation (TRPG = $4V^2$), the systolic gradient of pressures between the right ventricle and the right atrium — tricuspid regurgitant peak gradient (TRPG) was calculated. Left ventricular ejection fraction (LVEF) was calculated by the Simpson method using 2D images of the LV chamber in systole and

diastole in the apical 4- and 2-chamber views [7]. In addition, in the apical 4-chamber view, using the M-mode presentation, the tricuspid annular plane systolic excursion was recorded. In the substernal view, at peak expiration, the inferior vena cava dimension was measured using the 2D presentation.

### *The exercise echocardiography protocol and the methodology for measuring right ventricular systolic pressure at rest and following exercise*

At the exercise testing laboratory, just before the exercise, the place of best visibility of the tricuspid regurgitant wave was identified in the patient lying on his or her left side. In the apical 4-chamber view, using continuous-wave Doppler, the peak velocity of the tricuspid regurgitant wave was recorded. Using the simplified Bernoulli equation the TRPG was calculated. The patient then performed a standard exercise on a treadmill according to the Bruce protocol until 100% of the maximum heart rate was achieved. The exercise was then stopped and the patient resumed the left lateral position as soon as possible. The TRPG was recorded within one minute after stopping the exercise.

The PH was suspected when TRPG at rest exceeded 31 mm Hg ($V_{max}$ > 2.8 m/s) or increased by at least 20 mm Hg *vs* baseline following exercise [2, 3]. Patients with suspicion of PH were refered to cardiac catheterisation. During the entire examination ECG was recorded and blood pressure was monitored at 3-min intervals. The evaluation of the exercise test also included the standard assessment of ST segment changes, duration of exercise and the achieved metabolic equivalent of task values (METs).

### *Haemodynamic assessment of the right heart*

Cardiac catheterisation was performed within 6 weeks of exercise echocardiography. The vascular access in all the cases was obtained through the right internal carotid artery. The Swan-Ganz catheter was passed under fluoroscopic guidance to the pulmonary artery. The following variables were recorded: PAP (systolic, diastolic and mean), mean pulmonary capillary wedge pressure (PCWP) and mean right atrial pressure. Systemic blood pressure was recorded with a sphygmomanometer. Cardiac output was determined by thermodilution injecting cooled saline until a variability of less than 10% was achieved in 3 consecutive measurements. The vascular resistance values in the pulmonary and systemic circulation were calculated using typical formulas. The exercise test was performed on a cycloergometer in the lying position, aiming to achieve the maximum load of 125 W. After 5 min of maximal tolerated exercise the same measurements as those at rest were performed.

In accordance with the ESC recommendations, PAH at rest was diagnosed when mPAP exceeded 25 mm Hg and PCWP did not exceed 15 mm Hg. An excessive increase in precapillary PAP was identified when mPAP during exercise exceeded 30 mm Hg in the presence of normal PCWP. The PVH at rest was diagnosed when mPAP at rest exceeded 25 mm Hg and PCWP exceeded 15 mm Hg. Post-exercise abnormal increase in postcapillary PAP was diagnosed when mPAP during exercise exceeded 30 mm Hg and PCWP exceeded 15 mm Hg [3].

### *Statistical analysis*

The results obtained for variables with a normal distribution are presented as means and SD, while those which did not meet the requirements for a normal distribution are shown as medians and ranges. Variables with a normal distribution were compared using the t-Student test, while those which did not meet the requirements for a normal distribution were compared with the Mann-Whitney test (for 2 groups). The $\chi^2$ test was used to compare qualitative variables in contingency tables. A p value $< 0.05$ was considered statistically significant. The statistical analysis was performed using STATISTICA 9.0.

## RESULTS

None of the patients included in our study had any clinical symptoms at rest that would suggest PH. Fourteen (20%) patients complained of moderate exertional dyspnoea. Four (6%) patients were excluded due to orthopaedic conditions preventing them from undergoing an adequate physical exercise. The exercise testing was performed in 67 patients. The clinical characteristics and the values of the pulmonary function parameters in the 67 patients undergoing exercise testing are summarised in Table 1. Diffuse disease was demonstrated in 41 (61%) patients and limited disease in the remaining 26 (39%) patients. The ANA, ACA and anti-Scl 70 antibodies were demonstrated in 47 (70%), 18 (27%) and 29 (43%) patients, respectively. In all the patients the quality of imaging during echocardiography at rest enabled a reliable asses-

**Table 1**. Overall characteristics of 67 patients with systemic sclerosis undergoing exercise echocardiography

| | |
|---|---|
| Age [years] | 56.9 ± 17.1 |
| Female-to-male ratio | 64/3 |
| Height [cm] | 162.9 ± 7.5 |
| Weight [kg] | 65.2 ± 13.7 |
| Body surface area [m$^2$] | 1.37 ± 0.2 |
| Pulmonary function parameters: | |
| FVC [% predicted] | 97.8 ± 16.6 |
| FEV1 [% predicted] | 95.0 ± 17.5 |
| FEV1/FVC [% predicted] | 82.4 ± 9.1 |
| Total lung capacity [% predicted] (n = 24) | 101.8 ± 18.4 |
| Carbon monoxide diffusing capacity (n = 21) | 71.2 ± 19.9 |

FVC — forced vital capacity; FEV1 — forced expiratory volume in 1 s

**Table 2.** Echocardiographic parameters at rest in patients with systemic sclerosis

| | |
|---|---|
| LVEDD [mm] | 44.0 ± 5.2 |
| LA dimension [mm] | 33.0 ± 5.1 |
| LVEF [%] | 66.1 ± 3.9 |
| Mitral inflow E/A | 0.92 ± 0.27 |
| TRPG [mm Hg] | 26.9 ± 7.6 |
| RV dimension | 25.2 ± 3.5 |
| TAPSE | 21.4 ± 2.9 |
| IVC dimension | 15.9 ± 2.9 |

LVEDD — left ventricular end-diastolic diameter; LA — left atrial; LVEF — left ventricular ejection fraction; TRPG — tricuspid regurgitation peak gradient; RVD — right ventricular; TAPSE — tricuspid annular plane systolic excursion; IVC — inferior vena cava

**Table 3.** Exercise characteristics of the study patients

| | |
|---|---|
| Resting SBP | 120.9 ± 17.2 |
| Resting DBP | 71.1 ± 8.6 |
| Maximum SBP | 170.9 ± 26.7 |
| Maximum DBP | 76.0 ± 9.7 |
| Resting HR | 81.7 ± 18.7 |
| Maximum HR during exercise | 149.6 ± 22.8 |
| Duration of exercise [min] | 6.1 ± 2.5 |
| Maximum load [MET] | 8.3 ± 2.4 |
| % HRmax | 93.1 ± 15.5 |
| TRPG post-exercise | 40.3 ± 14.1 |
| ΔTRPG | 12.9 ± 8.5 |

SBP — systolic blood pressure; DBP — diastolic blood pressure; HR — heart rate; TRPG — tricuspid regurgitation peak gradient

sment of cardiac structure and function. The TRPG could not be measured at rest in 2 (3%) patients.

Table 2 summarises echocardiographic parameters at rest in patients with SSc. Normal LV systolic function was demonstrated in all the patients. The TRPG values exceeding 31 mm Hg at rest, suggestive of the possibility of PH, were found in 14 (21%) patients.

Table 3 summarises the parameters obtained during exercise testing. A total of 56 (84%) patients achieved 85% of their maximum heart rate. The reason for early discontinuation of the exercise test in the remaining 11 (16%) patients was increasing fatigue preventing further exercise. During echocardiography a Doppler spectrum enabling the measurement of TRPG post-exercise was obtained in 66 (98.5%) patients. The gradient following the exercise could not be measured in 1 patient with a resting TRPG of 30 mm Hg.

In the entire study group, the mean post-exercise TRPG was 40.3 ± 4.1 mm Hg (range 17–70 mm Hg) and the mean post-exercise increase in TRPG was 12.9 ± 8.5 mm Hg (range 2–38 mm Hg). A TRPG increase of > 20 mm Hg from baseline was observed in 11 (16%) patients, including 7 patients with normal TRPG at rest. In 4 (6%) patients an elevation in TRPG above 31 mm Hg at rest and a further increase in TRPG by more than 20 mm Hg following exertion was observed (from 32 to 50 mm Hg, from 32 to 70 mm Hg, from 33 to 54 mm Hg and from 36 to 69 mm Hg, respectively).

During exercise testing the percentage of age-adjusted maximum heart rate in the 11 patients with a TRPG increase exceeding 20 mm Hg was 93.92 ± 15.6 and did not differ significantly form the maximum heart rate in the group of patients without a significant TRPG increase (93.18 ± 15.5); p = 0.9.

### *The significance of exercise echocardiography in the qualification of patients for cardiac catheterisation*

Twenty-one (31%) patients with TRPG exceeding 31 mm Hg at rest and/or a post-exercise increase in TRPG exceeding 20 mm Hg were referred for cardiac catheterisation. Three refused consent to undergo the procedure, 1 patient could not undergo the procedure due to a worsening general condition and 1 patient died while awaiting the procedure due to bleeding from oesophageal varices. In the end, haemodynamic assessment of the right heart was performed in 16 (24%) patients. Based on exercise echocardiography (TRPG at rest below 31 mm Hg and an increase in TRPG exceeding 20 mm Hg from baseline) 7 patients were qualified for catheterisation. Three patients refused consent. In the end, out of the 16 patients undergoing catheterisation 4 (25%) were qualified for haemodynamic assessment because of the "positive" exercise echocardiography in the presence of normal TRPG values. During catheterisation PAH was found in 2 patients, and excessive elevation in precapillary pressure in the pulmonary artery during exercise in 2 further patients. Resting PVH was found in 1 patient and an excessive elevation in postcapillary pressure in the pulmonary artery at rest was demonstrated in 11 patients (Fig. 1).

### *Safety of exercise echocardiography*

None of the 67 patients developed cardiovascular complications during exercise testing. Significant signs of ischaemia on ECG and coronary symptoms were observed during exercise testing in 2 (3%) patients without a typical history of coronary artery disease. These patients were referred for coronary angiography, which confirmed significant coronary atherosclerosis. One patient underwent coronary artery bypass grafting and the other was selected for conservative treatment due to disseminated atherosclerotic changes in the coronary vessels.

## DISCUSSION

The incidence of PH in patients with SSc ranges from 7% to 12% [8, 9]. In a multicentre prospective study conducted in

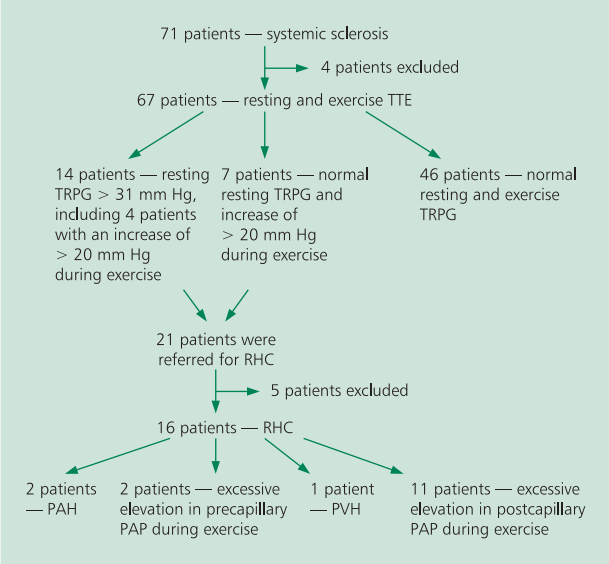


**Figure 1**. Qualification of patients for cardiac catherisation; TTE — transthoracic ehocardiography; TRPG — tricuspid regurgitation peak gradient; RHC — right heart catherisation; PAH — pulmonary arterial hypertension; PVH — pulmonary venous hypertension; PAP — pulmonary artery pressure

the French population, Hachulla et al. [8] demonstrated PAH in 47 out of 599 (8%) patients with SSc undergoing echocardiography and cardiac catheterisation. Appropriate and early detection of this complication is very important, as patients with SSc and overt PH have a poor prognosis. Kawut et al. [10] showed that the risk of death in patients with SSc and PAH is 2.9 times higher than in patients with idiopathic PH. With the advent of modern pharmacological management the prognosis improved, although high mortality rates still persist [11].

The diagnosis of PH can only be confirmed by cardiac catheterisation, which due to its invasive nature cannot be used as a screening tool in all the patients with SSc. For this purpose echocardiography is used. The latest ESC recommendations on the diagnosis and treatment of PH are critical about echocardiographic diagnosis of PH and indicate the need to verify the diagnosis using haemodynamic assessment. The guidelines also recommend performing catheterisation once a year to look for signs suggestive of PH in patients with SSc [3].

Exercise echocardiography is a non-invasive diagnostic method potentially useful in the evaluation of PH. However, according to the European recommendations, it is not indicated as a screening tool for PH due to the lack of sufficient data on the methodology of the test or a value of echocardiographically assessed PAP which might serve as a cutoff point for diagnosing exertional PH [3]. According to the American recommendations published in parallel, exercise echocardiography is mentioned as a valuable research method that expands the understanding of exertional PH, although it is also stated that therapeutic decisions should not be based solely on exercise testing [4]. According to both the European and the American recommendations, definite diagnosis of PH is made solely on the basis of mPAP of at least 25 mm Hg measured during cardiac catheterisation: the definition of exertional PH as an increase in mPAP exceeding 30 mm Hg during exercise included in the previous edition of ESC guidelines published in 2004 has not been carried forward to the present edition [3, 4]. There is an opinion, however, that a considerable elevation in mPAP during exercise should not be considered normal.

The low-pressure and low-resistance pulmonary circulation undergoes rapid adaptation to increased blood supply during exercise. In healthy individuals, PAP during exercise remains unchanged or increases only slightly [12, 13]. Based on an analysis of exercise testing in 191 healthy young individuals Grunig et al. [14] arbitrarily considered systolic PAP (sPAP) of less than 43 mm Hg as normal and concluded that values above this threshold might suggest an excessive exertional increase in PAP. According to other literature data, post-exercise sPAP values below 40 mm Hg should be considered normal [15, 16]. Isolated studies reported PAP increases during exercise in well-trained athletes [17].

The clinical relevance of excessive elevation in pulmonary pressure during exercise is unclear. One might suspect that in patients with SSc and normal PAP at rest, physical exertion results in an excessive elevation of PAP, which is an early sign of vasculopathy of the pulmonary arterioles. It may well be that these patients, who represent the preclinical stage of PAH associated with SSc, could, in the future, take advantage of early treatment targeting the pulmonary arterioles.

In our study a satisfactory spectrum of the tricuspid regurgitant jet was recorded during echocardiography in 66 (98.5%) patients. In our study group TRPG was 26.9 ± ± 7.6 mm Hg at rest, 40.3 ± 14.1 mm Hg post-exercise and the mean increase in TRPG was 12.9 ± 8.5 mm Hg. In the study by Grunig et al. [14] the mean increase in sPAP during exercise in the group of healthy individuals was 15.2 ± 7.1 mm Hg and was significantly lower than that among the relatives of patients with idiopathic PAH (18.8 ± 10.6; $p = 0.0001$). Steen et al. [2] demonstrated an increase in sPAP post-exercise exceeding 20 mm Hg in 44% with a mean increase in sPAP of 17.1 mm Hg. Alkotob et al. [18] observed an increase in sPAP during exercise in 46% of the 65 patients with SSc they investigated. Pignone et al. [19] showed a post-exercise increase in sPAP assessed echocardiographically above 40 mm Hg in 18 out of 27 (67%) patients with SSc. Kovacs et al. [20] carried out exercise echocardiography in 52 patients with connective tissue diseases (including 26 patients with SSc). In 26 patients, despite normal values of sPAP at rest, an increase in exertional sPAP above 40 mm Hg was observed. Twenty-one patients underwent cardiac catheterisation, which confirmed normal sPAP at rest and the exertional increase in

sPAP above 40 mm Hg in 19 of them [20]. In all our patients referred for cardiac catheterisation based on resting and exertional echocardiography PH at rest or a significant increase in PAP during exercise were confirmed.

However, in the majority of cases the final diagnosis was PVH, whereas PAH was diagnosed in only 4 patients. In our study PAH was diagnosed only in 2 cases, excessive increase in precapillary PAP during exercise in 2 further patients, PVH at rest in 1 patient and excessive increase in postcapillary PAP during exercise in 11 patients, which may suggest diastolic dysfunction in this group of patients. A number of studies showed diastolic dysfunction of cardiac ventricles assessed at rest in patients with SSc [21, 22]. In the study by Kovacs et al. [20] an elevation in PCWP was found in 8 out of 21 patients undergoing exertional RHC, which also suggests diastolic dysfunction. The results of our study confirm the possibility of frequent diastolic dysfunction in patients with SSc, which, however, requires further prospective studies using advanced Doppler techniques. It therefore seems that Doppler echocardiography is a useful method for identification of PH in patients with SSc. The definition of the type of PH requires, however, cardiac catheterisation. Undoubtedly, patients with normal sPAP at rest and an excessive increase during exercise should be regularly monitored, as they may develop a full-blown PH at rest in the future.

### *Limitations of the study*

Cardiac catheterisation was performed within 6 weeks after exercise echocardiography, which might have resulted in changes of the haemodynamic status of the patients during that time. On the other hand, the clinical condition of patients while awaiting the catheterisation was stable and we did not modify the drug treatment.

We did not analyse Doppler parameters of LV diastolic function. It may well be that the analysis of mitral inflow, pulmonary vein inflow and tissue Doppler might be helpful in detecting LV diastolic dysfunction and therefore aid in differentiating the aetiology of the detected PH.

## CONCLUSIONS

Exercise echocardiography is a safe and useful screening tool for PH diagnosis in patients with SSc. Among other things, it enables to identify patients with normal sPAP but a significant increase during exercise. The final confirmation of PH and differentiation between precapillary arterial and postcapillary PVH requires RHC.

*The study was supported by the KBN N402 085034 grant.*

### *References*

1. Steen VD, Medsger TA. Changes in causes of death in systemic sclerosis, 1972–2002. Ann Rheum Dis, 2007; 66: 940–944.
2. Steen V, Chou M, Shanmugam V et al. Exercise-induced pulmonary arterial hypertension in patients with systemic sclerosis. Chest, 2008; 134: 146–151.
3. Galie N, Hoeper MM, Humbert M et al. Guidelines for the diagnosis and treatment of pulmonary hypertension. Eur Heart J, 2009; 30: 2493–2537.
4. McLaughlin VV, Archer SL, Badesch DB et al. ACCF/AHA 2009 Expert Consensus Document on Pulmonary Hypertension. J Am Coll Cardiol, 2009; 53: 1573–1619.
5. Subcommittee for Scleroderma Criteria of the American Rheumatism Association Diagnostic and Therapeutic Criteria Committee. Preliminary criteria for the classification of systemic sclerosis (scleroderma). Arthritis Rheumatol, 1980; 23: 581–590.
6. Kasprzak JD, Hoffman P, Płońska E et al. Echokardiografia w praktyce klinicznej — Standardy Sekcji Echokardiografii Polskiego Towarzystwa Kardiologicznego 2007. Kardiol Pol, 2007; 65: 1–21.
7. Feigenbaum H, Armstrong WF, Ryan T. Feigenbaum's echocardiography. 6th Ed. Lippincott, Williams & Wilkins, Philadelphia, PA 2005: 105–129.
8. Hachulla E, Gressin V, Guillevin L et al. Early detection of pulmonary arterial hypertension in systemic sclerosis: a French nationwide prospective multicenter study. Arthritis Rheumatol, 2005; 52: 3792–3800.
9. Mukerjee D, St George D, Coleiro B et al. Prevalence and outcome in systemic sclerosis associated pulmonary arterial hypertension: application of a registry approach. Ann Rheum Dis, 2003; 62: 1088–1093.
10. Kawut SM, Taichman DB, Archer-Chicko CL et al. Hemodynamics and survival in patients with pulmonary arterial hypertension related to systemic sclerosis. Chest, 2003; 123: 344–350.
11. Williams MH, Das C, Handler CE et al. Systemic sclerosis associated pulmonary hypertension: improved survival in the current era. Heart, 2006; 92: 926–932.
12. Reaside DA, Brown A, Patel KR et al. Ambulatory pulmonary artery pressure monitoring during sleep and exercise in normal individuals and patients with COPD. Thorax, 2002; 57: 1050–1053.
13. Palevsky HI. Exercise and the pulmonary circulation. In: Leff A ed. Cardiopulmonary exercise testing. Grune and Stratton, Orlando, FL 1986: 89–106.
14. Grunig E, Weissmann S, Ehlken N et al. Stress Doppler echocardiography in relatives of patients with idiopathic and familial pulmonary arterial hypertension: results of a multicenter European analysis of pulmonary artery pressure response to exercise and hypoxia. Circulation, 2009; 119: 1747–1757.
15. Schachna L, Wigley F, Chang B et al. Age and risk of pulmonary arterial hypertension in scleroderma. Chest, 2003; 124: 2098–2104.
16. Grunig E, Janssen D, Mereles D et al. Abnormal pulmonary artery pressure response in asymptomatic carries of primary pulmonary hypertension gene. Circulation, 2000; 102: 1145–1150.
17. Bevegard S, Holmagren A, Jonsson B. Circulatory studies in well trained athletes at rest and during heavy exercise, with special reference to stroke volume and the influence of body position. Acta Physiol Scand, 1963; 57: 26–50.
18. Alkotob MA, Soltani P, Sheatt MA et al. Reduced exercise capacity and stress-induced pulmonary hypertension in patients with scleroderma. Chest, 2006; 130: 176–181.
19. Pignone A, Mori F, Pieri F et al. Exercise Doppler echocardiography identifies preclinic asymptomatic pulmonary hypertension in systemic sclerosis. Ann NY Acad Sci, 2007; 1108: 291–304.
20. Kovacs G, Maier R, Aberer E et al. Assessment of pulmonary arterial pressure during exercise in collagen vascular disease: echocardiography versus right heart catheterization. Chest, 2010 (Epub ahead of print).
21. Ciurzyński M, Bienias P, Lichodziejewska B et al. Assessment of left and right ventricular diastolic function in patients with systemiec sclerosis. Kardiol Pol, 2008; 66: 269–276.
22. Meune Ch, Avouac J, Wahbi K et al. Cardiac involvement in systemic sclerosis assessed by tissue-Doppler echocardiography during routine care. Arthritis Rheumatol, 2008; 58: 1803–1809.

# Przydatność echokardiografii wysiłkowej w identyfikacji nadmiernego wzrostu ciśnienia w tętnicy płucnej u chorych z twardziną układową

Michał Ciurzyński[1], Piotr Bienias[1], Katarzyna Irzyk[1], Zuzanna Rymarczyk[1], Maciej Kostrubiec[1], Agnieszka Szewczyk[2], Maria Glińska-Wielochowska[2], Joanna Żyłkowska[3], Marcin Kurzyna[3], Piotr Pruszczyk[1]

[1]Klinika Chorób Wewnętrznych i Kardiologii, Warszawski Uniwersytet Medyczny, Warszawa; [2]Klinika Dermatologiczna, Warszawski Uniwersytet Medyczny, Warszawa; [3]Klinika Chorób Wewnętrznych Klatki Piersiowej, Instytut Gruźlicy i Chorób Płuc, Warszawa

## Streszczenie

**Wstęp:** W przebiegu twardziny układowej (SSc) zmiany dotyczące płuc i nadciśnienie płucne (PH) są powikłaniami najbardziej obciążającymi rokowanie. U części pacjentów występuje tętnicze PH, spowodowane izolowaną arteriopatią naczyń płucnych lub PH rozwija się na podłożu śródmiąższowej choroby płuc. Może także występować żylne PH związane z upośledzeniem czynności rozkurczowej lewej komory i zakrzepowo-zatorowe PH. Według zaleceń ESC cewnikowanie prawego serca (RHC) jest wciąż referencyjną metodą rozpoznawania PH, jednak zaleca się coroczne, przesiewowe, badanie echokardiograficzne u chorych z SSc. Echokardiografia wysiłkowa, zwiększając rzut minutowy serca, pozwala na identyfikację pacjentów, u których dochodzi do wzrostu ciśnienia w tętnicy płucnej (PAP) podczas wysiłku. Przydatność diagnostyczna echokardiografii wysiłkowej jest wciąż niepewna, głównie ze względu na brak badań prospektywnych.

**Cel:** Celem pracy jest próba echokardiograficznego wyodrębnienia pacjentów z SSc z nieprawidłowym PAP w spoczynku lub jego istotnym wzrostem podczas wysiłku, weryfikowana RHC.

**Metody:** Prospektywnymi badaniami objęto 71 kolejnych osób (67 kobiet, 4 mężczyzn, śr. wiek 56,9 ± 17,1 roku) z SSc rozpoznaną na podstawie kryteriów Amerykańskiego Towarzystwa Reumatologicznego. U chorych wykonano echokardiograficzne badanie przezklatkowe aparatem Philips iE33 z pomiarem maksymalnego gradientu niedomykalności trójdzielnej (TRPG) i próbę wysiłkową obejmującą standardowy wysiłek na bieżni ruchomej wg protokołu Bruce'a z oceną TRPG w czasie 1 minuty po zakończeniu wysiłku. Nadciśnienie płucne podejrzewano, gdy TRPG w spoczynku wynosiło > 31 mm Hg ($V_{max}$ > 2,8 m/s) lub wzrastało o co najmniej 20 mm Hg po wysiłku w porównaniu z wartościami spoczynkowymi. Pacjentów z podejrzeniem PH kierowano na spoczynkowe i wysiłkowe RHC.

**Wyniki:** Test wysiłkowy wykonano u 67 pacjentów. U wszystkich chorych stwierdzono prawidłową funkcję skurczową lewej komory. Średnia wartość frakcji wyrzutowej wynosiła 66,1 ± 3,9%. U 65 (97%) pacjentów w spoczynku zarejestrowano TRPG, którego wartość wynosiła średnio 26,9 ± 7,6 mm Hg (zakres 17–57). Spoczynkową wartość TRPG > 31 mm Hg sugerującą obecność PH stwierdzono u 14 (21%) pacjentów. Podczas testu wysiłkowego u 56 (84%) osób osiągnięto 85% maksymalnej częstotliwości rytmu serca. Powodem przedwczesnego przerwania testu wysiłkowego u pozostałych 11 (16%) chorych było narastające zmęczenie. Podczas badania echokardiograficznego u 66 (98,5%) osób uzyskano spektrum doplerowskie pozwalające na pomiar TRPG po wysiłku. Średnia wartość TRPG po wysiłku wyniosła 40,3 ± 14,1 mm Hg (zakres 17–70), a średni powysiłkowy przyrost TRPG 12,9 ± 8,5 mm Hg (zakres 2–38). Wzrost TRPG > 20 mm Hg stwierdzono u 11 (16%) pacjentów (4 chorych z TRPG w spoczynku > 31 mm Hg i 7 z prawidłowym spoczynkowym TRPG). Dwudziestu jeden (31%) chorych z echokardiograficznym podejrzeniem PH skierowano na RHC, które ostatecznie wykonano u 16 osób. Spośród nich 4 chorych zostało zakwalifikowanych do RHC ze względu na „dodatni" echokardiograficznie test wysiłkowy przy prawidłowych spoczynkowych wartościach TRPG. W trakcie RHC u 2 osób stwierdzono tętnicze PH, u 2 kolejnych nadmierny wzrost przedkapilarnego PAP podczas wysiłku. Spoczynkowe żylne PH zaobserwowano u 1 chorego, a nadmierny wysiłkowy wzrost postkapilarnego PAP — u 11 osób.

**Wnioski:** Echokardiografia wysiłkowa to bezpieczna i przydatna przesiewowa metoda diagnostyczna w kierunku PH u chorych z SSc.

**Słowa kluczowe:** twardzina układowa, choroby tkanki łącznej, nadciśnienie płucne, echokardiografia

Kardiol Pol 2011; 69, 1: 9–15

**Adres do korespondencji:**
dr n. med. Michał Ciurzyński, Klinika Chorób Wewnętrznych i Kardiologii, Warszawski Uniwersytet Medyczny, ul. Lindleya 4, 02–005 Warszawa, e-mail: michal.ciurzynski@wum.edu.pl
**Praca wpłynęła:** 28.06.2010 r. **Zaakceptowana do druku:** 20.10.2010 r.