SUBXIPHOID ECHOCARDIOGRAPHIC EVALUATION OF RIGHT HEART FUNCTION IN PATIENTS WITH CHRONIC OBSTRUCTIVE PULMONARY DISEASE

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ABSTRACT

PURPOSE: The purpose of this study is to evaluate by subxiphoid echocardiography the sensitivity and specificity of various echocardiographic parameters for early diagnosis and survival of patients with chronic obstructive pulmonary disease (COPD).

MATERIAL AND METHODS: Subxiphoid echocardiography was performed in 75 COPD patients to evaluate inferior vena cava dimension (IVCD), its collapsibility index (CI), end-diastolic right ventricular dimension (EDRVD), end-diastolic right ventricular thickness (EDRVT) (M-mode), right atrial area (RAA), right ventricular areas and right ventricular area shortening fraction. Results were compared to those of 30 healthy controls. Patients in sinus rhythm were divided in two according to there NYHA class (I+II and III+IV) an in three according to there acid-base blood gases status.

RESULTS: All the indexes were equally and significantly changed in the patients with RVH/PH and those with COPD and atrial fibrillation (AF) when compared to controls. COPD patients with neither ECG criteria for RV hypertrophy (RVH), nor x-ray evidence of pulmonary hypertension (PH) presented with significantly greater EDRVA and RAA and normal IVC/CI. In both cases, according to cardiac and respiratory severity status subdivision, significant changes in any indexes with worsening of cardiac and respiratory failure were observed. Best sensitivity, specificity and predictive accuracy for early diagnosis were established for IVCD/CI and EDRVT. During the two-year study period, seven (9%) patients died in end stage respiratory and heart failure because of considerably reduced right heart performance.

CONCLUSION: Subxiphoid echocardiography may be used for early detection of cor pulmonale, evaluation of right heart dysfunction and prognosis in COPD patients

Key words: *echocardiography, COPD, right heart function, inferior vena cava, survival*

INTRODUCTION

It is known that in patients with chronic obstructive pulmonary disease (COPD), right heart function is impaired (6) and severity of pulmonary hypertension (PH) relates to prognosis (13). Long-term oxygen therapy (14) and potentiating medication (5) may improve the prognosis by reducing pulmonary hypertension. This determines the necessity for non-invasive evaluation of pulmonary hypertension (1) and associated disorders in right ventricular (RV) function. The non-invasive estimation of pulmonary artery (PA) pressures is accompanied by a series of

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pitfalls. Subxiphoid approach of two-dimensional echocardiography is frequently used, however, its capacities in COPD patients are not completely explored yet (1,2,9,11,15).

MATERIAL AND METHODS

In the present study, inclusion criteria were history of bronchitis, emphysema on x-ray, physical findings of crackles and wheezing, acid-base status and spirometry (4). Exclusion criteria were hypertension, myocardial infarction, angina pectoris, acquired and congenital cardiac defects. Hypertension was allowed in the group of patients with COPD and atrial fibrillation (AF).

Using two-dimensional and M-mode subxiphoid echocardiography, the following parameters were studied in 75 COPD patients: dimensions of inferior vena cava (IVC) and percentage of inspiratory collapse-inspiratory collapsibility index (ICI), end-diastolic thickness of the right ventricular wall (EDRVWT) by two-dimensional directed M-mode echocardiography, end-diastolic inflow diameter of the right ventricle (RV) at the level of the tricuspid valve (EDDRV), right atrial area (RAA) and RV end-systolic and end-diastolic areas (ESRVA and EDRVAd), and RV area (RVA) change. All the indices were corrected for body surface area (BSA) (Table 1).

After exclusion of AF patients, COPD ones in sinus rhythm were divided in three ways depending on:

i) the presence or absence of pulmonary hypertension and/or RV hypertrophy by x-ray criteria or ECG (8,16);

ii) right heart failure of NYHA I-II class, i.e. no episodes of peripheral edema and NYHA III-IV class with one or more episodes of peripheral edema, and

iii) the severity of respiratory failure of grade 0-I with or without hypoxemia at rest, of grade II with presence of hypercapnia, and of grade III with persistent decompensated acidosis despite 7-14 days of standard hospital treatment.

Results were compared to those of 30 healthy subjects. ANOVA and statistical indices such as sensitivity, specificity and predictive accuracy were used (Table 2).

RESULTS

Subxiphoid approach proved successful for visualization of IVC in 95%, - for EDRVWT measurement in 87% and for two-dimensional echocardiography measurements in 69% of the cases.

Demographic and respiratory status of the patients and controls was shown on Table 3. Any ultrasound parameters in COPD patients were significantly changed compared to healthy controls. The same was true for COPD patients with AF whose indices were equally changed from the control group and did not differ from the patients in sinus rhythm. The parameters of the patients without PH

Table 1. Echocardiographic parameter definitions

Echocardiographic parameters	Measurements
IVC in mm	Largest diameter after IVC 'A' wave at normal expiration and smallest diameter at end-expiration by 2-D oriented M-mode
Collapsibility index (CI) in %	(Expiratory diameter-inspiratory diameter):expiratory diameter x 100
EDRVWT in mm	Subxiphoid 2-D oriented M-mode of EDRVWT
EDRVD in mm	Subxiphoid 4-chamber 2-D echocardiography of inflow tract EDRVD
RAA in cm^2	Subxiphoid 4-chamber 2-D echocardiography of end-systolic area
EDRVA in cm^2	Subxiphoid 4-chamber 2-D echocardiography of end-diastolic area at slight held inspiration
ESRVA in cm^2	Subxiphoid 4-chamber 2-D echocardiography of end-systolic area at slight held inspiration
RVAFS in %	(EDRVA-ESRVA):EDRVA x 100

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Table 2. COPD patients' distribution according to cardiac and pulmonary status and evidence of PH

Patients	M-mode	2D-Echo
total	75	48
in sinus rhythm	65	40
with AF	10	8
sinus rhythm	65	40
with PH	48	28
without PH	28	12
in sinus rhythm	65	40
NYHA I+II class	43	24
NYHA III+IV class	22	16
in sinus rhythm	65	40
with hypoxemia only	23	13
with hypercapnia	33	22
with acidosis	9	5
controls	30	15
two-year mortality	7	5

heart failure because of considerably reduced right heart performance (Table 4 and Table 5).

Normal values of various echocardiographic indices were estimated and upper normal reference limits were used for calculating the sensitivity and specificity. Using normal reference limits from healthy volunteers, at least 50% of COPD patients without PH presented with altered parameters, including the patients with no hypoxemia at rest. At specificity and predictive accuracy of 100%, sensitivity for PH group varied from 71% to 93% for various echocardiographic parameters, the highest being for EDRVWT and IVC/IC. RVAFS was characterized by exceptionally low sensitivity in all the groups (Table 6).

DISCUSSION

Right-heart echocardiagraphic subxiphoid parameters distinguish highly significantly the healthy subjects from COPD patients and this has already been observed in several studies of

Table 3. Demographic and respiratory data of COPD patients and controls

Patients	n (%)	age (years)	BSA	FEO (α)	PO_2 (kPa)	pCO_2 (kPa)
total	65 53 m+12 f	59±10 NS	1,73±0,19 NS	1,2±0,4	7,7±1,9	5,9±1,3
with PH*	48 (74%) 41 m+7 f	60±9 NS	1,74±0,2 NS	1,0±0,4	7,1±1,7	6,3±1,4
without PH	17 (16%) 12 m+5 f	58±12 NS	1,69±0,13 NS	1,6±0,4	8,9±1,7	5,3±0,5
with AF	10 8 m+2 f	63±8 NS	1,7±0,22 NS	1,3±0,4	7,2±1,1	6,2±0,6
controls	30 22 m+8 f	49±12 NS	1,71±0,11 NS			

*m - males; f - females; * - $p < 0,001$; NS - not significant*

were also statistically significantly different from those of healthy controls except for IVC and RV area fractional shortening. The characteristics of these patients differed from those of the patients with PH except RVA fractional shortening (RVAFS), too. Statistically significant changes were found out for any parameters with advancement of cardiac and respiratory failure. During the two-year study period, seven (9%) patients died in end stage respiratory and lung diseases, too. Subxiphoid echocardiography correlates both with radionuclide angiography and magnetic resonance imaging (10,11).

Doppler studies, on the other hand, are deemed suitable for screening purposes, however, they lack accuracy (12). Doppler method of formula estimation of PA pressure using the velocity of tricuspid regurgitation in pulmonary diseases is considered the most convenient one (3).

Table 4. Echocardiographic results in COPD patients and controls

COPD patients and controls	VCI mm/m²	CI %	RVWT mm	RVD mm	RAA cm²/m²	RVEDA cm²/m²	RVESA cm²/m²	RVSFS %
in sinus rhythm	9,4±3 (4,4-18,1) *	35,5±11,4 (0-62) *	7,1±2 (4-13) *	38,2±7,8 (24-60) *	9,4±2,2 (6,4-16,4) *	10,4±3,3 (5,7-19,3) *	6,8±2,5 (3,2-13,8) *	34,6±7,9 (22-51) •
controls	6,7±1,2 (4,5-8,7) *	50,1±8,1 (38-71) *	3,96±0,7 (3-5) *	31,2±5,5 (10-38) *	7,0±1,2 (5,1-8,4) *	6,3±1,3 (4,5-8,2) *	3,7±1,0 (1,7-5,3) *	41,3±8,8 (33-59) •
with PH	10,0±2,9 (4,7-18,1) *	31,3±11,9 (0-53) *	7,9±1,7 (5-13) *	42,2±7,1 (33-60) •	9,7±2,3 (6,4-16,4) ▫	10,9±3,7 (5,7-19,3) •	7,2±2,7 (3,2-13,8) •	33,9±8,4 (22-48) NS
without PH	7,4±2,0 (4,4-11) NS	41,2±7,5 (24-62) *	5,7±1,2 (4-8) *	36,6±5,2 (24-40) •	8,3±1,3 (6,6-10,8) ▫	8,7±1,4 (6,6-10,6) •	5,45±1,1 (3,8-6,9) •	37,3±6,3 (27-51) NS
controls	6,7±1,2 *	50,1±8,1 *	3,96±0,7 *	31,2 ± 5,5 *	7,0±1,2 *	6,3±1,3 *	3,7±1,0 *	41,3±8,8 •
with AF	10,2±1,85 (7-13) *	28,4±10,5 (9-40) *	8,1±2,3 (6-13) *	40,8±5,1 (34-51) *	9,9±1,8 (7,4-13,1) *	11,9±3,4 (7,8-18,1) *	8,3±3 (3,4-11,8) *	30,2±6,3 (18-44) *

** - p < 0,001; • - p < 0,01; ▫ - p < 0,02; Δ - p < 0,05; NS - not significant*

Table 5. Echocardiographic results in COPD patients according to cardiac and respiratory status

Patients	VCI mm/m²	CI %	RVWT mm	EDRVD mm	RAA cm²/m²	EDRVA cm²/m²	ESRVA cm²/m²	STROKE area %
NYHA I+II class	8,3±2,2 (4,4-14,4) *	37,3±7,3 (18-62) *	6,0±1,4 (4-9) *	37,2±4,0 (34-45) •	8,5±1,5 (6,6-13,5) *	8,9±1,2 (5,5-13,2) *	5,6±1,7 (3,2-10,4) *	37,1±6,8 (27-48) •
NYHA III+IV class	11,6±2,9 (7,9-18,1)	25,2±12 (0-45)	8,8±1,6 (6-13)	44,1±6,7 (34-60)	11,0±2,3 (7,3-16,4)	12,4±3,7 (6,6-19,8)	8,7±2,5 (4,4-13,8)	29,8±8,1 (22-48)
hypoxemia only	7,7±2,1 (4,4-11,9) •	40,1±8,6 (24-62) •	6±1,7 (4-9) •	36,4±3,4 (30-45) ▫	8,0±0,9 (6,9±8,8) *	8,2±1,0 (6,6-9,8) •	5,0±0,9 (3,8-6,7) *	39±6,7 (27-51) •
hypercapnia and hypoxemia	9,5±2,2 (6,5-14,4) Δ	32,9±10,6 (11-46) NS	7,6±1,9 (6-13) •	39,7±4,5 (34-50) Δ	9,9±2,1 (6,6-16,4) NS	10,4±2,9 (6,5-16,5) NS	6,9±2,2 (3,2-10,5) NS	33,7±8,3 (22-48) NS
persistent acidosis	12,6±4,2 (5,3-18,1)	25,5±15,6 (0-44)	8,9±1,0 (7-10)	50±9,1 (42-60)	11,3±2,9 (7,4-13,8)	13,5±5,1 (6,6-19,1)	9,6±3,61 (4,4-13,3)	28,9±3,6 (22-33)
two-year mortality	12,7±4,2 (5,3-18,1)	25,0±15,9 (10-44)	8,9±1,1 (7-10)	50,0±9,1 (42-60)	11,3±2,9 (7,4-13,8)	13,5±5,1 (6,6-19,1)	9,6±3,61 (4,4-13,3)	28,9±3,6 (22-33)

** - p < 0,001; • - p < 0,01; ▫ - p < 0,02; Δ - p < 0,05; NS - not significant*

RV dimension below the level of the tricuspid valve, tricuspid annulus dimension and RV free wall differentiate COPD patients from healthy controls and correlate with PA pressures (15). Mean PA pressure at rest and during exercise correlates with RV diameters and areas in end-systole and end-diastole, whereas RVAFS does not correlate with hemodynamic parameters (4).

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Table 6. Statistical parameters in COPD patients

Statistical parameters	VCI mm/m²	CI %	RVWT mm	RVD mm	RAA cm²/m²	RVEDA cm²/m²	RVESA cm²/m²	RVAFS %
upper normal limit for healthy controls	8,7	38	5,0	38	8,4	8,2	5,3	33
specificity and predictive accuracy	100	100	100	100	100	100	100	100
sensitivity	70	74 – 88	93	78	75	71	71	46
percentage of abnormalities in COPD without PH	42	50 – 58	50	50	50	50	50	33
sensitivity for COPD NYHA I+II class	50	62 – 86	84	67	67	67	62	42
sensitivity for COPD NYHA III+IV class	86	86 – 100	100	100	93	93	93	64

Controlled AF does not change statistically these parameters in comparison with PH patients. Evolution of chronic cardiac and respiratory failure significantly worsens all the parameters of right heart function. Normal values of subxiphoid echocardiographic indices of the group of healthy volunteers correspond to those reported in the literature available. At 100% specificity, all the indicators possess high sensitivity in PH patients with highest EDRVWT and IVC/IC rates. This can be used for early diagnosis of cor pulmonale in chronic respiratory disease. Subxiphoid echocardiography enables an improved recognition of cor pulmonale in severe COPD (7).

Echocardiographic examination has the potential to distinguish patients with and without PH on x-ray and RV hypertrophy on ECG. These indices possess certain predictive value in COPD patients and worsen with advancement of cardiac functional class and severity of respiratory failure. COPD patient's survival is shortened above certain levels of deterioration of right heart function evaluated by echocardiography.

CONCLUSIONS

1. Subxiphoid M-mode and two-dimensional echocardiographic parameters in non-catheterized COPD patients separate them quite accurately from healthy subjects in everyday clinical practice.
2. IVC diameter, its inspiratory collapse and RVWT are of highest sensitivity, specificity and predictive accuracy for early diagnosis of cor pulmonale.
3. The presence of RVH/PH (on ECG and x-ray), hypercapnia and overt cardiac failure significantly change any echocardiographic parameters from the subxiphoid view.
4. These parameters are changed in at least 50% of COPD patients without RVH/PH studied by both M-mode and two-dimensional echocardiography as IVCD/CI is most sensitive.
5. RVAFS is the least sensitive parameter.
6. Controlled AF in COPD patients seems not to change adversely right heart indexes.

7. Subxiphoid echocardiography might have certain prognostic value concerning COPD patient's survival.

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