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Tissue Doppler evaluation of the right ventricle in major pulmonary resections

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Aim: To analyze the consequences of major pulmonary resections on right ventricle (RV) function by using the tissue Doppler imaging (TDI) technique.

Materials and methods: Twenty patients (16 males and 4 females) who received pulmonary resection for primary non-small cell lung cancer underwent echocardiographic examinations before surgery on the 2nd and 7th postoperative days.

Results: Tricuspid E wave significantly decreased from the postoperative 2nd day to the 7th day (45.93 ± 8.0 to 35.77 ± 7.4 cm/s; P = 0.02). On the postoperative 2nd and 7th days, tricuspid A wave values (58.27 ± 9.6 and 58.94 ± 8.4 cm/s) were significantly higher compared to preoperative values (45.71 ± 12.2 cm/s; P = 0.02 for both). The S' wave measured at the basal segment of the right ventricle markedly decreased on the postoperative 2nd day (12.35 ± 2.2 to 10.15 ± 3.2 cm/s; P = 0.03). Tricuspid annular S' wave velocity of patients who underwent pneumonectomy was lower than in patients who underwent lobectomy (10.65 ± 2.4 versus 14.42 ± 3.3 cm/s; P = 0.04).

Conclusion: In the early postoperative period, significant dilatation and dysfunction of the RV is caused by pulmonary resection. Early detection of this deterioration by means of this noninvasive technique could make swift interventional therapy possible, which is an important step towards avoiding future right heart failure.

Key words: Right ventricle, tissue Doppler imaging, pulmonary resection

1. Introduction

The most efficient treatment option for operable non-small cell lung cancer (NSCLC) patients remains pulmonary resection. Pulmonary resections can still cause surgical morbidity and mortality regardless of the remarkable advances in operative techniques. Therefore, patients should be assessed both before and after operation in order to avoid complications and diminish postoperative morbidity (1). The importance of right ventricle (RV) function after pulmonary resection has been evaluated previously with techniques such as invasive hemodynamic procedures and routine echocardiography (2–5). However, no reports evaluating the effects of pulmonary operations on RV by using tissue Doppler imaging (TDI) have been encountered. Myocardial and annular systolic/diastolic velocities are recorded with the TDI technique. TDI has been proven to deliver more precise quantification of regional and global cardiac functions than standard echocardiographic techniques (6,7). In this study, we analyze the effects of major pulmonary resections on RV function by using a novel echocardiographic technique, i.e. TDI.

2. Materials and methods

Twenty patients (16 males, 4 females; ages 44–77 years, mean 59.2 years) who had undergone pulmonary resection (14 lobectomies, 6 pneumonectomies) for primary NSCLC were included in this prospective study. TDI examinations were carried out before surgery and 2 days and 7 days after the surgery. Preoperative chest X-ray, ECG, spirometry, and blood gas analysis were performed for every patient. Patients with a history of myocardial infarction, atrial fibrillation, valvular heart disease, major arrhythmias, and heart surgery were excluded from this study. Since chronic obstructive pulmonary disease has additional detrimental effects on the RV similar to those

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from pulmonary resections, patients with FEV_1/FVC ratios lower than 70% were also excluded from this study. Our institutional review board approved the study, and the patients included signed an informed consent form. Surgical and preoperative clinical data are presented in Table 1.

2.1. Tissue Doppler echocardiography technique

Echocardiographic studies were carried out using a Philips HP SONOS 5500 imaging system (Koninklijke Philips Electronics N.V., Eindhoven, the Netherlands). Subjects were examined in supine, left-lateral position. The standard pulsed Doppler tricuspid inflow velocities were recorded from the apical 4-chamber view with a sample volume introduced between the leaflet tips in the center of the flow stream. Early diastolic (E) and late diastolic (A) transtricuspid velocities were measured. Color TDI function was activated, and a digitized real time cineloop of a minimum of 5 cardiac cycles was obtained from an apical 4-chamber view. TDI sample volume was placed at the lateral tricuspid annulus, basal, and middle segment of the RV-free wall. The following specific longitudinal waveform velocities were measured in 5 consecutive cycles and averaged: systolic velocity (S'), early diastolic velocity (E'), and late diastolic velocities (A'). All color TDI calculations were performed by a highly experienced sonographer who was completely unaware of the clinical or previous echocardiographic parameters. The average of all measurements was calculated for each patient and employed for statistical analysis.

Table 1. Surgical and preoperative clinical data.

	n	%	Mean
Age (years)			59.15
Male	16	80	
Smoking	18	90	
Diabetes mellitus	3	15	
Hypertension	3	15	
Body mass index (kg/m^2)			24.12
FEV_1/FEV (%)			72.13
Surgical procedures			
Left pneumonectomy	3	15	
Right pneumonectomy	3	15	
Right superior bilobectomy	1	5	
Left upper lobectomy	5	25	
Left lower lobectomy	2	10	
Right upper lobectomy	5	25	
Right middle lobectomy	1	5	

FEV_1: forced expiratory volume in first second, FVC: forced vital capacity.

2.2. Statistical analysis

We carried out the statistical analysis with SPSS 11.5 (SPSS Inc., Chicago, IL, USA). We present the numerical values as mean ± standard deviation (SD) and categorical variables as percentages unless stated otherwise. Group comparisons were done with Mann–Whitney U test. Post hoc comparisons were evaluated by Wilcoxon test with Bonferroni adjustment. We considered $P < 0.05$ as statistically significant.

3. Results

There was no operative mortality. Doppler recordings of the tricuspid valve are presented in Table 2. Peak velocity of early diastolic filling (E wave) significantly decreased from the postoperative 2nd day to the 7th day ($P = 0.02$). On both the postoperative 2nd and 7th days, the peak velocity of late diastolic filling (A wave) values were significantly higher compared to preoperative values ($P = 0.02$ for both). There was no difference in other measurements. Table 3 summarizes the values of TDI measurements of the study population. Peak systolic velocity (S' wave) measured at the basal segment of the RV was observed to decrease significantly on the postoperative 2nd day ($P = 0.03$). No statistically significant differences regarding other parameters were noted in patients after resection.

The TDI measurements were also compared according to the extent (pneumonectomy versus lobectomy) and the side (right versus left) of the resection (Tables 4 and 5). On the postoperative 2nd day, the annular S' wave velocity of patients who underwent pneumonectomy was lower than in patients who underwent lobectomy (10.65 ± 2.4 cm/s versus 14.42 ± 3.3 cm/s; $P = 0.04$). Moreover, A' velocities measured at both tricuspid annular and right ventricular basal segments on the postoperative 2nd day were significantly lower in right-sided resections compared to left-sided ones (14.23 ± 3.3 and 12.67 ± 2.1 cm/s versus 20.20 ± 3.9 and 21.30 ± 4.2 cm/s; $P = 0.03$ and 0.008, respectively). The remaining measurements were not statistically different for both comparisons.

4. Discussion

Numerous studies have primarily assessed RV function after major lung surgery with techniques such as standard echocardiography and Doppler imaging (4,5,8,9). However, evaluation of RV function remains challenging because the RV has complex geometry, an asynchronous contraction pattern, and complex mechanical and physiologic interaction with the left ventricle (LV). These factors limit the validity of geometric assumptions required for functional analysis and, thus, limit the use of noninvasive imaging techniques for assessing RV function. Accordingly, RV function evaluation by echocardiography is considered quite difficult (10–12).

Table 2. Doppler recordings of the tricuspid valve.

Tricuspid velocities	Preop	Postop 2nd day	Postop 7th day	P-value
E (cm/s)	43.04 ± 8.5	45.93 ± 8.0	35.77 ± 7.4	<0.05*
A (cm/s)	45.71 ± 12.2	58.27 ± 9.6	58.94 ± 8.4	<0.05†

Data are given as means ± SD. E: peak velocity of early diastolic filling, A: peak velocity of late diastolic filling.
*: P < 0.05 for postop 2nd versus 7th day. †: P < 0.05 for preop versus postop 2nd and 7th days.

Table 3. Tissue Doppler imaging parameters.

TDI parameters (cm/s)	Preop	Postop 2nd day	Postop 7th day	P-value
Tricuspid annular				
E'	10.90 ± 2.4	10.37 ± 2.1	11.4 ± 2.8	NS
A'	16.86 ± 3.1	16.06 ± 2.9	16.45 ± 4.1	NS
S'	13.65 ± 2.1	13.26 ± 2.8	13.82 ± 2.4	NS
Ventricular basal				
E'	11.83 ± 2.2	10.40 ± 2.5	10.30 ± 1.9	NS
A'	15.22 ± 1.9	15.55 ± 2.7	16.27 ± 3.3	NS
S'	12.35 ± 2.2	10.15 ± 3.2	12.30 ± 2.8	<0.05*
Ventricular mid				
E'	9.58 ± 1.8	9.46 ± 2.0	9.40 ± 1.1	NS
A'	13.22 ± 4.9	13.77 ± 2.4	14.67 ± 3.2	NS
S'	10.29 ± 1.1	9.54 ± 2.6	10.08 ± 1.8	NS

Data are given as means ± SD. E': peak early diastolic velocity, A': peak late diastolic velocity, S': peak systolic velocity,
NS: not significant. *: P < 0.05 for preop versus postop 2nd day.

Table 4. Tricuspid annular S' wave values according to extent of resection.

TDI measurement on postop 2nd day (cm/s)	Pneumonectomy (n = 6)	Lobectomy (n = 14)	P-value
Tricuspid annular S'	10.65 ± 2.4	14.42 ± 3.3	0.04

Data are given as means ± SD. S': peak systolic velocity.

Table 5. A' wave values according to side of the resection.

TDI measurements on post-op 2nd day (cm/s)	Right-sided resection (n = 10)	Left-sidedresection (n = 10)	P value
Tricuspid annular A'	14.23 ± 3.3	20.20 ± 3.9	0.03
Ventricular basal A'	12.67 ± 2.1	21.30 ± 4.2	0.008

Data are given as means ± SD. A': peak late diastolic velocity.

TDI is a noninvasive echocardiographic technique that allows quantitative assessment of RV systolic and diastolic function through measurement of myocardial tissue velocities, quantification of intramyocardial velocities, and detection of consecutive phase shifts of the ultrasound signals reflected from the contracting myocardium. Thus, TDI is now being used for the measurable assessment of systolic and diastolic LV function and it provides regional information about the magnitude and timing of cardiac wall motion (13). TDI objectively assesses the regional RV function; however, more data are still needed to understand the clinical value of this technique (14). Here, we determined the role of TDI to quantitatively evaluate regional RV properties following major pulmonary resections. Diagnosis of RV dysfunction or failure by means of such a noninvasive technique is advantageous; by skipping alternative invasive methods, additional morbidities due to invasive diagnostic approaches are also prevented.

As far as we know there have not been any studies that assess RV systolic and diastolic functions by using TDI in patients undergoing pulmonary resection surgery. In our study, the E wave significantly decreased from the postoperative 2nd day to 7th day and the A wave increased at the postoperative 2nd day and remained high thereafter. Correspondingly, we presume that RV diastolic relaxation deteriorated on the postoperative 7th day in spite of right atrial compensation. The postoperative early decline and rapid increase of S’ wave recordings may indicate an early deterioration of RV systolic function due to an increase of after-load following pulmonary resection, since the RV is more sensitive to changes in after-load because of its small muscle mass and dependence on swift compensation by the Frank–Starling mechanism.

The extent of lung parenchyma resection is also critical in RV functions (4,8,15). Amar et al. found a small increase in pulmonary artery systolic pressure (PASP) by using standard echocardiography following pulmonary resections in their series. Additionally, pneumonectomy patients had significantly higher PASP than the lobectomy patients in their study (8). We also measured lower tricuspid annular S’ wave velocities in pneumonectomy patients than in lobectomy patients, which again proved the theory of higher after-load on the RV following larger resections. Furthermore, the observed significant differences in right-sided resections (lower A’ velocities measured at both tricuspid annular and right ventricular basal segments) might have been related to the varying extent of pulmonary vascular burden removed in each operation. Major lung parenchyma resection influences right heart function, which was supported by our study as well. On the contrary, Mlczoch et al. found that the extent of lung resection had no impact on PASP; instead, they proposed ischemic heart disease as the cause of pulmonary hypertension (16). We believe it would be more appropriate to further evaluate right heart function of patients for whom extended resection is considered preoperatively. The TDI method has a significant added value, especially in determining the status of right heart function in such patients in the postoperative period.

Our study has the following limitations: it is based on a small population whose characteristics were heterogeneous, and its duration was short. Studies with larger populations and with prolonged follow-up periods would provide more evidence regarding postsurgery ventricular systolic and diastolic changes.

Our results suggest that pulmonary resections can cause significant dilatation and dysfunction of the RV in the early postoperative period. However, systolic function was observed to ameliorate immediately within the first week by compensation. In addition, with a great extent of pulmonary vascular bed resection, more RV dysfunction occurs. This study also demonstrates that echocardiography incorporating the TDI method is useful in the analysis of the RV in patients who underwent pulmonary resection. Moreover, this technique could ease swift interventional therapy by helping to detect this deterioration at earlier stages. This may have a considerable impact on avoiding irreversible right heart failure. Nevertheless, this paper should be considered a limited, preliminary study that will hopefully lead to further studies detailing the outcomes of this approach by expanding the study population.

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