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ORIGINAL ARTICLE

The impact of pulmonary hypertension on morbidity and mortality following major lung resection†

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Abstract

OBJECTIVES: Pulmonary hypertension is considered a poor prognostic factor for or even a contraindication to major lung resection, but evidence for this claim is lacking. This study evaluates the impact of pulmonary hypertension on morbidity and mortality following pulmonary lobectomy.

METHODS: Adult patients who underwent a lobectomy for cancer and had a transthoracic echocardiogram (TTE) performed within the year prior to the operation were included. Pulmonary hypertension was defined as an estimated right ventricular systolic pressure (RVSP) of ≥36 mmHg by TTE. The preoperative characteristics, intraoperative data and postoperative outcomes of patients with and those without pulmonary hypertension based on TTE were compared. A model for morbidity including published risk factors as well as pulmonary hypertension was developed by multivariable logistic regression.

RESULTS: There were 279 patients without pulmonary hypertension and 19 patients with pulmonary hypertension. Patients with pulmonary hypertension had a lower preoperative forced expiratory volume in 1 s and diffusing capacity of the lung for carbon monoxide than patients without pulmonary hypertension and a higher incidence of tricuspid regurgitation and mitral regurgitation, but the groups were otherwise similar. The mean RVSP in the group of patients with pulmonary hypertension was 47 mmHg. Perioperative mortality (0.0 vs 2.9%; $P = 1.0$) and postoperative complications (57.9 vs 47.7%; $P = 0.48$) were not significantly different between patients with and those without pulmonary hypertension. The presence of pulmonary hypertension was not a predictor of adverse outcomes in either univariate or multivariate analysis.

CONCLUSIONS: Lobectomy may be performed safely in selected patients with pulmonary hypertension, with complication rates comparable with those experienced by patients without pulmonary hypertension.

Keywords: Pulmonary hypertension • Lobectomy • Lung cancer

INTRODUCTION

Although pulmonary hypertension has historically been considered a predictor of poor postoperative outcomes or even a contraindication to lung resection, there are little data supporting this belief. The presence of pulmonary hypertension (PHTN) has been shown to be a predictor of morbidity in select case series of patients undergoing pneumonectomy and lung biopsy to diagnose interstitial lung disease (ILD) [1, 2]. Case reports of patients with pulmonary hypertension developing bleeding complications following lung surgery have also been published [3]. However, a large-scale study of the effect of pulmonary hypertension on the general population of patients undergoing lung resection does not exist. Considering that a large percentage of patients undergoing lung resection have some degree of chronic obstructive pulmonary disease (COPD), which is associated with elevated pulmonary arterial pressures, the effect of pulmonary hypertension on outcomes following lung resection may be more significant than currently recognized [4]. This study aims to elucidate the relationship between pulmonary hypertension and outcomes for patients undergoing lobectomy for malignancy.

MATERIALS AND METHODS

This retrospective study was approved by the Institutional Review Board of Duke University Medical Center, including waiver of the need for informed consent. All patients older than 18 years ($n = 298$) who underwent pulmonary lobectomy or bilobectomy between January 1996 and December 2011 and also had a transthoracic echocardiogram (TTE) performed within 1 year prior to the operation were included in the study. The presence of significant pulmonary hypertension was defined as having an estimated right ventricular systolic pressure (RVSP) of greater than 35 mmHg

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on TTE. This criterion for pulmonary hypertension was based on guidelines published by the American Society of Echocardiography in 2010 [5]. If more than one TTE was performed during that time span, the results from the most recent study were used for analysis.

Review of an institutional prospective database documented demographics, significant comorbidities, use of induction therapy, smoking history, operative indication, intraoperative details and postoperative course. Chart review was used as necessary to complete data collection. Any postoperative event prolonging or otherwise altering the postoperative course was recorded along with all operative deaths, which were defined as deaths that occurred within 30 days of the operation or those that occurred later but during the same hospitalization. Deaths were captured both by means of chart review and by use of the Social Security Death Index Database. Overall morbidity was defined as the occurrence of at least one postoperative event.

Multivariable analysis was performed to assess whether pulmonary hypertension is an independent risk factor when other known risk factors for complications are considered. The number of risk factors to consider in the model was chosen after review of the number of outcome events. The risk factors chosen for analysis were those previously shown or considered to be associated with complications: age, operative approach (thoracoscopy vs thoracotomy), congestive heart failure, preoperative pulmonary function (percent predicted diffusing capacity of the lung for carbon monoxide [DLCO] and percent predicted forced expiratory volume in 1 s [FEV1]), previous thoracic surgery, diabetes, coronary artery disease, preoperative radiation and preoperative chemotherapy. The model was created using stepwise selection of the above variables with a *P*-value of 0.1 both for entry into and to stay in the model, with the outcome of interest (pulmonary hypertension) forced into inclusion in the model.

The results of this logistic regression analysis were also assessed with a sensitivity analysis in which only patients with potentially more severe pulmonary hypertension were included. In this analysis, only patients with an RVSP of ≥40 mmHg on TTE were classified as having pulmonary hypertension. The multivariable logistic regression analysis was reperformed as described above.

All data were summarized with descriptive statistics, including mean ± standard deviation (SD) for continuous measures and counts with percentages for categorical measures. Unpaired Student's *t*-tests were used to compare means for continuous data. Fisher's exact tests were used for dichotomous data when expected contingency table cells were <5, and χ^2 tests were used in all other cases of categorical variables. The Mann–Whitney *U*-test was used to compare median values. A two-tailed *P*-value of <0.05 was considered significant. The SAS 9.0 statistical package (SAS Institute, Inc.; Cary, NC, USA) was used for statistical analyses.

RESULTS

During the entire study period, 298 patients who underwent either lobectomy or bilobectomy also had a TTE performed within a year prior to the operation. Evidence of pulmonary hypertension with an estimated RVSP of > 35 mmHg by TTE was found in 19 patients, while 279 patients had no evidence of pulmonary hypertension. The baseline demographic characteristics, indications for procedure, comorbid conditions, operative approach and pulmonary function studies for these two groups of patients are given in Table 1. Patients with and those without pulmonary hypertension had similar preoperative and operative characteristics, except patients with pulmonary hypertension had lower preoperative FEV1 and DLCO and higher rates of chest wall resection compared with patients without pulmonary hypertension.

Echocardiographic data for the patients are given in Table 2. The mean RVSP (±SD) in the pulmonary hypertension group was 47 mmHg (±12 mmHg), while the mean RVSP (±SD) in the group of patients without pulmonary hypertension was 28 mmHg (±5 mmHg). Tricuspid regurgitation was more common in the pulmonary hypertension group, an expected finding given that RVSP is calculated from the velocity of the regurgitant jet through the tricuspid valve. Mitral regurgitation was also more common in the pulmonary hypertension group ($P < 0.001$). Left and right ventricular function on TTE was comparable between the two groups.

In terms of the intraoperative anaesthetic approach to these patients, a specific algorithm that called for more invasive haemodynamic monitoring or use of specific vasoactive medications was not utilized. Management was determined by the operating surgeon in conjunction with consultation with anaesthesia. Three of the 19 patients (15.7%) with pulmonary hypertension (PHTN) had a central line placed. Only 1 of the 19 patients (5.2%) had a pulmonary artery catheter placed; this was performed at the discretion of the anaesthesiologist because the patient had both moderate mitral stenosis and mild aortic stenosis along with elevated RVSP on preoperative TTE. Eighteen of the 19 patients (94.7%) patients were extubated in the operating theatre prior to transfer to the recovery room, and none was treated with inhaled nitric oxide, intravenous or oral phosphodiesterase inhibitors (e.g. milrinone and sildenafil) or intravenous or inhaled prostaglandins.

Postoperative outcomes are given in Table 3. Overall operative mortality was 2.7% (8 patients) and morbidity was 47.7% (144 patients). There were no perioperative deaths in the PHTN group undergoing lobectomy, compared with 2.9% ($n = 8$) of patients in the group without PHTN ($P = 1.0$). The most common postoperative events were atrial dysrhythmias, prolonged air leak, need for blood transfusion and need for postoperative bronchoscopy. In univariate analysis, overall morbidity was similar for patients with and those without pulmonary hypertension (57.9% [11 of 19] vs 47.7% [133 of 279], $P = 0.48$). The rate of blood transfusion was significantly higher in the PHTN group (31.5 vs 12.5%, $P = 0.032$). The rates of the remaining individual complications were similar between the two groups (Table 3). Median duration of chest tube drainage and median length of stay were also similar.

Univariate and multivariate analyses of the association between preoperative variables and post-lobectomy morbidity for our cohort of patients are given in Table 4. Increasing age, thoracotomy (vs thoracoscopy), decreasing DLCO and decreasing FEV1 were predictors of morbidity in univariate analysis ($P < 0.05$). Increasing age, thoracotomy (vs thoracoscopy) and congestive heart failure proved to be predictors of morbidity in multivariable analysis ($P < 0.05$). The presence of pulmonary hypertension was not a significant predictor of morbidity following lobectomy by either univariate or multivariate analysis.

Thirteen of the 19 pulmonary hypertension patients had an RVSP of ≥40 mmHg and were classified as having severe pulmonary hypertension in the sensitivity analysis. The results of the sensitivity analysis were consistent with the initial analysis. In this sensitivity analysis, age (odds ratio [OR] 1.08/year [1.04–1.11], $P < 0.0001$), approach (OR 2.82 [1.62–4.90], $P = 0.0002$) and congestive heart failure (OR 2.84 [1.01–8.00], $P = 0.048$) remained the only significant predictors or morbidity. There continued to be no significant association between morbidity and pulmonary hypertension (OR 2.61 [0.63–10.87], $P = 0.2$).

Table 1: Preoperative demographic and clinical characteristics

Characteristic	Patients without PHTN (*n* = 279)	Patients with PHTN (*n* = 19)	*P*-value
Age (mean ± SD)	69 ± 9	70 ± 12	0.56
Gender			
Male	174 (62.0%)	8 (42.0%)	0.092
Female	105 (38.0%)	11 (58.0%)	
Tobacco abuse	185 (66.3%)	14 (73.7%)	0.33
Hypertension	184 (65.9%)	13 (68.4%)	1.0
Coronary artery disease	85 (30.5%)	6 (31.6%)	1.0
Congestive heart failure	18 (6.5%)	3 (15.8%)	0.14
Chronic renal insufficiency	23 (8.2%)	2 (10.5%)	0.38
Diabetes	73 (26.2%)	2 (10.5%)	0.17
COPD	93 (33.3%)	9 (47.4%)	0.22
FEV1 (% predicted, mean ± SD)	70 +/− 18	59 +/− 23	0.015
DLCO (% predicted, mean ± SD)	75 +/− 19	57 +/− 15	<0.001
Cerebrovascular disease	37 (13.3%)	2 (10.5%)	1.0
Preoperative chemotherapy	35 (12.5%)	1 (5.3%)	0.49
Preoperative radiation	24 (8.6%)	1 (5.3%)	1.0
Operative approach			
VATS	174 (62.4%)	9 (47.4%)	0.22
Thoracotomy	104 (37.3%)	10 (52.6%)	
Median sternotomy	1 (0.4%)	0 (0%)	
Conversion[a]	6 (3.4%)	1 (10%)	0.34
Resection			
Lobectomy	261 (93.5%)	17 (89.5%)	0.13
Right upper	103 (39.5%)	6 (35.3%)	
Right middle	17 (6.5%)	3 (17.6%)	
Right lower	34 (13.0%)	2 (11.8%)	
Left upper	71 (27.2%)	3 (17.6%)	
Left lower	36 (13.8%)	3 (17.6%)	
Bilobectomy	18 (6.5%)	2 (10.5%)	
Indication for lobectomy			
NSCLC	264 (94.6%)	18 (94.7%)	0.075
Stage IA	71 (26.9%)	4 (22.2%)	
Stage IB	61 (23.1%)	2 (11.1%)	
Stage IIA	43 (16.3%)	4 (22.2%)	
Stage IIB	37 (14.0%)	7 (38.9%)	
Stage IIIA	45 (17.0%)	1 (5.6%)	
Stage IIIB	2 (0.8%)	0 (0%)	
Stage IV	5 (1.9%)	0 (0%)	
Mesothelioma	2 (0.7%)	0 (0%)	
Metastasis	12 (4.3%)	1 (5.3%)	
Lymphoma	1 (0.4%)	0 (0%)	
Additional procedures			
Chest wall resection	9 (3.2%)	3 (15.8%)	0.034
Bronchoplastic	22 (7.9%)	1 (5.3%)	1.0

COPD: chronic obstructive pulmonary disease; DLCO: diffusing capacity of the lung for carbon monoxide; FEV1: forced expiratory volume in 1 s; NSCLC: non-small-cell lung cancer; PHTN: pulmonary hypertension; VATS: video-assisted thoracoscopic surgery.
[a]Conversion refers to switching from a VATS approach to thoracotomy in the course of the operation.

DISCUSSION

Pulmonary hypertension has been demonstrated to be a risk factor for complications following a wide array of surgical procedures. Among cardiac surgical patients undergoing aortic valve replacement for aortic stenosis and mitral valve repair/replacement for mitral regurgitation, the presence of preoperative pulmonary hypertension has been associated with both increased perioperative mortality and decreased long-term survival [6, 7]. An elevated preoperative mean pulmonary artery (PAP) pressure of >30 mmHg was found to be a significant independent predictor for postoperative death in a study of over 2000 patients who underwent coronary artery bypass grafting [8]. Patients with pulmonary hypertension undergoing non-cardiac surgery have also been found to have higher perioperative morbidity and mortality, predominantly due to hypoxia and/or hypotension secondary to respiratory failure, congestive heart failure or cardiac dysrhythmia [9–15]. Unsurprisingly, patients with PHTN undergoing emergency or high-risk surgery were found to do especially poorly [10].

Ramakrishna *et al*. [9] state that patients with PHTN undergoing thoracic surgical procedures are at a higher risk of perioperative morbidity (>60%) compared with those undergoing gynecological, urological, dermatological, breast or plastic surgery (16.7%), but do not elaborate further regarding the types of thoracic surgical procedures evaluated or the nature of the complications. One study of patients with ILD undergoing video-assisted thoracoscopic surgery (VATS) lung biopsy demonstrated that out of 18 patients for whom echocardiographic or right heart catheterization data were available, the presence of a pulmonary artery systolic pressure (PASP) of >40 (*n* = 8) was associated with a 50%

Table 2: Echocardiographic characteristics

Characteristic	Patients without PHTN (n = 279)	Patients with PHTN (n = 19)	P-value
Estimated RVSP (mean ± SD)	28 mmHg ± 5	47 mmHg ± 12	
Left ventricular ejection fraction			
>55%	244 (87.5%)	15 (78.9%)	0.22
45–54%	14 (5.0%)	2 (10.5%)	
30–44%	17 (6.1%)	1 (5.3%)	
<30%	3 (1.1%)	1 (5.3%)	
Mitral regurgitation			
None/trivial	228 (81.7%)	13 (68.4%)	<0.001
Mild	31 (16.5%)	3 (15.8%)	
Moderate	4 (1.4%)	3 (15.8%)	
Severe	1 (0.4%)	0 (0%)	
Tricuspid regurgitation			
None/trivial	244 (87.5%)	6 (31.6%)	<0.001
Mild	31 (11.1%)	11 (57.9%)	
Moderate	4 (1.4%)	1 (5.3%)	
Severe	0 (0%)	2 (10.5%)	
Right ventricular dysfunction			
Yes	6 (2.2%)	2 (10.5%)	0.086
No	273 (97.8%)	17 (89.5%)	
Right ventricular enlargement			
Yes	6 (2.2%)	2 (10.5%)	0.086
No	273 (97.8%)	17 (89.5%)	

PHTN: pulmonary hypertension; RVSP: right ventricular systolic pressure.

Table 3: Postoperative outcomes

Characteristic	Patients without PHTN (n = 279)	Patients with PHTN (n = 19)	P value
Perioperative mortality	8 (2.9%)	0 (0%)	1.0
Perioperative morbidity	133 (47.7%)	11 (57.9%)	0.48
Median hospital stay (day)	5	5	0.15
Median chest tube duration (day)	3	4	0.45
Complications			
Overall	133 (47.7%)	11 (57.9%)	0.48
Prolonged air leak	38 (13.6%)	3 (15.8%)	0.73
Blood transfusion	35 (12.5%)	6 (31.5%)	0.032
Postoperative bronchoscopy	29 (10.4%)	3 (15.8%)	0.44
Pneumonia	13 (4.7%)	3 (15.8%)	0.073
Reintubation	8 (2.9%)	2 (10.5%)	0.13
Tracheostomy	3 (1.1%)	1 (5.3%)	0.23
Myocardial infarction	4 (1.4%)	0 (0%)	1.0
Atrial dysrhythmia	58 (20.8%)	6 (31.6%)	0.26
PE	1 (0.4%)	1 (5.3%)	0.12
DVT	0 (0%)	1 (5.3%)	0.064
Renal failure	6 (2.2%)	1 (5.3%)	0.37
Confusion	12 (4.3%)	1 (5.3%)	0.58
Need for enteral feeding tube	9 (3.2%)	1 (5.3%)	0.49
Empyema	1 (0.4%)	1 (5.3%)	0.12
Wound infection	1 (0.4%)	1 (5.3%)	0.12

DVT: deep venous thrombosis; PE: pulmonary embolus; PHTN: pulmonary hypertension.

morbidity rate, compared with 0% in those without (n = 10) [2]. Two of the 3 perioperative deaths in the study were in patients with PHTN, yielding a 25% mortality rate in the patients with PHTN (the third patient who died did not undergo haemodynamic assessment for PHTN). Hasegawa *et al*. [3] concluded that VATS lung biopsy should not be performed on patients with PHTN, in a case report examining the death of a 43-year old woman with a preoperative PAP of 65/30 on right heart catheterization (RHC). In spite of the absence of more compelling and specific data, pulmonary resection for malignancy in patients with PHTN has traditionally been considered a high-risk endeavour due to the increased risk of bleeding and other perioperative complications. Recently, evidence of a PASP of >40 mmHg was judged to represent PHTN by the ACOSOG Z4032 and Z4033 trials involving sublobar resection and radiofrequency ablation (RFA), respectively, and considered one of the criteria for classifying someone as a high-risk patient [16]. Furthermore, severe PHTN was one of the suggested criteria for judging a patient medically inoperable in the RTOG 0236 trial examining SBRT for stage I lung cancer; no specific echocardiographic or cardiac catheterization threshold was specified [17]. Quantitative data on which to base this cut-off is lacking.

Our data, however, suggest that lobectomy can be performed relatively safely in patients with echocardiographic criteria for PHTN, with a negligible mortality rate (0%, compared with 2.9% among patient without PHTN) and without increased risk of morbidity compared with patients without PTHN. Prior studies of non-cardiac surgery in patients with PHTN have identified respiratory failure and congestive heart failure as the predominant complications [9–12]. We observed similar overall and individual respiratory and cardiovascular complication rates between patients with and those without PHTN. One hypothetical risk involved in performing major lung resection in patients with PHTN would be an increased tendency for intraoperative bleeding due to higher pressures at vascular staple lines and thinner walled pulmonary vessels. The need for blood transfusion was found to be significantly higher in the group with PHTN in our study. The use of VATS approach and the conversion rate from VATS to thoracotomy, however, were similar between the PHTN and no PHTN groups.

Major limitations of our retrospective study include selection bias and generalizability. The patients that we categorized as having PHTN likely comprise a lower risk cohort than the population of patients carrying a pre-existing diagnosis of PHTN. These patients fulfill our echocardiographic criteria for PHTN, but would not necessarily be categorized as such based on right heart catheterization, the gold standard for diagnosis. Conversely, some patients with pulmonary hypertension on right heart catheterization would not be captured with echocardiographic criteria; the sensitivity of echocardiography for detecting PHTN has been estimated as 83–90% [18–20]. Patients with PHTN significant enough to result in a requirement for home oxygen or medical treatment with vasoactive medications are unlikely to be referred for pulmonary resection. Other studies have chosen stricter criteria for definition of PHTN; the mean RVSP for patients defined as having PHTN in our study was 47 mmHg (+/– 11 mmHg) compared with mean RVSP ranging from 49 to 79 mmHg in other studies using echocardiography to assess for PHTN [9–12]. The use of an RVSP of >35 mmHg, a fairly low parameter, as a threshold for inclusion in the PHTN group may have made our study less likely to identify differences in outcomes between the 2 populations. We had a rational basis for our cut-off, however,

Table 4: Multivariable logistic regression model of risk factors for morbidity

Variable	Univariate			Multivariate		
	Odds ratio	95% CI	*P*-value	Odds ratio	95% CI	*P*-value
Age (per 1-year increase)	1.05	1.02–1.08	<0.001	1.08	1.04–1.12	<0.001
Approach (VATS vs thoracotomy)	2.23	1.38–3.59	<0.001	2.81	1.62–4.87	<0.001
Congestive heart failure	1.81	0.73–4.50	0.2	2.90	1.03–8.13	0.04
% predicted DLCO (per 10-point decrease)	1.14	1.01–1.30	0.04	1.14	0.99–1.30	0.06
Pulmonary hypertension	1.51	0.59–3.86	0.39	1.03	0.35–3.00	0.9
% predicted FEV1 (per 10-point decrease)	1.16	1.02–1.32	0.02			
Preoperative chemotherapy	0.56	0.28–1.16	0.12			
Previous thoracic surgery	1.41	0.83–2.40	0.2			
Coronary artery disease	1.38	0.84–2.26	0.2			
Preoperative radiation	0.83	0.36–1.89	0.7			
Diabetes	0.98	0.58–1.66	0.9			

CI: confidence interval; DLCO: diffusing capacity of the lung for carbon monoxide; FEV1: forced expiratory volume in 1 s; VATS: video-assisted thoracoscopic surgery.

as we selected this value based on the American Society of Echocardiography's 2010 guidelines and the recent establishment of a PASP of > = 40 mmHg as indicative of a high-risk patient in the ACOSOG sublobar resection (Z4032) and RFA (Z4033) trials [5, 21]. It is notable that there were no perioperative deaths in the PHTN group, which included 6 patients with an RVSP of ≥ 50 mmHg. Still, we urge caution about applying the findings in our study to patients who are being actively treated for PHTN, as they likely represent a higher risk population.

In addition, a potential limitation of our statistical analysis is that some of the potential morbidity risk factors that were assumed to be independent could indeed have some degree of correlation, specifically pulmonary hypertension and a history of congestive heart failure as well as pulmonary function measurements. The small sample size of our study does not allow what is likely the ideal way to correct for this potential collinearity, that is by creating a large sample size with one or more of the potentially collinear variables relatively invariant. However, we did do additional analysis to evaluate the potential impact of collinearity by rerunning our morbidity models with all potentially collinear variables excluded. Age and approach continue to predict morbidity in this reduced model, while pulmonary hypertension remained insignificant, suggesting that the main results had not been skewed by correlation between these variables (data not shown).

Furthermore, echocardiography can be an unreliable modality in the evaluation of PHTN; estimates of PASP by TTE have been shown to differ by ≥10 mmHg compared with RHC in almost 50% of patients [21, 22]. In addition, because of the absence of RHC data on these patients, further investigation into the nature of PHTN was not possible; namely, we could not determine whether PHTN was caused by elevated pulmonary vascular resistance, elevated left-sided cardiac pressures or right heart dysfunction. Nonetheless, given the invasive nature of RHC and its infrequent use in preoperative evaluation of patients undergoing lung resection, TTE is the most realistic modality to evaluate the impact of PHTN on outcomes for lobectomy either on a prospective or on a retrospective basis.

In conclusion, we believe that pulmonary lobectomy may be performed with reasonable morbidity and a low mortality rate in patients with echocardiographic evidence of elevated RVSP suggesting pulmonary hypertension. In particular, our data clearly show that simply judging a patient to be medically inoperable simply based on echocardiographic evidence of pulmonary hypertension based on RVSP would inappropriately exclude patients from surgical resection. We do not believe that placement of a pulmonary artery catheter or use of vasoactive agents tailored to the treatment of PHTN is necessary, unless dictated by other aspects of the patient's medical condition. We should note, though, that the patients in our study had, at worst, mild right ventricular hypokinesis and enlargement, and none of them carried a pre-existing diagnosis of PHTN by RHC criteria. Therefore, we do urge caution to those considering lobectomy in patients with both elevated RVSP and moderately/severely hypokinetic or enlarged right ventricles or significant left ventricular dysfunction, and in patients being actively treated for PHTN. In these patients, non-operative management may be justified. If lobectomy is to be attempted, we would consider invasive cardiac monitoring with swan-ganz catheter and potential use of pulmonary vasodilators such as inhaled nitric oxide, phosphodiesterase inhibitors, dobutamine and prostaglandins to maintain stable haemodynamics during the perioperative period. Although classically considered inoperable, the likelihood of morbidity and mortality in this group of patients is currently unknown.

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APPENDIX. CONFERENCE DISCUSSION

***Dr A. Toker** (Istanbul, Turkey)*: Did you check the records of the intraoperative period? Did anaesthesiology take any preventive measures in these patients?

Dr Wei: I don't believe so. We reviewed the perioperative management of these patients. Out of the 19 patients with pulmonary hypertension, only one of them received a Swan-Ganz catheter. In this patient, the pulmonary arterial pressures were similar to the preoperative data obtained by the echocardiogram. None of the patients received inotropes, vasodilators, nitric oxide. So, no, they were not treated differently, at least according to what I found.

***Dr M. Lanuti** (Boston, MA, USA)*: This is a small series of 19 pulmonary hypertensive patients. I agree that you have a big selection bias here where patients with severe pulmonary hypertension and significant comorbidities were probably never offered an operation. So here is my question. Your conclusion is that you should offer pulmonary resection to people with pulmonary hypertension. The problem is that you don't address the severity of pulmonary hypertension: are you recommending surgery for patients with pulmonary systolic pressures of 60 mmHg versus 80 mmHg? Did you look in your 19 patients to identify a cutoff for acceptable PA pressure?

Dr Wei: Based on what we found, the patients with what some would consider severe pulmonary hypertension, when pressure is greater than 60 mmHg, were five in number, and those patients had no mortality and the morbidity was not higher. Now that said, I agree with your point that the patients who are diagnosed with pulmonary hypertension preoperatively are probably not going to get referred to us. I would say that if they have any evidence of echocardiographic abnormalities other than the elevated pressure, such as right ventricular dysfunction or enlargement, those patients should perhaps be a different subgroup, and this analysis really does not reflect those patients.

***Dr N. Novoa** (Salamanca, Spain)*: Taking into account that you have only 19 patients with pulmonary hypertension, I would like to know if you made an analysis looking at the different lobectomy procedures you did, because I wonder if it is different when the upper left lobe is removed compared to the middle lobe. Did you analyse this or find anything related to this point?

Dr Wie: Our numbers were fairly small to begin with, 19 patients, and in the different lobectomy categories we had maybe five upper lobectomies on the right and perhaps two to three in terms of the other lobes. I think that would be a very interesting question to answer; however, I don't think our numbers will allow us to see any differences between those groups.

***Dr G. Leschber** (Berlin, Germany)*: To my knowledge, the ejection fraction and the pulmonary pressure that is estimated just by doing a transoesophageal echocardiography is very dependent on who is doing this. So you are looking at a long time span of I think 14 years or so. Was it always the same person doing it? Can you really rely on values that were taken by many different people doing the examination?

Dr Wie: I agree that the measurement of right ventricular systolic pressure is problematic for the reason you mentioned, which is that it is operator-dependent, and also the fact that it doesn't reflect a true value for right heart pressures as seen in catheterization. We did not take into account the different operators, but it was the best available data we had.