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Comparative analysis of the gasometric and hemodynamic parameters in preoperative evaluation of patients with lung cancer

Whenever lung resection is planned, it is important to know the extent to which the diseased lung participates in the overall pulmonary function. This knowledge is essential in cases of lung cancer, since the bronchogenic malignancy is often accompanied by chronic bronchitis and emphysema. It is well known that lung function in these patients as a rule is decreased (1). Testing patients to predict complications after thoracotomy has been popular since the days of surgery for tuberculosis (3). Over 40 years later, we are still searching for the ideal test which, when performed before surgery, will identify those who will suffer complications after surgery. This search is important because lung cancer, a disease with virtually 100 percent mortality when untreated, is most commonly treated surgically (4).

Measurements including spirographic examination, arterial blood gas tensions, standard electrocardiogram are routinely used to define the risk factors for patients undergoing lung tissue resection.

In some instances routine functional check-ups should be accompanied by the assessment of the hemodynamics of pulmonary circulation. Disregarding the fact that the widely used Swan-Ganz technique of heart catheterization bears some risk of complications, such risk always exists. Moreover, making assessment and doing relevant measurements requires free space and is only possible with the use of specialized equipment, hardly available at every surgery department.

The purpose of the study was to evaluate the correlations between gasometric and hemodynamic parameters measured at rest and after exercise. In case of the presence of such correlations I wanted to find the principles to provide pulmonary artery hypertension in order to avoid right heart catheterization.

MATERIAL AND METHODS

The study population consisted of 50 consecutive male patients 21 to 72 years old (average of 55.8) with bronchial carcinoma, considered to be candidates for lung tissue resection in the Department of Cardiothoracic Surgery, Medical University in Lublin.

The hemodynamic examination of pulmonary circulation was performed using Swan--Ganz Monitoring Thermodilution Catheter Model 93-115-7F manufactured by Edwards Lab. Inc. California USA connected to the Statham P 23SD pressure transducer. Pressure was read using Simonsen and Weel system 8000 monitor. The catheter was entered into the pulmonary artery in local anaesthesia through the dissected free left basilic or external jugular vein or through right subclavian vein using the Seldinger's method. The catheter was introduced to the wedged position under constant pressure curve monitoring.

The systolic, diastolic and medium of central venous pressure (CVP), pulmonary artery pressure (PAP) and pulmonary capillary wedge pressure (PCWP) were measured in mmHg.

Gasometric examination was performed on all patients. There were measured PaO_2, $PaCO_2$, pH, SaO_2 (in systemic blood) and PvO_2, $PvCO_2$, pHv, SvO_2 (in mixed venous blood). Gasometric tests were performed using 168pH Blood Gas Analyser manufactured by Corning. Hemodynamic calculations were performed using Ergooxyscreen – Erich Jager pulmonary hemodynamic computer.

There were calculated: cardiac index (CI), pulmonary vascular resistance (PVR) and systemic vascular resistance (SVR). All measurements were taken at rest ("r") and after exercise test ("e") – 5 minutes, 50W workload on the Medicor type KE 11 cycle ergometer in supine position.

The results were subject to statistical analysis. The correlations between gasometric and hemodynamic parameters were studied. Spearman correlation coefficient and "r" correlation coefficient were calculated (11).

The nature of relation was described employing the regression analysis. Regression lines for indices were calculated checking whether the value of the coefficient of regression line significantly differs from zero. Confidence curves at the significance level 0.01 were also calculated.

RESULTS

GASOMETRIC EXAMINATION

In over 50 % of patients pH of arterial and mixed venous blood at rest was in normal range 7.35 – 7.45 (60% and 52% respectively). After the exercise, in all patients pH was decreased, the average arterial blood pH 7.44 ± 0.06 and mixed venous blood pH 7.42 ± 0.07 decreased to 7.42 ± 0.06 and 7.37 ± 0.07 respectively to normal range.

The values of partial oxygen pressure at arteral blood (PaO_2) at rest did not change after exercise while the partial oxygen pressure in mixed venues blood (PvO_2) decreased after exercise from average 36.74 ± 5.14 to 29.16 ± 4.06 mmHg

The partial pressure of carbon dioxide in systemic blood and in mixed venous blood after exercise ($PaCO_2$ and $PvCO_2$) increased from average 38.35 to 40.76 mmHg and from 44.6 to 52.31 mmHg respectively.

Oxygen saturation in systemic arterial blood measured at rest did not change after exercise, only oxygen saturation in mixed venous blood decreased from 70.45% (at rest) to 50.78 after exercise.

HEMODYNAMIC EXAMINATIONS

The average of mean pulmonary artery pressure was 19.5 mmHg (14 – 49 mmHg) at rest and 33.5 mmHg (18 – 59 mmHg) after exercise, 31 patients had normal mean pulmonary artery pressure (≤ 19 mmHg), in 4 patients the mean PAP was over 29 mmHg at rest. In 18 patients the mean PAP increased after exercise not more than 10 mmHg and in 6 patients mean PAP increased more than 20 mmHg.

The mean pulmonary capillary wedge pressure (PCWP) oscillated between 2 and 17 mmHg (average 5 mmHg) at rest and between 4 and 45 mmHg (average 11.6) after exercise. The mean of central venous pressure (CVP) oscillated between 1 and 8 mmHg (average 4.2 mmHg) at rest and between 3 and 17 mmHg (average 6.8 mmHg) after exercise. Average systemic vascular resistance (SVR) 16.7 u (9.1 u – 23.4 u) at rest de-

Table 1. Correlations between gasometric and hemodynamic parameters at rest "r" and after exercise "e"

	CVP^r	PAP^r	PAPe	$PCWP^r$	$PCWP^e$	CI^r	CI^e	SVR^r	PVR^r	PVR^r
PH^r	NS	p<0.01	NS	NS	NS	NS	NS	NS	NS	NS
PaO_2^r	p<0.01	NS	NS	NS	NS	NS	NS	NS	NS	NS
$PaCO_2^r$	p<0.001	NS	NS	NS	NS	NS	NS	NS	NS	NS
SaO_2^r	p<0.01	p<0.01	p<0.01	NS	p<0.01	NS	NS	NS	NS	NS
pH^e	NS	NS	NS	NS	NS	NS	NS	NS	NS	p<0.01
PaO_2^e	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
$PaCO_2^e$	p<0.01	p<0.001	p<0.01	NS	NS	p<0.01	NS	NS	NS	NS
SaO_2^e	p<0.001	p<0.001	p<0.001	p<0.01	p<0.001	NS	NS	NS	p<0.001	NS
pvH^r	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
PvO_2^r	NS	NS	NS	NS	NS	p<0.001	p<0.01	p<0.001	NS	NS
$PvCO_2^r$	NS	p<0.001	p<0.01	NS	NS	NS	NS	NS	NS	NS
SvO_2^r	NS	NS	NS	NS	NS	p<0.001	p<0.001	p<0.001	NS	NS
pvH^e	NS	p<0.01	p<0.01	NS	NS	NS	NS	NS	p<0.01	P<0.01
PvO_2^e	NS	NS	NS	NS	NS	NS	NS	p<0.01	NS	P<0.01
$PvCO_2^e$	P<0.01	p<0.001	p<0.001	NS	NS	NS	NS	NS	NS	P<0.01
SvO_2^e	NS	NS	NS	NS	NS	NS	NS	p<0.001	NS	P<0.001

creased to 12.4 u (7.9 u – 17.1 u) after exercise. Resting average pulmonary vascular resistance (PVR) did not change significance after exercise (2.3 u and 2 u respectively).

CORRELATION BETWEEN GASOMETRIC AND HEMODYNAMIC PARAMETERS

38 out of 160 examined correlations between gasometric and hemodynamic parameters turned out to be statistically significant (Table 1).

SYSTEMIC ARTERIAL BLOOD

In the study there were found statistical correlations between arterial blood oxygen pressure at rest (PaO_2^r) and CVP^r, PAP^r, CI^r and $RVSWI^r$ at rest ($p < 0.01$) which was not found after exercise. Carbon dioxide arterial blood partial pressure at rest ($PaCO_2^r$) correlated with statistical significance with CVP^r at rest ($p < 0.001$) and $PaCO_2^c$ (after

Table 2. Regression equations for calculating likely values of some hemodynamic parameters at rest on the basis of arterial blood gasometric parameters

	At rest	After exercise	
pH^r	y = - 35.269x + 282.06		PAP^r
PaO_2^r	y = - 0.228x + 36.07		PAP^r
SaO_2^r	y = - 0.6424x + 80.06	y = - 1.018x + 126.25	PAP^r
$PaCO_2^c$	y = 0.4535x + 0.86	y = 0.55x + 10.58	PAP^r
SaO_2^c	y = - 1.302x + 142.41	y = - 1.744x + 197.86	PAP^r
PaO_2^r	y = - 0.034x + 6.14		CI^r
$PaCO_2^c$	y = 0.048x + 1.71	y = 0.063x + 3.36	CI^r
pH^r	y = - 337.21x + 2682.68		PVR^r
pH^c		y = 3.472x + 140.24	PVR^r

exercise) with CVP^r, PAP^c, CI^r ($p < 0.1$) and with PAP^r ($p < 0.001$). SaO_2^r correlated with CVP^r , PAP^r , PAP^c , PWP^c ($p < 0.01$) and SaO_2^c correlated with CVP^r, $PAP^{r,c}$, PWP^c, PVR^r ($p < 0.001$).

MIXED VENOUS BLOOD

Statistical significance correlations were noted between pH^c and PAP^r , PAP^c ($p < 0.01$); PvO_2^r and CI^c ($p < 0.01$), CI^r , SVR^r ($p < 0.001$); PvO_2^c and SVR^r , PVR^c ($p < 0.01$); $PvCO_2^r$ and PAP^c ($p < 0.01$), PAP^r ($p < 0.001$); $PvCO_2^c$ and CVP^r , PVR^c (p <

0.01), PAP^r, PAP^c, PVR^r ($p < 0.001$); SvO_2^r and CI^c ($p < 0.01$), CI^r, SVR^r ($p < 0.001$); SvO_2^c and PVR^r ($p < 0.01$), SVR^r, PVR^c ($p < 0.001$)

On the ground of these correlations regression equations were calculated (Table 2).

DISCUSSION

There are several factors responsible for secondary hypertension in the pulmonary artery. The majority of authors (5, 10) maintain that vesicular hypoxia which causes immediate and slow reaction is the most important mechanism of secondary hypertension. The reaction, originally described by Von Euler and Liljesstrand, consists in the contraction of large precapillary vessels that pump blood to hypoventilated alveoli, which changes to relation between ventilation and perfusion (12).

A large number of insufficiently ventilated alveoli may cause hypertension in the pulmonary artery. A prolonged hypoxia of the pulmonary parenchyma can lead to anatomic changes such as the internal layer fibrosis and the growth of muscle fibers in pulmonary arterioles, which do not contain any muscle layer under normal conditions. The muscular coat of bigger arteries also increases, which causes the shrinking of the peripheral pulmonary placenta and reduces lung compliance. These changes lead to permanent pulmonary hypertension, which, at the later stage, results in the hypertrophy of the right ventricle of the heart.

The purpose of preoperative functional analysis of patients is to determine the type and degree of irregularities in the circulatory and respiratory systems and to identify patients with a high operation risk. The introduction of precise hemodynamic evaluation tests allows the extension of surgical treatment to patients diagnosed for lung cancer who suffer from respiratory disorder (2, 6). This is of particular importance given an increase in blood pressure in the pulmonary artery after removal of pulmonary tissue (8).

The monitoring of blood pressure in the pulmonary circulation system during the course of an operation revealed that the application of ligature of the pulmonary artery in patients aged over forty can cause permanent increasing blood pressure in the arterial trunk in approximately 50% of cases (9).

Some authors question the validity of hemodynamic tests in determining the mortality and irregularity risk after surgical procedures concerning removal of pulmonary tissue. They claim that the role of preoperation pulmonary hypertension in developing postoperation disorders is overrated (7). The fact is, that the postoperation problems can develop due to several factors including the age of the patient, retention of secretion in bronchial tubes, the shortering of breath, atelectasis, etc. Preoperation pulmonary artery hypertension is one of such risk factors. Cardiac insufficiency can also be caused by increased resistance of the pulmonary vessels, a decrease of blood pressure in the coronary system, and electrolyte disorders.

CONCLUSIONS

Cardiac catheterization remains the method of measurement against which all others have to be judged, but it is invasive and expensive to perform. This study proved statistically significant correlations between gasometric and hemodynamic parameters. These correlations made possible to calculate the regression lines equations, which help to predict pulmonary artery pressure before pulmonary tissue resection.

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SUMMARY

Measurements including spirographic examination, arterial blood gas tensions, standard electrocardiogram are routinely used to define risk factors for patients undergoing lung tissue resection. In some instances routine functional check-ups should be accompanied by the assessment of the hemodynamics of pulmonary circulation. The purpose of the study was to evaluate the correlations between gasometric and hemodynamic parameters measured at rest and after exercise. In case of the presence of such correlations I wanted to find the principles to provide pulmonary artery hypertension in order to avoid right heart catheterization.

The gasometric parameters in systemic and in mixed venous blood (pH, PaO_2, $PaCO_2$, SaO_2) as well as hemodynamic parameters of pulmonary circulation (PAP, PCWP, CVP) were measured in 50 male patients with lung carcinoma. All measurements were taken at rest and after an exercise test – 5 minutes, 50W workload on cycle ergometer in supine position. CI, PVR and SVR were calculated.

The study proved statistically significant correlations between gasometric and hemodynamic parameters and made possible to calculate the regression lines equations, which help to predict pulmonary artery pressure before tissue resection.

Przedoperacyjna ocena porównawcza parametrów gazometrycznych i hemodynamicznych u pacjentów z rakiem płuca

Badania spirograficzne, gazometryczne krwi tętniczej oraz elektrokardiograficzne są stosowane rutynowo u pacjentów kwalifikowanych do resekcji miąższu płucnego. U pacjentów z podwyższonym ryzykiem operacyjnym (zaawansowany wiek, współistniejące choroby układu krążeniowo-oddechowego, planowana rozległa resekcja) badania rutynowe należy rozszerzyć o scyntygrafię perfuzyjną płuc, a także o badanie hemodynamiczne krążenia płucnego. Celem badania była porównawcza ocena parametrów gazometrycznych i hemodynamicznych krążenia płucnego oraz próba wyliczenia równań prostych regresji na podstawie stwierdzonych współzależności.

Badaniami objęto 50 mężczyzn w wieku 21–72 roku życia z rakiem płuca kwalifikowanych wstępnie do wycięcia tkanki płucnej. U wszystkich pacjentów wykonano badanie gazometryczne, mierząc pH, prężność tlenu, prężność dwutlenku węgla, wysycenie tlenem krwi tętniczej oraz mieszanej krwi żylnej, a także badanie hemodynamiczne krążenia płucnego, mierząc PAP, PCWP, CVP. Pomiary wykonywano w spoczynku i po obciążeniu pięciominutowym wysiłkiem 50 W na ergometrze rowerowym w pozycji leżącej. W oparciu o te wyniki obliczono CI, SVR, PVR.

Uzyskane parametry poddano analizie statystycznej. Stwierdzono współzależności pomiędzy parametrami gazometrycznymi i hemodynamicznymi krążenia płucnego. Na ich podstawie wyliczono równania prostych regresji, pozwalające wyliczyć przybliżone wartości parametrów hemodynamicznych krążenia płucnego w oparciu o parametry gazometrii krwi tętniczej.