Virchows Arch [Pathol Anat] (1985) 407:249–257

Virchows Archiv A

Weights of the body and cardiac ventricles in pulmonary emphysema

Seppo Sutinen[1], **Paavo Pääkkö**[1], **and Juha Tienari**[2]

Departments of [1] Pathology and [2] Applied Mathematics and Statistics, University of Oulu, Kajaanintie 52 D, SF-90220 Oulu, Finnland

Summary. We analysed statistically the association of emphysema, determined on inflation fixed specimens, with the weights of the body and heart, and of the cardiac ventricles, weighed separately, in 170 male and 86 female adult autopsies. The cases were grouped according to the cause of death into cardiovascular, cancer and other deaths. In men the body weight was inversely proportional to the severity of emphysema, but no association existed between the body weight and the cause of death. In male cardiovascular deaths the total heart weight, total ventricular weight and the weight of the left ventricle with the septum were also inversely proportional to the severity of emphysema while this was not true in the other deaths. In male cardiovascular deaths a decrease, and in the other deaths an increase, of the weight of the free wall of the right ventricle was associated with an increasing severity of emphysema. In all male deaths, however, the left to right ratio decreased with an increasing severity of emphysema. Thus, pulmonary emphysema is associated both with a general atrophy, including the myocardium, and a mainly relative right ventricular hypertrophy. An absolute right ventricular hypertrophy, however, seems to accompany emphysema only in the absence of other major cardiovascular diseases.

Key words: Pulmonary emphysema – Body weight – Myocardial hypertrophy

Introduction

Chronic obstructive lung disease is frequently accompanied by weight loss (Mitchell and Filley 1964; Burrows et al. 1965), which seems to have serious effects on the prognosis of the patients (Vandenberg et al. 1967; Hunter et al. 1981; Openbrier et al. 1983). To our knowledge, however, there are

Offprint requests to: S. Sutinen at the above address

no postmortem studies correlating body weight with the severity of anatomical emphysema determined with adequate methods. Clinically, chronic obstructive lung disease is the most common cause of right ventricular enlargement due to hypoxic pulmonary hypertension (Ferrer 1975), and pathologically, right ventricular hypertrophy has often been observed in patients with emphysema (Kounz et al. 1936; Hasleton 1973). At autopsy right ventricular hypertrophy may be reliably demonstrated by weighing the free wall of the right ventricle (RV) and the left ventricle with the septum (LV + S) separately (Fulton et al. 1952). Several studies, however, which have been performed using adequate anatomical methods, have ended up with controversial results, for example with regard to the association between the muscular mass of the right ventricle and the degree of tissue destruction caused by emphysema (Hasleton 1973; Hicken et al. 1966a, b, Bignon et al. 1970), and the presence of hypertrophy or atrohy of the left ventricle (Hasleton 1973; Edwards 1974; Foraker et al. 1970).

The purpose of this study was to elucidate the relationship between emphysema and the weights of the body and cardiac ventricles in postmortem material.

Patients and methods

The material consisted of 170 male and 86 female adult hospital autopsies with an age range of men from 22 to 91 (mean 66.5) and of women from 33 to 84 (mean 70.5) years. Some patients were included because they had had clinical chronic airflow obstruction, but mostly the patients were unselected. At autopsy the weight of the body and the total weight of the heart were first obtained. Then the left ventricle with the septum (LV+S) and the free wall of the right ventricle (RV) were weighed separately and the ratio of LV+S to RV, the so-called left to right ratio, was calculated (Fulton et al. 1952). For the assessment of emphysema one lung of each patient was fixed intrabronchially with a solution containing formalin, polyethylene glycol and alcohol, dried with air insufflation, and sliced sagitally (Markarian 1975; Sutinen et al. 1979). The severity of emphysema was evaluated using a set of photographs of standard grades (Thurlbeck et al. 1970). Grades 5 to 40 were called mild to moderate, and grade 50 or more severe emphysema. Finally, the underlying cause of death was recorded from the patients death certificate. Statistical dependence was determined by the Student's *t*-test, the chi square test or by a two-way analysis of variance and linear regression using a Univac 1100/20 computer and BMDP computer programs (Dixon and Brown 1977).

Results

The distribution of the underlying causes of death according to the International Classification of Diseases (World Health Organization 1975), recorded on the patients' death certificates, in the series is shown in Table 1. The distribution emphysema, verified anatomically, is shown in Table 2. In women the number of patients exhibiting emphysema was insufficient for further statistical analysis. Table 3 shows the mean weights of the body, heart and cardiac ventricles, and the left to right ratios in men and women. All mean weights in men were highly significantly greater than the same weights in women.

Table 4 shows the association between emphysema and the underlying cause of death in men. In the group of cardiovascular deaths there was

Table 1. Underlying causes of death according to the International Classification of Diseases (World Health Organization 1977) in men and women

Causes of death	ICD code	No of patients		
		Men	Women	Total
Cardiovascular diseases	390–458			
Ischaemic heart diseases	410–414	64	24	88
Cerebrovascular disease	430–438	22	12	34
Others		19	10	29
Total		105	45	151
Malignant neoplasms	140–208			
Respiratory organs	160–165	9	3	12
Others		23	18	41
Total		32	21	53
Respiratory diseases	460–519			
Emphysema	492	8	0	8
Asthma	493	2	3	5
Others		6	4	10
Total		16	7	23
Other causes of death		17	12	29
Total		170	86	256

Table 2. Distribution of emphysema in men and women

Severity of emphysema	Number of patients		
	Men	Women	Total
None	79	70	149
Mild to Moderate	50	11	61
Severe	41	5	46
Total	170	86	256

Explanations: Grade of emphysema according to Thurlbeck et al. (1970): mild to moderate: 5–40, severe 50 or more

significantly less emphysema than in the other deaths. The mean weights of the body, heart and the mean left to right ratios in groups of men with different underlying causes of death are shown in Table 5. The group of cardiovascular deaths differed significantly from the others regarding the total heart weight, total ventricular weight, weight of the left ventricle with septum and the left to right ratio.

The weights of the body and cardiac ventricles as well as the left to right ratio were compared by means of two-way analyses of variance both with the severity of emphysema (SE) and the underlying cause of death (CD). According to them the body weight was associated with SE ($F=5.91$, $p=0.003$) but not with CD. The total heart weight and total ventricular

Table 3. Mean weights of the body, heart and cardiac ventricles and left to right ratios according to Fulton et al. (1970) in men and women

Item	Men ($n=170$)		Women ($n=86$)	
	Mean	SD	Mean	SD
Weight of				
Body (kg)	66.1	14.8	59.1	14.3
Heart (g)	476.4	127.3	429.0	119.3
Both ventricles (g)	283.5	89.3	232.1	70.9
LV+S (g)	219.6	72.8	182.7	59.7
RV (g)	63.9	23.3	49.9	19.8
Left to right ratio	3.59	1.01	3.87	1.20

Explanations: LV+S=left ventricle with septum, RV=free wall of right ventricle, Left to right ratio=(LV+S):RV

Table 4. Association between emhysema and underlying cause of death in men

Underlying cause of death	Severity of emphysema			
	Mild to			Total
	None	Moderate	Severe	
	n	*n*	*n*	*n*
Cardiovascular	57	33	15	105
Cancer	10	13	9	32
Other	12	4	17	33
Total	79	50	41	170

Chi square=23.26, $p<0.0005$;
Explanations: see Table 2

weight were associated with CD ($F=9.82$, $p=0.0001$ and $F=9.94$, $p=0.0001$, respectively) but not with SE. The weight of the left ventricle with septum was associated more significantly with CD ($F=12.51$, $p=0.0000$) than with SE ($F=3.9$, $p=0.02$). The weight of the free wall of the right ventricle was not associated with CD or SE. The left to right ratio was associated both with SE ($F=4.55$, $p=0.012$) and CD ($F=4.42$, $p=0.014$).

Figure 1 illustrates the results of linear regression analyses correlating the weights of the body, heart and cardiac ventricles and the left to right ratio with the grade of emphysema performed separately on the group of male cardiovascular deaths and on that of the other male deaths. In both groups (Fig. 1 A) the body weight showed a highly significant negative correlation with the grade of emphysema ($r=-0.38$, $p<0.0005$ and $r=-0.33$, $p<0.005$, respectively). In the group of cardiovascular deaths the total heart weight, total ventricular weight and the weight of the left ventricle with the septum (Fig. 1 B–D) had also a highly significant negative correlation with the grade of emphysema ($r=-0.25$, $p<0.005$, $r=-0.28$, $p<0.0005$ and $r=-0.30$, $p<0.0025$, respectively), while this was not observed in the group of other deaths. The weight of the free wall of the right ventricle

Table 5. Mean weights of the body, heart and cardiac ventricles and mean left to right ratios according to Fulton et al. (1952) in men with different causes of death

Item	Underlying cause of death		
	Cardio-vascular ($n=105$)	Cancer ($n=32$)	Other ($n=33$)
Weight of			
Body (kg)	68.3	60.6	64.2
Heart (g)	513.9	390.0	440.9
Both ventricles (g)	309.6	220.1	261.9
LV+S (g)	243.6	165.6	195.6
RV (g)	66.1	54.6	66.3
Left to right ratio	3.84	3.20	3.21

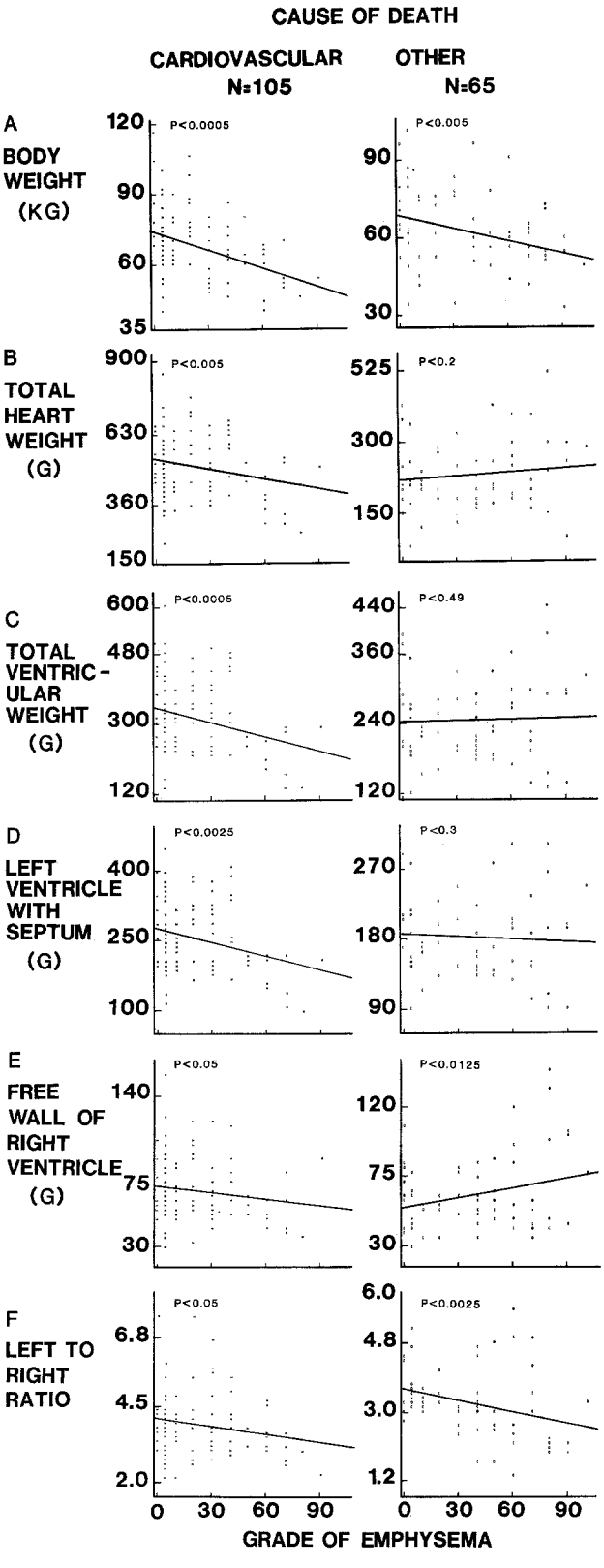
Explanations: see Table 3

(Fig. 1 E) showed a weak but significant negative correlation with the grade of emphysema in the group of cardiovascular deaths ($r=-0.17$, $p>0.05$) while a more significant positive correlation between the same variables was observed in the group of other deaths ($r=0.28$, $p<0.0125$). The left to right ratio (Fig. 1 F) had a negative correlation with the grade of emphysema in both groups being weak but significant in the group of cardiovascular deaths and fairly strong and highly significnt in the group of other deaths ($r=-0.17$, $p<0.05$ and $r=-0.35$, $p<0.0025$, respectively).

Discussion

The occurrence of a marked weight loss during the terminal stages of chronic obstructive lung disease and emphysema has been documented in many clinical studies (Mitchell and Filley 1964; Burrows et al. 1965; Vandenberg et al. 1967; Hunter et al. 1981; Openbrier et al. 1983; Nemery et al. 1983). The patients with severe obstructive lung disease are known to suffer from protein calorie type of malnutrition, which is not due to reduced intake of food, and they often have various immunological deficiencies (Hunter et al. 1981). In the men of the present series an association was found between the body weight and the grade of anatomic emphysema but not between the body weight and the underlying cause of death. Thus, alveolar tissue destruction with deleterious effects on respiratory function might be one of the most important factors leading to generalized atrophy and even to cachexia in these patients.

Significant differences in the weights of the heart and its ventricles between the sexes have been observed previously (Berblinger 1947; Reiner et al. 1959; Lehti 1971; Lamb 1973). In the present series, too, all mean weights in men were significantly higher than in women. In fact, the differences between the sexes completely obscured the differences associated with emphysema when the statistical analyses were performed on the total material. However, in some published studies on the limits of the normal weights of the cardiac ventricles (Fulton et al. 1952; Bove et al. 1966) as well as on the correlation of ventricuar weights with pulmonary emphysema (Hasle-


CAUSE OF DEATH
CARDIOVASCULAR
N=105
OTHER
N=65
A
BODY WEIGHT (KG)
120
90
60
35
P<0.0005
90
60
30
P<0.005
B
TOTAL HEART WEIGHT (G)
900
630
360
150
P<0.005
525
300
150
P<0.2
C
TOTAL VENTRIC-ULAR WEIGHT (G)
600
480
300
120
P<0.0005
440
360
240
120
P<0.49
D
LEFT VENTRICLE WITH SEPTUM (G)
400
250
100
P<0.0025
270
180
90
P<0.3
E
FREE WALL OF RIGHT VENTRICLE (G)
140
75
30
P<0.05
120
75
30
P<0.0125
F
LEFT TO RIGHT RATIO
6.8
4.5
2.0
P<0.05
6.0
4.8
3.0
1.2
P<0.0025
0 30 60 90
0 30 60 90
GRADE OF EMPHYSEMA

ton 1973; Hicken et al. 1966a; Edwards 1974) men and women have not been dealt with separately. The bias caused by the sex factor might well explain some of the controversial results.

In an extensive postmortem study of normal weights of human organs based on cases of death from external causes the mean heart weight of Finnish men aged 15–69 years was 371 g (SD = 53 g) (Lehti 1971). As might have been expected, the mean total heart weight of male cardiovascular deaths in our series differed by more than two standard deviations from the normal while that of the others did not. It thus seems justified to analyse the correlation of emphysema with heart weights separately in the group of male cardiovascular deaths and in that of the other deaths.

An association between pulmonary emphysema and right ventricular hypertrophy has been observed by several authors (Bignon et al. 1970; Foraker et al. 1970; Hasleton 1973; Mitchell et al. 1976), although some authors have failed to show any association between the anatomical extent of tissue destruction and the weight of the right ventricle (Hicken et al. 1966a; 1966b). From the two-way analysis of variance in our series no association between the severity of emphysema and the absolute weight of the right ventricle could be elicited in either sex. When, however, the group of male cardiovascular deaths was separated from the other male deaths a striking result was obtained in linear regression analysis. In the former group a significant decrease of the weight of the free wall of the right ventricle was associated with an increasing severity of emhysema, while in the latter group an even more significant increase in the same weight was associated with an increasing severity of emphysema. In both groups, however, the left to right ratio decreased significantly with increasing severity of emphysema. This means that emphysema seems to be associated with right ventricular hypertrophy which, however, in patients with other major cardiovascular diseases is generally relative.

According to Fulton et al. (1952) right ventricular hypertrophy is present if the absolute weight of the free wall of the right ventricle is more than 80 g and/or the left to right ratio is less than 2 (Lamb 1973). In our series, however, a relative and possibly even absolute right ventricular hypertrophy could not have been diagnosed on the basis of Fulton's criteria. We agree with Thurlbeck according to whom a right ventricular mass of more than 60 g would be most unusual in the absence of cardiac or pulmonary disease (Thurlbeck 1976). In addition, even lesser degrees of a right sided preponderance might be significant. It is evident that new studies, based on sufficient material in both sexes, are needed on the normal limits of the weights of the cardiac ventricles.

Fig. 1A–F. Correlation between the severity of emphysema and body weight (**A**), total heart weight (**B**), total ventricular weight (**C**), weight of left ventricle with septum (**D**) weight of free wall of right ventricle (**E**), and left to right ratio (**F**) in male hospital autopsies. The left scattergram shows the relation in cardiovascular deaths and the right in the other deaths. Grade of emphysema according to Thurlebeck et al. (1970) and weights of cardiac ventricles and left to right ratio according to Fulton et al. (1952). The vertical scales in the pairs are not uniform because the scattergrams have been photographed directly from computer output

Left ventricular hypertrophy has also been associated with pulmonary emphysema (Edwards 1974) and certainly occurs in a large proportion of patients with the disease (Thurlbeck 1976). In the present series, too, many patients with pulmonary emphysema had hypertrophic left ventricles. But we could not find a statistical association with emphysema and left ventricular hypertrophy. According to Murphy et al. (1974) left ventricular hypertrophy in patients with chronic bronchitis and emphysema results mostly from associated disease states.

On the other hand, Burrows et al. (1966) observed that the total weight of the heart is inversely related to the severity of emphysema, and Foraker et al. (1970) concluded that severe emphysema is accompanied by an atrohy of the left ventricle. In male cardiovascular deaths in our series a decrease in the weight of the left ventricle with the septum was associated with an increasing severity of emphysema. A similar association was also observed in the total ventricular and heart weights on one hand and emphysema on the other. However, no association of the weight of the left ventricle with the septum, total ventricular weight nor total heart weight with the grade of emphysema was observed in men dying of other causes. Evidently, emphysema may cause a reduction in the muscular mass of a hypertrophic but not of a normal heart.

Acknowledgements. Mr. Tapio Leinonen is acknowledged for technical assistance and Mrs. Liisa Kärki for preparation of illustrations. This study has been supported by grants from the Sigrid Juselius Foundation, the Finnish Anti-Tuberculosis Association and the Finnish Foundation for Cardiovascular Reasearch, Helsinki, Finland.

References

Berblinger W (1947) Formen und Ursachen der Herzhypertrophie bei Lungentuberkulose. Hans Huber, Bern

Bignon J, Andre-Bougaran J, Brouet G (1970) Parenchymal, bronchiolar, and bronchial measurements in centrilobular emphysema: Relation to weight of right ventricle. Thorax 25:556–567

Bove KE, Rowlands DT, Scott RC (1966) Observations on the assessment of cardiac hypertrophy utilizing a chamber partition technique. Circulation 33:558–568

Burrows B, Fletcher CM, Heard BE, Jones NL, Wootliff JS (1966) The emphysematous and bronchial types of chronic airways obstruction. A clinicopathological study of patients in London and Chicago. Lancet I:830–835

Burrows BA, Niden AH, Barclay WR, Kasik JE (1965) Chronic obstructive lung disease: II Relationship of clinical and physiologic findings to the severity of airways obstruction. Am Rev Respir Dis 91:665–678

Dixon WJ, Brown MB eds (1977) BMDP-77: Biomedical computer programs P-series. University of California Press, Berkeley, Los Angeles, London

Edwards CW (1974) Left ventricular hypertrophy in emphysema. Thorax 29:75–80

Ferrer MI (1975) Cor pulmonale (pulmonary heart disease): present-day status. Am Heart J 89:657–664

Foraker AG, Bedrossian WM, Anderson AE Jr (1970) Myocardial dimensions and proportions in pulmonary emphysema. Arch Pathol 90:344–347

Fulton RM, Hutchinson EC, Jones M (1952) Ventricular weight in cardiac hypertrophy. Br Heart J 14:413–420

Hasleton PS (1973) Right ventricular hypertrophy in emphysema. J Pathol 110:27–36

Hicken P, Brewer D, Heath D (1966a) The relation between the weight of the right ventricle

of the heart and the internal surface area and number of alveoli in the human lung in emphysema. J Pathol Bact 92:529–546
Hicken P, Heath D, Brewer D (1966b) The relation between the weight of the right ventricle and the percentage of abnormal air space in the lung in emphysema. J Pathol Bact 92:519–528
Hunter AMB, Carey MA, Larsh HW (1981) The nutritional status of patients with chronic obstructive pulmonary disease. Am Rev Respir Dis 124:376–381
Kounz WB, Alexander HL, Prinzmetal M (1936) The heart in emphysema. Am Heart J 11:163–172
Lamb D (1973) Heart weight and assessment of ventricular hypertrophy. In: Dyke SD et al., eds, Recent Advances in Clinical Pathology, Series 6. Churchill Livingstone, Edinburg, London, pp 133–148
Lehti H (1971) Normal weights of human organs. A postmortem study on cases of death from external causes. Helsinki
Markarian B (1975) A simple method of inflation-fixation and air drying of lungs. Am J Clin Pathol 63:20–24
Mitchell RS, Filley GF (1964) Chronic obstructive bronchopulmonary disease: Clinical features. Am Rev Respir Dis 89:360–371
Mitchell RS, Stanford RE, Silvers GW, Dart G (1976) The right ventricle in chronic airway obstruction: A clinicopathologic study. Am Rev Respir Dis 114:147–154
Murphy ML, Adamson J, Hutcheson F (1974) Left ventricular hypertrophy in patients with chronic bronchitis and emphysema. Ann Int Med 81:307–313
Nemery B, Moavero NE, Brasseur L, Stanescu DC (1983) Smoking, lung function, and body weight. Br Med J 286:249–251
Openbrier DR, Irwin MM, Rogers RM et al. (1983) Nutritional status and lung function in patients with emphysema and chronic bronchitis. Chest 83:17–22
Reiner L, Mazzoleni A, Rodriquez FL, Fredenthal RR (1959) The weight of the human heart. Arch Pathol 68:58–73
Sutinen S, Pääkkö P, Lahti R (1979) Post-mortem inflation, radiography, and fixation of human lungs: A method for radiological and pathological correlations and morphometric studies. Scand J Respir Dis 60:29–35
Thurlbeck WM, Dunnill MS, Hartung W, Heard BE, Heppleston AG, Ryder RC (1970) A comparison of three methods of measuring emphysema. Hum Pathol 1:215–226
Thurlbeck WM (1976) Chronic airflow obstruction in lung disease. Volume V in: Dennington JL, ed, Major problems in pathology. WB Saunders Company, Philadelphia, London, Toronto
Vandenberg E, van de Woestijine KP, Gyselen A (1967) Weight changes in the terminal stages of chronic obstructive pulmonary disease: Relation to respiratory function and prognosis. Am Rev Respir Dis 95:556–566
World Health Organization (1977) International classification of diseases. 1975 revision. Vol 1. Geneva

Accepted May 10, 1985