THE ÆTIOLOGY OF LUNG INFARCTION

BY

THOMAS H. BELT

From the British Postgraduate Medical School, London

Received June 8, 1939

The purpose of this communication is to try to show that the common hæmorrhagic infarct of the lung is usually an embolic rather than an autochthonous phenomenon. This is by no means a new idea; as will be evident enough from Ceelen's (1931) exhaustive review of the subject. But the alternative view, which supposes the pulmonary arteries to be a common site of autochthonous thrombosis, is still widely prevalent.

This report is concerned with a series of 1990 consecutive autopsies in which special attention has been given to dissection of the pulmonary arteries. These autopsies, as a series, may be regarded as fairly representative of general hospital cases. More than half of them were performed in the Department of Pathology at the University of Toronto from 1931 to 1936, and the rest at this School from 1937 to 1939.

There were in this series 155 cases presenting gross hæmorrhagic infarction of the lung. This was exclusive of septic infarction, for here we were concerned only with the bland, non-infective type of lesion. According to our interpretation of the autopsy findings no less than 136 of these were due to embolism, 10 only were due to thrombosis, and in 9 no definite arterial occlusion was found.

IDENTIFICATION OF EMBOLI

It is not always easy to distinguish between thrombus and embolus, but there are criteria that make it possible in most instances. The identification of an embolus may rest upon some of the following features: it may be loose-lying, coiled, jumbled, twisted, impacted (Fig. 1), or riding a bifurcation; it may have a branching conformity that does not correspond with that of the vessel in which it lies, or it may have freshly broken ends. More important perhaps than its shape and location is the quality of the clot. The type of embolus with which we are concerned is usually a red clot composed chiefly of fibrin and red blood cells. Because it takes origin in slowly moving or stagnant venous streams, it is not unlike the clot that freshly drawn blood will form on standing in a test tube. On the other hand, thrombus that takes origin in the pul-

monary arteries is usually white or light pink, and composed chiefly of platelets and white cells, because it is laid down in a faster moving stream. It is always attached more or less securely to the vessel wall. It usually has a sessile base with gently shelving margins, and it is moulded to the shape of the vessel in

FIG. 1.—Embolus in a tertiary branch of the pulmonary artery. It looked like an autochthonous thrombus until it was hemisected, as seen here, when its jumbled and distorted laminations became apparent and also the fact that it was lodged at the mouth of a smaller branch. (Museum specimen, 24.25.1, B.P.M.S.)

which it lies. If one can find in the peripheral veins a potential source for the embolism, the problem is often facilitated ; for the embolus will then resemble the parent clot.

Difficulty may be encountered when both embolus and thrombus are present together, but this only happens in a minority of cases. More than half of the emboli in this series occurred alone, about one-third were accompanied by small amounts of autochthonous thrombus, and only a few, perhaps less than five per cent., were sufficiently obscured by superadded thrombus to render their identification difficult. In such doubtful cases we have usually put it down as thrombosis.

In order to make the distinction between thrombus and embolus it is obvious that one must have a satisfactory exposure of the whole clot. To accomplish this requires a technique of dissection that will permit of opening the second, third, and even fourth divisions of the pulmonary arteries without

too much mutilation of the lungs. We have found it relatively easy to adopt such a technique (Belt, 1936) as a routine procedure.

HÆMORRHAGIC INFARCTION OF THE LUNG

The following table indicates the nature of the 155 cases in which infarcts were found.

TABLE I
ANALYSIS OF HÆMORRHAGIC INFARCTION OF LUNG

Certifiable Cause of Death	Cause of Infarction			
	Embolism	Thrombosis	Unknown	Total
Heart disease	70	3	1	74
Pulmonary embolism	22	—	—	22
Malignant neoplasm	17	2	2	21
Pulmonary tuberculosis	8	1	—	9
Cerebral softening	8	1	2	11
Various	11	3	4	18
Total number of cases	136	10	9	155

CASES WITH EMBOLIC INFARCTS

Pulmonary embolism was regarded as the main cause of death for purposes of certification in 22 cases, and as a contributory cause in 77; the remaining 37 of the 136 cases were examples of minor embolism, some of them showing only a single infarct.

Of all the pulmonary emboli encountered in this series of 1990 autopsies, not more than half were associated with infarction; that is to say, there were about twice as many cases of embolism as of infarction. Since Virchow's time it has been well known that occlusion of a pulmonary artery is in itself insufficient to produce an infarct. There must be added factors, and it cannot be said that we know precisely what these are; nor does it lie within the scope of this paper to define them. Certain it is, however, that heart disease outshadows all other conditions as a concomitant of lung infarction. The theoretical explanation is that any lesion retarding the normal flow of blood through the left auricle produces increased pressure in the pulmonary veins, and this may lead to complete stasis and necrosis (hæmorrhagic infarct) in the event of an arterial occlusion.

In this series of 1990 autopsies there were 235 deaths registerable as from heart disease. The majority of them had congestive failure. Almost a third (70 cases) died with embolic infarcts of the lungs. Table II gives a survey of these.

There were 27 cases of rheumatic disease, 24 with mitral stenosis; with an average age of 39 years. An equal number had coronary disease, 21 with

coronary occlusion (old or recent) and 16 with angina pectoris ; their average age was 63 years. The remaining 16 were miscellaneous cardiopathies, with an average age of 54 years.

The second largest group in Table I consists of 22 cases of sudden death from pulmonary embolism. Twelve were recovering from operations (9 laparotomies and 3 prostatectomies), 7 from fractures (5 of the femur, 1 of the pelvis, and 1 of the ribs), and 3 were medical cases in which the embolism arose more or less *de novo*.

TABLE II
SEVENTY CASES OF HEART DISEASE WITH EMBOLIC INFARCTS

Certifiable Cause of Death	Number of Cases				
	Total	With Congestive Failure	With Major Embolism *	Clinical State	
				Bed-ridden	Ambulatory
Rheumatic heart disease	27	25	21	20	7
Coronary disease	27	18	18	19	8
Other cardiopathies ..	16	9	8	12	4
Total	70	52	47	51	19

* Pulmonary embolism severe enough to be entered on the death certificate as a contributory cause of death.

The interval between operation and death varied from three to seventeen days and averaged eleven days. In the fracture cases the interval averaged twenty-two days. Infarction of the lung is not uncommon in deaths from pulmonary embolism after operation or after trauma, and indicates, as a rule, that smaller emboli have preceded the fatal seizure by hours or days.

It was possible to find the *apparent source of the emboli* in 116 cases. Usually it was a thrombus in the veins of the pelvis or thigh. The actual figures, as shown in Table III, were: pelvic veins 52, leg veins 42, right heart 16, veins of upper extremity (including subclavian) 6.

In the pelvis the commonest sites were the peri-prostatic, the uterine, and the internal iliac vein ; in the thigh, the femoral and saphenous veins.

Seldom was the venous thrombosis accompanied by obvious phlebitis and this, of course, is a factor which tended to obscure the clinical recognition of embolism in many of our cases. Perhaps the commonest and most distinctive symptom recorded in the histories of these cases was the coughing up of blood, either as rusty sputum or as frank hæmoptysis. In addition, pleural pain and pleural rubs were frequently observed. Under such circumstances the infarction was commonly mistaken for pneumonia with pleurisy. Another common

symptom was a sudden attack of breathlessness, accompanied by cyanosis, anxiety, and sweating; and this was often put down to a sudden change for the worse in the function of the heart rather than to embolism.

TABLE III
APPARENT SOURCE OF EMBOLI

Certifiable Cause of Death	Thrombus in				
	Pelvic Veins	Leg Veins	Arm Veins	Right Heart	All Sites
Rheumatic heart disease	7	6	5	5	23
Coronary disease	11	8	—	5	24
Other cardiopathies	6	5	1	4	16
Pulmonary embolism	8	10	—	—	18
Malignant neoplasm	10	5	—	—	15
Pulmonary tuberculosis	1	3	—	2	6
Cerebral softening	4	3	—	—	7
Miscellaneous	5	2	—	—	7
All Causes	52	42	6	16	116

PRIMARY PULMONARY THROMBOSIS

The ten cases of pulmonary thrombosis were of miscellaneous origin and scarcely permit of generalizations. In two instances there was tumour invasion of the vessel wall and in a third an arteritis due to tuberculous disease of the lung. Three others had small thromboses as a concomitant of severe toxæmia. In the remaining four the thrombosis was probably attributable to antecedent embolism.

Endarteritis of the pulmonary arteries has often been cited as a cause of pulmonary thrombosis, but in my experience this is rare. What may sometimes be mistaken for endarteritis is an involutional change in a vessel wall beyond a point of embolic occlusion. It is something like the change that occurs in the umbilical artery after birth. The intima proliferates to a considerable thickness (Fig. 2) and might well be taken for endarteritic change, if one did not know the vessel had been rendered defunct by an embolus lying proximal to the point where the section was taken.

DISCUSSION

Virchow (1856) introduced the term embolus and first described the phenomenon of thrombo-embolism; he said that ante-mortem clots in the

FIG. 2.—Intimal thickening in a pulmonary artery, distal to the point of embolic occlusion. This change, which is involutinal, may be mistaken for endarteritis. Magnification, $\times 30$. (Museum specimen, 152.25.2, B.P.M.S.)

pulmonary arteries were, in his experience, practically always embolic, and that their occurrence was an almost sure indication of older thrombus somewhere in the venous circulation. Others who have carried out large scale investigations on autopsy material have reached a similar conclusion (Lubarsch, 1905; Møller, 1922). Ribbert (1902) seems to have been the chief protagonist of the alternative view. His grounds for dissent seem somewhat obscure, but he denied the importance that Virchow attached to embolism and held the majority of pulmonary clots to be formed *in situ*. Ribbert's teaching became firmly established in the minds of many of his followers and to this day it is not easily shaken. My former chief, the late Professor Oskar Klotz, was one of Ribbert's students, and it was only after painstaking examinations in a large series of autopsies (Belt, 1934) that he became convinced of the relative frequency of embolism.

One would find it difficult to decide between the conflicting views of Virchow and Ribbert without putting the matter to an actual test. The important point is : What are the criteria by which an embolus may be recognized ? There are perhaps no hard-and-fast criteria, and those which have been set down here may be as arbitrary as any yet devised. On paper one can but convey a general impression of how an embolus is identified ; in practice it becomes relatively easy provided a satisfactory dissection of the pulmonary arteries is carried out.

If, as we suppose, 85 per cent. or more of lung infarcts are due to embolism,

then the problem of ætiology is largely a consideration of venous thrombosis, and that is a matter which remains obscure. In another place (Belt, 1939) I have indicated that most cases of thrombo-embolism present evidence of a prolonged circulation time, and I have emphasized again the mechanical factors to which Aschoff drew attention years ago—stasis, stagnation, and eddying—as important in the causation of the embolizing type of thrombus.

SUMMARY

In 1990 consecutive autopsies on adults, there were 155 cases of hæmorrhagic infarction of the lung. Pulmonary embolism was regarded as the immediate cause of 136 (approximately 87 per cent.) of these infarcts.

In 22 (14 per cent.) a massive pulmonary embolism was the main diagnosis, and most of these were after operations or fractures. In 74 (47 per cent.) heart disease appeared to be a predisposing factor.

A potential source of emboli was demonstrated in 116 (75 per cent.) of the infarct cases.

Means of identifying emboli at autopsy are discussed, and evidence adduced to show that embolism of the pulmonary arteries is of very common occurrence, while primary pulmonary thrombosis is relatively rare.

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NOTE BY THE EDITOR

A recent paper by H. J. Atkins (*Guy's Hospital Reports*, **88**, 92, 1938), dealing with post-operative thrombosis and embolism, reaches the same conclusion that pulmonary infarction is nearly always caused by embolism from venous thrombosis. He finds that massive embolism may occur any time in the first fifteen days, most often about the tenth day; and that it is independent of sepsis, and therefore depends on the stagnation of the blood stream, especially from the mechanical conditions of rest. Smaller infarcts

are more closely associated with sepsis (which suggests that the embolism is more often due to the breaking off of a small part of the thrombus), and are more erratic in the time of their appearance. He emphasizes the importance of the pressure of the right common iliac artery on the left common iliac vein in producing the thrombosis. His figures cannot be given in detail here, but are interesting in comparison with the relevant figures of Belt.