PULMONARY EMBOLISM

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Pulmonary embolism is a common disease and because of its often serious consequences is deserving of study. It has been estimated that in the USA over 33,000 persons die annually as a result of pulmonary embolism and at least 6% of post-operative deaths are due to this cause.[1] So common is the condition that it is held to be the commonest pulmonary disease found in a general hospital.[2,3]

Post-operative embolism is somewhat commoner in the presence of obesity, anaemia, cardiac disease, varicose veins, previous thrombophlebitis, severe infections and carcinoma. Trauma either to muscle or skeleton, fractures, and burns, are among the predisposing causes of thromboembolism as well.

The risk of embolism is proportional to the severity of the surgical procedure; the ratio being lowest after surgery for hernia and chronic appendicitis and highest after gastrectomy, cholecystectomy, splenectomy and hysterectomy.

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AETIOLOGY

Venous Thrombosis

The commonest cause of pulmonary embolism is venous thrombosis, in which pulmonary embolism is a complication in 15% of cases.[4] The loosely attached clot of phlebothrombosis may readily be detached by unaccustomed exercise such as getting up after prolonged recumbency, or straining at stool. The more firmly attached clot of thrombophlebitis is less dangerous, but a relatively safe superficial thrombophlebitis may often be associated with a dangerous deep phlebothrombosis.[2]

A common type of traumatic phlebitis encountered in hospital practice is that due to repeated venipuncture, to prolonged insertion of polythene tubes in veins, and to the intravenous administration of agents such as hypertonic glucose and saline solutions and mercurial diuretics.[5]

The site of venous thrombosis is most commonly in the veins of the calf. A clot in the thigh usually involves the whole femoral vein and may end at the junction with the profunda vein but more commonly extends to the bifurcation of the common iliac. Occasionally the common iliac may be involved as the result of direct spread from the pelvic veins, which are frequently involved in pelvic surgery.

Thrombosis resulting from stasis is a known hazard of prolonged recumbency. Beware of the case that has languished for a long period in a non-surgical ward without exercise and physiotherapy and then is transferred to a surgical unit for a major operation. Here surgery may be followed by an acute embolus within a day or two.

Cardiac Disease

Pulmonary embolism is far commoner in patients with cardiac disease than in the general population. Primary pulmonary thrombosis rather than embolism may develop in cardiac patients, particularly in cases with mitral disease. But, unless some predisposing factor such as pulmonary hypertension is present, primary pulmonary thrombosis is rare. In cardiac failure, circulatory stasis frequently leads to venous thrombosis and pulmonary embolism. The onset of auricular fibrillation in mitral stenosis, or a rapid return of normal rhythm with drugs such as quinidine, may result in pulmonary embolism. Here the embolus arises from a thrombosis situated in the auricular appendix or right atrium. The fibrotic plaque in the right ventricle as a result of myocardial infarction may also lead to thrombosis and embolisms.

PATHOLOGY

Most commonly the embolus is small and frequently multiple. With a large embolus which more or less occludes the pulmonary trunk, the effects on the heart dominate the scene, resulting in acute cor pulmonale.

The lower lobes of the lung are involved most often, the right side more frequently than the left. It is seen less commonly in the mid-portion and rarely in the upper portion. This is explained by the fact that the pulmonary arteries to the upper and middle lobes leave the main pulmonary artery at an acute angle. The infarct is always applied to a pleural surface.

After occlusion of a medium-sized vessel, a haemorrhagic infarct may result, but in healthy lungs the usual result of embolism is incomplete infarction with ultimate complete resolution. Complete infarction is seen more commonly where embolism complicates cases with pulmonary hypertension or congestion, and here healing will be by fibrosis.

The embolus causes congestion and oedema, which is most marked at the pleural surface. In an incomplete infarction, the resultant anoxia causes some alveolar haemorrhage without destruction of the wall, and the ultimate result is complete resolution. In complete infarction, the ischaemia causes destruction of the alveolar walls with resultant haemorrhagic necrosis and later fibrosis.

It has been demonstrated in experimental animals that 60% of the total pulmonary circulation must be obstructed before the blood pressure falls and the right ventricle is embarrassed, and probably 80% before death is likely.[6] Acute circulatory arrest after a massive embolism totally occluding the pulmonary arterial trunk results in sudden death. A less total obstruction (60 - 80%) will cause acute circulatory failure and severe shock. The obstruction to the right ventricular flow reduces the blood return *via* the lungs to the left ventricle and results in a fall of ventricular and systemic pressures. The fall in aortic pressure may reduce the coronary flow and this may simulate a cardiac infarction. In cases with disease of the coronary artery, actual coronary thrombosis may result.

CLINICAL FEATURES

Embolism occurs most commonly 8 - 14 days after surgery. With a massive embolus the essential dominating picture is one of cardiac embarrassment and collapse. With a smaller embolus the common findings are chest pain, haemoptysis, pyrexia, tachycardia and leucocytosis.

The pain is pleuritic; it occurs in the majority of cases because the pleural surface is always involved. In a few cases the pain may be anginal in type, when, in some instances, pleuritic pain may also be present but may be overshadowed by the more severe precordial oppression. A careful history may thus provide the lead to the correct diagnosis.[5] Haemoptysis is characteristic of embolus but occurs in less than 50% of cases and may not be present at the onset. It is frank blood mixed with clear sputum, which differentiates embolism from the rusty infected sputum of pulmonary infection. It is not to be expected in the early stages of incomplete infarction where there is only congestion and oedema. Pyrexia is almost invariably present; it is not influenced by antibiotics but often responds to anticoagulant therapy. The temperature may rise as high as 103°F and last for a few days. A rise in temperature may precede the pulmonary incident as a reflexion of a pre-existing thrombophlebitis.

Other less common features are dyspnoea, cyanosis and jaundice. Dyspnoea may be marked in the large embolus and may be associated with cyanosis. Jaundice as a result of haemolysis of blood in the infarct is very rare indeed except in patients with large pulmonary emboli and cardiac failure. Hepatic dysfunction in these cases may be the more likely cause.

Physical signs are usually inconspicuous in the incomplete infarction. A pleural friction rub is not commonly detected, for it may take 24 hours to develop. Frequent and careful auscultation of the chest is necessary to elicit this important sign, which is often faint and localized to a small area. Exquisite local chest tenderness to palpation may also be elicited. This occurs in pneumonia patients with pleuritic pain but is said to be commoner with em-

bolism.[5] It is apparently produced by spasm of the intercostal muscles secondary to the inflammation of the pleura. Other features are slight dullness on percussion, impaired air entry and a few crepitations localized to the affected area. In the complete infarct the signs are more obvious—the dullness is more marked, there may be bronchial breathing as well as crepitations, and often there are signs of a pleural effusion.

Repeated careful examination of the extremities for evidence of tenderness along the course of the deep veins is necessary in every case. The signs of venous thrombosis may only appear a week after the attack of pulmonary embolism. With prompt diagnosis of pulmonary embolism and the early institution of anticoagulant therapy, late thrombosis will appear less often.

ELECTROCARDIOGRAPHY

An ECG is useful to exclude primary cardiac pathology in the case with a large embolus. Coronary thrombosis can be ruled out on ECG except in the rare cases where there is poor coronary flow, which may simulate this condition. In doubtful cases repeated recordings are useful, because in pulmonary embolism there is a rapid return to normal.

The changes seen are the result of altered position of the heart as a consequence of right ventricular dilatation. The main features are the following: Large S deflection in lead I, prominent Q and inverted T waves in lead III, and in some cases inverted T waves in the right-sided precordial leads.

Case Report

F.S., a rather obese European woman aged 44, was admitted to the Johannesburg General Hospital with a twisted right ovarian cist of 4 days' duration. At laparotomy the cyst was found to be grossly haemorrhagic and the ovarian and uterine vessels appeared to be thrombosed. The cyst and ovary were removed and the patient made a good initial recovery from the operation. Next day, about 12 hours after operation, she suddenly became collapsed, complaining of dyspnoea and substernal discomfort. She was deeply cyanosed and dyspnoeic. Her extremities were cold and the blood pressure could not be recorded. No evidence of deep-vein thrombosis could be elicited in the extremities. An ECG taken shortly after the pulmonary embolus occurred showed changes consistent with an acute massive pulmonary embolus (Fig. 1). It also showed features of coronary ischaemia but another ECG, taken after the patient had been resuscitated with levophed and a blood transfusion, showed no features of coronary ischaemia (Fig. 2). The patient recovered after treatment in the manner described below.

RADIOLOGICAL FEATURES

It is important to realize that the chest radiograph may look normal after embolism. This is true of major emboli which do not produce infarctions and of minor emboli which may or may not produce small infarctions at the lung periphery. Some patients may have showers of emboli for years and eventually develop chronic cor pulmonale without radiographic shadows indicative of infarction. The changes produced by infarction may only become visible after a period varying from hours to days and, unless repeated radiographs are taken, the diagnosis may be missed. Hazy densities may appear and then, after 24 - 48 hours, disappear. These represent alveoli filled with blood, with rapid resolution in the absence of actual infarction.

Another difficulty is that the patient is often too ill for other than bedside X-rays and these are all too frequently of poor quality. Every effort should be made to obtain good X-rays, even if it means moving the patient to the radiology department in his bed.

Lastly the interpretation of findings may be difficult because the signs may mimic other conditions. Practically any shape of opacity can be caused by an infarct. With acute cor pulmonale, lateral and oblique radiographs may show a suggestive bulge of the right ventricle. In cases where there are no pulmonary or pleural changes, the mid-right (Mr) diameter of the heart may lead to the diagnosis of major embolus.[7] The Mr diameter of the cardiac silhouette is the greatest horizontal distance between the mid-spinal line and the right border of the cardiac silhouette in the frontal plane. It rarely exceeds 50 mm. in the normal. An Mr diameter greater than 50 mm. tends to be associated with an increased right atrial volume. Other conditions,

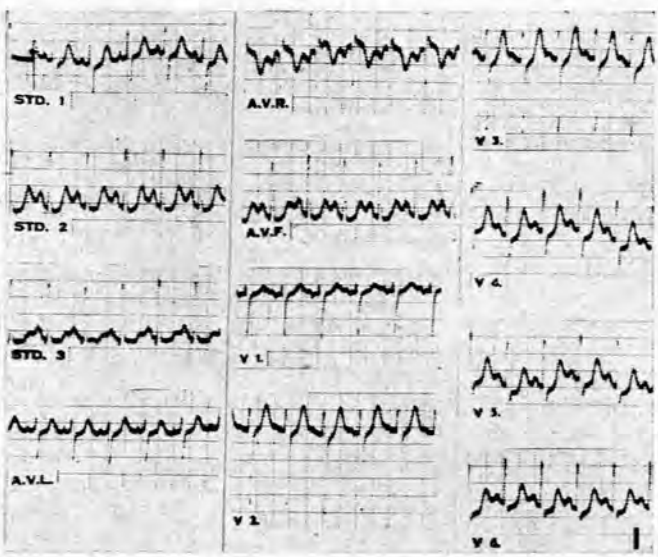


Fig. 1. Case F.S. Note the tachycardia. The standard leads show marked right axis deviation with large peaked P waves in the 2nd standard lead. There is an ST depression over the left anterior chest leads with rather high, peaked and symmetrical T waves, indicating myocardial ischaemia.

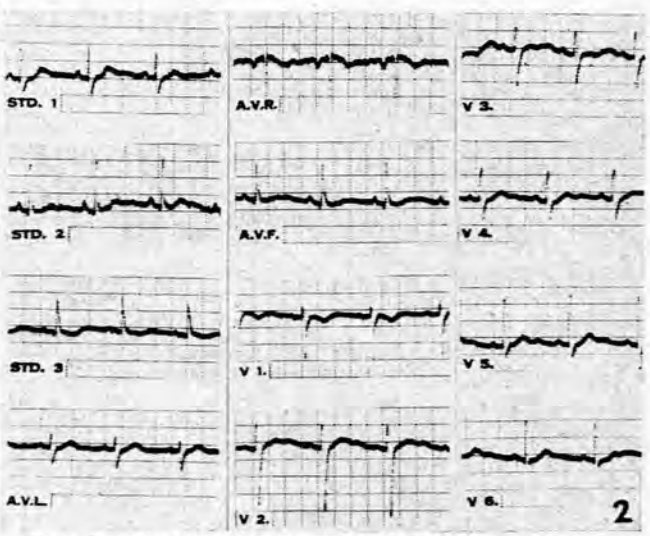
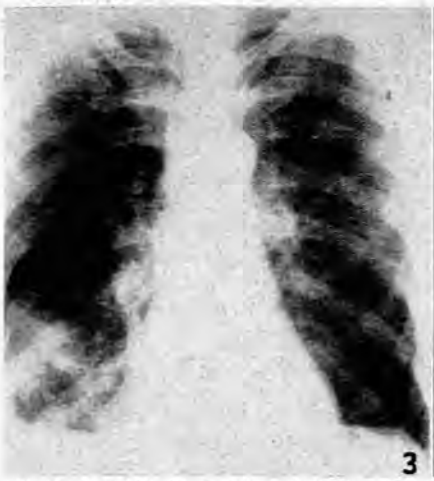
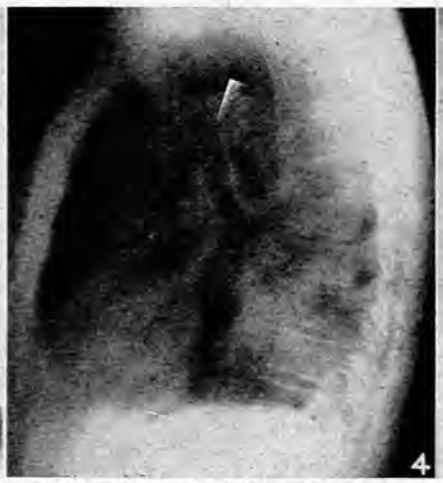


Fig. 2. Case F.S. The rate is now much slower. There is still some evidence of right axis deviation. The P waves in standard 2 are still sharp but of normal amplitude. The ST depression previously noted over the anterior chest leads has disappeared and the T waves have returned to normal.





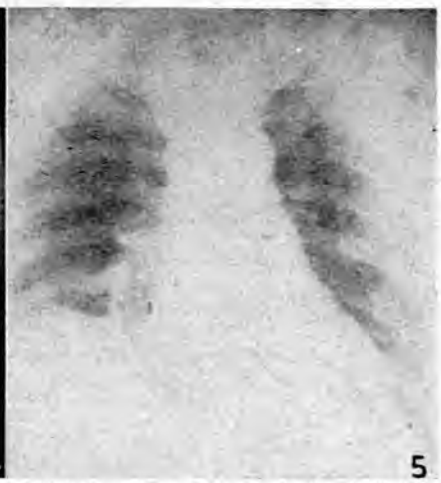


Fig. 3. Case J.S. Chest radiograph in the postero-anterior plane showing a rounded opacity in the base of the right lung. There is also a small pleural effusion at the right base.
Fig. 4. Case J.S. A lateral chest radiograph of the same patient as in Fig. 3, demonstrating the relationship of the opacity to the interlobar pleura (oblique fissure) of the lung.
Fig. 5. Elderly European woman with pulmonary embolism who presented with upper abdominal pain. Chest radiograph showing a markedly raised diaphragm on the right side. The raised diaphragm was found to be immobile (fixed) on screening.

such as pericardial effusion and diaphragmatic hernia, may also increase the Mr diameter and these have to be excluded first.

A pulmonary opacity is to be expected when complete infarction predominates. The triangular shadow which at one time was thought to be the typical finding is rarely encountered. An ill-defined non-homogenous opacity is much more characteristic.[2] If the opacity can be shown to be related to a pleural surface it is then in keeping with a diagnosis of pulmonary embolism. Routine postero-anterior or lateral views sometimes reveal this relation to the pleura but, if not, then careful screening in varying degrees of obliquity may establish such a relationship of an apparently nondescript opacity, seemingly centrally located (Figs. 3 and 4).

Case Report

J.S., a European man aged 58, was admitted for haemoptysis and chest pain. He had once had an amputation of his right leg for 'thrombosis'. On examination he showed no evidence of dyspnoea, cyanosis or jaundice, and no obvious distress. Temperature 98°F, pulse 72 per minute and regular respiratory rate 18 per minute, blood pressure 110/70 mm. Hg. The right leg had been amputated at the mid-thigh level. The left leg showed varicose pigmentation with varicosities of the long saphenous system. Peripheral pulses were present in the leg and there was no evidence of thrombosis of the deep veins. Examination of his chest revealed dullness and crepitations at the right base. A radiograph of the chest showed a right-sided pulmonary opacity and an effusion at the right base (Fig. 3). A lateral radiograph showed the opacity to be related to the pleura of the oblique fissure. (Fig. 4.)

When pulmonary embolism occurs without infarction, the radiograph may show a prominent pulmonary artery and an abnormal translucency of the lung supplied by this vessel, as a result of absence of vascular markings. This is known as Westermark's sign, but in practice it is too difficult to evaluate to be reliable.

The diaphragm is frequently raised on one or both sides as a result of impaired ventilation. This may be the only feature noted in an early X-ray (Fig. 5). Sometimes diminished excursion of the diaphragm is seen on radioscopy; occasionally it is seen to move paradoxically. The cause of this seeming diaphragmatic paralysis is unknown.

Pleural involvement is almost invariable. A small pleural effusion is often found and sometimes may be large (Fig. 3). A minimal pleural reaction of the costophrenic angle with a hump-shaped medial border, known by American radiologists as an 'ice-cube' appearance, is considered diagnostic[8] (Fig. 6).

In incomplete infarction, when the infarct has shrunk to a flat subpleural fibrotic plaque it appears on X-ray as a linear opacity. This is characteristically transient, but it constitutes the most typical finding of all. These lines, sometimes converging, may be the only recognizable residue pointing to the diagnosis (Fig. 7).

DIFFERENTIAL DIAGNOSIS

Post-operative atelectasis may be difficult to differentiate from pulmonary embolism. Atelectasis tends to occur in the immediate post-operative phase, and infarction usually later. Obstruction of a lobar bronchus gives rise to lobar collapse or massive collapse. Obstruction of several smaller bronchi causes a more scattered and patchy form of collapse. With infection the picture eventually resembles lobar pneumonia or bronchopneumonia. The radiological picture is thus either a wedge-shaped or triangular shadow at one base or numerous fluffy opacities, usually basal and often bilateral.

Pneumonia may resemble infarction both clinically and on X-ray; but pneumonia is almost invariably preceded by an infection of the upper respiratory tract and the absence of such illness should lead to the suspicion of embolism. Recurrent episodes involving one lung and then the other —the characteristic picture of embolism—are relatively infrequently due to pneumonia.

Myocardial infarction is the disorder most commonly confused with acute pulmonary embolism. Besides ECG, estimation of the serum-transaminase level is also useful in the determination of the diagnosis. Elevation of the serum transaminase occurs in association with myocardial, hepatic or muscular lesions.

Abdominal catastrophe. Pulmonary embolism has been known to present with severe abdominal pain and muscular guarding simulating true rigidity.[5]

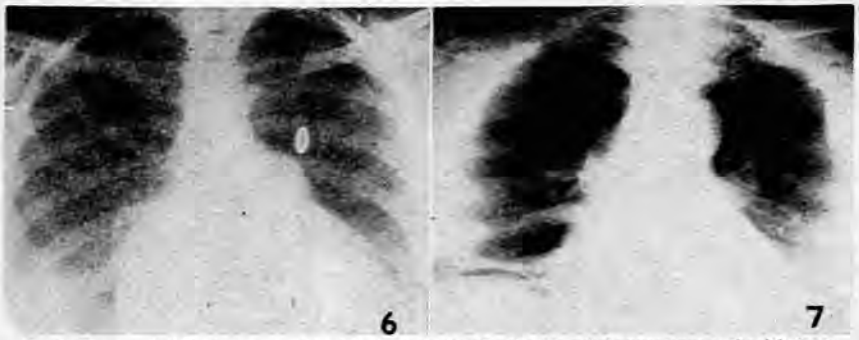


Fig. 6. Young adult Bantu woman. Chest radiograph showing the 'ice-cube' appearance at the right base. Note the enlarged heart due to mitral disease.
Fig. 7. Chest radiograph showing a linear shadow running above the right leaf of the diaphragm.

TREATMENT

Antibiotics are necessary in order to prevent secondary infection after pulmonary embolism. Cavitation has been known to follow pulmonary infarction, and secondary infection may lead to a lung abscess. Cardiac drugs such as digitalis will be necessary in the event of cardiac failure. Cardiac embarrassment in itself, without obvious cor pulmonale, will benefit with digitalis.

Mercurial diuretics are useful to relieve pulmonary congestion and may cause dramatic resolution of infarction.[2]

Omnopon, $\frac{1}{3}$ of a grain, will allay restlessness and anxiety.

Oxygen should be administered if there is breathlessness and cyanosis. Dyspnoea and cyanosis are best treated by propping the patient up, but a precipitous fall in blood pressure with a large embolus is best relieved in the first instance by laying the patient flat and, if necessary, propping up the foot of the bed. This will immediately relieve the effects of cerebral anaemia. For vascular collapse, venesection is considered inadvisable and blood transfusion in small amounts, until the blood pressure has recovered, is now being advised.[9] Drugs such as methridrene or wyamine should be given in the first instance to help restore the blood pressure but one should not hesitate to use levophed (noradrenaline) if the systolic blood pressure falls below 90 mg. Hg. Blood and plasma given with levophed (into a separate vein) will shorten the time otherwise needed by levophed.

Atropine, 1/100th of a grain, and papaverine, $\frac{1}{2}$ - 1 grain, will tend to relieve any bronchial spasm. Where there is any degree of shock, intravenous cortisone (100 mg. of solucortef) should be administered and repeated if necessary.

Anticoagulants should be given in all cases of pulmonary embolism. Their aim is to prevent secondary thrombosis at the site of embolism and to promote canalization of the clot. If anticoagulant therapy is applied early in cases of venous thrombosis, pulmonary embolism almost never occurs. What has to be avoided is inadequate dosage. Heparin is the only agent that can be expected to achieve immediate halting of clot propagation. The oral anticoagulants, or coumarin drugs, act by prolonging the 'prothrombin time' without altering the actual clotting time. Moreover, the response of patients to oral anticoagulants is unpredictable and thus it is difficult to procure a constant effect on prothrombin activity. Therapy should therefore commence with heparin, and the oral anticoagulants should be timed to take over on the 4th - 5th day, by which time clot fixation at the site of venous thrombosis will have been established. The oral anticoagulants are then used to discourage further thrombosis.

Heparin acts directly upon the clotting mechanism by inactivating thrombin. It also halts prothrombin activity and this should be remembered when heparin and oral anticoagulants are used together. The action of heparin is rapid and lasts from 4 to 6 hours according to the dose used. Blood should be taken 1 hour after injection to measure the clotting time. The aim is to produce a clotting time of 15 - 20 minutes, or 3 times the normal. Heparin is best given intravenously, but the deep subcutaneous route is useful when there are vein difficulties, and then pain can be overcome and absorption speeded up by the addition of procaine and hyaluronidase. The recommended adult intravenous dose of heparin is 15,000 units, followed by 10,000 - 15,000 units 4 or 6 hourly, depending upon the clotting time. One should not hesitate to step up the dose if necessary; my own experience is that 10,000 units is frequently inadequate. In massive pulmonary embolism, the initial loading dose should be 25,000 units.[9] During subsequent days, with clinical improvement and when the oral anticoagulants are exerting their full effect, heparin is successively cut to 8 hourly, 12 hourly, and daily; and then stopped.

The oral anticoagulants all have a time lag of 24 - 48 hours or longer before their clinical effects become evident. Patients vary in their sensitivity to the coumarin drugs; they may even vary from day to day. A patient may be resistant to one drug and not to another. The withdrawal of oral anticoagulants after prolonged therapy should be slow, for 'rebound clotting' may follow and in an elderly cardiac this may result in a further coronary occlusion. Dosage is controlled by estimating the prothrombin time. The last heparin dose should be given at least 4 hours before the test, for it also tends to prolong the prothrombin time.

Vein ligation. During the past few years ligation of the femoral vein and the inferior vena cava has to a great extent been abandoned. Experience has shown that after adequate anticoagulant therapy further embolism is rare and operation thus unnecessary. Surgery still has a place in the management of recurrent or pyaemic emboli, or when anticoagulants are contra-indicated as in patients with hepatic renal insufficiency, ulcerative colitis, etc.

Mitral valvulotomy. Where recurrent infarction occurs in the presence of mitral stenosis, it is probable that the infarction is caused not by emboli but by primary thrombosis due to pulmonary hypertension. These cases are often dramatically relieved by mitral valvulotomy.[2]

Pulmonary embolectomy. In 1908 Trendelenberg described his operation for pulmonary embolectomy, but the first successful case was performed by Kirschner in 1924. In 1938 Lewis performed the first successful operation in Great Britain, by which time 11 successful cases had been reported.[10] For all this, most people would contend that patients well enough for surgery are not in need of embolectomy.

Prognosis

The source of the embolus is the uncertain factor in prognosis and so long as this remains, the prognosis is uncertain. The effect on the lungs is the least important because, unless an infarct is extensive, the residual scar will be negligible. The heart is fortunately not embarrassed in the majority of cases, but sometimes recurrent emboli ultimately lead to chronic cor pulmonale.

Prophylaxis

Certain primary principles, such as suitable preparation of the patient for operation, gentle surgical technique, and the prevention of stasis in the veins of the legs during convalescence, are cardinal rules. One should avoid trauma to the limbs on the operating table and, if possible, saphenous vein drips should not be used. The patient in hospital for investigation should not lie idly in bed. Breathing exercises to speed the venous flow should be taught. Early ambulation is also important, and where this is contraindicated leg exercises in bed should be instituted. It has been shown that wearing elastic stockings increases the venous flow from the veins of the legs and reduces the incidence of pulmonary embolism. In a New England hospital where elastic stockings were supplied as a routine measure to a series of 5,467 medical, surgical and obstetric patients over 20 years of age, the incidence of pulmonary embolism was reduced by half.[11] This clearly suggests that elastic stockings should be supplied before surgery to all patients with varicose veins or with a previous history of thrombosis.

SUMMARY

1. A review of pulmonary embolism is presented, with case reports. At least 5% of post-operative deaths are due to this cause. The incidence is in direct proportion to the severity of the operative procedure and conditions such as severe trauma, including burns, are among the predisposing causes as well.

2. Venous thrombosis is the commonest cause of pulmonary embolism. Primary pulmonary thrombosis can also occur in conditions associated with pulmonary hypertension and oedema as seen with cardiac patients. In these cases complete infarction will commonly result whereas, in cases where the lungs were otherwise healthy, incomplete infarction is the rule. The infarct is always applied to a pleural surface.

3. An electrocardiograph is useful, mostly to exclude coronary thrombosis in cases with a major embolus.

4. The X-ray features are presented. A negative X-ray does not exclude pulmonary embolus. The usual picture is a pulmonary opacity related to a pleural surface. The diaphragm may be elevated on the affected side, may be fixed, or may move paradoxically. There may also be a pleural effusion, or an 'ice-cube' appearance at the costophrenic angle. If linear opacities are seen, they constitute the most typical finding of all. With a major embolus the enlarged right border of the heart may be the only clue to the diagnosis. In these cases the mid-right (Mr) diameter of the heart is greater than normal.

5. The differential diagnosis, clinical features and treatment are also presented. Heparin is the anticoagulant of choice in the first instance. The danger with heparin is inadequate therapy, not overdosage.

6. The prognosis as regards the heart and lungs is good but so long as the primary source of the embolus remains, the prognosis as regards further embolization is uncertain. Prophylaxis is discussed and the value of elastic stockings is mentioned.

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REFERENCES

1. Smith, M. J. (1953): Dis. Chest, **23**, 532.
2. MacLeod, J. (1956): J. Roy. Coll. Surg. Edinb., **1**, 213.
3. Short, D. S. (1952): Brit. Med. J., **1**, 790.
4. Allen, A. (1947): Surg. Gynec. Obstet., **84**, 519.
5. Israel, H. and Goldstein, F. (1957): Ann. Intern. Med., **47**, 202.
6. Gibbon, J. H., Hopkinson, M. and Churchill, E. D. (1932): J. Clin. Invest., **11**, 543.
7. Soloff, L. and Zatuchni, J. (1959): Amer. J. Med. Sci., **237**, 608.
8. Arendt, J. and Rosenberg, M. (1959): Amer. J. Roentgenol., **81**, 245.
9. Cohen S. *In* Maingot, R. (1957): *The Management of Abdominal Operations.* London: Lewis.
10. Lewis, I. (1939): Lancet, **1**, 1037.
11. Wilkins, R. W. and Stanton, J. R. (1953): New Engl. J. Med., **248**, 1087.

ADDITIONAL BIBLIOGRAPHY

Sellers, T. H. (1948): *Modern Trends in Radiology.* London: Butterworth.
Fleischner, F. G. (1958): Canad. Med. Assoc. J., **78**, 653.
Lillie, R., Buxton, R. and Duff, I. F. (1949): Arch. Surg., **59**, 609.
Trendelenberg, F. (1908): Arch. klin. Chir., **86**, 686.
Torrance D. J. (1959): Amer. J. Med. Sci., **237**, 651.