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PULMONARY EMBOLISM

BY

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In a previous study of myocardial infarction (Honey and Truelove, 1957) it was concluded that: "The overall effect of anticoagulant therapy on the fatality-rate has not been very great, and the improvement can be accounted for by the almost complete abolition of deaths from pulmonary embolism." As an incidental observation it was noticed at that time that, although death from pulmonary embolism had become infrequent in patients with myocardial infarction since the introduction of anticoagulant therapy, pulmonary embolism was responsible for a considerable number of deaths in the whole hospital population and that the number was increasing from year to year. The present study is an analysis of the experience of two Oxford hospitals with respect to pulmonary embolism during the decade 1952–61.

Sources of Data

The case notes of all patients in the Radcliffe Infirmary and Churchill Hospital diagnosed as having sustained a pulmonary embolism during the period under review have been examined. Patients attending the maternity department, which keeps its own case notes, were excluded. Relevant information was extracted and put on punch-cards for mechanical sorting. As pulmonary embolism is frequently a subsidiary diagnosis, it is important to place on record the fact that the particular records clerk responsible for the diagnostic index makes an invariable practice of reading the entire case history of every patient in order that such subsidiary diagnoses should not be omitted. All case notes bearing the diagnosis of pulmonary embolism were examined in detail by one of us, and some of these were rejected because the evidence in them favouring a pulmonary embolism was judged to be inadequate. Among the patients who died, a considerable proportion of the diagnoses were either confirmed by post-mortem examination or were first made then. After rejecting the doubtful cases there were 853 case notes left for analysis.

Increasing Frequency of Pulmonary Embolism in the Hospital Population

During the decade under review there was an impressive rise in the frequency of recorded cases of pulmonary embolism, there being nearly five times as many in 1961 as in 1952. Throughout the whole period, in approximately one-half of the recorded cases, the patient died, so that the

fatal cases similarly show a pronounced rise, there being four times as many in the last year of the period as in the first (Table I, Fig. 1).

TABLE I.—*Annual Totals of Recorded Cases of Pulmonary Embolism, of Deaths from Pulmonary Embolism, and of Potentially Preventable Deaths from Pulmonary Embolism by Year from 1952 to 1961 inclusive (Both Sexes Combined)*

Year	Pulmonary Embolism		
	No. of Recorded Cases	No. of Deaths	No. of Potentially Preventable Deaths
1952	33	18	11
1953	48	27	19
1954	46	23	13
1955	54	28	13
1956	75	43	26
1957	81	45	23
1958	122	64	36
1959	114	57	25
1960	126	62	23
1961	154	72	24
Total	853	439	213

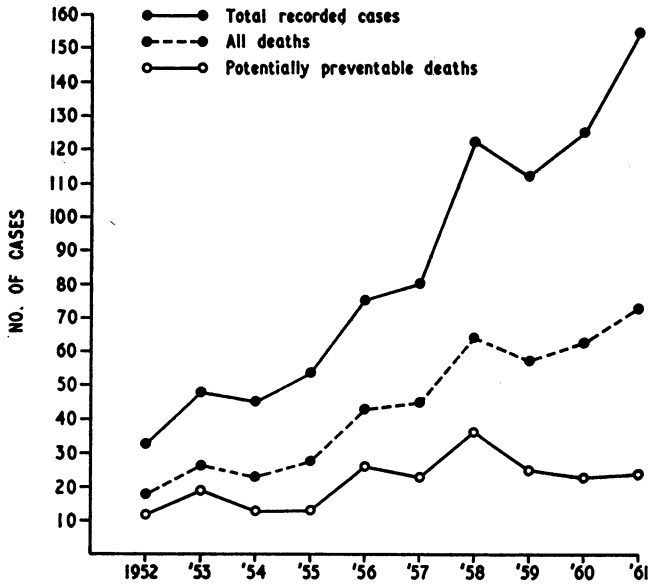

FIG. 1.—Number of cases of pulmonary embolism in two Oxford hospitals during 1952–61 inclusive.

It is probable that the main reason for the rise in the number of recorded cases and recorded deaths is a true increase in the frequency of pulmonary embolism. As already mentioned, it is the practice for all case notes to be examined in the records department for the diagnostic index, and this system has been completely standardized since 1954; so far as this aspect of the data is concerned, some uncertainty may exist for 1952 and 1953, but does not apply thereafter. As the great majority of patients who died with pulmonary embolism were examined after death, the figures for the deaths can be regarded as fairly reliable, especially as about 97% of all patients who die in the two hospitals are brought to post-mortem study (Table II). So far as the deaths are concerned it is most improbable that errors of omission in the earlier years of the period could account for the fourfold rise in recorded deaths.

The increase in recorded frequency of pulmonary embolism may merely reflect a growth in the in-patient populations of the two hospitals; some growth has occurred, as is shown in Table II, but it is of a much smaller magnitude. A marked increase in the number of elderly patients may also be responsible; we do not have information on the age and sex structure of the hospital in-patient population for the entire period under review,

TABLE II.—*Number of In-patients in the Radcliffe Infirmary and Churchill Hospital During 1952–61 (Patients Admitted to Certain Specialized Units Not Covered by the Present Study Have Been Excluded), Number of Deaths in this Hospital Population, and Number of Post-mortem Examinations Carried Out*

Year	No. of In-patients	No. of Deaths	Post-mortem Examinations	
			No.	%
1952	18,370	510	475	85·7
1953	20,353	538	526	95·9
1954	20,694	530	522	98·5
1955	19,872	598	576	96·0
1956	20,008	631	618	97·9
1957	20,062	549	633	97·1
1958	20,710	613	612	99·9
1959	21,489	603	601	99·9
1960	22,161	638	625	98·3
1961	23,486	693	*	*

* Data not available in final form at time of writing.

but it is available on the basis of a 1 in 10 sample for the three years 1958, 1959, and 1960, and within this time the change in the age and sex structure of the hospital population was negligible. Yet another possibility is that physicians and surgeons may be more aware of pulmonary embolism nowadays than they were at the beginning of the study: this seems unlikely, as there was a wave of interest in venous thrombosis and in pulmonary embolism during 1940–50, so that by the beginning of the period embraced by the present study a general awareness of pulmonary embolism was usual among the medical staffs of hospitals, and anticoagulant therapy and ligation of veins were already generally established means of preventing pulmonary embolism in patients with leg-vein thrombosis.

Further evidence suggesting that the increase in recorded pulmonary embolism represents a true increase in frequency of occurrence comes from analysing the cases into a number of clinical categories, as is done in Fig. 2. This shows the number of cases of recorded pulmonary embolism occurring in various groupings separately for the first and second

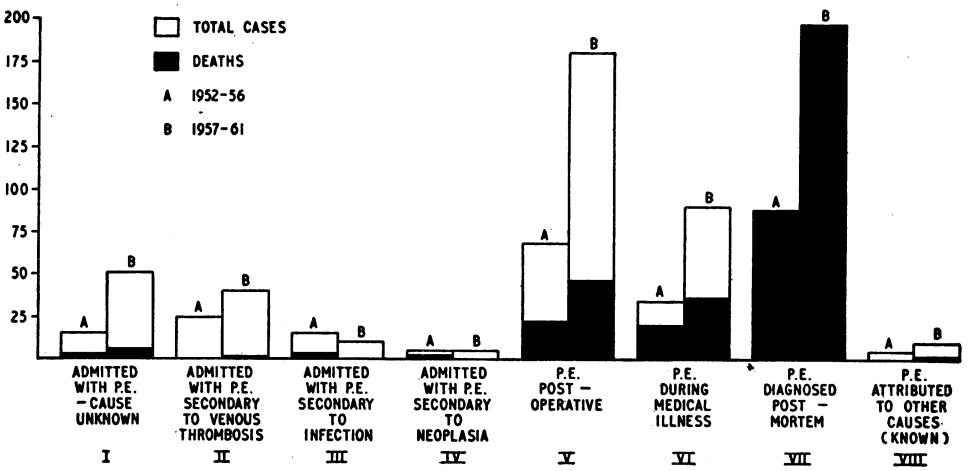

FIG. 2.—Various clinical categories of pulmonary embolism broken down into two five-year periods, with the number of deaths.

five-year periods of the decade under review. Although there has been an increase in the number of patients admitted to hospital with pulmonary embolism, either from unknown cause or secondary to known leg-vein thrombosis, these groups represent a small fraction of the total cases, and the increase in their numbers in the second five years is not a major factor in the general increase. It can be seen that cases of pulmonary embolism occurring post-operatively (Category V), in the course of a medically treated illness (Category VI), and those first found at post-mortem examination (Category VII), all showed a marked increase during the second five-year period. Although the numbers of recorded cases in all these categories have increased, the fatality rate among the patients diagnosed before death has undergone a moderate decline in all major categories, as shown in Fig. 3, in which certain categories

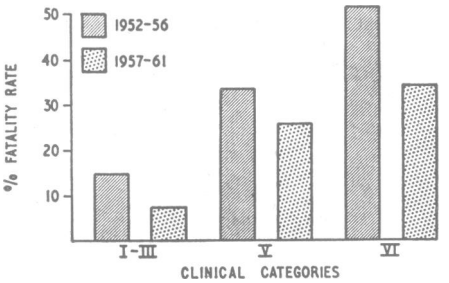

FIG. 3.—Compressed version of some of the data given in Fig. 2.

are condensed to overcome the problem of small numbers. In other words, the large rise in deaths from pulmonary embolism has occurred in the face of a moderate reduction in the fatality rate among the patients diagnosed in life.

Estimated Incidence of Pulmonary Embolism in the Hospital Population

Table III shows for the two five-year periods the actual numbers of recorded cases by sex among post-operative patients and the remainder. By itself this table gives no exact information about the frequency of occurrence of pulmonary embolism among patients in the hospitals because it does not show the numbers at risk in the various categories.

TABLE III.—*Number of Cases of Pulmonary Embolism During 1952–61 by Sex and Treatment*

Period	Sex	Operation	No Operation	Total
1952–6	M	61	65	126
	F	52	78	130
1957–61	M	127	179	306
	F	124	164	288
1952–61	M	188	244	432
	F	176	242	418
All cases		364	486	850*

* Excludes 3 cases (2 with operation, 1 without operation) where the sex was not available.

Fortunately, the national Hospital In-Patient Enquiry (H.I.P.E.) organized by the Ministry of Health in collaboration with the General Register Office enables a fairly precise estimate to be made of the actual incidence of recorded pulmonary embolism during the second five-year period of the present study. H.I.P.E. consists of a 1 in 10 sample of all hospital admissions and includes information in respect of age, sex, and whether or not an operation was performed. By taking the H.I.P.E. values for the in-patient population of the two hospitals for the years 1958, 1959, and 1960, an estimate of the population at risk for the period 1957–61 has been made. (Patients admitted to the maternity department not covered by this study have been excluded when estimating the population at risk.) From the denominators provided by the H.I.P.E. figures, estimated rates per thousand have been calculated.

From the results it appears that the sex of the patient has little bearing on the risk of developing pulmonary embolism and therefore both sexes are considered together

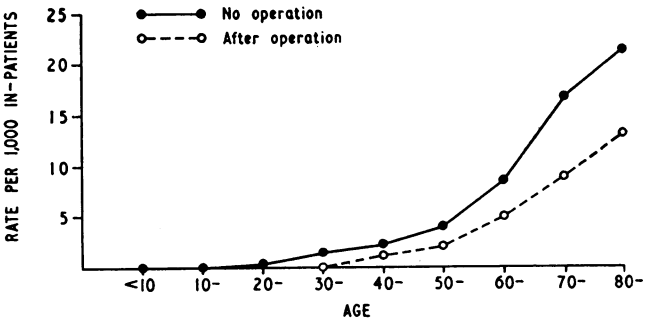

FIG. 4.—Age-specific rates for pulmonary embolism in the hospital population, shown separately for medical and surgical cases, for the second five-year period of the study, 1957–61, inclyusive.

in what follows. Fig. 4 shows the estimated rate per 1,000 admissions by age and by whether or not an operation had been performed. It will be seen that the risk of pulmonary embolism is lower at each age-group in the post-operative patients than in the remainder. In each of these main categories the age of the patient has a profound influence on the liability to pulmonary embolism. In the " medical group " pulmonary embolism becomes an appreciable risk after the age of 30, and thereafter climbs with advancing age, especially after the age of 50. Among the post-operative patients, pulmonary embolism virtually does not occur below the age of 40, and only begins to become frequent after the age of 50.

Potentially Preventable Deaths

The patients dying with pulmonary embolism have been divided into three main groups: (1) those who were more or less bound to die in any event from the main illness which brought them into hospital (" inevitable deaths "); (2) those who might have survived the main illness but the pulmonary embolism tipped the balance and caused their deaths; and (3) those who could confidently have been expected to live if the pulmonary embolism had not occurred.

Groups 2 and 3 represent what we have called " potentially preventable deaths " so far as pulmonary embolism is concerned. These cases are plotted in Fig. 1, from which it can be seen that the increase in preventable deaths has not been so pronounced as has the increase in total recorded cases of pulmonary embolism or in total deaths associated with it. Nevertheless, the cases of potentially preventable death are not negligible and have been occurring at the rate of one a fortnight during the past five years in the two hospitals studied. The relatively slower rate of increase in the potentially preventable deaths may possibly reflect a partial success from the use of anticoagulant therapy, but it is is impossible to examine the issue in a sufficiently precise manner to be able to confirm this possibility.

Anticoagulant Therapy

The use of anticoagulant therapy appears to have been remarkably constant during the period covered by this study. Table IV shows that the proportion of all diagnosed

cases of pulmonary embolism that were treated with anticoagulant therapy was the same in the two quinquennia, because the small differences between subgroups are not statistically significant. Table V deals with the use of

TABLE IV.—*Proportion of All Cases Treated by Anticoagulants*

Period	Post-operative Group			Non-operative Group			Both Groups		
	Total Cases	Treated with Anticoagulants		Total Cases	Treated with Anticoagulants		Total Cases	Treated with Anticoagulants	
		No.	%		No.	%		No.	%
1952–6	113	37	32·7	143	64	44·8	256	101	39·5
1957–61	251	97	38·6	343	153	44·6	594	250	42·1
Total	364	134	36·8	486	217	44·7	850	351	41·3

TABLE V.—*Proportion of Cases Diagnosed in Life and Not Dying Immediately that were Treated by Anticoagulants*

Period	Total Cases	Treated with Anticoagulants		Total Cases	Treated with Anticoagulants		Total Cases	Treated with Anticoagulants	
		No.	%		No.	%		No.	%
1952–6	51	37	72·6	85	64	75·3	136	101	74·3
1957–61	148	97	65·5	194	153	78·9	342	250	73·1
Total	199	134	67·3	279	217	77·8	478	351	73·4

anticoagulants in patients diagnosed during life but excluding those who died so suddenly that there was no opportunity to apply anticoagulant therapy ; this also shows that the rise of anticoagulants has been constant. The fact that the use of anticoagulant therapy has not altered during the period under review implies that an explanation for the marked increase in total diagnosed cases and deaths from pulmonary embolism is not related to any major variation in treatment.

Fig. 5 shows that the patients diagnosed in life (but excluding those who died suddenly) had a much better prognosis if treated with anticoagulants. Of course, considerable caution must be exercised before accepting these figures at their face value because the patients were not allotted at random to anticoagulant therapy and therefore the treated and untreated groups are likely to have been different in respect of factors other than anticoagulants. Subject to this caveat, however, the figures strongly support the view than anticoagulant therapy is highly beneficial in pulmonary embolism.

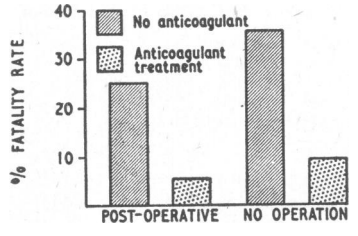

FIG. 5.—Fatality rate in patients treated and not treated with anticoagulants, after excluding patients who died so quickly after pulmonary embolism that institution of anticoagulant therapy was not practicable.

Discussion

The present study has shown that pulmonary embolism has become much more frequent in two acute general hospitals in Oxford during the past decade. European studies undertaken since the latter part of the nineteenth century have shown an irregular wave-like pattern in the numbers of fatal pulmonary emboli, with a general trend upwards. From examination of post-mortem records covering the years 1890 to 1951 Zietlhofer and Reiffenstuhl (1952) found that the frequency of pulmonary embolism decreased during and immediately after each world war, with the intervening peaks reaching a higher point each time, the highest being in 1951. Hillemans (quoted by de Bakey, 1954) found a similar pattern. Meister (1960) showed a rise in the frequency of pulmonary emboli from 1948 to 1956 and a slight fall during the next three years.

American reports have shown varying incidences of pulmonary embolism. Comparison of them is difficult because of different criteria used, but in general an increase over the past 60 years is indicated (Ochsner *et al.*, 1951 ; de Bakey, 1954).

Anticoagulant therapy is undoubtedly beneficial in the treatment of venous thrombosis and pulmonary embolism (Zilliacus, 1946 ; Bauer, 1946 ; Coon *et al.*, 1958 ; Barritt and Jordan, 1960). Thus a decrease rather than an increase in the frequency of pulmonary emboli since anticoagulant drugs became universally available 15 years ago would be expected. The implication is that the increase would have been even greater without anticoagulant therapy.

As the majority of pulmonary emboli originate in venous thromboses of the legs, the increase in pulmonary emboli must reflect on increase in leg-vein thrombosis, though the two need not necessarily be of the same magnitude. The frequencies of leg-vein thrombosis and pulmonary embolism rise concomitantly with age, especially after 40 years. The age–frequency relationship may be directly correlated with the progressive enlargement of the intramuscular calf veins which occurs with advancing years (Gibbs, 1959).

Any factor leading to stasis and coagulation of blood in the calf veins will be associated with an increased risk of pulmonary embolism and that risk will increase with the age of the patient. Rest in bed is the most potent immediate cause ; the incidence of calf-vein thrombosis rises with increasing length of bed rest (Gibbs, 1957).

An operation is one of the major precipitating factors because the mobility of the patient is impeded, there are a greater number of circulating platelets, and probably other mechanisms are brought into action. When all patients suffering from pulmonary emboli are considered, approximately one-third or more are post-operative. They comprised 30% and 37.2% of the series of Hermann *et al.* (1961) and de Bakey (1954) respectively, and 42.6% of the present series. Examination of post-mortem material will not produce the true comparative numbers of pulmonary emboli in medical and surgical patients, because the case fatality rate from pulmonary embolism is greater in the former than in the latter. The estimation of the effect of a specific type of operation on the risk of subsequent pulmonary embolism is fraught with difficulties. Although consideration of the total figures suggests that exploratory laparotomies and gastric, biliary, and prostate operations are most often concerned (Henderson, 1927 ; Lam and Hooker, 1946 ; Byrne, 1960), in none of the reported series is both the number of each type of operation followed by pulmonary embolism related to the total number of such operations and to the ages of the patients. In the present study the denominators for calculation of the incidence of pulmonary emboli for each type of operation were not available without an enormous amount of work, owing to the type of records system in use.

Fractures of the lower limbs and pelvis in elderly patients are often followed by venous thrombosis and embolism. In a study of patients over 55 years of age, Sevitt and Gallagher (1959) found that of the patients who died after such a fracture 80% had thrombosis in the lower limbs and 40–50% had pulmonary embolism.

Heart disease, especially when there is heart failure, and malignant disease have figured prominently in the aetiology of venous thrombosis.

In the series of 517 cases of pulmonary embolism reported by Hermann *et al.* (1961) 67% had heart disease and 10% cancer. In Byrne's (1960) series of 979 cases of phlebitis 283 had heart failure and 32 cancer; there were 52 patients with hemiplegia.

The prevention of death from pulmonary embolism is dependent on the prophylaxis, early diagnosis, and treatment of venous thrombosis. In many instances a pulmonary embolus, often resulting in the untimely death of a favourably progressing patient, is the first indication of thrombotic disease. This fact, together with the finding that at present there is one potentially preventable death every fortnight in the Radcliffe Infirmary and Churchill Hospital emphasizes the necessity for prophylactic treatment.

Prophylactic Anticoagulant Treatment

The actual incidence of pulmonary embolism in the hospital population is very small, and prophylaxis by means of anticoagulant drugs in all patients, except where contraindications exist, would be extremely expensive in relation to the number of deaths prevented and would carry its own dangers. Prophylactic treatment may be indicated in certain groups of patients known to be greatly at risk; the beneficial value of this approach in post-operative patients and in those suffering from cardiac failure and fractured femora has been shown (Barker *et al.*, 1945; Harvey and Finch, 1950; Sevitt and Gallagher, 1959; Eskeland, 1962). Treatment should be given to any other patient suspected of harbouring a leg-vein thrombosis or pulmonary embolism unless specific contraindications are present.

Position in Bed and Early Ambulation

The effective and inexpensive measure of promoting leg-vein drainage by raising the foot of the bed could be applied to almost every patient, and theoretically should reduce the frequency of leg-vein thrombosis and pulmonary embolism. Payling Wright and Osborn (1952) found that in 10 degrees head-down position venous drainage of the legs was almost double that in the horizontal position, and McLachlin *et al.* (1960) showed that the time of emptying of the calf veins increased with age in the horizontal position, and that raising the foot of the bed 15 degrees resulted in a marked reduction in the time of emptying and was more effective than vigorous contractions of the thigh and calf muscles in the horizontal position. The patient should get out of bed and walk about several times a day, returning to bed each time, until fully mobile. Patients with severe cardiac failure or respiratory distress are unable to lie flat, but the compromise of a sitting position with the foot of the bed elevated introduces the danger of venous stasis in the iliac veins. The common hospital practice of sitting patients out of bed with their legs dependent may be more dangerous in the elderly than keeping them in bed, if they are not constantly encouraged in leg movement.

Ligation of Veins

Venous ligation to prevent emboli from leg-vein thrombosis has enjoyed a vogue in the United States but has never been favoured in this country.

Is There an Epidemic of Thrombotic Disease?

In view of the evidence for a massive increase in the number of cases of pulmonary embolism in hospital, there is the possibility that this represents merely one facet of an epidemic of thrombotic disease affecting Western society. During the period under review the number of patients with coronary thrombosis and cerebral thrombosis admitted to the Radcliffe Infirmary and Churchill Hospital have likewise shown a steep increase, although the rise is not so pronounced as with pulmonary embolism. The study of a hospital population permits of only very limited epidemiological conclusions and is more useful for posing a question than for settling it. In effect, it is suggested that the present study indicates that pulmonary embolism is a problem of mounting importance which deserves to be investigated from a variety of approaches.

Summary

The incidence of pulmonary embolism in an Oxford hospital population has been studied over the period 1952–61, inclusive. The entire in-patient population of the Radcliffe Infirmary and Churchill Hospital has been examined with the exception of patients admitted to the maternity department.

Throughout the period under review there was a pronounced rise in the number of patients diagnosed as suffering from pulmonary embolism, the number in the last year being approximately five times that in the first year. The total number for the 10-year period was 853.

Approximately one-half of the recorded cases of pulmonary embolism throughout the entire period were fatal, so that there were about four times as many deaths in the last year as in the first.

Although some of the increase in recorded cases may be artificial and represent improved diagnosis, we think it probable that the main reason for the rise in the number of recorded cases is a true increase in the frequency of pulmonary embolism. A particular point is the sharp increase of fatal cases, because the great majority of all patients dying in the Radcliffe Infirmary and Churchill Hospital are examined after death, the figure being more than 95% in every year except one of the period under review.

On the basis of information yielded by the National Hospital In-Patient Enquiry (H.I.P.E.) it has been possible to calculate age-specific rates for the incidence of pulmonary embolism in surgical and medical patients respectively for the second five-year period of the study.

Sex has little influence on the liability to pulmonary embolism. Age has a pronounced influence, and the incidence increases steadily after the age of 50. Medical cases are more liable than surgical cases to suffer from pulmonary embolism in each age-group.

The patients dying from pulmonary embolism have been divided into "inevitable" deaths and "potentially preventable" deaths. The increase in potentially preventable deaths has not been so steep as the increase in total deaths, and this relatively slower rate of increase may represent a partial success of anticoagulant therapy.

With the exclusion of patients who died so quickly that institution of anticoagulant therapy was impracticable, the patients who received anticoagulant therapy had a much lower chance of dying than those not so treated. Although the data are inferior to those obtained in a formal therapeutic trial, they support the idea that anticoagulant therapy is highly beneficial in venous thrombosis.

The various measures which have been employed to treat pulmonary embolism, both prophylactically and after its actual occurrence, are briefly discussed.

The factors leading to pulmonary embolism are likewise discussed and the possibility is raised that the mounting

incidence of pulmonary embolism in hospital is one aspect of an epidemic of thrombotic disease at present affecting Western society.

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CEREBRAL AND PERIPHERAL EMBOLI CAUSED BY CERVICAL RIBS

BY

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Lewis and Pickering (1934), Flint (1937), and Eden (1939) demonstrated that when a cervical rib or abnormal first rib produces complications it does so by direct damage to the third part of the subclavian artery, with subsequent thrombosis. Compression of the artery between the rib and scalenus anterior causes stenosis of the vessel with a post-stenotic dilatation, and the dilated part made prominent by the rib may be damaged by movements of the clavicle. Emboli may break off from the thrombus. Small emboli lodged peripherally cause minimal disturbance. Large emboli lodged in the brachial artery may induce further thrombosis and blockage of the axillary artery, which jeopardizes the fingers, but when the thrombus extends proximal to the damaged third part of the subclavian artery not only are paralysis of the hand muscles and gangrene of the fingers certain but cerebral embolism may also occur.

The common clinical picture of the effects of peripheral emboli is well documented (Rob and Standeven, 1958), but descriptions of cerebral emboli caused by cervical ribs are rare. Thrombosis in the subclavian artery proximal to the site of damage by a cervical rib, causing hemiplegia, was recorded by Symonds (1927) and by Hoobler (1942). Hoobler noted that Gould had recorded an instance in 1884; that Smith in 1941 had described the necropsy findings in a patient whose death had been caused by a cerebral embolus arising from a saccular aneurysm of the right axillary artery, which had blocked the right internal carotid; and that Yates and Guest in 1928 had described the necropsy findings in a patient having a thrombus in the right subclavian artery due to an un-united fracture of the clavicle and an embolus at the division of the basilar artery, which had travelled up the vertebral artery. A further example is described here. So long as the damaged subclavian artery is left *in situ* the patient must be at risk and the injured vessel must be treated as described by Schein *et al.* (1956), Wickham and Martin (1962), and Eastcott (1962).

Case 1

A girl aged 19 (1960) had felt pain in the right shoulder region two years previously and for two months had experienced coldness and numbness of the right hand and forearm, and eventually she lost the use of the limb. A right cervical rib was palpable, pulsation in the subclavian artery was increased and a systolic murmur was present over it, the radial and brachial pulses were impalpable, and the right hand was cool. The blood-pressure in the left arm was 120/80 mm. Hg.

An arteriogram (Fig. 1) showed the subclavian artery arching over a cervical rib and for 3 cm. from this point filling was poor; the axillary artery was of normal calibre, but there was no filling beyond the junction of the upper and middle thirds of the brachial artery.

The scalenus anterior was divided, the distal part of the cervical rib was excised, and the first and second thoracic ganglia were removed, but the subclavian artery (dilated for 2–3 cm. from the level of the inner border of the cervical rib) was left alone. The radial pulse was restored and full function regained. The blood-pressure in each arm was 120/80.

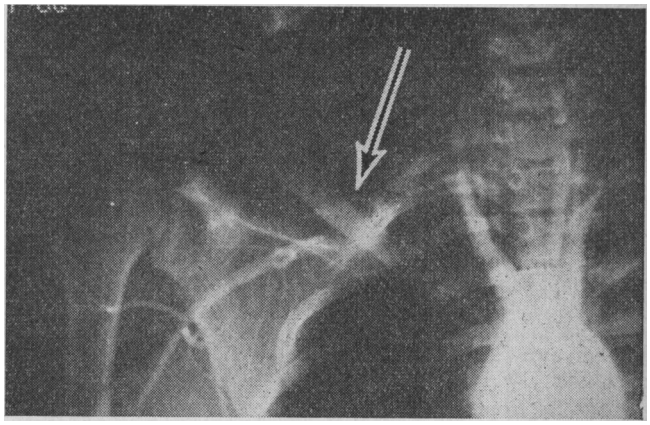

Fig. 1.—Case 1. Arteriogram. The arrow points to site of block.

Case 2

In 1962 a girl aged 17 had for five months experienced tingling in all the finger-tips of the right hand (particularly in the index and middle fingers) and attacks of pain with pallor of the whole hand in cold weather. An unhealed paronychia on the right middle finger had been present for three months. There was general swelling of the right hand, particularly of the index finger, the tip of which was gangrenous; the hand was erythrocyanotic. The right subclavian, brachial, and radial pulses were impalpable. The blood-pressure in the left arm was 120/80. A radiograph showed bilateral cervical ribs. Some days later, after running for a bus, the patient felt dizzy and faint for a few minutes, and in an hour she experienced weakness of the left arm and leg, which recovered; a few hours later, however, weakness of the left face, arm, and leg reappeared and persisted. There was no loss of consciousness. The distribution of the paralysis pointed to a lesion in the