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Etiology and treatment of postoperative pulmonary embolism

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by

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Contents

Introduction

Embolism is the impaction in some part of the vascular system of any undissolved material brought there by the blood current. The transported material is called an embolus. Substances of the most varied character, solid, liquid or gaseous, may enter the circulation and be conveyed as emboli. An embolus is generally understood as a detached thrombus and is the most important source of postoperative pulmonary embolism. Other emboli, such as fragments of diseased heart valves, calcified masses, tumor cells, fat, air, and foreign bodies may give rise to pulmonary complications. Emboli in the lungs come from systemic veins, the right heart or the pulmonary artery. Such emboli may be of any size from that sufficient to give a pulmonary infarction so small that only subjective symptoms would lead to a diagnosis, to that of sufficient size to fill the entire pulmonary artery and cause death within a few minutes.

From the statistical standpoint of view, the incidence of pulmonary embolism seems to be rather low, but just the same the dreadful calamity which is associated with such a complication is in every surgeons mind after most surgical and gynecological operations. The medical doctor fears it in many cases of bacterial infection and certain cardiac diseases. The layman can usually tell you of an incidence where one of his

friends or somebody elses friend had practically recover-
ed from an operation and upon rising from the bed, suddenly
died.

Since pulmonary embolism is a postoperative
complication, with which all surgeons are familiar, and
although occurring in only a small number of operated
cases, the certainty with which death soon follows its
unexpected sudden development, interrupting an other-
wise uneventful convalescence, establishes it as one of
the most dreaded complications. Postoperative pulmon-
ary embolism may be caused by a dislodged thrombus or
the entrance of fat into the circulation. The throm-
botic type is by far the most important source of pul-
monary embolism, and in consequence, only the etiology
and treatment of this type will be considered. Ob-
viously, since embolism is the end result of thrombosis,
factors which may give rise to thrombosis should be con-
sidered and means of preventing their occurrence should
be established. I shall attempt in my paper to cover
all etiological factors which may or may not give rise
to pulmonary embolism, prophylaxis and the Trendelenberg
operation.

Historical Note

The plugging of vessels by foreign bodies
in the blood stream was first brought to the attention of
the medical world by Virchow. His studies were principally
between 1846 to 1856 and were confirmed by numerous
clinical, experimental and postmortem observations by
others, chief among whom were Cohnheim and Cohn. Virchow
first pointed out the importance and significance of the
slowing of the blood stream as an etiological factor of
thrombosis and embolism. There were, however, foreshadowings
of his work as early as the seventeenth and eighteenth
centuries, notably by Bonetus and Van Swieten. Virchow's
work was followed by Cohn and Cohnheim. In 1860 Cohn
published a book which was extraordinarily rich in anatomical,
experimental and clinical facts concerning embolism.
Cohnheim's, "Studies on the Embolic Process", was pub-
lished in 1872. The same year, Zahn first launched the
theory that thrombi were due to localized clumping of
the leucocytes with a secondary fibrin deposit. Eberth and
Schimmelbuch shortly after changed this conception to that of
platelet origin. After and increased knowledge of bacteriology,
Vidal and Vasquez ascribed the cause to thrombi to micro-
organisms as numerous cultures showed micro-organisms to be
often present in the clot. Welch in 1899 published a classical
review of "Thrombosis and Embolism". Conner in 1913,

emphasized the importance of the relation of the coagulation
of the blood to the action of calcium salts and their
relationship to prothrombin. Later Aschoff concluded that
the slowing of the blood stream plus the alteration of the
blood elements themselves, especially the platelets were the
chief factors in the production of thrombosis. It was not
until 1900, that prophylactic measures were instituted against
thrombosis and embolism and in 1908, the first attempt of
extracting an embolus from the pulmonary artery was performed.

Etiology

The surgical calamities of embolism face every surgeon in almost any operation he may perform. They arise without noticeable warning, and the results are heartbreaking. To have a patient, following an interval appendicitis operation, suddenly die on the eve of leaving the hospital is a very disturbing calamity.

Pulmonary embolism may occur as the result of many different morbid conditions. The most important condition seems to be the after-result of an operation. According to many different authorities, the phenomenon may occur at any period after operation up to several weeks.

The question of the etiology of pulmonary is closely bound up with that of thrombosis. Any factor which influences the formation and the dislodgement or breaking down of a thrombus, would consequently be a factor in the etiology of pulmonary embolism. Obviously, a thrombus which is firmly attached to the vessel wall is harmless, and becomes dangerous only when it becomes wholly or partly detached. A detached thrombus if not stopped anywhere along the blood stream will finally reach the right heart and terminate in the pulmonary artery or in the lung substance itself. The following

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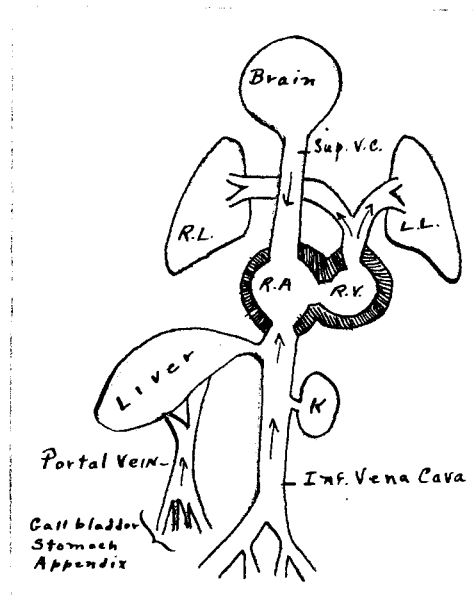factors are concerned in the production of thrombosis:

(1) The slowing of the blood stream. This factor was first pointed out by Virchow in 1846-1856 for its importance and significance. He believed that slowing of the blood stream was the principal factor in the development of thrombi. According to Ochsner and Schneider, Zurheile claims that retardation of the blood stream is the main factor in the production of a thrombus in that the blood platelets pile up mechanically in the more sluggish blood. Aschoff also considers this factor of marked importance. He assumes a slowing and eddying of the venous circulation, most marked in the veins of the leg, the upper part of the femoral veins and the pelvic plexus, with a resulting deposit of blood platelets near the valves. He states, that as a result of operation or disease, these platelets probably are increased in number and have increased power of agglutination. They become adherent to the vessel wall and are augmented with leucocytes and fibrin forming a white thrombus which blocks the vein, followed by the formation of a red clot which extends as far as the next entering vein. Lockhart-Mummery, Rogers, Miller, Wilson, McCartney, DeCourcy as well as many other writers consider slowing of the blood stream a primary factor in venous thrombus and pulmonary embolism. We have venous stasis in varicose veins, but Rogers and Miller conclude from their statistics that such veins are of little or no significance in the incidence of pulmonary embolism. McCartney says that many surgeons attribute the greater frequency of

of post operative thrombosis and embolism after
abdominal operations to the slowing of the venous
circulation in the lower half of the body which results
from the absence of muscular contractions in the ab-
domen and lower extremities. Farr and Spiegel state that
slowing of the blood stream alone is not sufficient to
cause thrombosis, as Baumgarten's experiments have shown
that careful ligation of vessels is not followed by
thrombosis. Besides slowing of the blood stream, they
consider changes in the composition of the blood and toxic
factors as necessary. Lister states that slowing of the
blood stream is due to loss of fluid from purging, vomiting
and hemorrhage; lowering of blood pressure from shock,
morphia or prolonged anesthesia; and posture during operation.
Slowing of the blood stream is apparently a very important
etiological factor, but the works of Farr and Spiegel,
Lockhart-Mummery and the experiments of Baumgarten convince
me that other factors are also necessary in the formation of
a thrombus which may break down and give rise to pulmonary
embolism.

(2) Trauma. This is another important factor,
which many writers consider as necessary in the production
of a thrombus. Ochsner and Schneider state that any changes
such as inflammation, atheroma, calcification necrosis,

tumors, compression and injury which impair or destroy the

smooth surface of the normal inner lining of the vessel,

play and important part in the etiology of thrombosis. The

amount of trauma which may occur depending upon the type of

operation and upon the surgeon has been stressed by many as

being a very important etiologic factor. With trauma,

thrombokinase is released from injured leucocytes, blood

platelets and tissue cells. Thrombokinase is not found

normally in the blood, but is present in other tissues of

the body and is liberated when a wound is made, and is thus

able to enter the blood stream. Farr and Spiegel say that

thrombi depend upon the release of fibrin by the interaction of

fibrinogen, prothrombin and calcium salts in the plasma with

thrombokinase. Lockhart-Mummery concludes that thrombokinase

and slowing of the blood stream are the two necessary factors

in thrombus formation. He found from his series of cases

that operations on the gall-bladder, stomach and appendix

accounted for over half of the cases of pulmonary embolism.

These organs have their veins draining into the portal vein,

yet the embolus which caused death passed into the right auri-

cle and plugged the pulmonary artery. The clot, therefore,

did not come from the operative area, but proably formed in

the large iliac veins or vena cava. With the release of

thrombokinase from the contributing veins, into the stagnated

large venous trunks, they believe, that you have an ideal

environment for thrombus formation. On the other hand, Farr and Spiegel could find no difference in the incidence of pulmonary embolism after operations performed under blunt dissection or under fine dissection. According to Lister trauma to the veins of the abdominal wall by powerful retractors does not seem to cause embolism as operations in which these are used do not carry an undue rate of incidence. If the liberation of thrombokinase from injured cells predisposes to thrombosis, it would seem that such operations as Halstead's amputation of the breast or nephrectomy would show a high rate of embolism as in these more muscle and cellular tissue are exposed than in any operation through the anterior wall of the abdomen, but on the contrary according to the postmortem records examined by Lister, Halstead's operation carries a very low rate of incidence. In the article of Lockhart-Mummery, Professor Collingwood states that if thrombokinase is introduced into a vein, it will produce intravascular clotting if the blood is stationary, but apparently fails to do so if the circulation is active.

The venous circulation in relation to the formation of pulmonary embolism. (Lockhart-Mummery)

(3) Infection. As to this factor, there are
a few writers that go so far as to say that there can
be no thrombosis in the absence of infection. According to Ochsner and Schneider in 1909, Bland-Sutton is
convinced that the formation of thrombi in the great
veins after pelvic operations is due in all cases to
sepsis. McLean considers infection and necrosis or the
toxins derived from an infectious and necrotic process as
probably the most important factors in the production of
a thrombus and considers slowing of the blood stream and
trauma to the blood vessels as contributory factors.
Hampton and Wharton, from their series of gynecological
operations consider infection and trauma as primary factors
and slowing of the blood stream as contributory. Allen (1)
believes that thrombosis and pulmonary embolism is more
prone to occur in cases where there is infection present
at the time of a surgical procedure. Through animal
experiments, Bancroft, Kugelmass and Brown have shown that
there is an increase in the clotting factors of the blood
following postoperative infection and gangrene. Schenck
states that thrombi originate from the conglutination of
blood platelets and red blood corpuscles and that hemolysis
is the most important cause of conglutination. He states that
the most important hemolytic agents are micro-organisms
and many of those which are the least virulent as regards
to sepsis are the most potent as regard to hemolysis. He

cites an example from Heller's and Greifsinald's work,
who found that the colon bacillus has a greater power
than the streptococcus to produce thrombsis in the
presence of a slowing of the blood stream, and believe
that the colon bacillus plays an important part in
thrombosis in the neighborhood of the intestine. Rosenow
concludes from his works, that the diplostreptococcus
isolated from postoperative emboli and thrombi, and used
experimentally in different animals, is the most common
cause of postoperative massive thrombosis, leading to
fatal pulmonary embolism. According to Rosenthal, Dietrich
championed the importance of infection in thrombosis. He
states that a thin layer of a homogeneous substance forms
on the endothelium at the site of the thrombus. This, he
explained, is the result of a sensitization of the en-
dothelium, after which there is a direct reaction between
endothelium and blood to form the thrombus and that
stasis merely acts in localizing the clot. From the same
article, Dietrich, Schroder, Miller, and Rogers have pro-
duced actual thrombosis when suppuration was introduced
with stases. Rosenthal states that in this country there
have been no reports of any increase in infections or in
thrombosis and embolism but in Central Europe with a
higher incidence of infections and suppurations, there is
increased incidence of thrombosis and embolism. According
to McCartney, Kretz is reported to have seen no incidences

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of thrombosis without previous infection in six thousand
five hundred autopsies. On the other hand there are many
writers which do not consider infection as an important
etiological factor. Watson states that sepsis is the
exception, rather than the rule in the causation of
pulmonary embolism. Lockhart-Mummery cannot accept the
belief that embolism is due to infection, since they find
the majority of cases followed by pulmonary embolism are
clean cases in which there is no evidence of infection.
They consider infection contributory only to the extent
that the patient because of more pain keeps much quieter
with infected wounds than with non-infected, the patient's
general health is lowered, and blood changes probably occur
which encourage intravascular clotting. Farr and Spiegel
state that Moller had sixty five cases in which it was
impossible to demonstrate bacteria in the emboli. Ac-
cording to McCartney, Helly is reported to have found two
hundred forty cases of thrombosis in two thousand two hundred
twenty five autopsies from which he was unable to extablish
infectious foci in either sex, and De Quervain is reported
saying that sixty five percent of emboli arise in infectious
fields. Henderson found postoperative infections in sixty
percent of two hundred sixty seven cases of postoperative
embolism. DeCourcy finds that the majority of deaths from
surgical pulmonary embolism occur in non-infected cases and
has been unable to find post-mortem evidences of infection

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after the most careful macroscopic and microscopic studies
of the lesion. He cites two cases that failed to reveal any
evidence of infection. One patient had a surgically clean
inguinal herniotomy and while dressing to go home on the
sixteenth day postoperative, he suddenly collapsed and died.
The other patient had a hysterectomy who showed no signs
of infection and died suddenly on the seventh day. Thrombo-
phlebitis is an infectious postoperative complication which
seemingly may or may not lead to embolic phenomena. Hosoi
states that Cordier from a study of two hundred thirty two
collected cases concluded that phlebitis occurs in about
two percent of all abdominal operations. According to Hosoi's
statistics most of the postoperative femoral thrombo-phlebitis
occurs on the left side. This is thought by many to be due
to the slowing of the blood stream on that side, believed
to be caused by the greater length and obliquity of the
left iliac vein, by pressure of the distended recto-sigmoid on
the iliac veins and by pressure of the right common iliac
artery. In Brown' study of eighty seven cases of post-
operative phlebitis, pulmonary infarction was found to be
a frequent complication but no incidence of fatal pulmonary
embolism was encountered. Miller and Rogers consider
phlebitis as a potential forerunner of pulmonary embolism,
but only to the extent of two and five tenth percent in
their series of two hundred six cases. They consider
phlebitis of slight importance but of definite and

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dangerous significance. Up to the present day, infection
is an open question. In all probability infection plays
a part but cannot be considered a primary factor, as there
are a large number of cases in which infection cannot be
established.

(4) Changes in the composition of the blood.
Allen (2) finds definite changes occurring after opera-
tions, in the erythrocyte and leucocyte count, in the
fatty acid content in obese individuals, in the coag-
ulation time, in the blood calcium content and in the
fibrinogen and pro-thrombin content. Hosoi states that
Andrews and Reuterfield after extensive postoperative
blood chemical studies for twenty-four and thirty-six
hours after operation, found no significant changes in
the leucocytes, blood pressure, temperature, pulse,
blood sugar, water content of blood, chlorides or
carbon dioxides. In every case there was an enormous
rise in the calcium in the blood, accompanied in severe
cases by an equally large fall in the potassium so that
the potassium calcium ratio often fell below one. Bancroft,
Kugelmass and Brown studied eleven cases of proven thrombosis
and embolism and found all of these cases had a high clotting
index and a low antithrombin and in addition a small percentage
of postoperative cases, not proven to have thrombosis or
embolism showed high clotting factors. Miller and Rogers
state that Fahraeus has noted that decreased sedimentation

time of the red blood cells may have some influence in the starting of a thrombus, but there is no definite evidence supporting this statement. Very little work has been done in this field as far as thrombosis and embolism is concerned. Its importance as an etiological factor is of question.

(5) Diet. Mills and Necheles suggest that the protein in diet of postoperative patients because of its specific dynamic action may be an important etiological factor in the production of thrombosis and pulmonary embolism, as the tendency of thrombosis appears during convalescence, usually shortly after the patient has begun to partake a full diet. They found experimentally that there was a marked shortening of the blood clotting time following protein intake and strenuous exercise. They found that pure carbohydrates or fats produced little or no change in the blood coagulability. They believed the change to be due to an increased reactivity of the clotting factors in both platelets and plasma, correlated with the greater cellular activity occurring throughout the body. Hosoi states that from the monographic work of Benedict and Carpenter, it is well known that the specific dynamic action is greatest and more prolonged after protein indigestion than after carbohydrate or fat ingestion. Of the twenty five postoperative cases of Hosoi's series, fourteen were on a general diet at the time of onset of symptoms, eight on soft and three on liquid diets. All those on soft and liquid diets were given foods rich in proteins. He states

that protein may have some etiological relationship to

postoperative thrombosis and embolism but cannot be con-

sidered a dominant factor since all postoperative cases in

the Albany hospital are given relatively the same type of

diet and the incidence of thrombosis of these patients is

very low. Much more work must be done on the etiological

relationship of diet to thrombosis and pulmonary embolism.

(6) Seasonal influence. No reliable conclusions

can be drawn in regards to seasonal influence, as a factor

in the incidence of pulmonary embolism. Hosoi states that

DeQuervain found the highest incidence of pulmonary embolism

in February and March, and on the other hand, states that

Geissendorfer found the highest incidence in May and the

lowest in March. From Hosoi's own series of sixty four cases

of pulmonary embolism in the Albany hospital, the highest

incidence occurred in mid winter and mid summer, but also the

greatest percentage of autopsies occurred during these periods.

Henderson found, according to Mayo Clinic statistics, that there

was some monthly variation during a single year, but that there

was little change from month to month when a period of ten years

was considered. Five cases of pulmonary embolism in the Univer-

sity of Nebraska hospital occurred during the autumn and winter

months. According to Rosenthal, Killian of Freiburg Germany,

stated that during July and August, the dry south winds favored

the formation of thrombi because of the increased prespiration

and evaporation which tends to dehydrate the blood and produce

a slowing of the circulation. He found most cases of thrombosis and embolism to be in October, July, and August and the fewest in June and September. On the contrary, according to Rosenthal, many German authorities such as Fritzsche, Klinke, Geissendorfer, Bauer, and Sarafoff showed that the most cases of thrombosis occurred during the wet, stormy and cold weather. Bauer said that this was due to the fact that there were twice as many illnesses in the winter as in the summer. Fritzche's theory is, that during the wet and stormy weather, the increase of electric charge of the air acts on the autonomic system and influences the vascular mechanism which promotes stasis and leads to thrombosis. Fritzche also states that the present mode of living, results in instability of the autonomic system. Apparently pulmonary embolism may occur during any season of the year, consequently, I do not think that season can be regarded as an influential factor in the incidence of pulmonary embolism.

(7) Sex. All writers seem to agree that sex does not play a part in the incidence of pulmonary embolism. Most statistics show the incidence to be more or less equal in both sexes. There were thirty five males to twenty nine females in Hosoi's series of sixty four cases of pulmonary embolism. Lister's statistics showed the proportion of embolism in the two sexes to be almost the same. In McCartney's series of seventy three cases, there were forty males to thirty three females. There were one hundred sixty women to one hundred fifty three men in Henderson's

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series of three hundred thirteen cases of fatal pulmonary embolism. Of the five cases in the University of Nebraska there were four females and one male, however, the number of cases here are too small to be considered.

(8) Age. Practically all writers consider age as an important etiological factor. Farr and Spiegel conclude from their statistics that no age is immune, but the possibility of fatal outcome from disease, injury or surgical procedures increases with advancing age. Lister states that after thirty years of age the number of cases of pulmonary embolism rises steadily up to seventy years. Henderson found the number of surgical cases who came to necropsy with pulmonary embolism at the Mayo Clinic were patients that were older than the average surgical patient. From his series of three hundred thirteen cases of fatal pulmonary embolism he found the average age to be fifty-three and two tenths years. Watson states that children seem to be immuned and that the great majority of cases occur in patients over forty-five years of age. Lockhart-Mummery states that children never suffer from pulmonary embolism after operation because of their more active circulation which does not allow stasis in the veins. In McCartney's series of seventy three cases, the age varied from nineteen to eighty-three years, the average being above forty years. The age of sixty-one percent of Hosoi's thirty five male cases varied between fifty-one and seventy and seventy-three and three tenths percent of the twenty nine females, varied between forty-one and fifty years of age.

According to other writers in Hosoi's article, Axhausen found
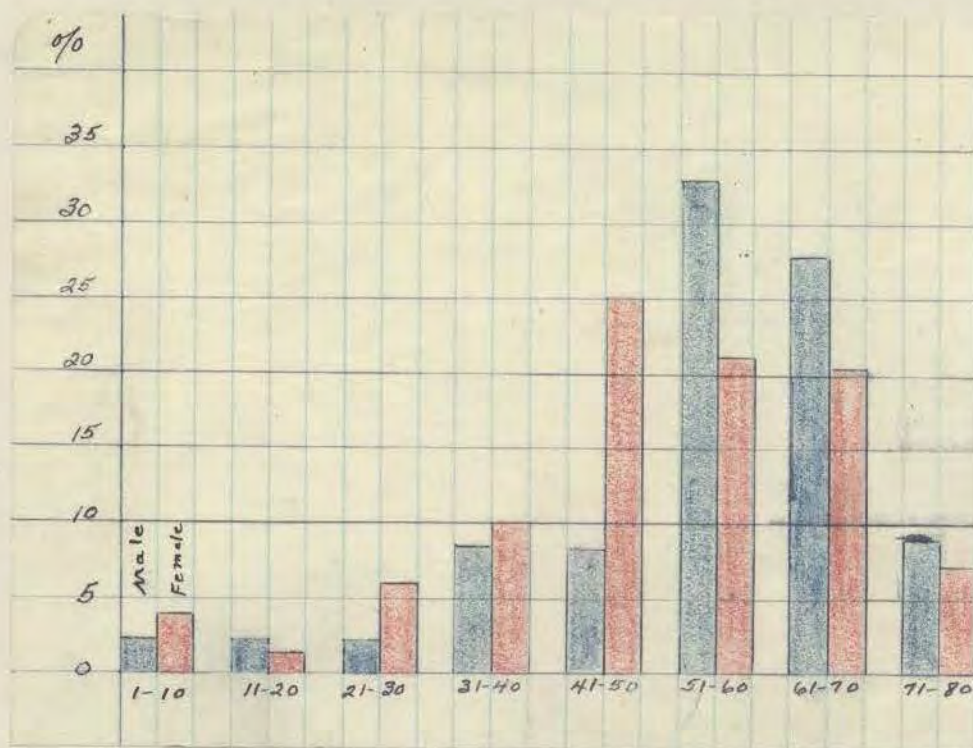
Histogram showing percentage frequency of pulmonary
embolism in each decade for male and female from Hosoi's
series of cases.

the highest age incidence of pulmonary embolism to be in the

sixth decade. DeQuervain, from his cases, found the highest

incidence between fifty and sixty-nine for both male and female

and ninety percent of his patients were over forty years of age.

About two thirds of all cases of both Killian and Gruber, as

cited by Hosoi, occurred after fifty years of age. Hampton and

Wharton found a lower age of incidence, sixty-six percent of their

gynecological cases occurring between the ages of twenty and forty.

Miller and Rogers find that the majority of their one hundred

thirteen cases are fifty years of age or more. Hall finds the

average age of his series to be forty-six. The average of the

five University of Nebraska cases was forty years.

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(9) Constitution. Most writers consider the constitutional make up of a patient as an important etiological factor. According to Snell's statistics taken from the Mayo Clinic, pulmonary embolism following operation seems to be a more common cause of death of the obese patient than of the average patient. Snell believes there is a group of patients over fifty years of age, obese and with normal or subnormal blood pressure who are particularly susceptable to pulmonary embolism as a postoperative complication. Allen (1) states that it is definitely known that obese and elderly individuals have a higher percentage of pulmonary embolism than those of normal weight, possibly because the former do not move so easily and are naturally more lethargic. Patients of such type usually have normal or low blood pressure, with a tendency to slowing of the blood stream which has previously been considered as an important factor in the formation of thrombosis. Henderson states that from his series of three hundred thirteen cases of pulmonary embolism, there was an average of thirteen pounds overweight and that the blood pressure was normal or somewhat subnormal. Rygh claims that patients with weakened heart action and hypotension are undoubtedly more prone to embolism, including chronic myocarditis, secondary anemia, pernicious anemia, Addison's disease, traumatic shock, myasthenia gravis, adiposis dolorosa and cachexia due to tuberculosis or malignant disease. Hellwig states that the coincidence of adiposity and embolism and the occurrence of embolism in families suggest a certain

relationship between constitution and embolism. Since certain
constitutional make ups predispose to slowing of the blood
stream such must be taken into consideration as influential
in the incidence of pulmonary embolism.

(10) Internal Secretion. Hellwig believes that
internal secretion may play an important role in the etiology
of thrombosis. He states that there is almost a complete
absence of embolism after operations for goitre and a
prevalence of embolism during menapause. Other than this, I
have been unable to find any evidence where internal secretion
may be considered as a factor. I might, however, mention here
that Scott and Thatcher reported plugs of mononuclear cells in
vessels of the lungs of double suprarenalectomized rats into
which fifty percent egg albumin in physiologic sodium choloride
solution had been injected. These plugs were not found in rats
with one suprarenal intact which had been similar treated and
killed a few hours after injection. One year later Thatcher and
Robinson observed the same phenomenon and concluded that endothel-
ial phagocytes were active in the formation of the plugs and that
they were not thrombi. Evidently, secretion from suprarenal glands
prevent the formation of these endothelial cell plugs in the
lungs, but cannot be considered as an etiological factor of the
formation of thrombotic processes.

(11) Anesthesia. The length and kind of anesthetic
during an operation has been considered by a few, but only as a
very minor factor in the incidence of pulmonary embolism.

Lockhart-Mummery states that the present methods of anesthesia
which include a preliminary injection of morphine, probably
tend to encourage thrombosis by slowing of the blood stream.
According to Hall's article, Cutter and Hunt in their series
have found pulmonary embolism just as frequently following
local anesthesia as with general anesthesia. From the same
article, Mann, at the Mayo Clinic, in experimenting with dogs
found no difference in the rate of incidence when he injected
artifically formed emboli into the blood stream of dogs who were
weakened by prolonged anesthesia. In that anesthesia tends to
lower the blood pressure, which I have observed in many operations
at the University of Nebraska hospital, and with consequent slowing
of the blood stream, should be considered as a predisposing factor
in the formation of thrombosis.

Primary Site of Thrombosis

The primary site of a thrombus may occur anywhere
in the venous circulation or it may even be primary in the
lung itself in so far as the pulmonary phenomenon is concerned.
(Hosoi). Speaking in general, a thrombus may occur anywhere in the
circulation, but the incidence is far greater in the veins
than in the arteries. Sydney and Barlow believe this to be due
to the greater tendency toward stagnation in the veins, because
of the greater diameter and thinner walls of these vessels.
Lockhart-Mummery states that there are fewer cases of pulmonary
embolism after operations in the upper part of the body than
in the lower, because there is not such a degree of venous stases

in the vena cava, and venous stasis does not occur in the superior vena caca as a free flow of blood through the brain is essential to life. He also states that operations upon the pelvic organs, tend to a greater degree of immobility with consequent stases, both during and after operations elsewhere. Henderson reports from Mayo Clinic statistics that the site of thrombosis was found in one hundred eighty nine of a total series of three hundred thirteen cases of pulmonary embolism. In some instances two or even three of these sites of thrombosis were found in the same case. The four most common sites were the iliac vein in sixty four cases, the femoral vein in fifty five cases, the pelvic vein in forty three and the prostatic plexus in eighteen. Seventy-nine percent of the sites of thrombosis were in these situations. In fourteen percent of these cases, operation had not been performed, in fifteen percent, the operation had been extra abdominal, in twenty-five percent, the operation had been performed in the upper part of the abdomen and in forty-six percent, the operation was performed in the lower part of the abdomen. Only two of the eighteen patients with thrombosis of the prostatic plexus had undergone prostatectomy. These statistics would indicate that the site of operation is not of importance in determining the site of thrombosis and consequent source of emboli. Henderson agrees with Lockhart-Mummery in that such factors as posture, stagnation of blood in dependent parts and decreased movement probably account for the more frequent occurrence of thrombosis in the

veins of the pelvis and lower extremities. In only one case of
Henderson's series was the probable source determined to be in
the subclavian vein and in three cases in the axillary veins.
In McCartney's series of seventy three cases of pulmonary
embolism, the source of emboli was found in forty-five cases,
he also states that DeQervain could not find the primary site
in sixteen percent of his series. Miller and Rogers conclude
from their statistics that the primary thrombus is usually in
the femoral or iliac veins, and on the left side more often then
on the right. In McCartney's cases of postoperative thrombosis
and embolism, the thrombosis was found to lie within the operative
field or distantly removed from it. He found the iliac, femoral,
and pelvic veins to be the most common sites of the primary
thrombosis, and the veins of the left side to be most often in-
volved. His statistics showed that pulmonary embolism usually
followed operations below the level of the diaphragm and only
rarely above the diaphragm and that the phenomenon occurred
most often following operations of the prostate, intestinal and
biliary tracts. According to the statistics collected by Rowntree
from the Mayo Clinic between 1917 and 1926, the incidence of
pulmonary embolism occurred most often after operations on the
stomach, duodenum, gall-bladder and biliary tracts and prostat-
ectomies and less often in cystostomy preliminary to operation
of the prostate and appendicitis. The chief sites for the thrombus
formation was in the iliac veins, femoral, pelvic, prostatic
plexus, vena cava and right auricle of the heart in the order
mentioned. Trinkler found thrombosis of the veins of the lower

extremities in twenty-seven cases of appendicitis, and the thrombi were always found to be on the left side. On the other hand, Bernheim states that he has never seen a fatal case of pulmonary embolism result from thrombosis of the femoral and saphenous veins. He concludes that most of the fatal pulmonary emboli that occur after surgical operations come from thrombi that are concealed, unsuspected and silent. He states it is not the long veins of extremity that are dangerous, but the short ones of the pelvis and neck. Miller and Rogers also find that most instances of fatal pulmonary embolism occur in cases in which there is no evidence of thrombosis and state that an explanation must be found for this clinically hidden thrombus formation. Vietor also finds that pulmonary emboli usually occur without warning and without clinical evidence of a pre-existing thrombosis. Schenck states that it is from the developing thrombus that emboli arise, rather than from the mature thrombus which has formed sufficiently to occlude the vein and produce symptoms, in consequence, thrombosis of the saphenous veins with redness of the skin and palpable veins are never the source of emboli. This statement of Schencks tends to answer the cause of Bernheim's and Miller and Rogers clinically hidden thrombus formation. According to the general view of writers the primary site of thrombus formation are the large veins of the pelvis and lower extremities with envolement usually occurring on the left side.

Fat Embolism

Since fat embolism is a minor cause in the production of
fatal pulmonary embolism, I shall briefly mention some of its
sources and its significance in relation to pulmonary embolism.
Post-traumatic bone injuries is the most common source of fatty
embolism of the lungs, however, fat may also enter the circulation
as the result of injury to any tissue or organs which contain fat.
According to Caldwell and Huber, Buerger in 1910, examined the
lungs of one hundred individuals who had received severe bone
fractures and found emboli of fat lacking in only one case of
severe bone injury. In the same article, Warthin reports, that
in eight fatalities following fractures in his pathological
service on which autopsies were performed, all showed a marked
fatty embolism as the cause of death. Bissel in 1913, states
that death clinically supposed to be due to surgical shock are
due in so far as his experience goes pulmonary embolism. Accord-
ing to Warthin, fat is a common form of embolism but is in the
majority of cases of very little pathological significance. He
states that amputations, fractures, crushing, orthopedic
manipulations, etc., of bones containing fatty marrow are the
most common causes of fatty pulmonary embolism. He also states
that congestion or inflammation of the marrow may lead to fat
embolism and injury to adipose tissue in breat amputations, in
laparotomy, during child birth, in laceration or necrosis of
fatty liver, in destruction of brain tissue, etc., may cause the
entrance of fat into the circulation. He continues to say that

fat droplets floating in the blood stream collect for the greater part in the lung capillaries, and in severe cases the majority of these vessels may be found greatly distended and filled with plugs of oil; death resulting from lung edema. Warthin did his work upon fat embolism in 1931, and since that time very little has been added to the literature. According to Wright in 1932, endogenous fat embolism is almost always the result of physical injury to one or another of the fat depots of the body and that injury, especially fractures of the long bone, is by far the most common cause. He states that there is no parallelism between the extent of trauma and the amount of fat liberated into the circulation, since fatalities are sometimes seen as a result of fracture of a single bone, while in other instances fractures of a number of long bones have not produced symptoms of fat embolism. From the medico-legal standpoint, Milaslavich has recently reported a case where the finding of fat embolism in a body recovered from a burning dwelling was admitted as evidence in court and helped to show that the woman's husband murdered her and then burned the house to conceal the crime. Practically all writers agree that fat is the most common type of emboli, but of the least significance in so much as producing clinical symptoms of pulmonary embolism.

Medical Cases of Pulmonary Embolism

This is an important topic in itself but will only be considered briefly here to show that we can have instances of pulmonary embolism after medical diseases as well as after operative conditions. There are a wide variety of medical conditions which may be complicated by pulmonary embolism. Those recorded by

McCartney are hypertension with cardiac failure, carcinoma of the
lung, nephroma, varicose veins, general paralysis, broncho-
pneumonia, otitis media, prostatic obstruction, pulmonary
tuberculosis and cerebral spinal syphilis. He had sixteen cases of
medical embolism of which six were heart cases all of which were
essential hypertension with cardiac failure. The thrombus was
located in the right auricle in four, in the left common iliac
vein in one and in the vena cava in the other. Of Hosoi's thirty-
six medical cases of pulmonary embolism from the Albany hospital,
fifteen were cardiac patients--six with cardiac infarction, four
with cardiac decompensation, five with vegetative endocarditis
and two with rheumatic pancarditis. Eighteen of the patients
showed evidence of marked bacterial infection somewhere in the
body. Some of the other conditions which were complicated by
pulmonary embolism were carcinoma of ovary, aortic aneurism,
Parkinson's disease and tabes dorsalis. Many writers state that
emboli in the pulmonary artery have been found to consist wholly
of tumor cells, in certain patients who previously suffered from
malignant tumors. Tumor cells were found to obstruct the pulmonary
artery in one of Hosoi's cases of ovarian carcinoma and in a case
of malignant endothelioma primary in the gluteal region. Warren
observed a chondrosarcoma of the sacro-iliac synchondrosis which
apparently gained access to the venous system through the left
hypogastric vein to the common iliac vein and then extending up
into the vena cava, where a considerable portion of the tumor
mass apparently broke away and was sweft by the blood stream into

the left pulmonary artery where it lodged. According to Hosoi,
Schmidt reported several cases of gastric carcinoma where the
smaller branches of the pulmonary artery were occluded with
emboli of tumor cells. Welch has found instances of sudden death
due to the blockage of the pulmonary artery by cancerous and sar-
comatous emboli. Shennan had a case of spindle celled sarcoma of
the mediastinum which extends through the wall of the right side
of the heart and bulged into the auricle. As to frequency of
occurrence, many clinics have found medical embolism to compete
with postoperative embolism.

Treatment

Since the mortality of pulmonary embolism is very high, measures to prevent such a complication would be the important treatment. In those cases, where all measures instituted, have failed to prevent death, the immediate Trendelenberg operation becomes the necessary procedure.

In regarding prophylaxis, measures should be instituted to prevent the formation of thrombosis which is the main forerunner of pulmonary embolism. If thrombosis occurs then measures should be instituted to prevent the detachment or breaking down of such a formation. If the thrombus becomes detached or broken down and the embolus produced is not large enough to cause death, the treatment should be symptomatic, with the patient under very close observation as immediate extraction of the embolus from the pulmonary artery may become necessary at any time, as a last chance of saving the life of the patient. Difficulities arise, however, in determining the right time to operate. The mortality of the Trendelenberg operation, itself, is very high, and a life that might have been saved by symptomatic treatment was destroyed by the operation. Nyer, Nystrom and Westerborn select that time for operation when death is obviously apparent.

Of all the factors which may or may not contribute to the etiology of pulmonary embolism, the outstanding single factor, seems to be the slowing of the blood stream, especially in the large veins of the pelvis. The majority of the clinics agree that the slowing of the blood stream is a necessary factor

but cannot be considered wholly as the only cause, as it alone
cannot cause thrombosis and embolism which was proven by the
experimental work of Baumgarten (Farr and Spiegel). Other
factors such as trauma, changes in the blood plasma, infection
are more or less respected too, certain clinics respecting one
more than the other.

Slowing of the blood stream is a relatively old
factor, as Virchow recognized it as early as the middle of the
nineteenth century. Measures for prevention, however, were not
instituted until the beginning of the twentieth century. The
majority of surgeons at this time were very skeptical and believed
the complications that would arise following operations, in the
attempt of preventing slowing of the blood stream would be far
more marked than the dangers and chances of pulmonary embolism.
occurring. In 1899, as a measure in preventing slowing of the
blood stream, Ries and Boldt, as cited by Schenck, first advocated
the getting of patients out of bed early after operations. Such
a procedure was under much discussion in relation to other
complications which were apt to follow. Klein, quoted by Schenck,
states that early rising of the patients at the University Clinic
in Vienna has reduced the thrombosis morbidity from two percent
to one half of one percent. The Mayo Clinic reduced their per-
centage from two to one fourth of one percent. Kummel of Hamberg
Germany, as cited by Schenck, has had one fifth as many fatal
pulmonary emboli since the adoption of early rising. In the
literature up to 1913, Schenck states that Jayle, Kelling,

Goldmann, Zurhelle, Busse, Brothers and Kuster think that early
rising after operation tends to prevent thrombosis, while on the
other hand Schauts, Von Huff, Veit, Bland-Sutton, Mendel, Sippel,
Lomer, Roth, Zweifel and Fromme, also cited by Schenck, are not
convinced that early rising is of any advantage so far as
thrombosis is concerned. In 1909, Klemperer, as quoted by
Schenck, advocated passive motion of the hips and knees in all
typhoid patients, and has reduced his cases of thrombosis from
ten percent to practically nothing. In 1913, Pool practiced more
extensive systematic postoperative exercises and suggested that
this practice would speed up the circulatory stream and tend to
prevent the formation of thrombosis. The Mayo Clinic has rendered
Pool's postoperative exercises since that time up to the present
day and have in consequence, reduced their percentage of thrombotic
patients.

Symonds, quoted by Heard, states that after he
abanded the enforcement of dorsal position and knee pillows
after laparotomy, except in grave cases of peritonitis, he has
not had a case of pulmonary embolism for years. In 1928, DeCourcy
stated that the use of Fowler's position, except where there is in-
fection and drainage is required, should be avoided, since this
position where the head of the patient's bed is raised eighteen to
twenty inches above the level, favors slowing of the blood in the
pelvic veins. He recommends the reverse Fowler position, where the
patient is allowed to remain flat but the foot of the bed is
raised about six inches and a small fixed pillow is placed under

the small of the back. He also applies heat by means of an arc
lamp and occasionally diathermy at intervals over the abdomen to
facilatate increased circulation. In 1929, Rygh writes an arti-
cle, stating that absolute quietness of the patient after operation
should be avoided. He agrees that the patient should be allowed
to move about in bed. He recommends the Lennander position where
the limbs are elevated and the body flat. (This is similar to
DeCourcy's reverse Fowler position.) Rygh also states that
varicose veins should be eradicated prior to operation, either by
excision or the injection of sclerosing solutions. In 1914,
Kocher and Volker, as quoted by Ochsner and Schneider, believed
that all varices of the leg should be cured before subjecting
patients to major operations. Volker made multiple intermediate
ligations of the varices in the hopes of preventing thrombotic
processes which may break down and cause death by pulmonary embolism.

Most clinics at the present time practice active
movement on the part of the patient and early rising after
operations and have reduced their incidence of thrombosis and
pulmonary embolism enough to advocate the procedure; there are,
however, a few clinics that are still quite skeptical.

Many advocate that slowing of the blood stream,
through faulty position of the patient on the operating table
should be avoided. Thane, according to Ochsner and Schneider
in 1912, suggested the undesirability of the prolonged use of
the Trendelenberg position, where the patient lies on his back
at an incline of forty-five degrees, with his legs and feet

hanging over the edge of the table, which tended to retard the
return flow of the venous blood. In the same article, Zweifel
reports eighteen pulmonary thrombosis deaths in one thousand
thirty-two cases operated upon a table interfering with the veins
of the lower extremities and only three in eight hundred sixty
cases operated upon a table which did not have this feature. In
comparing the two conditions, there was one death out of a
hundred in the former and one in two hundred eighty-six in the
latter procedure. In consequence, Zweifel advises to avoid all
pressure upon the veins of the lower extremities, such as occur
from permitting the legs to hang over the edge of the lower end
of the table in operations in the Trendelenberg position, with
the use of tables which prop the lower end. In this same
article by Ochsner and Schneider, Olshausen is also quoted as
stating to have very gratifying operative results after operating
upon a table where compression of the veins of the legs was avoided.
Lockhart-Mummery also advocates the avoidance of any constrained
position of the patient on the operating table that might cause
pressure on the veins. He believes that the high frequency of
pulmonary embolism after gynecological and gall-bladder surgery
are probably attributable to the unnatural positions in which
the patients are placed. After operation, he advises active
movement on the part of the patient and massage of the lower
extremities.

At the present day the majority of surgeons in due
respect to postoperative thrombosis and embolism avoid improper
positions of the patient on the operating table.

In 1909, Hoehne, Illman-Duncan, and Cleantimesse, according to Schenck, attempted prophylactic medication as a means of combatting thrombosis and embolism. They attempted to lessen the coagulability of the blood by giving citric acid or leech extract. As to their results, I have been unable to find ranything in the literature. According to Trendelenberg, quoted by Myer in 1913, also stated that the coagulation of the blood and recurrence of embolic accident could be avoided by injections of hirudin which is the active principle of the secretion of the buccal glands of leeches. Trendelenberg's assistants found that one milligram of hirudin prevents the coagulation of five cubic centimeters of bloods for four and one half hours. For a patient of average weight one gram would be necessary. This was almost impracticable from the economical stand point, since a gram of hirudin at that time was worth twenty dollars. The drug was injected intravenously in large dosages and proved itself, however, to be harmless. Whether or not such medication has proved to be any advantage from the statistical standpoint I have been unable to learn. Wilson states that postoperative administration of drugs to decrease the coagulability of the blood is of questionable value in so far as thrombosis and embolism are concerned. During the period between 1924 and 1926, Walters performed one thousand seven hundred forty-five major operations, in which thyroid extract was given and the patients were urged to move side to side in bed. No patient less than seventy years of age died from pulmonary embolism. He cites the experimental work of

Shionnya and Rowndtree, who used an extra corporeal loop, in studying the circulation of rabbits. Through their study of the circulation, they noted that thrombosis occurred in the vascular loop from four to ten minutes. When on milligram of thyroxin was administrered daily for three days to each rabbit, thrombosis in the loop did not occur for twenty-five to thirty minutes and the change produced in the blood was sustained for three days. In a later article written by Walters in 1930, four thousand five hundred cases are reported and treated as above. Pulmonary emboli were found in four cases. Three of the patients were more than seventy years of age and had advanced cardiac disease. The other patient was a woman fifty-four years of age and had auricular fibrillation; she died on the sixth day following operation. This patient, however, had only received four grains of thyroxin the preceding day. Walters states that pulmonary embolism is due to decrease in metabolic activity, in blood pressure, and in rate of blood flow and that such conditions may be brought about by rest in bed without food, intestinal quietness after operations and muscular splinting of abdominal wall because of painful incision. In combatting the above factors, he used tablets of dessicated thyroid gland in two grain doses, administered three times daily, in all cases except those in which there has been an abnormal increase in pulse rate and temperature occurring as a spontaneous postoperative reaction. Because of these latter signs which mean an increase in metabolism and flow of blood it was thought

unnecessary to administer the dessicated gland. The dessicated thyroid gland is given as soon after operation as the gastro-intestinal tract tolerates fluids and drugs. This is usually from the second to fourth day and is continued usually until the patient is out of bed. If marked elevation of the pulse rate and temperature occur, it is discontinued sooner. It is also discontinued if the patient becomes nauseated or vomits. Contrary to the good results that Walters obtained from his therapy, Frazer reports two instances of fatal pulmonary embolism in 1932, where thyroid extract had been given daily to both patients from the time of admittance. He states that thyroid extract in these two instances, has proved itself to be an infallible preventative and did not support the claims made in its favor. Under this article in letters of correspondence, Hannon and Smyth suggest that proper technique was undoubtedly not used. Smyth states that in order to obtain the proper effect of the extract, it must be given at least a week before operation. (Walters, however, did not give the extract until the second or fourth day postoperative.) Hannon is convinced of its effectiveness and states that the extract will speed up the circulation very effectively and forms a ready means of attaining the desired end. He states that large dosages of extract are often required and that his technique has been to push the dosage until the pulse rate rises to one hundred twenty beats per minute, at which point sweating and tremor are usually present. Thyroid extract has been used quite extensively in

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Germany and results have been both pro and con in the pre-
vention of thrombosis, and pulmonary embolism.

Wilson stresses as precautionary measures the
reduction of vascular traumatism to a minimum and the encouragement
of early free movement of the patient. He also institutes measures
leading to the reduction of baceremia by eliminating foci of
infection, giving vaccines, etc..

McCann thinks that transfixion of pedicles and
tissue is a cause of pulmonary embolism and warns against
stitching to tightly and cutting into blood vessels. He stresses
the point that vessels should be picked up cleanly and ligated
without encompassing masses of tissue. He recommends the
adoption of a technique and the use of instruments that cause
the least amount of trauma to vessels and surrounding tissue,
stating that he has had no case of embolism since he adopted this
method.

Wyder, cited by Ochsner and Schneider, states that
in cases of operation avoid hematomata, because thrombosis is
readily set up in adjoining veins.

Bidwell in 1909, quoted by Ochsner and Schneider,
gives the following prophylactic treatment for pulmonary
embolism. "If the patient has anemia, treat such before operation.
After operation give excess of fluids, citrates and get patient
up as soon as possible. The coagulation of the blood is
decreased by oxygen, by improving force of circulation, by
alcohol, excess fluids, citric acid, rhubarb, acid fruits, wines,

and tobacco. During the operation avoid risk of injury to the edges of the wound by placing gauze pads beneath retractors and using them as gently as possible. Keep lower bowel unloaded, so as to minimize the interference with the blood stream through the common iliac vein by pressure from the sigmoid."

Schenck (1913) believes that thrombosis is due to the action of hemolytic bacteria acting in conjunction with stagnation of the blood stream and injury to vessel walls. He advocates the following prophylactic treatment. "Make careful examination of veins of the legs, groins and abdomen prior to operation and plan the abdominal incision to miss the superficial veins, for in so doing the deeper vessels will usually not be encountered. During the operation avoid the high Trendelenberg posture in fleshy patients and flexure of the knees to maintain the position; avoid undue injury by large and deep retractors. All veins should be ligated before an infected organ is opened or removed and no vessels should be tied enmasse. Avoid undue cooling of the abdominal cavity and avoid too tight of bandage which cause constriction in the groins. After operation render prophylactic measures to prevent slowing of the blood stream."

Vietor in 1925, recommended the removal of foci of infection and the building up of the general health of the patient before operation. During the operation, he recommends that the patient be placed in a proper position on the operating table, and that too strong a pull on retractors, poor control of stases, undue traumatism of tissues, too tight of suturing and too free use of needles, be avoided. For postoperative treatment he recommends, systematic exercises, as ad-

vocated by Pool and Wilson, and proper care of the intestinal tract. In respect to other authors who attribute the dislodgement of a clot due to the passage of a hard feces through the sigmoid and rectum over the iliac vessels, he advises against straining of hard formed feces.

Henderson in 1927, agrees that in order to obviate thrombosis in the veins, patients are encouraged to change their positions often and early passive and active movement of the extremities are instituted. His patients are encouraged to breathe deeply since the principal force causing blood to flow through the large abdominal veins is the negative pressure created in the chest during inspiration. In order to splint the abdomen and facilatate deep breathing in patients who on account of age or obesity are regarded as being more susceptable to embolism (Snell) are supplied with elastic abdominal belts.

Rygh in 1929, recognized the importance of preventing weak heart action and hypotension. To prevent shock from operation, fluids are given, anesthetic is carefully given, patient is kept warm, and proper hemostasis and gentle handling of the tissues are instituted. In cases associated with chronic myocarditis, digitalis is effected and foci of infection removed. In secondary anemia and cachexia, blood transfusions, forcing of fluids and digitalis are employed prior to operation. Pelvic stasis is prevented by avoiding absolute quietness of the patient, by allowing deep breathing and movement on the part of the patient.

In cases of suspected thrombosis, Welch recommends absolute

rest, suitable position, immobilization of the thrombosed part and a nourishing diet to ward off pulmonary embolism. Palpation of the affected limb should be of the gentlest sort or better omitted altogether. The patient should not be allowed to walk in less than forty days. After the danger of embolism has passed, he states that massage and bandaging may be employed. Ochsner and Schneider agree with Welch that elastic bandaging, massage and movements of the patient should not be allowed in suspected cases of thrombosis. They state that the patient should not sit up in bed and that straining at the stool should be avoided by the use of proper cathartics, and that rest in bed is mandatory as long as symptoms of thromosis are present and that the patient should remain in bed several days even after the symptoms have disappeared.

Treatment in cases of suspected thrombosis as practiced by Welch, Ochsner and Schneider, is similarly practised at the present day in due respect to emboli which may detach themselves and produce sudden tragic death by blocking the pulmonary artery.

Upon the detachment or breaking down of a thrombotic process, followed by the occurrence of pulmonary embolism, Wyder, according to Ochsner and Schneider advocate the rapid administration of therapeutic measures. He recommends subcutaneous injections of ether and camphor oil. He states that von Kenezy gave ether injections every hour for two days and claims that the patient felt definite alleviation after each injection, and that Oeder gave two tenths grams of camphor every five minutes and claims a recovery with this.

Wyder also states that caffein and digitalis may be given intravenously. He also states that two hundredths of a gram of morphia will counteract shock and if death supervenes, makes this less painful. After infarction, which is due to small emboli restricting the blood supply to small areas of lung tissue, he combats the dyspnoea and distress produced by opiates. He does not hold artificial respiration as useful because death does not occur from respiratory obstruction but rather from lack of oxygen in the blood. Bidwell, also quoted by Ochsner and Schneider, states that he prolonged in one case, a life fifteen hours after total obstruction of the right pulmonary artery, by giving oxygen, strychnine and saline injections. This, however, seems to me improbable, because I do not believe that Bidwell had any means of determining how long this artery was completely blocked. Heard states that when death does not follow immediately with first symptoms of pulmonary embolism, the patient should be elevated to favor respiration. Oxygen inhalations may be given and rapid stimlulation with caffein, camphor, strychnine, ammonia and ether may be given. Lockhart-Mummery states that stimulants are contra-indicated, as they tend to increase the pressure in front of the heart. To relieve this pressure he recommends amyl nitrate which will dilate the vessels.

After all efforts of medical therapy have failed in the hopes of preserving the life of the unfortunate victim of pulmonary embolism, Trendlenberg, as a last resort, advocates immediate extraction of the embolus from the pulmonary artery.

According to Meyer, Trendelenberg distinguishes three classes of pulmonary embolism. (1) The one causing immediate exitus.

(2) The one causing death within a few minutes. (3) The one of protracted course. The third class furnishes cases with indication for operation and the task of establishing this indication is rendered difficult on account of the experience that some of these patients get better under conservative treatment. Trendelenberg considers operation imperative if medical treatment fails to bring improvement. Trendelenberg first practised in extracting emboli from the pulmonary artery of calves. A piece of lung, one centimeter thick and fifteen centimeters long, under aseptic conditions was introduced through the deep jugular vein of a calf into the circulation. As soon as symptoms of pulmonary embolism became manifest, access to the pulmonary artery was obtained and the artificial embolus was removed. The calf was eight weeks old and recovered from the operation. (Dec. 1907) Later in the year, he had the opportunity of applying the operation upon a man forty-five years of age. One embolus was removed and the patient lived until the next day, when autopsy showed that a second embolus had been overlooked. The same year Sievers, an assistant of Trendelenberg, removed two emboli, one fifteen centimeters and the other thirty-one centimeters long. The operation was satisfactorily completed and the patient lived fifteen hours. The operation, as described by Myer, is as follows: "A horizontal incision about ten centimeters long is made upon the left second rib, beginning at the left border of the sternum and dividing skin, fascia, and fibers of the pectoralis major muscle. This is crossed by a perpendicular cut which starts right below the sterno-clavicular articulation and passes the cartilage of the third rib about one inch outside of the sternal border; it avoids the left

internal mammary artery. The two triangular flaps with underlying

muscle are turned back, isolation and division of the second rib out-

wardly. In raising and twisting its sternal portion the cartilage

breaks; this portion of the rib is removed; division of the third

cartilage in a perpendicular line. Usually by this time the pleura

has been opened and the use of differential pressure is welcome,

provided time and a sufficient number of assistants are at the surgeon's

disposal. If the pleura has not been opened an incision corresponding

to the outer one has to be made. The lung is allowed to collapse some-

what and thereby the pericardium exposed. Upon it the phrenic nerve

with phrenic vessels becomes visible. Inwardly of the same the

pericardium is incised at the level of the third rib and the wound

lengthened in an upward and backward direction until the entire upper

half of the pericardium is divided; the lower half remains closed and

the heart itself in its normal position. All this can be well done

within five minutes. A rubber tube with the help of Trendelenberg's

sound is then drawn through the transverse sinus of the pericardium

around the ascending aorta and pulmonary artery, held, and pulled upon

for compression by an assistant, immediately before the surgeon puntures

the vessel with a sharp bistoury. A one half inch wound is made. With-

out a moments loss of time, a specially curved, blunt forceps is

introduced, first into the main artery, then into its branches, the

thrombus or thrombi grasped and extracted. Only forty-five seconds are

at the disposal of the surgeon for this, the principal part of the

operation, since observations have shown that the interruption of the

circulation in this part of the body is not tolerated longer. Now the

lips of the vessel wound are lifted by special forceps and temporarily
closed by a clamp after which the assistant interrupts the elastic
compression. Circulation, therewith, having been re-established, the
heart immediately begins to work, often violently, if the patient has
not died before."

Up to the present time there have only been some thirty
operations for pulmonary embolism, which have been published or briefly
mentioned in the literture. Nystrom states that in all probability,
there have been many more such operations performed, but because of
unsuccessful attempts have been regarded as not meriting publication.

Since 1908, I have only found seventeen cases reported in
the literature that have survived the operation. Eight of the cases
survived only a few hours or few days, one survived a month, and eight
recovered entirely.

In 1908, Trendelenberg and Sievers had two cases that sur-
vived the operation for thirty-seven and fifteen hours respectively.

In 1909, Kruger, according to Nystrom, had one case that
survived the operation for five and one fourth days.

In 1914, Schumacher and Sauerbruch, according to Nystrom,
had a case that survived the operation for fifty hours.

In 1924, Kirchner, according to Nystrom and Myer, was the
first one to perform a successful Trendelenberg operation, after which
the patient was discharged healed. Kirchner performed the operation
upon a young woman who undoubtly had a strong, healthy heart and was
able to withstand the great shock of the original Trendelenberg
operation.

In 1925, Myer's first attempt to save a patient dying of embolism of the lungs was unsuccessful, but in consequence, he recognized the need of certain modifications of the Trendelenberg operation. He learned that opening the pleura, as Trendelenberg had done, implied the infliction of a stupendous shock upon the already injured heart; that the Trendelenberg sound and clip must be improved, and that the strangulation period of forty-five seconds caused by the introduction of the rubber tube around the great vessels puts too much strain upon the already laboring dilated heart, and that this period of strangulation evidently induces a paralysis of the respiratory centers which becomes irreparable. After Myer constructed a pulmonary artery clip with weaker and narrower branches so as to restrict the side stream of blood as little as possible and reduced the size of Trendelenberg's sound which caused great inconvenience when it was inserted, he saved the life of his next two victims upon whom he operated by using these improvements and reaching the pulmonary artery through an extra pleural route. The first patient was fifty-four years of age and had a gynecological operation, six days previous to the onset of severe embolism of the lungs. The Trendelenberg operation as modified by Myer was performed. During the operation the patient's heart began to beat more feebly and the breathing became more labored. At this moment the operator had a happy inspiration and squeezed the slit in the pulmonary artery between the thumb and forefinger. This made it possible for the blood to circulate more freely, since the rubber tube which was compressing the large vessels could be released. At once there was improvement of the heart beat and respiration. After the heart action

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had greatly improved investigation for emboli was continued. Again the heart became more labored and began to flutter; respirations ceased. Djialoszynski, a doctor present at the operation, suggested giving carbon dioxide, and after this was given the patient drew a deep breath and the heart beats became more regular. After the operation was completed the woman had revived sufficiently to cry out in pain. After a number of days she made a complete recovery. Meyer's other patient was a woman sixty years of age who twenty days previous to her attack of pulmonary embolism was operated upon for a gangrenous appendix. For the pulmonary complication, the Trendelenberg operation as modified, was performed. The woman survived for four months at which time she died of another embolus which unfortunately occurred when Myer was absent.

The same year 1925, Crafoord, according to Myer, performed two successful Trendelenberg operations where both patients survived the operation and were discharged healed. Whether Crafoord used the original Trendelenberg operation or the one modified by Myer, I have been unable to learn.

In 1927, Nystrom performed two Trendelenberg operations as modified by Meyer and with a few added features of his own at the University hospital at Uppsala, Sweden. His first case survived thirty hours after the operation. The patient was a female, forty-eight years of age who suddenly became inflicted with pulmonary embolism twenty-one days after a hemorrhoidectomy. His second case was a female, forty-five years of age who had a cholecystectomy for cholelithiasis, ten days previous to her unfortunate attack of pulmonary

embolism. The attack did not call for immediate operation. Three days later, however, the attack reoccurred and the patient became markedly dyspnoeic and cyanotic. The Trendelenberg operation as modified was immediately performed. The patient survived the operation for five hours. Postmortem showed that a second embolus had occurred.

The following year, 1928, Nystrom had his first case that was discharge healed after the operation. The patient was a male, aged thirty-five who had an acute gangrenous appendix removed, followed by the embolic phenomenon.

The same year, 1928, Myer claims a third successful operation where the patient was discharged healed, counting the one that survived one month after operation. The patient was a female who developed a pulmonary embolism ten days after an operation for a ruptured tumor.

In 1929, Nystrom performed the operation upon a patient with wrong diagnosis. The patient had uremia and survived the operation for three hours. During the same year, Nystrom performed another operation where the patient was discharged healed. The operation was performed upon a female, aged forty-six who previously had been operated upon for an acute catarrhal appendix. The pulmonic complication occurred twenty-one days later.

In 1930, Westerborn performed a successful Trendelenberg operation at Uppsala, Sweden where the patient succumbed the next day. He endeavored to use the modified Trendelenberg as described by Myer, and found his greatest difficulty in preserving the pleura. He states that the pleura is thin and easily injured and if the pleura is to be kept intact, the ribs to be resected must be carefully detached. He says that this may take a good deal of time and considers it more

important to carry out the operation rapidly, even at the risk of injuring the pleura, than to lose time in carefully freeing it, when the patient is already almost in agony. In all other cases, however, he considers it necessary to avoid injuring the pleura. Nystrom states that Myer is entirely right in insisting for an operation without the opening of the pleura, but is under estimating the difficulties of avoiding injury to the pleura. Nystrom, however, had two successful cases with permanent recovery in which the pleura was accidently injured.

Every large hospital, I think should have machinery to cope with a massive pulmonary embolism and the Trendelenberg operation should be attempted in those cases where death is obviously apparent, by properly trained surgeons and assistants.

With progress, from experience with the Trendelenberg operation, the mortality of the operation would undoubtedly be reduced and many lives of unfortunate pulmonary embolic victims who have heretofore been given up as hopeless could be spared in the light of the operation.

SUMMARY

Etiology -- On the whole, the definite etiology of
pulmonary embolism is not as yet, fully understood. Changes in the
blood plasma and slowing of the blood stream are two factors which are
more or less generally accepted as being essential in the formation of
trombosis, which is the important forerunner of pulmonary embolism.

Infection is a factor which is more or less upon the fence.
Much more work must be done before infection can be definitely
established or ruled out as etiological factor. A point to remember,
however, is that aseptic surgery has not decreased the incidence of
pulmonary embolism.

Trauma is a factor more or less accepted, as most clinics
are convinced that trauma predisposes to changes in the blood plasma
which favors coagulation.

Diet, because of its specific dynamic action may cause
changes in the blood that favors thrombosis, but this has not been
definitely proven.

Sex does not influence the incidence of pulmonary embolism,
as both sexes are equally susceptable.

Age is a factor considered by practically all clinics as
being very influential to the incidence of pulmonary embolism.
Children are found to be practically immuned and with increasing age
the incidence of pulmonary embolism becomes higher.

The constitutional make up of a patient undoubtedly has
some influence upon the incidence of pulmonary embolism. Obese patients,
who are more or less sluggish in nature, show a greater tendency to

pulmonary embolism as was shown by Snell. Most clinics find that the incidence of pulmonary embolism is higher in those patients who are overweight and have a normal or subnormal blood pressure. Such factors predispose to slowing of the blood stream which is considered an important etiological factor in the formation of thrombosis.

Internal secretion, in so much as hyperthyroidism is concerned, probably influences the incidence of pulmonary embolism, as most clinics find that such postoperative cases are practically never victims of pulmonary embolism. This is explained on the grounds that there is increased metabolism and rate of blood flow in this disease.

The type and length of anesthetic is only considered by a few as having little or not effect on the incidence of pulmonary embolism. We know that the present day type of anesthesia tends to lower the blood pressure with a consequent decrease in rate of blood flow which would predispose to thrombosis. Its effect, however, on the incidence of pulmonary embolism has not been measured statistically.

Most authorities agree that the primary site of thrombosis is found most often on the left side in the larger veins of the pelvis and lower extremities, as there is a greater tendency of blood stagnation in these locations.

Fat embolism was briefly mentioned because of its frequency following post-traumatic bone and fatty tissue injuries.

Medical embolism is a topic that could have with-held much more discussion than I gave it. It was mentioned simply to demonstrate the fact, that tragic pulmonary embolic deaths may occur after certain infections and cardiac disorders as well as postoperative cases.

Treatment -- Prophylactic measures are instituted
before, during and after operations. Before operation, the
general condition of the patient is improved by tonics,
blood transfusions, removal of focal infections, etc., to
meet the requirements of a good surgical risk. During operation,
care is taken to avoid those positions of the patient upon
the operating table which favor stasis in the veins of the
pelvis and lower extremities. Most surgeons aim to work
aseptically and avoid undue injury to the blood vessels. After
operation, most surgeons agree to active movement on the part
of the patient and early rising from the bed. Many, however,
are skeptical to this procedure, stating that other complications
must also be thought of. Many have advocated medical
therapeutics, such that reduce the coagulability of the
blood and increase its rate of flow. The use of intravenous
leech extract for reducing coagulation was found to be harmless
but rather impracticable from the economic standpoint. The
recent use of thyroid extract to increase metabolism and rate
of blood flow as advocated by Walters influenced markedly the
incidence of pulmonary embolism in his four thousand five
hundred postoperative cases. Many have obtained good results
with thyroid extract while a few have not.

In cases where pulmonary embolism has occurred,
symptomatic treatment is rendered. Patient is usually elevated
to favor respiration and oxygen inhalations are sometime given.

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Stimulants are usually given and opiates to relieve the pain.

There have been some thirty Trendelenberg operations performed. There have been seventeen cases reported who have survived the operation,- nine dying within a few hours or days and eight completely healed. In 1908, the operation as performed by Trendelenberg was unsuccessful to the extent that his patient died thirty-seven hours later. Kirchman in 1924, was the first to have a patient discharged after using the origianl Trendelenberg operation. Since, Crafoord has had two, Meyer two, and Nystrom three, recovering completely from the operation after slight modification.

Bibliography

1. Allen, A. W. : Embolism. Nelson, 4:544-547

2. Allen, E. V. : Changes in the Blood Stream Following Operation.
   Arch. Surg., 15:254-264, 1927

3. Armentrout, W. A. : Embolism and Thrombosis. Arch. Path., 11:519-
   545, 1931

4. Aschoff, L. : Thrombosis and Embolism. Lectures on Pathology,
   253-278, 1924

5. Bancroft, F. W., Kugelmass, I. N., Brown, M. : Evaluation of
   Blood Clotting Factors in Surgical Diseases.
   Ann. Surg., 90:161-189, 1929

6. Bernheim, B. M. : Fatal Emboli from Thrombosis of Great Blood
   Vessels. So. Med. Jour., 22:464-466, 1929

7. Bissel, W. W. : Pulmonary Fat Embolism. Surg., Gynec., & Obstet.,
   25:8-22, 1917

8. Brown, G. E. : Postoperative Phlebitis. Arch. Surg., 14:245-253, 1927

9. Cutler, E. C. and Morton, J. J. : Postoperative Pulmonary
   Complications, Surg., Gynec., & Obstet.,
   25:621-649, 1917

10. DeCourcy, L. J. : Postoperative Embolism. Intern. Jour. Med.
    & Surg., 41:179-183, 1928

11. Farr, C. E. and Spiegel, R. : Pulmonary Infarction and Em-
    bolism. Ann. Surg., 89:481-511, 1929

12. Frazer, I. : Thyroid Extract and Embolus. Brit. Med. Jour.,
    1:659, 1932

13. Fuller, C. J. : An Analysis of Postoperative Pulmonary Com-
    plications. Lancet., 218:115-121, 1930

14. Glynn, E. : Embolism and Thrombosis. Brit. Med. Jour.,
    1:323, 1924

15. Gordon, W. S. : Embolism. Sojous's Anal. Cyclo. Pract.,
    Med., 4:443-446

16. Hall, L. S. : Pulmonary Embolism. Ann. Surg., 87:528-535,
    1928

17. Hampton, H. and Wharton, L. R. : Venous Thrombosis, Pulmonary
    Infarction and Embolism Following Gynecological
    Operations. Bull. Johns Hopkin Hosp., 31:95-117,
    1920

18. Heard, J. E. : Postoperative Pulmonary Embolism. New Orlean's
                Med. & Surg. Jour., 76:451-459, 1924

19. Henderson, E. F. : Fatal Pulmonary Embolism. Arch. Surg.,
                15:231-236, 1927

20. Hillwig, C. A. : Fatal Pulmonary Embolism. Arch. Path.,
                13:331-332, 1932

21. Hosoi, K. : Embolism and Infaction. Ann. Surg., 95:67-92, 1932

22. Kilbourne, N. J. : Treatment of Varicose Veins of the Legs
                J. A. M. A., 92:1320, 1929

23. Lister, W. A. : A. Statistical Investigation into the Causation
                of Pulmonary Embolism Following Operation.
                Lancet, 212:111-116, 1927

24. Lockhart-Mummery : Discussion on Postoperative Pulmonary Embolism.
                Brit. Med. Jour., 2:850-854, 1924

25. McCann, F. : Suggestions for the Prevention of Postoperative
                Thrombosis and Embolism. Brit. Med. Jour., 1:277,
                1918

26. McCartney, J. S. : Pulmonary Embolism. Arch. Path., 3:921-937,
                1927

27. McLean, A. : Thrombosis and Embolism. Surg., Gynec. & Obstet.,
                20:457-461, 1915

28. Mastas, R. : Postoperative Pulmonary Embolism and the Revival of
                Arterial Embolectomy and the Trendelenberg Operation
                in Scandinavia and Germany. Am. Jour. Surg.,
                8:1293-1297, 1930

29. Meyer, W. : Surgery of the Pulmonary Artery. Tr. Am. Surg. Ass.,
                31:223-248, 1913

30. Meyer, W. : The Operative Treatment of Embolism of the Lungs.
                Surg., Gynec. & Obstet., 50:891-898, 1930

31. Milaslavich, E. L. : Fat Embolism. Wis. Med. Jour., 29:139, 1930

32. Miller, R. H. and Rogers, H. : Postoperative Embolism and
                Phlebitis. J.A.M.A., 93:1452-1456, 1929

33. Mills, C. A. and Necheles, H. : Specific Dynamic Action of
                Food and Blood Coagulability. Proc. Soc. Exper.
                Biol. Med., 25:195-196, 1927

34. Nystrom, G. : Experiences with Trendelenberg Operation for

Pulmonary Embolism. Ann. Surg. 92:498-532, 1930

35. Ochsner, A. J. and Schneider, C. C. : Fatal Postoperative Pulmonary Thrombosis. Ann Surg., 72:91-107, 1920

36. Pool, E. H. : Systematic Exercises in Postoperative Treatment. J.A.M.A., 60:1202-1204, 1913

37. Rosenow, E. C., : A. Bacteriologic Study of Pulmonary Embolism. Jour. Infect. Dis., 40:389-398, 1927

38. Rosenthal, S. R. : Thrombosis and Fatal Pulmonary Embolism. Arch. Path., 14:215-235, 1932

39. Rowntree, L. G. : Cardio-vascular Complications and their Relation to Surgery. Surg., Gynec., & Obstet., 47:17-19, 1928

40. Rygh, E. A. : Fatal Pulmonary Embolism with Special Regard to Prophylactic Measures. Am. Jour. Surg., 7:245-248, 1929

41. Schenck, B. R. : Thrombosis and Embolism Following Operation and Childbirth. Surg., Gynec., & Obstet., 17: 603-610, 1913

42. Scott, W. J. M. and Thatcher, H. S. : Pulmonary Emboli in Suprarenal Insufficiency. Arch. Path., 2:806-814, 1926

43. Shennan, T. : Tumors of Mediastinum and Lung. Jour. Path. Bact., 31:365-402, 1928

44. Snell, A. M. : The Relation of Obesity to Fatal Postoperative Pulmonary Embolism. Arch, Surg., 15:237-244, 1927

45. Speed, K. : Postoperative Pulmonary Embolism. Ann. Surg., 85:44-53, 1927

46. Strauss, M. : Lungenembolie als Spatum fallsfolge. Beitr. z. klin. Chir., 88:637-640, 1914

47. Sydney, W. and Barlow, L. : Embolism. Ency. Brit., 24:162-163, (Edition 14)

48. Thatcher, H. S. and Robinson, B. L. : Origin of Pulmonary Plugs in Suprarenalectomized Rats. Arch. Path., 4:974-978, 1927

49. Trendelenberg, F. : Zur Operation der Embolie der Lungenarterien.

Zentralbl. f. Chir., 1:92-94, 1908

50. Trinkler, N. : Beitrage zur Enstetrung der Thromein in den
Venen der unteren Extremitat vorzug weise
der linken. Arch. f. klin. Chir., 120:653-
657, 1922

51.Vietor, J. A. : Clinical Considerations of Thrombosis and
Embolism. Ann. Surg., 82:193-198, 1925

52.Walters, W. : The Suggested Use of Thyroid Extract to Reduce
the Incidence of Postoperative Pulmonary
Embolism. Sur., Gynec., & Obstet., 50:154-157,
1930

53. Walters, W. : A. Method of Reducing the Incidence of Post-
operative Pulmonary Embolism. Minn. Med.
10:25-28, 1927

54. Warren, S. : Chondrosarcom with Intravascular Growth and
Tumor Emboli to Lungs. Am. Jour. Path.,
7:161-167, 1931

55. Warthin, A. S. : Fat Embolism, Ref. Hand. Med. Sc., 3:920-921,
1927

56.Watson, G. C. : Pulmonary Embolism after Operations. Practitioner,
108:381-393, 1922

57. Welch, W. H. : Embolism. Papers and Addresses, 1:193-258, 1920

58. Westerborn, A. : Trendelenberg Operation for Pulmonary
Embolism, Ann. Surg., 93:816-818, 1931

59. Wilson, L. B. : Fatal Postoperative Embolism. Ann. Surg.,
56:809-817, 1912

60. Wright, R. B. : Fat Embolism. Ann. Surg., 96:75-83, 1932