Limitations in the Feasibility of Pulmonary Embolectomy

A Clinicopathologic Study of 101 Cases of Massive Pulmonary Embolism

By Ray W. Gifford, Jr., M.D., and Laurence K. Groves, M.D.

SUMMARY

Of 101 patients who had major pulmonary emboli confirmed at autopsy, 44 died within 1 hour of the onset of symptoms; 26 had no abrupt change in the clinical course to indicate the presence of emboli; and three died while they were under anesthesia. Of the 28 patients who survived for more than 1 hour after onset of symptoms, seven had incurable malignant lesions, four were unconscious with irreversible brain damage, six were too ill from other diseases to undergo embolectomy, and the diagnosis was not suspected for five. Consequently, of the 101 patients only six have been selected to undergo pulmonary embolectomy. Only by increasing our diagnostic acumen and by obtaining pulmonary angiograms as soon as possible after onset of symptoms can this salvage rate be improved.

Additional Indexing Words:
Pulmonary angiography  Pulmonary infarction  Shock  Sudden death  Thrombophlebitis

BECAUSE of recent enthusiasm for pulmonary embolectomy, this study was undertaken to estimate the percentage of patients with massive pulmonary embolism who might be appropriate subjects for embolectomy.

Methods

A review of the records of postmortem examinations performed at the Cleveland Clinic Hospital from January 1955 to July 1966 revealed 101 cases of major pulmonary emboli. In 47 cases the main pulmonary artery or its two branches or both contained large emboli. In 17 cases either the right or left pulmonary artery, but not both arteries, contained occlusive emboli. In 37 cases only one or more lobar branches were occluded. Although experimental observations in animals as well as measurements of pulmonary arterial pressure in humans during balloon occlusion either of the right or of the left pulmonary artery or after pneumonectomy indicate that more than 50% of the cross-sectional area of the pulmonary arterial tree must be occluded by large emboli before significant hemodynamic changes occur, we included in our study cases of lesser embolic occlusion for the following reasons:

1. In some of the cases no other cause for sudden death could be ascertained at necropsy, and the mode of death strongly suggested embolization. In a clinical setting, those patients would have to be considered for embolectomy. The decision regarding surgical treatment would then be made after pulmonary angiography.

2. It is possible that multiple micro-emboli may have been overlooked in some of these cases at postmortem examination. In this situation, one or two emboli to lobar branches might be critically important. Similarly, an embolus to one branch of the main pulmonary artery or to one or more lobar branches might be fatal if the patient had pre-existing cardiac or pulmonary disease.

3. There is evidence from animal experiments as well as from observations in humans to indicate that small pulmonary emboli may produce severe, if not fatal, hemodynamic alterations, presumably owing to reflex mechanisms or to the release of serotonin from the embolus.
At postmortem examination, the heart and lungs were removed from the thoracic cavity en bloc. The main pulmonary artery and its major branches were opened longitudinally with scissors down to and including the branches of the lobar arteries before the cardiac chambers were examined.

Because emboli are sometimes adherent to the pulmonary arteries, the postmortem protocols were carefully reviewed by a thoracic surgeon (L.K.G.) to judge from the prospector's description whether embolectomy would or would not have been technically feasible.

Clinical data from the patient's chart were correlated with the postmortem findings to determine which patients would have been suitable subjects for embolectomy. In the majority of cases the clinical records accurately described the nature and duration of the patients' terminal episodes. Usually there was good correlation between the clinical events and the postmortem findings, leaving little doubt that massive pulmonary embolism was the cause of death. In some cases it was impossible from reviewing the record to document any sudden change in the clinical course of a seriously ill patient, and it is very likely that the pulmonary embolus found at postmortem examination in these patients was no more than a contributing cause of death. Most of these patients had emboli in only one or two lobar arteries and the postmortem examination usually revealed major pathology in addition to the emboli. These cases will be categorized separately in the tabulation of data.

Results

Sex and Age

There were 65 men and 36 women in the group of patients whose records were reviewed (table 1). Fifty-five percent of the men and 67% of the women were older than 60 years of age at the time of death. Only three patients, all men, were younger than 40 years of age at the time of death.

Predisposing Factors

Fifty-one patients died after one or more surgical procedures, whereas 50 had pulmonary emboli that complicated medical illnesses (table 2). Of the 101 patients, 21 had malignant neoplasms or lymphomas. Operations on the aorta or peripheral arteries or both, were the predisposing factor in 20 of the patients with postoperative pulmonary emboli, while 13 of the patients with medical illnesses had cardiac disease.

<table>
<thead>
<tr>
<th>Sex and Age of 101 Patients with Massive Pulmonary Embolism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at death (yr)</td>
</tr>
<tr>
<td>&lt;20</td>
</tr>
<tr>
<td>20-40</td>
</tr>
<tr>
<td>41-60</td>
</tr>
<tr>
<td>61-80</td>
</tr>
<tr>
<td>&gt;80</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Of 51 patients who had pulmonary emboli postoperatively three died on the day of operation, before they had recovered from the anesthetic, and 20 died between the first and sixth postoperative days. Eight died from 21 to 49 days after the operations. Only 15 (29%) died between the sixth and fifteenth postoperative days, the traditional period in which it is purported that pulmonary emboli are most frequent. Coon and Coller reported that in their series 52% of 205 patients with postoperative pulmonary emboli had their first clinical episode of embolism within 1 week after operation. Fifteen of the patients in our group underwent more than one operation during the same period of hospitalization, and since the time of survival was calculated from the second operation it is likely that in some cases a thrombus that had been

<table>
<thead>
<tr>
<th>Factors Predisposing to Massive Pulmonary Embolism: 101 Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predisposing factors</td>
</tr>
<tr>
<td>Postoperative</td>
</tr>
<tr>
<td>Vascular operations</td>
</tr>
<tr>
<td>Laparotomy</td>
</tr>
<tr>
<td>Other operations</td>
</tr>
<tr>
<td>Thoracotomy</td>
</tr>
<tr>
<td>Neurosurgical operations</td>
</tr>
<tr>
<td>Medical conditions</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Cardiac</td>
</tr>
<tr>
<td>Malignant neoplasms</td>
</tr>
<tr>
<td>Cerebrovascular accident</td>
</tr>
<tr>
<td>Thrombophlebitis</td>
</tr>
</tbody>
</table>

* Malignancy in 5 patients.
present as a result of the first operation became detached shortly after the second operation.

**Clinical Features**

Twenty-one patients died so suddenly that no symptoms were recorded, because they were either dead or moribund before a nurse or a physician could reach them (table 3). Twenty-six patients experienced a gradual demise without any sudden change in clinical course which could be identified, even in retrospect, as an embolic catastrophe. All of those patients were seriously ill from other disease to which their deaths could easily be attributed without invoking thromboembolism. Eighteen of these 26 patients had embolic occlusion of only one or two lobar arteries, whereas one patient had emboli in three lobar arteries. Of the 54 patients who had symptoms that at least in retrospect could be attributed to pulmonary emboli, 35 had dyspnea, including 10 whose only symptom was dyspnea. Next in frequency to dyspnea was shock, noted in 28 cases. Pain was mentioned by only nine patients, and in each case it was the aching, diffuse, anterior chest distress similar to angina described by Gorham. Pleuritic chest pain characteristic of pulmonary infarction does not result from massive pulmonary embolism, and even the anginoid distress occurs in fewer than 25% of patients with massive pulmonary embolism.

Six patients had grand mal seizures, and 14 were comatose as the result of pulmonary embolism. The neurologic manifestations of massive pulmonary embolism have been emphasized by other investigators. It is worth mentioning that hemoptysis was not a symptom of massive pulmonary embolism in our series of cases and was infrequently observed in other large series of fatal massive pulmonary embolism in the absence of previous pulmonary infarction. The most frequent combination of clinical findings or symptoms observed in this study was shock and dyspnea (seven cases), and shock, dyspnea, and cyanosis (four cases).

Only 19 of the 101 patients had clinical evidence of thrombophlebitis preceding pulmonary emboli. Other authors have reported antecedent clinically detectable thrombophlebitis in from 4% to 53% of patients with pulmonary emboli, but, in most series, thrombophlebitis was evident before the embolic episode in less than one third of the patients.

In retrospect, we concluded that of the 101 patients 29 each presented clinical or roentgenologic evidence of small pulmonary emboli preceding the massive terminal embolus, although this diagnosis was rarely made antemortem. Other authors have emphasized that small warning emboli precede the fatal one in at least 15% of cases, sometimes more. Forty-three of the patients in our series had pulmonary infarctions reported at postmortem examinations. Since massive pulmonary embolism rarely, if ever, causes pulmonary infarction, this finding indicates that more than 40% of patients had smaller emboli that preceded the massive one, but most of these were not detected clinically. The actual number of patients with small antecedent pulmonary emboli was probably considerably greater than 43, because experiments in animals have shown that emboli usually do not produce pulmonary infarction unless pulmonary congestion or chronic pulmonary disease is also present.

The clinical diagnosis of massive pulmonary embolism was suspected antemortem for only 20 of the 101 patients of our series. This com-

### Table 3

**Symptoms of Massive Pulmonary Embolism in 101 Patients**

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Times observed (no.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Gradual demise</td>
<td>26</td>
</tr>
<tr>
<td>Sudden death</td>
<td>21</td>
</tr>
<tr>
<td>Dyspnea</td>
<td>10</td>
</tr>
<tr>
<td>Shock</td>
<td>5</td>
</tr>
<tr>
<td>Pain</td>
<td>2</td>
</tr>
<tr>
<td>Seizures</td>
<td>1</td>
</tr>
<tr>
<td>Coma</td>
<td>3</td>
</tr>
<tr>
<td>Cyanosis</td>
<td>1</td>
</tr>
</tbody>
</table>

* Not pleuritic in any case.
pares favorably with the experience of other
authors who have reported that correct ante-
mortem diagnosis of pulmonary embolism was
made in from 7%\textsuperscript{27} to 68%\textsuperscript{26} of cases. In three
series the correct diagnosis was made in less
than 10% of cases.\textsuperscript{27, 36, 41}

The Relationship Between Duration of
Survival after Onset of Symptoms
and the Site of Emboli

Many patients with massive pulmonary embo-
libolism died so suddenly that embolectomy
would have been infeasible. In this series,
26 were dead within 10 min, 32 within 30 min
and only 28 survived for more than one hour (table 4). Twenty-six seriously ill pa-
tients had no abrupt change in their clinical
course to indicate embolization, and it is

likely that in most of these cases death would
have occurred irrespective of the emboli. Only
three of these patients had emboli in the
main pulmonary artery or its two major
branches or both. Of the 32 patients who
died within 30 min, 21 had emboli in the
main pulmonary artery or two major branches
or both. Of 28 patients who survived for more
than 1 hour, 15 had emboli in the main pulmo-
mary artery or its two major branches or both.
Thus, one third of the patients who died within 
\( \frac{1}{3} \) hour of onset of symptoms, did
not have occlusion of both main pulmonary
arteries with emboli.

The Feasibility of Pulmonary Embolectomy

Beall and Cooley\textsuperscript{2} have recommended im-
mediate institution of temporary cardiopul-
monary bypass from femoral vein to femoral
artery at the bedside of critically ill patients,
after which pulmonary angiography can be
performed to confirm or refute the diagnosis.
In their opinion, any patient who survives
for at least 30 min may be salvaged in this
manner. In our opinion, patients must survive
for at least 1 hour to make pulmonary embo-
lectomy feasible, simply because of the
logistic problems of instituting partial bypass
when necessary, obtaining pulmonary angio-
grams, and transporting the patient to the
operating room. If the limit of 30 min is ac-
cetable, it would have been logistically pos-
sible for 40 of the patients in our series to have
undergone pulmonary embolectomy. On the
basis of a limit of 60 min, only 28 patients

\[ \text{Table 4} \]

<table>
<thead>
<tr>
<th>Site of Pulmonary Emboli and Survival Time of 101 Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site of pulmonary emboli at autopsy (no. of cases)</td>
</tr>
<tr>
<td>Pulmonary arteries</td>
</tr>
<tr>
<td>Main</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>&lt;31 min</td>
</tr>
<tr>
<td>31–60 min</td>
</tr>
<tr>
<td>&gt;60 min</td>
</tr>
<tr>
<td>No abrupt change in clinical course</td>
</tr>
<tr>
<td>Operative death</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

\[ \text{Table 5} \]

<table>
<thead>
<tr>
<th>Clinical Status of 30 Patients with Massive Pulmonary Embolism who Survived More Than 30 Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical status</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Carcinomatosis or leukemia</td>
</tr>
<tr>
<td>Prohibitive operative risk</td>
</tr>
<tr>
<td>Irreversible anoxic brain damage</td>
</tr>
<tr>
<td>Potential subjects for embolectomy</td>
</tr>
<tr>
<td>Diagnosis not suspected</td>
</tr>
<tr>
<td>Diagnosis suspected</td>
</tr>
</tbody>
</table>

* Single lobar branch embolus in both patients.
† Two patients had paradoxic cerebral emboli.
‡ One patient had single lobar branch embolus.
§ One patient had only right pulmonary artery occluded.
FEASIBILITY OF PULMONARY EMBOLECTOMY

would have been able to undergo surgical treatment (table 4). Because of this disagreement as to feasibility, data in table 5 are presented separately for the 12 patients who survived from 30 to 60 min and for the 28 patients who survived for more than 60 min. In the former group, two patients had incurable malignant neoplasms and two were considered to be prohibitive operative risks because one had severe congestive heart failure, oliguria, and pneumonia, and one was semicomatose from a recent cerebrovascular accident. Eight patients who survived for 30 to 60 min were therefore appropriate subjects for embolectomy, but the diagnosis was not suspected for five patients. Of the three patients for whom the correct diagnosis was made, one had adrenal carcinoma and one had such adherent emboli that embolectomy would have been technically extremely difficult, if not impossible.

Of the 28 patients who survived for more than 1 hour, seven had carcinomatosis or leukemia, three were comatose from massive cerebral infarction, and one was decerebrate after an episode of cardiac arrest that presumably occurred at the time of embolization. With heroic resuscitative measures she survived the cardiac arrest, but died 5 days later from the results of cerebral anoxia. Six patients were considered to have prohibitive operative risks because of massive gastrointestinal bleeding in one patient, diffuse peritonitis in one patient, septicemia shock in one patient, and severe heart disease with congestive heart failure in three patients, one of whom had a recent myocardial infarction. Therefore, only 11 patients were potential subjects for embolectomy, and for five of these, the correct diagnosis was not suspected. Embolectomy, without benefit of cardiopulmonary bypass was attempted unsuccessfully in two of the six patients for whom the correct diagnosis was made and was considered in another. Another patient, who died while being prepared for embolectomy, had only one lobar artery occluded by emboli, but a recent myocardial infarction was also found at necropsy.

Discussion

If the criteria for pulmonary embolectomy in this group of patients with fatal pulmonary emboli were: (1) survival for at least 1 hour; (2) clinical suspicion of the correct diagnosis; (3) acceptable surgical risk; and (4) reasonable prognosis from the primary disease; then, of 101 patients only six met these criteria. If the length of survival is reduced to a minimum of 30 min, nine of 101 patients met the criteria.

If we excluded patients who did not have obstruction of both main pulmonary arteries, then five of 47 patients (10%) met the criteria for embolectomy, including survival for at least 1 hour after the correct diagnosis was made; eight of 47 (17%) survived at least 30 min with the correct diagnosis.

Our results are in remarkably close agreement with those who have made similar studies on the feasibility of pulmonary embolectomy. Meyerowitz27 reviewed the records of 62 patients with massive pulmonary embolism proved by necropsy, and concluded that only seven (11%) could have been salvaged by embolectomy, an average of one a year. Madsen and Buhl12 reported that of 171 patients with major pulmonary emboli only 27 (16%) would have been subjects for embolectomy, and the authors stipulated a minimal survival time of only 15 min. On the basis of their findings, they concluded that only one or two patients per year could have been saved by embolectomy. Morrison28 reviewed the records of 90 patients who died of pulmonary embolism, and found only seven (8%) who might have been salvaged by embolectomy.

The frequency of sudden death, of serious underlying disease, and of erroneous diagnoses in patients with massive pulmonary embolism, greatly limits the number of these patients who can be salvaged by pulmonary embolectomy.

*Six successful pulmonary embolectomies employing cardiopulmonary bypass have been performed and these will be the subject of a separate report.

Circulation, Volume XXXIX, April 1969
It appears that there are only two ways to improve on this discouragingly low salvageability rate: (1) to improve accuracy of diagnosis and (2) to shorten the time between onset of symptoms and the obtaining of a pulmonary angiogram to confirm the diagnosis. This necessarily means that a pulmonary embolectomy team composed of an internist, a radiologist, and a surgeon must be available within minutes 24 hours a day. The immediate institution of partial cardiopulmonary bypass at the bedside of critically ill patients should improve the salvage rate by permitting more time for the embolectomy team to assemble.

If our diagnostic accuracy had been 100%, the potential salvageability rate would have increased to 19% provided that the patients survived at least 30 min, and to 11% if patients survived 1 hour or more (table 5). Most of the erroneous diagnoses were acute coronary insufficiency with or without myocardial infarction. Because of the confusingly similar clinical manifestations of massive pulmonary embolism and acute myocardial infarction, it is doubtful that the accuracy of clinical diagnosis will improve appreciably unless all patients who suddenly develop shock with or without dyspnea or chest pain are subjected routinely to pulmonary angiography. Hildner and Ormond43 have reported that pulmonary angiograms showed no emboli in 59% of 78 patients suspected clinically of having pulmonary emboli. The hazards of pulmonary angiography for patients with acute myocardial infarction and shock are not yet known, but it has long been taught that simply moving these patients is undesirable. Nevertheless, the experience of our group, as well as that of others,4,44,45 has shown that pulmonary angiography is remarkably safe, even in critically ill patients, although Del Guercio and colleagues46 warned that hemodynamic studies have shown a marked decrease in cardiovascular function immediately after pulmonary angiography in patients in shock not due to pulmonary emboli.

Unanswered by this postmortem study is the percentage of patients with massive pulmonary emboli who survive without operation because of spontaneous lysis of the embolus—an arteriographically proved phenomenon.4,32,47-50 When one considers that the mortality rate for pulmonary embolectomy is in the range of 50%,1-2,4,45 frequency of spontaneous lysis becomes an important consideration. In this regard, the statement of Madsen and Buhl42 bears repeating: “If the choice is to operate at the earliest possible moment after the onset of embolism, which we believe to be the correct approach, it must be understood that there is a danger of operating upon patients who would have survived without surgery...”

In a retrospective review of records, the frequency of signs and symptoms, including the presence of thrombophlebitis will be underestimated because the failure to record certain clinical features does not necessarily mean that they were sought and not found, although in many cases the records specifically stated that certain findings often associated with pulmonary embolism were absent.

Our postmortem study quite obviously presents the unfavorable aspects of pulmonary embolism. Pulmonary embolism in the present antibiotic era has, to some extent, assumed the role previously played by pneumonia as the “old man’s friend.” However, massive pulmonary embolism also occurs in salvageable patients with nonlethal disease. All such patients who have unexplained, sudden cardiorespiratory catastrophes should undergo emergency pulmonary angiography. At this institution within the last 2 years the last six emergency pulmonary embolectomies have been successful, and all six patients are living.

References
FEASIBILITY OF PULMONARY EMBOLECTOMY


Limitations in the Feasibility of Pulmonary Embolectomy: A Clinicopathologic Study of 101 Cases of Massive Pulmonary Embolism
RAY W. GIFFORD, JR. and LAURENCE K. GROVES

Circulation. 1969;39:523-530
doi: 10.1161/01.CIR.39.4.523

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/39/4/523

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/