5-1-1932

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POST-OPERATIVE PNEUMONITIS

A Senior Thesis

By
D. C. Malcolm

April 15, 1932
POST-OPERATIVE PNEUMONITIS

The classification post-operative pneumonitis was evolved to replace the inaccurate terms "ether pneumonia," "post-anesthetic pneumonia," and "post-operative reaction." It refers to a comparatively small group of cases which develop difficulties referable to the respiratory tract after operation, which are not serious unless prolonged. Lemon and Mahle state that it occurs once in every fifty cases who are operated upon and that one in every 185 cases who are operated upon succumb to this disease but that these are usually complicated by other factors.

It is the aim of this presentation to discuss a form of respiratory difficulty and associated conditions which develops in the first few days after operation and which is characterized by unexplained fever, cough and respiratory impairment with physical signs similar to a mild medical pneumonia. Accurate investigations into the nature of this surgical complication have only been carried on in the last sixteen to twenty years.

With the advent of ether as an anesthetic, coeliotomies became more common. Ether was first used very cautiously by only a few persons, later almost any one in the medical profession and many without the profession attempted to administer ether as a general anesthetic.
The results were quite serious in many cases and post-operative complications referable to the respiratory tract became quite common. However, these complications were passed off glibly as being "post-operative reactions."

Certain investigators eventually inquired into the cause of these post-operative reactions. In this regard, Mikulicz, 1898, discarded ether for chloroform in an attempt to protect patients from post-operative pulmonary complications but found that narcosis was evidently not a cause of pneumonia since his change in anesthetics effected no apparent diminution in post-operative pulmonary complications.

At the 34th Congress of German Surgeons meeting in 1905, Zibergiil and Korte reported that pulmonary complications occurred in 3.5% of 3,909 patients on whom coeliotomies had been done. Others gave similar statistics. The morbidity reported apparently refers to those cases who developed rather prominent pulmonary symptoms and not to mild cases.

William Pasteur, 1908, advanced the theory that collapse of portions of the lungs occurred following coeliotomies. He reported sixteen cases who developed collapse in 1914 coeliotomies.
 Featherstone conducted an extensive survey of the literature on the subject and found that in 60,244 cases up to 1908, to whom an anesthetic had been administered, only .068% developed post-operative pneumonia. The early and accurate diagnosis of all cases including the mild ones apparently was not done.

Whipple became interested in this condition in 1914 after seeing an unusual thoracic roentgenogram in a case with pulmonary complications following operation. He has since become the leading investigator and experimenter in pulmonary complications particularly of a pneumonic nature. He was the first one to vigorously attack the classification of "ether pneumonia" and "post-operative reaction". He developed an exacting method of checking all patients pre and post-operatively concerning the occurrence of pneumococci in the sputum, bacteriologic studies of those who developed a post-operative pneumonitis, roentgenograms and physical examinations of those who had an unexplained rise in post-operative temperature.

Coryllos, Henderson and other have experimented on the matter of the actual mode of production but Whipple was the first to call attention to the mild clinical forms of post-operative pneumonitis which often went unnoticed.
ETIOLOGY

Inasmuch as Whipple has conducted the most thorough search into the clinical significance of post-operative pneumonitis, his routine examination of patients and his etiologic discussion shall be of chief interest. The work of various investigators who have looked into the smaller phases of the subject but who have placed considerable emphasis on only a few factors which they thought to be of paramount importance shall be considered as discussions of Whipple's larger precepts.

Whipple has carried his investigation upon bacteriological, radiographic and prophylactic lines. His routine is as follows: The sputum of each patient is taken on the morning of operation and injected into a mouse. If the patient shows signs and symptoms suggestive of respiratory complications, a post-operative specimen is sent for mouse inoculation. The patient's chest is radiographed unless the patient is too seriously ill to be moved about. If the radiogram exhibits a shadow indicative of lung involvement, a blood culture is made and if the pre-operative and post-operative sputum shows pneumococcus Group IV, a specimen of the patient's blood is sent every third day for agglutination tests with the isolated pneumococcus strain obtained from the sputum to determine the identity and grouping of the pneumococcus in relation to the lesion found.
A chart dealing with the following factors is kept of all operative cases: symptoms during anesthesia; history of respiratory infections; mode of living as regards clothing worn; physical signs elicited from the chest and upper respiratory tract on admission; condition of the cardio-renal-vascular system on admission; symptoms in order of appearance referable to the chest; temperature, pulse and blood counts; physical findings after onset of post-operative pneumonitis; activity of the cardio-renal system during the disease; blood pressure, pulse and cardiac activity after complications occur; post-operative respiratory disease not pneumonic in nature; bacteriological findings; prophylaxis; treatment; final result.

During 1915 and 1916 Whipple investigated 3,719 surgical patients at the Presbyterian Hospital, New York. He found 97 cases of pneumonitis which were diagnosed and studied. He has considered the following factors to be predisposing in the acquisition of a post-operative pneumonitis: Local inflammation in the upper respiratory tract and factors favoring them; vasomotor changes causing a congestion of the pulmonary vessels; factors inhibiting the normal thoracic and abdominal respiratory movements and favoring atelectasis and hypostasis in the lung; local or general infections elsewhere than in the
respiratory tract; debilitated states resulting in a lowered natural or acquired immunity to the particular organism inciting the pneumonitis; factors increasing the virulence of the inciting organism.

Local changes in the respiratory tract due to infection or congestion and factors favoring them. First, the inflammatory changes complained of by the patient as a "cold" in the form of a coryza, tonsillitis, pharyngitis, laryngitis or bronchitis. Any one or several of these conditions may be actively present or subsiding when the patient enters the hospital. The patient may contract a cold after hospital entry. Many patients wear too much clothing on entry, they become exposed in the hospital by examinations, hot baths, cool rooms, draughts, inadequate gowns, bed covers which fail to cover the shoulders particularly after operation when they are in a depressed condition. Elwyn states that chilling of the body surface is a factor in occasional cases but that it does not explain its occurrence in different persons under similar conditions in an institution. Nor does it explain why it occurs more frequently after abdominal operations. Cleveland states that true post-operative pneumonia which is often called ether-pneumonia is a disease coming on the first few days after operation, accompanied by cough, rise in temperature and
is usually due to some exposure. He reports an incidence of 58 cases of post-operative pneumonia occurring in 1940 operations or a morbidity of 2.3% at the Presbyterian Hospital in 1918. Every case with a temperature of 101 degrees Fahrenheit or over after operation without known infection elsewhere has had pulmonary examinations and roentgenograms of the chest. The first physical sign evident was the presence of rales heard at the bases posteriorly. He found that this phenomenon occurred four times as frequently in males as in females, that 65% of the cases occurred in the six months of winter and early spring and 52% of the cases were in the third and fourth decades of life. Coughs, colds and upper respiratory infections previous to or on admission to the hospital or while in the hospital, condition of the patient, type of operation and type of anesthetic are the chief predisposing factors according to Cleveland.

<table>
<thead>
<tr>
<th>Incidence</th>
<th>No. of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-9</td>
<td>3</td>
</tr>
<tr>
<td>10-19</td>
<td>11</td>
</tr>
<tr>
<td>20-29</td>
<td>25</td>
</tr>
<tr>
<td>30-39</td>
<td>25</td>
</tr>
<tr>
<td>40-49</td>
<td>9</td>
</tr>
<tr>
<td>50-59</td>
<td>15</td>
</tr>
<tr>
<td>60-69</td>
<td>5</td>
</tr>
<tr>
<td>70-79</td>
<td>3</td>
</tr>
</tbody>
</table>

The above table represents the incidence of post-operative incidence at the Presbyterian Hospital, New York,
for 1915 and 1916. 64 of the cases occurred in males and only 33 in females. Also he found that March showed the largest number of cases of any month. These 97 cases occurred in 3,719 operative cases. 25 of the 97 died making a mortality of 25.8% but there were only nine who died of pneumonitis as the only complication. Seven autopsies were done and three of these showed a lobar pneumonia while four exhibited a lobular involvement in the nine dying of no other complication.

Cleveland has arranged the following table:

<table>
<thead>
<tr>
<th>Hospital</th>
<th>Operative cases</th>
<th>Pneumonia morbidity</th>
<th>Pneumonia mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mayo, 1910</td>
<td>3,657</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Mayo, 1912</td>
<td>5,835</td>
<td>19</td>
<td>6</td>
</tr>
<tr>
<td>Mayo, 1913</td>
<td>6,825</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td>Leipzig Laeven</td>
<td>9,755</td>
<td>180</td>
<td>113</td>
</tr>
<tr>
<td>Montreal General</td>
<td>2,500</td>
<td>30</td>
<td>22</td>
</tr>
<tr>
<td>Massachusetts General</td>
<td>3,490</td>
<td>40</td>
<td>22</td>
</tr>
</tbody>
</table>

Of the 65 cases developing post-operative pulmonary complications out of 1940 operations performed at the Presbyterian Hospital, New York City, seven or 10.7% died. However, no healthy person undergoing operation died as a result of post-operative pneumonitis. They either died as a result of specific associated causes or succumbed several weeks after the pneumonitis had cleared.

Whipple's next consideration has to deal with
factors causing an irritation of the mucosa of the respiratory tract. Irritation may then lead to bacterial infection and extension beyond normal barriers into the bronchi and the alveoli. Of all the general anesthetics, ether causes the most irritation and stertorous breathing while the patient is under anesthesia mixes the saprophytes of the tonsils and mouth with mucus which is later aspirated. The chief saprophyte to be considered is the Group IV pneumococcus.

An analysis of the 97 cases developing post-operative pneumonitis as regards the type of anesthesia used.

- Gas and ether, closed method: 57
- Ether, drop method: 10
- Ether, intrapharyngeal: 3
- Gas, oxygen and ether: 7
- Gas and oxygen: 13
- Chloroform: 1
- Local anesthesia with novocain: 6

Ether was given to 23 patients who had recent or concurrent colds and who later developed post-operative pneumonitis. Gas, oxygen and ether to 3, gas and oxygen to six and local anesthesia with novocain to two.

Cleveland states that anesthesia prepares the way for entry of organisms already in the respiratory tract by lowering lung tissue resistance. The commonest organism is the Group IV pneumococcus and it is the commonest one causing post-operative pneumonitis. Aspiration of
mucus draws down the organisms into the bronchioles and alveoli. Cyanosis due to lack of aeration or oxygenation favors descending infection. The length of anesthesia has little effect. Post-operative pneumonitis developed in one case who was anesthetized for only three minutes and did not occur in one patient who was anesthetized for two hours and twenty minutes. This type of complication has most frequently occurred in young adults in otherwise good health. About one half develop a lobular type while the remaining ones exhibit lobar findings.

Elwyn states that the aspiration of mucus and saliva from the mouth or regurgitated stomach contents is chiefly responsible for the formation of lung abscesses and that the first evident signs of an involvement occur thirteen to fourteen days post-operative. He states that aspiration does not explain the occurrence of pneumonia in one to two days after operation and of a pneumonia which disappears within three to seven days without evidence of pus formation. Nor does it explain occurrence of pneumonia after the use of local anesthesia. However, he concurs in Whipple's statement is due in part to the irritating effect of the anesthetic on the respiratory tract in producing mild or even severe forms of bronchitis which one sees after ether anesthesia.

Darnall states that it has been taught that ether
irritates the bronchi and thus causes pneumonia. He contends that ether pneumonia as such is rare and that the intratracheal method of administering ether is safe. Rovsing proved that ether causes an increase in the secretion of the salivary glands, the mouth, larynx and trachea and that the bronchi are not irritated at all by ether even if given through a tracheotomy tube. Aspiration of the mucus into the bronchi occurs if it is allowed to collect in the throat. In fact ether was first used for the relief of asthma, emphysema, and bronchitis. He also states that ether is not only well tolerated in badly affected lung patients but it seems to have a specific beneficial effect upon the lung conditions. Post-operative pneumonia occurs rarely except with abdominal operations and then it is due to an infection already existing in the bronchi of the lungs at the time of operation or to imperfect aeration and ventilation of the lungs by reason of fear of deep breathing. However, ether and chloroform do cause a vascular stage similar to the congestion of pneumonia when administered to dogs. Then the organisms from the mouth and the throat or abdomen lodge therein and the lack of ventilation allows them to remain.

Featherstone found that the administration of inferior ether was a decided factor in the production of post-operative pulmonary complications. He states that one
of the London hospitals instructed their chemist to manufacture their ether in order that they might realize a saving on this item. However, the incidence of post-operative pulmonary complications immediately mounted. He quotes Holscher as saying that ether causes the nose and mouth to produce a watery secretion but that the only effect upon the trachea was the paralysis of its cilia. He found that the amount and kind of secretion varies with the individual. Large doses of ether produced a petechial hemorrhage and oedema in the lungs of rabbits but this occurrence is probably unusual in human subjects since no blood is found in the sputum.

Poppert found less oedema and hemorrhage in the lungs of dogs after using chloroform than he did when ether was used. The reversal was true with Lichtenburg who found that chloroform caused swelling and disintegration of the epithelial cells of the pulmonary alveoli of rabbits. Marshall found that 54% of coeliotomies developed bronchitis or pneumonia with open ether and that only 14.7% developed these complications when warmed ether vapor was given.

Whipple finds that anesthesia relaxes the trachea and bronchi and allows fluids to run into the bronchioles and the alveoli from the mouth. Aspiration of infected material from the teeth and tonsils may thus occur and since the Group IV pneumococcus is the most common saprophyte in the upper respiratory tract the conditions are all in order for the production of post-operative pneumonitis. In this respect, Featherstone believes the
Trendelenburg position should be used for part of the operation so as to prevent aspiration of mucus and vomitus. Otherwise the method of administration plays little part in its production. It is his further observation that alcoholics require large amounts of anesthetic and are more exhausted post-operatively, they easily catch cold, pneumonia develops easily and the mortality rate is high amongst this class. The pre-operative use of atropin 1/100 grain dried the secretions of the respiratory tract but did not reduce the post-operative incidence. The expired air is cooled as much as thirty degrees Fahrenheit, therefore, it should be warmed to prevent chilling of the alveoli and chemical irritation from inhaling a fog of cold ether droplets.

Lemon and Mahle designate the condition in which irritation of the bronchi occurs with a descending infection from anesthesia as aspiration pneumonia. They find that gangrenous pneumonia may result from the aspiration of much mucus especially if the patient is debilitated by hemorrhage or toxemia. There may be no symptoms from the aspiration of mucus and the patient may drown in his own mucus if there is a sufficient quantity of it.

The following results were derived by Elwyn upon
investigating 2,932 operative cases at the Mt. Sinai Hospital who received ether, nitrous oxide and ether or nitrous oxide and oxygen as a general anesthetic. The morbidity rate as concerns those patients developing post-operative pneumonia was 2.76%.

Duration of the pneumonia

<table>
<thead>
<tr>
<th>Days</th>
<th>Cases</th>
</tr>
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<tbody>
<tr>
<td>2</td>
<td>1</td>
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<tr>
<td>3</td>
<td>2</td>
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<tr>
<td>4</td>
<td>11</td>
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<td>27</td>
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<td>6</td>
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<td>7</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
</tr>
</tbody>
</table>

Nitrous oxide and ether was used in 73 cases, nitrous oxide and oxygen seven cases and local anesthesia in eight cases.

Now as to the factors causing a congestion of the pulmonary vessels. Whipple believes that the congestion may be due to one phase of inflammation which is in turn dependent upon bacterial invasion causing a bronchitis. Or it may be caused by an increase of carbon dioxide in the blood as seen in cyanosis of gas and oxygen anesthesia. It may also be due to obstructed respiration.
before or after anesthesia, to defective respiratory excursion or in the feeble and aged to undisturbed and unchanged recumbent posture. Cardiac decompensation associated with valvular disease or lowered blood pressure following a shocking and prolonged operation may also be causative agents.

Congestion follows exposure same as in croupous pneumonia. Four cases had cyanosis one to four hours after operation with pulmonary congestion which went on to pulmonary oedema. The oedema was cleared by means of active counter irritation.

Elwyn held that cardiac exhaustion might lead to congestion of the lungs. Digitalis is now used in the Viennese clinics as a preventative while Kellog used cold sponges and packs to the chest to promote circulation. Emboli may form on account of the pulmonary stasis. Featherstone believes that patients with weak cardiac apparatus survive the operation providing it is shockless and not attendant with exposure.

Terminal pneumonia occurring usually as an incident in patients in extremis after a short or protracted postoperative course is usually discovered by the pathologist inasmuch as it is not abrupt and there is no rise in
temperature and there is no cough. This condition is not to be considered in this presentation.

The third major consideration as to the causation of post-operative pneumonitis is that of local or general infections elsewhere that in the respiratory tract. Bacteria in the blood stream as an embolus or free in the stream form an infected thrombus which is liable to produce a so-called septic pneumonia. This is usually the late or terminal pneumonia. Featherstone reports that a lung which has lost its bactericidal powers is susceptible to blood stream infection. Septic emboli from a seat of primary infection such as a mastoiditis may induce small abscesses or the emboli may be aseptic and produce varying grades of pulmonary collapse up to that of fatal collapse.

Lemon and Mahle state that sudden pleuritic pain and bright red blood in the sputum several days post-operative is significant of embolism. If it is non-infective, it usually disappears rapidly. It usually affects the lower lobes and particularly the right lower lobe causing a small, circumscribed lobular involvement and is especially common following coeliotomies particularly if the operation has been done upon the stomach.
Cutler and Hunt are exponents of the embolic theory as explanatory of post-operative pulmonary complications in the majority of cases. Darnall also adheres to this tenet that most cases are attributable to secondary infection following a septic abdominal condition.

Cleveland holds that embolic pneumonia may occur at any time after operation and is one of the accidents of the post-operative course. Featherstone contends that infections may also occur through the medium of the lymph stream in which case a pleurisy first results but is often followed by a pneumonic involvement later.

Silk found that a former inflammation of the lung is a strong predisposing factor in the development of post-operative pneumonia and that it occurred with greater frequency during the influenzal pandemic than before it. Also a person who has had pneumonia during the preceding two years prior to operation is in more danger of sustaining an attack of post-operative pneumonia.

Henle reports 65 deaths of 143 patients having pneumonias incident to operations but that many of these were old, carcinomatous individuals or that they were in great shock following extensive resection of the stomach. Whipple's report of 97 cases of post-operative pneumonitis shows that 28 resulted after hernial
repairs, 21 following appendicectomies or a total of 88 coeliotomies considering the other abdominal operations. The mortality was 25.7% but this includes many terminal, septic and several embolic cases. Fatal cases occurring in patients previously well are usually attributable to Groups I, II or III pneumococcic infection or to an embolic form. Whereas there was a mortality of only nine of 61 cases in the case of an infection with the Group IV pneumococcus in which there were no other major complications.

Factors inhibiting the normal respiratory excursions and so decreasing the respiratory function. Whipple contends that trauma to the thoracic and abdominal walls incident to the incision and retraction of the operation cause persistent pain and splinting of the thoracic or the abdominal muscles of respiration. That inflammation of the peritoneum causes the same splinting of the respiratory muscles. That distention following peritonitis and coeliotomy causes limited diaphragmatic excursions. And that tight binders and surgical dressings also delimit respiratory excursions. These associated conditions probably account for a large percentage of post-operative pneumonitis associated with coeliotomies.

William Pasteur in 1908 stated that a paresis of
one-half of the diaphragm caused massive collapse of the lung following coeliotomies. Czerny has emphasized the fact that pain and splinting of the muscles prevent sufficient aeration of the lungs and expectoration of mucus from the trachea. According to Pasteur the collapse occurs as a result of reflex inhibition of diaphragmatic movements and of the synergistic and antagonistic muscles. It may be due to irritation of the diaphragm or of the pleura thereof. This explanation is not at all satisfactory.

Elwyn suspects that the clue to the essential element is to be found after eliminating the ordinary factors of exposure, previous infection, anesthesia, etc. On four cases going to autopsy with an incorrect diagnosis of post-operative pneumonia, the lower lobes of the lung were found to be collapsed and airless but there was no evidence of pneumonia. The lower lobes are often found to be dull and the patient exhibits diminished breathing one day with a disappearance the next day or else signs of pneumonia supervene. Collapse of small portions of the lungs then not uncommon after coeliotomies especially on operations upon the stomach, but the physical signs are usually absent in 24 to 48 hours.

The basal portions of the lungs of old persons in a weakened and debilitated condition is often found to
be congested and airless. If they do not expand after a certain time there is a tendency to infection of the bronchi with an inclination for spread to the hypostatic lung and pneumonia results. He thinks that it is likely that the same thing occurs in post-operative pneumonia.

Featherstone believes that the diaphragmatic paresis following many cases of appendicectomy and herniotomies is probably explained by reflex mechanism in which the phrenic nerve is the efferent path. That the tenseness of the abdominal muscles is explicable by Sherrington's synergic action of muscles in which condition the sympathetic sensory fibers are the afferent fibers resulting in a relaxation of the diaphragm and a tenseness of the abdominal muscles. The diaphragm may also be relaxed by severe injury in other parts of the body in such conditions as shell wounds. Massive collapse is then quite likely the precursor of many cases of post-operative pneumonia but the condition is often overlooked until pneumonia supervenes.

The chronology of events is: coeliotomy, diaphragmatic inhibition of varying duration, collapse of one or both lower lobes of the lungs, and in some cases pneumonia. Elliott has experimentally and clinically shown that a general bronchitis occurs from the plugging of the bron-
chioles with mucus: then if the lung collapses, the heart is drawn to the affected side and the diaphragm rises.

Pain in the abdomen from operative trauma or inflammation leads to rigidity of the abdominal wall and to a reflex inhibition of the diaphragm and perhaps to some degree of spasm of the lower intercostal muscles. The lower lobes of the lung do not freely expand and contract, so that congestion with some oedema sets in. The bronchioles of this disordered region are more or less choked by this swelling of their walls which has been increased from irritation by the anesthetic agent. Into this motionless and well nourished region, organisms and particles of debris arrive, either by air or blood or lymph streams. The patient cannot cough freely so the debris lies undisturbed. Closure of the bronchioles and absorption of the air now ensues. The result is massive collapse or pneumonitis according to Whipple.

When the infection is virulent and the patient's resistance is low, the diaphragmatic paresis persists. True bronchopneumonia as a sequel then may be expected, in the nature of a coalescing lobular distribution following the bronchiolar blocking which was the determining factor of the lung collapse.

Coryllos has recently conducted some searching experiments into the nature of pneumatosis and atelectasis.
He contends that the two conditions are merely two phases of the same morbid condition. The differences are of degree only and depend on the virulence and type of their most frequent causative organism, the pneumococcus. Both have the same etiology and the same mechanism of production according to experimental work carried out on dogs; similar clinical evolution and similar pathological changes were shown.

There is only one determining cause and that is Bronchial Obstruction with complete occlusion necessary. Neither paralysis of the respiratory muscles, nervous reflexes, nor embolism can be or have been proved to be the determining causes of apneumatosis. Posture, exposure and colds act as adjuncts only in decreasing the means of defence. Experimentally lobar pneumonia and atelectasis appear the same by roentgenograms: diaphragm is pulled up and the mediastinum is pulled to affected side. The pneumonic lung shrinks less than the atelectatic one because the alveoli are filled with fibrinous exudate.

The theory for the production of both post-operative and medical pneumonia. After operation, especially on the upper part of the abdomen, and this independently of the anesthetic used, general, local or spinal, and immobilization of the thoracic cage occurs. The vital
capacity is decreased and the means of defense of the lung is impaired. The impairment is increased by narcotics and post-operative posture. Stasis of the bronchial secretions in the bronchial tree follows, producing irritation of the bronchial mucosa, which responds by more secretion. A bronchiolitis occurs, which is due to more or less infected stagnating secretion; but this bronchitis generally clears up as soon as the lung has regained its means of defense. Pneumococcus Group IV is a frequent saprophyte of the upper respiratory tract but it can now invade the lower respiratory tract since this procedure is favored by bronchitis. A pneumococcal bronchitis is produced with characteristic pneumonic exudate, viscid and rich in fibrin and if not complicated may remain in a stage of bronchitis which most often clears up in from 24 to 48 hours. But bronchial obstruction occurs in some cases, and evolution of pathological condition depends on virulence of the pneumococcal and other invading organisms present in the occluding mucus. If the virulence is low, exudate poor in fibrin, toxic general symptoms are absent and pneumococcal cellulitis of the lung will not occur. A simple obstructive atelectasis will follow by absorption of the alveolar air. This atelectasis may be massive lobar or lobular according to the size of the obstructed bronchus.
This complication must necessarily occur within the first 24 to 48 hours post-operative and this would exclude an embolic origin.

If the ocluding mucus is expelled early by coughing, as it can be because of its low viscosity, the lung will be aerated rapidly and the temperature will drop by lysis or crisis, and the dyspnoea and cyanosis and cough, will rapidly disappear, unless another bronchus becomes involved. If the virulence of the pneumococcus is high, the exudate is more viscous because of more fibrin, and the toxic phenomena will be more marked. Dislodgement of the ocluding exudate will not be easy and the exudate is apt to fill up the alveoli and give a post-operative pneumonia which is massively lobar or lobular according to the size of the obstructed bronchus.

Furthermore, in post-operative atelectasis a number of bronchi may be liberated whereas others will remain obstructed. Post-operative pneumonia can follow atelectasis in this way; or after development of pneumonia occurs another big bronchus may be occluded, inviting atelectasis and complicating an already existing pneumonia.

Coryllos found the same circulatory disturbance in lungs of the two diseases by injecting the vessels with India ink in the living animals.

His theory easily explains the following features in apneumatosis and post-operative pneumonia and the
striking similarities between them.

In atelectasis: its productions within 24 to 48 hours after operation, generally on the upper part of the abdomen and exceptionally on the head and extremities; it is equally frequent after general, local or spinal anesthesia; it occurs more frequently when a "cold" exists previous to the operation; it is favored by a recumbent position and often prevented and cured by rolling the patient from side to side; it is localized in 75% of the cases in the lower lobes and especially the right lower lobe because of its more vertically placed bronchus, which renders the expulsion of the exudate more difficult; that pneumococcus Group IV is found in every case in which bacteriological studies were made.

In pneumonia: the lobar distribution; smaller size of the affected lobes as compared with the healthy ones and consequently the often reported displacement of the mediastinum on and the elevation of the diaphragm to the affected side; the development of the complication especially after operations on the upper abdomen irrespective of anesthetic used; its appearance within the first 24 to 48 hours post-operative; the constant presence of pneumococcus Group IV in the exudate; the great difficulty of differentiating pneumonia and lobar atelectasis
clinically and roentgenographically; the similarities in pathologic changes (fleshy parenchyma, liver-like, and sinking in water); the same distribution with predominance in the inferior lobes, especially the right one.

If the difference between atelectasis and post-operative pneumonia is only that of degree, the differences between post-operative and medical pneumonia are still smaller. Post-operative pneumonia is then the connecting link between atelectasis and medical pneumonia and the study of atelectasis gives the key to the pathogenesis of post-operative and medical pneumonia.

The dominant factor in post-operative disease of the lung is bronchial obstruction. Once obstruction is established, the fate of the parenchyma depends on the virulence of the microbes present in the exudate. Simple atelectasis will occur if the virulence is low; pneumonitis if it is higher. If pyogens are present, suppurative pneumonitis, abscess or even gangrene may follow with their corresponding local and general lesions and symptoms.

The conception then that post-operative bronchitis-atelectasis-pneumonia and possibly even abscess or gangrene are the successive evolution phases of one and the same form of post-operative pulmonary complication, namely bronchial occlusion.
Henderson believes that the sequence leading to surgical shock (apart from hemorrhage) and leading through atelectasis to post-operative pneumonia are closely related. Both originate in anemia, one through depression of the circulation; the other through depression of respiration. Depression of circulation after operation and anesthesia is due to the lowered activity of the respiratory and other nerve centers that influence skeletal muscles. After every major surgical operation there is a decrease in volume of air breathed and a prolonged loss of tonus and relaxation of the thoracic muscles and the diaphragm. The vital capacity of the lungs is thus greatly decreased; the lungs are correspondingly deflated, and occlusion of the pulmonary airways readily develops. Air in the occluded area is readily absorbed by the non-aerated blood and atelectasis is produced. Pneumonia results if pathogenic organisms are inclosed therein.

Some definite facts have been arrived at by Overholt in his work on post-operative pulmonary hypoventilation. In examining 25 cases in which upper abdominal section was done, he found that the lung fields at expiration pre-operatively occupied the same area as they did at full inspiration post-operatively. This was accomplished by the use of roentgenograms. Transient positive physical
signs of dullness are found frequently after operation. Before operation the average vital capacity was 2,900 cubic centimeters while it was only one third this amount after the operation and only 80% of the full capacity on the eleventh post-operative day. Pre-operative diaphragmatic excursion was 4.3 centimeters on the right side and 4.5 centimeters on the left side. The pre-operative chest expansion was 5.8 centimeters while the post-operative extent was 1.8 centimeters. The post-operative circumference was 2.8 centimeters greater than the pre-operative. Post-operative excursion of the diaphragm was 1.4 centimeters on the right side and 1.8 centimeters on the left. Diaphragm moved up an average of 4.8 centimeters on the right side and 3.5 centimeters on the left side after operation. Chest expansion was limited to an average of 79% after operation and diaphragmatic excursion was limited by 66%.

Summary of the etiological factors

Whipple believes that three pathological processes are involved in a consideration of post-operative pneumonitis. First, Anesthesia relaxes the trachea and bronchi and allows fluids to run into the trachea and eventually into the lung from the mouth and that aspiration of infected material occurs. Second, infarction due to emboli usually is serious and seldom occurs but that there is
a high mortality attendant if it does occur and the patients usually die suddenly. Third, he does not agree that all cases of pneumonitis are preceded by atelectasis and has found it in only a few autopsies.

Any one of three factors are needed to further enhance its likelihood of occurrence: increase in virulence of the exciting organisms at certain times of the year and in different years; lowered individual resistance as a result of concurrent upper respiratory infection; exposure before and after operation. He further points out that he has lowered the incidence of the disease in the Presbyterian Hospital, New York City, by a recognition of the causative factors and their prevention in so far as it is possible. During 1915 and 1916 there was an incidence of 2.3% among 3,719 operative cases; 1924 there was a 2% morbidity while in 1925 there was only 1.4% of the operative cases who developed post-operative pneumonitis.

Coryllos contends that the theories of diaphragmatic fixation by reflex mechanism either direct or indirect is untenable. That bronchial constriction by mucus plugs is the only cause which is always a determinant. That the etiology of post-operative pneumonitis is dependent upon aspiration, hypostatic congestion, chilling, embol-
ism and retention of the mucus secretions in the bronchi which is the most constant determining cause.
Pathological Considerations

The term surgical or post-operative pneumonia includes every well recognized pathological type of pneumonia such as lobar, lobular, bronchopneumonia, embolic, hypostatic and gangrenous as well as a variety that may be considered atypical. This atypical variety seldom comes to autopsy and has been hitherto so little appreciated clinically that it has not been recognized as a pathological entity. It occurs as a rule 24 to 48 hours after operation giving a lung shadow and physical signs of consolidation for not more than 24 hours in some cases. Its pathogenesis is probably attributable to infection of the bronchioles with subsequent incomplete aeration of the lung and atelectasis of some of the alveoli in the majority of pneumonitis cases. The characteristic feature is a marked engorgement of the pulmonary vessels with rapidly disappearing exudate in the alveoli but without organization of the exudate. At autopsy a beginning collection of red blood cells and white blood cells is found in the alveoli. This is the pathological picture of the first stage of inflammation and is usually seen at the border of a lobular type or in the lobe where the pneumonic process is beginning. Grossly that part
of the lung which is involved is heavier than normal, is less air containing, has a beefy feel and considerable pinkish fluid exudes from the cut surfaces. Hepatization is not seen grossly or microscopically. This corresponds to the earliest picture of a pneumonic process and occurs in many post-operative patients. A similar type occurs in mild medical cases of pneumonia.

Henle reports 52 autopsies in 65 deaths occurring in 143 surgical pneumonias after 1787 coeliotomies chiefly gastric resection and severe abdominal operations. There were seven lobar pneumonias in various stages of hepatization, 23 lobular with ten involving both the right and left sides and seven involving the right side and six the left, seventeen gangrenous twelve of which were double and five embolic.

Rovsing believed that peritoneal infection was carried by the lymphatics, veins and by embolism because pneumonitis occurred chiefly after laparotomies. Darnall holds that the relationship of the abdominal and pleural lymphatics is of prime importance in this consideration. Infections easily pass upward through the retroperitoneal system to involve the pleura, the base of the lungs or the bronchi. He contends that subphrenic abscess and pneumonia are analogous as concerns the point of infection.
One is below the diaphragm and the other above but both are carried by lymphatics and veins via the retroperitoneal route. Microscopic sections of the involved lung shows focal involvement and general involvement of the vascular interstices with hyperemia or even oedema of the lung tissue and a definite focus of infection.

However, Coryllos impresses one with the importance of the infection of the walls of the air tubes which produces an excessive and sticky secretion; occlusion of an air tube by this secretion shuts off the portion of the lung to which it leads; as the air is absorbed, atelectasis develops and secretions accumulate back of this occlusion and consolidation follows. Other factors are then only of minor import.

Whipple has been the foremost investigator along bacteriological lines in the matter of post-operative pneumonitis. He established a routine of collecting sputum from each patient prior to operation and again post-operatively if the patient exhibited signs of pneumonitis. The sputum was inoculated into mice with the finding that one-half of them showed no pneumococacic organism prior to operation and only one-sixth exhibited none after operation. Group IV pneumococcus was found in 33% of pre-operative sputa and in 57% of the post-
operative ones. Groups II and III were also found as well as occasional hemolytic streptococcus and mucosus capsulatus.

He concludes that the atypical features of the post-operative pneumonitis were explicable partly by the bacteriological findings in the sputum and the blood cultures of the cases. Blood cultures were taken every third day up to 14 days after a patient developed post-operative pneumonitis in which pneumococci were found in the sputum. They were positive in only three of 51 cases. Pneumococcal agglutination tests were done by immunizing rabbits with the patients Group IV sputum and then checking against the organisms in the sputum. Positive results were obtained in 24% of the attempts. Urine precipitation tests were done and found to be positive in 38% of the cases examined. This reaction depends upon the isolation of the specific protein of the pneumococcal organism from the urine.

The saprophytic or Group IV pneumococcus is found in 70% of normal throats which are not contact cases and Groups I, II and III are found only in contacts or those exposed to the disease. These three groups are parasitic and are not found in normal throats.

Bacteriological findings agreed with the atypical clinical manifestations of the post-operative pneumonitis. The Group IV pneumococcus was found in the sputum of a
majority of cases having this short atypical pneumonitis which appeared 48 hours after operation. The pre and post-operative sputa were of the same strain as proved by agglutination tests in many cases. Clinical histories suggest a lowering of local resistance in the lung due to the pneumococcus Group IV as a result of bronchial irritation or pulmonary congestion. Therefore, Group IV pneumococcus organism is the inciting factor in the majority of post-operative pneumonitic cases.
Symptoms and Signs of Post-operative Pneumonitis.

The symptoms of post-operative pneumonitis are usually ushered in within the first 48 hours post-operative by a sharp rise in temperature which is seldom as high as 103 degrees fahrenheit and often not above 100 degrees, there is usually a moderate cough and a times a moderate pleuritic pain low down in the chest but there is seldom an initial or preceding chill. The temperature seldom continues high but begins to fall within 24 to 48 hours by lysis. The cough and hyperpnoea are most important symptoms and usually occurs in over two-thirds of the cases. Rusty sputum is rare but often have a thick yellowish mucus which shows the pneumococcus Group IV in both pre and post-operative specimens.

On the first day there is diminished breathing over the areas involved and on the next day definite consolidation signs occur nearly always in the bases posteriorly and then chiefly on the right side. Bronchial voice and tubular or bronchial breathing are necessary for a diagnosis of consolidation but does not appear in the first 24 hours and then usually after a slight drop in temperature occurs. These signs are fleeting and usually gone in a day or so after their appearance.
Whipple made routine radiographic studies of the lungs of 72 of the 97 cases in 1915 and 1916 as soon as the temperature became elevated above 100 degrees Fahrenheit. Roentgenograms showed beginning consolidation before the physical signs appeared, where the signs became frank after the temperature dropped or where a search for pneumonitis would not have been made. Wedge-shaped shadows occurred with the base of the wedge toward the pleura and the apex separated from the region of the hilum by normal lung in 19 cases. The wedge later extended in size and became uniform from the periphery to the root of the lung and then bronchial voice and breath sounds then appeared.

In cases of massive collapse of the lung in which a considerable amount of fluid lies in the air passages, the shadows are more dense by roentgenogram. Delay in expansion may result in a chronic condition with a complete disappearance of air from the affected portion and bronchial dilatation. By means of the roentgenogram, a triangular area of dulness is seen, the diaphragm is usually high on the affected side and its movements are somewhat limited, and the mediastinum is pulled to the affected side. Hoover's sign is of value in which case the subcostal angle is widened because of the paresis of the
diaphragm and the pulling effect exerted by the intercostal muscles. It is differentiated from lung abscess by its triangular shape, its even density with no cavitation or mottling, its sharply defined margins with evidence of inflammatory reaction absent and the usual location in the lower lobes. In post-operative pneumonitis, the diaphragm is not fixed, the mediastinum is not displaced to the affected side, there may be dull areas in the opposite lung, the shadow clears on coughing or on changing position.

The signs and symptoms of post-operative pneumonitis then are its atypical onset, the rise in temperature without an initial chill, the absence of fastigium, a fall of temperature by lysis, absence of rusty sputum, presence as a rule of slight cough with a relatively slight increase in the respiratory rate, little toxemia in many cases, low mortality unless complicated by shock, infection or asthenia as compared with medical cases of pneumonia and its occurrence in young adults apparently in good health and who give a history of a "cold".

If the infection occurs with Groups I, II, or III pneumococcus, the disease is more severe and there is a syndrome of croupous pneumonia. With influenzal pneumonia the cough is severe.
Treatment

Whipple states that the prophylaxis is more important in post-operative pneumonitis that in so-called medical pneumonia because it can be more readily accomplished. The two outstanding predisposing factors are an inflamed condition of the upper respiratory tract and a congestion of the pulmonary blood vessels during and following the operation.

Prophylaxis begins first, with an elicitation of a recent or concurrent upper respiratory infection and a careful examination of the tract. If infection is present, wait at least one week after all evidence of such infection has disappeared before operating. Care in the use of an anesthetic and this to be administered by one skilled in its use is second. Either gas and oxygen or chloroform should be used in cases demanding immediate operation if the respiratory tract is not free from infection. Chloroform should be used from brown bottles so as to prevent its deterioration and ether should be used from small cans and remainder used for some other purpose than anesthesia. Third, prevent exposure of the patient both pre and post-operatively by protecting them from draughts, have the bathroom at 70 degrees Fahrenheit, give the pre-operative enemas in bed, provide the patient with adequate
clothing so as to prevent chilling. Mikulicz's incidence fell from 9% to 2.1% in four years by the utilization of these precautions. Fourth, prevent pulmonary congestion by the use of tincture of digitalis minims fifteen every four hours for 36 hours pre-operative to combat the weakened heart action which some individuals have post-operatively. This procedure is used routinely in Vienna.

Fifth, the use of some antiseptic such as dichloramine T 2% in chlorozahe in the mouth and throat twelve to 24 hours before operation.

Active treatment to consist first, of the prevention of aspiration of mucus and vomitus by turning him on his side while on the stretcher and in bed for the first few hours after the operation. Later the patient is to take deep breathing exercises to expel the mucus from the bronchi and he is to be turned from side to side frequently. A mixture of three parts of camphorated oil to one part of turpentine is to be applied to the chest to act as a counter-irritant and so promote circulation. This has been found to be of more value than the use of digitalis. Steam inhalations to ease the cough and the use of codein and the semi-recumbent posture for this purpose. Cold fresh air but no draught and the patient well covered if he is cyanotic and having dyspnoea. Colon irrigations to prevent distention.
A double tube is used so that the gas may pass off and fluid be given at the same time which is better than hypodermoclysis where the heart is easily embarrassed.

Scott, Henderson and Haggard believe that the most beneficial treatment lies in the use of 5 to 10% of carbon dioxide in oxygen. The purpose of administration being to produce hyperventilation of the lungs as a prophylactic measure in preventing pneumonia. They state that no cases of pneumonia developed after carbon monoxide gas in which carbon dioxide and oxygen were used in resuscitating the individual whereas it frequently occurred before that time because of the marked acapnia and collapse of portions of the lung. After anesthesia and asphyxiation alike, respiration tends to be depressed. During this period of shallow breathing, parts of the lungs may remain unventilated and thus may become atelectatic. Pneumonia may then develop in these areas unless special measures are taken for their reinflation. Distention of these unventilated areas by deep breathing, which inhalation of carbon dioxide occasions, counteracts the atelectasis and prevents the development of pneumonia. Carbon dioxide and oxygen should be used routinely after every major surgical operation and as often as needed thereafter to relieve pulmonary symptoms.
Case Histories

The four cases to be cited occurred during the winter and early spring months and were observed by me. Hospital records do not list post-operative pneumonia so that other cases could not be cited.

Male patient, age twenty, entered the hospital complaining of chronic appendicitis. He stated that he had been having a mild cold for the last two weeks prior to hospital entry. Physical examination of the chest was negative and the patient appeared to be robust. The tonsils were scarred and hypertrophied and exudate was expressed from them. The throat was injected. Red Blood cells 4,760,000 with a hemoglobin of 81% and a Leucocyte count of 7,800. Patient was operated under ether anesthesia, the operation consumed one hour and fifteen minutes. The next day the patient complained of left chest pain in the base. The fever was 102.6 degrees. Physical signs of dullness and moist rales were elicited over the left base posteriorly. The patient coughed up a thick, yellowish tenacious mucus for three days. The next day bronchial breathing could be elicited over the left base. Fever was 100.2 degrees. Fever was 99
degrees on the third day and the physical signs were absent in the left lower base. Diagnosis of post-operative pneumonia.

Male patient, 43 years of age, entered the hospital complaining of a right femoral hernia which had been present for twelve years, hemorrhoids. He had had chronic cough for three weeks prior to entry. Patient had sigmoid polyp removed by cautery and the femoral hernia was then repaired. The next day he was cyanotic, pulse of 122, fever 104 degrees and a leucocyte count of 11,500. Dullness was found in the right chest posteriorly, in the right base with fine moist rales heard in this region. He was given carbon dioxide and oxygen with slight improvement. The fever was 99 on the fourth post-operative day and the lung findings had disappeared. Diagnosis of post-operative pneumonitis was made.

Female patient, 23 years of age entered the hospital for tonsillectomy in January. She complained of mild arthritic pains involving the knees. Her temperature was 99. Tonsillectomy was done the next morning under local anesthesia by the injection of novocain. Patient had considerable hemorrhage after the operation and tampons were used for hemostasis. A window was opened widely and the patient lay in a draught for a few hours. The next day her temperature was 103.8 and she complained.
of severe pain in her right lower chest chiefly at the side and posterior. She then was coughing considerably and hemorrhaged considerably from the mouth. Sutures were necessary for hemostasis of the facial vessels. Physical examination disclosed a dull area in the posterior region of her chest. Moist rales were easily detected. Her temperature continued between 101 and 103 degrees for the next 10 days and gradually fell by lysis and the patient slowly recovered. The patient was severely ill. The dullness changed to flatness with the exclusion of all breath or voice sounds and there was still some dullness posteriorly with pleural friction rub when the patient left the hospital three weeks after the tonsillectomy. A diagnosis of post-operative pneumonitis attributable to aspiration of blood, mucus and organisms from the mouth which was later complicated by fibrinous pleurisy was made.

Female patient, 36 years of age entered the hospital complaining of metrorrhagia for several weeks. A hysterectomy was done after the detection of fibromyomata. The patient's temperature arose to 100 on the third post-operative day then subsided. There were no respiratory complaints at this time. The red blood cell count was 2,300,000 and the hemoglobin was 47%. On the ninth post-
operative day the patient complained of a slight discomfort in the left pelvic region with pain radiating down the left anterior thigh. Hot water bottles were applied. At 9:00 P. M., that same day, she used a bed pan and as the nurse returned within a few moments she complained of feeling faint. She became quite pallid, hyperpnoeic and covered with clammy perspiration. The pulse became weaker and weaker and the patient died at 9:20 P. M., apparently of respiratory failure. Pulmonary embolism was named as the cause. No autopsy was done.
Conclusions

1. Coughs, colds and other inflammations of the respiratory tract are most important factors predisposing to post-operative pneumonitis. Restriction of abdominal respiratory movements as a result of incisions, post-operative distention, and tight dressings are also definite but lesser factors.

2. Pneumococcus Group IV is the most frequent inciting organism and produces a definite clinical entity.

3. Except in operations on the abdomen, post-operative pneumonitis is a rare complication.

4. Collapse of the lower lobes of the lung is not uncommon after abdominal operation and if it persists long enough pneumonitis develops.

5. Determining factor in post-operative pneumonia is bronchial obstruction by viscid bronchial exudate. Impaired respiratory movements, and narcosis are only favoring factors.

6. Fate of the lung parenchyma after bronchial obstruction depends on the virulence of the infecting micro-organisms. The non-virulent Group IV pneumococcus will produce atelectasis, a more virulent one produces pneumonia, pyogenic and anaerobic
organisms cause lung abscesses or gangrene.

7. Post-operative pneumonitis is usually a mild complication which occurs mostly in young adults who were otherwise in good health and which often goes undetected.

8. Hyperventilation with carbon dioxide and oxygen at the termination of the operation and subsequently if necessary, has greatly diminished the incidence of massive atelectasis and probably other serious post-operative pulmonary complications.
Bibliography


