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## ORIGINAL MEMOIRS.

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### RECENT ADVANCES IN PULMONARY SURGERY.\*

WITH SPECIAL REFERENCE TO DIFFERENTIAL PRESSURE AND WOUNDS  
OF THE LUNG.

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THE great advances that have been made in pulmonary surgery within a short space of time are apparent to the most casual student. We have been interested in glancing over the contributions in this field to the Transactions of this Society in the last twelve years, and it seemed to us of interest to contrast our attitude ten or twelve years ago, and that which we assume to-day.

Take, for example, the report by Dr. R. N. Downs, Jr., in December, 1898, of a case of stab wound of the chest, operated by Le Conte, whose investigations and views on this subject are so well known and so respectfully quoted (except by some German authorities), and the discussion thereon participated in by the lamented Willard, who years before had pursued careful experimental studies in lung surgery. Le Conte and Willard had firm grasp of the physiological problems encountered, but alas, the modern appliances for solving them were then, with the exception of the Fell-O'Dwyer

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method, as yet unheard of, while the reaction of the pleura to infection and to pneumothorax was as yet unstudied, except on clinical grounds. Direct treatment of the bleeding lung was only mentioned as a last resort, and the introduction of a drainage tube and the establishment of lung collapse was a measure greatly in advance of any then in vogue. True it is that already at least two cases of lung suture were on record before 1898,—one by Omboni<sup>1</sup> in 1884 for gunshot wound, and one by Delorme<sup>2</sup> in 1893 for stab wound; but both patients had died, and they were as yet without imitators.

Da Costa's bold treatment of a case of secondary hemorrhage from the lung by thoracotomy and a huge tampon was looked upon, and rightly, with the experience then at our command, as an achievement demanding great surgical courage. Consider Stewart's report in April, 1900, of a pyo-pneumothorax associated with fracture of the ribs, and judging from the symptoms either a laceration or rupture of the lung, and a "tension pneumothorax." Repeated aspirations failed to relieve, and opening of the chest and the introduction of a rubber drainage tube were finally practised, and successfully. How would we then have considered Garre's recommendation that thoracotomy be practised without loss of time and the wound in the lung sought for and sutured? The ingenious Hopkins<sup>3</sup> had striven to devise valve systems of drainage for the air-containing and the infected pleura, but these were as yet Wills-of-the-wisp, or as Harte sarcastically remarked, "mechanical toys," and perhaps are little more to-day.

With the passing of time, however, we have learned some things and unlearned others; and at least two cases of suture of the wounded lung are now on record by Fellows of this Academy; although both, we remark with regret, are ignored by the patriotic German authorities (Jopson,<sup>4</sup> Kelly<sup>5</sup>).

But in this field, we would again emphasize, the advances have been so rapid that authorities are soon outworn, and the articles on chest surgery in our best and most recently published systems miss many of the most vital points of the subject.

It has seemed to us that in considering these revolutionary changes, they embrace from an operative stand-point those measures aimed at overcoming the symptoms, at times appalling and always to be borne in mind, which may attend pneumothorax and lung collapse; and secondly, those pertaining to operative technic, as modified by the nature and resistance to infection of the pleura and the thoracic contents.

We have undertaken a study of some recent literature on these general subjects, as well as on the special subject of the operative treatment of wounds of the chest.

A brief review of the physiological conditions found in the lungs and pleura in relationship to intrathoracic pressure as distinguished from intrapulmonic pressure may be useful and is necessary to a clear understanding of the problems involved in a study of methods of differential pressure. By intrathoracic pressure is meant the pressure in the thoracic cavity outside the lungs, and which is present in the unopened pleura and mediastinum. Intrapulmonic pressure is the pressure found in the air-passages and the alveoli. At the end of both inspiration and expiration the intrapulmonic pressure is equal to atmospheric pressure, as these passages are at this time in communication with the external air. During inspiration this pressure falls and becomes negative. The degree varies with the degree of constriction in the parts above, especially including, under normal conditions, the glottis. During expiration the pressure rises. Under normal conditions of quiet respiration these variations are not great—from 7 to 10 mm. of water as measured by the manometer. If the glottis be closed, the variations in pressure are greatly increased, and these variations have a marked effect upon the heart and circulation (Howell<sup>6</sup>).

Intrathoracic pressure, or that present in the pleura and mediastinum, is always negative under normal conditions; that is to say, it is always less than the atmosphere. The reason for this is, to quote Howell, that the lungs are smaller than the cavity which they occupy. "The lungs are distended to fill the thoracic cavity, and consequently the organs, like

the heart, which lie in this cavity outside the lungs are exposed to a pressure of one atmosphere, minus the force of elastic recoil of the lungs." Howell defines intrathoracic pressure, therefore, "as intrapulmonic pressure, minus the elastic pull of the lungs, and since under usual conditions the intrapulmonic pressure is equal to that of the atmosphere, the intrathoracic pressure is less than an atmosphere by an amount equal to the recoil of the lungs." This negative pressure is greater during inspiration than during expiration, being, according to Heynsius, equal to  $-7.5$  mm. of mercury at the end of inspiration, and to  $-4.5$  mm. of mercury at the end of expiration. If by opening the chest wall and parietal pleura this negative pressure is abolished, the entrance of air into that side of the chest is attended by collapse of the lung, and pneumothorax results on that side.

Space forbids any extensive inquiry into the causes of dyspnoea and collapse which may attend pneumothorax. That these symptoms are not always or even usually present in the human subject when only one side of the chest is opened is well known and long since emphasized by Matas, Trendelenburg, and many others; and many successful operations confirm the view that they may be absent or of but moderate gravity. A dog is killed by wide opening of one pleural cavity unless some form of differential pressure is employed. The thin and easily ruptured mediastinum is the animal's undoing. The rabbit can safely undergo the same operation without fear of collapse (Robinson and Leland<sup>7</sup>); and it has been well said by them that some human subjects have a dog's lungs, and some a rabbit's.

The margin of safety is not large enough to disregard the methods now at hand to guard against an alarming or fatal collapse; and to-day, in Germany at least, every large clinic has a positive pressure apparatus or a Sauerbruch chamber at its disposal (Wolf<sup>8</sup>); no less than 35 clinics being so equipped at the beginning of the year 1910 (Robinson<sup>9</sup>). In this country, Meyer, Green and Janeway, Robinson, Elsberg, Lilienthal, and others are equipped, and are doing

active clinical work. In plain words, haphazard surgery would seem to have reached its limit, and except in cases of emergency, the time is at hand when the surgeon doing thoracic work must equip himself accordingly.

A brief enumeration of the theories advanced in explanation of the dangerous symptoms of lung collapse is furnished by Wolfe;<sup>8</sup> Murphy and Garré seek the cause in an insufficient fixation of the mediastinal pleura, which flutters to and fro in respiration, hindering both inspiration and expiration, dyspnoea being more common than collapse in unilateral pneumothorax. Rehn attributes them to a displacement of the mediastinum to the opposite side, causing a kinking of the larger bronchi; while Friedrich sees the cause of collapse in circulatory disturbances due to kinking of the great vessels. If we add to these the view of Tiegel,<sup>10</sup> who believes that a deficiency of lung ventilation and of oxygen is the chief danger in pneumothorax, which deficiency might be explained by either of the first mentioned theories, it furnishes us with an explanation of the successful action of the several methods which have been adopted to prevent a collapse of the lung and to maintain respiration, and thus meet the complications of accidental and operative pneumothorax.

Under the head of differential pressure, we include the several methods of prevention of pneumothorax and collapse of the lung.

Differential pressure has been tersely defined by Willy Meyer as a higher pressure within the lungs than outside of them. As is well known, this is produced in one of two ways: either by increasing the intrapulmonic pressure—the positive pressure method; or by decreasing the atmospheric pressure on the surface of the lung—the negative pressure method.

Green and Janeway<sup>11</sup> divide the forms of apparatus for artificial respiration into four classes, and this classification will suit our purpose. They are, first, those providing either negative or positive pressure, as the operator desires, the cabinets of Sauerbruch and Meyer; second, the positive pressure cabinets of Brauer, Murphy, Janeway and Green; third, the

positive pressure masks of Robinson and Tiegel; and lastly, the devices for direct insufflation through the larynx or trachea, of Fell, O'Dwyer, Doyen, Matas, Green, Volhard, and Meltzer.

That there is not any essential difference between the results obtained by the positive and negative pressure is acknowledged by many of the experimenters in one or the other field. It would seem to be a case where indeed "The ways they are many. The end it is one."

While to Sauerbruch is due the credit for the tremendous impetus which his introduction of the negative pressure cabinet bearing his name gave to the study of the subject, and while it must not be forgotten that it was he also who pointed out that by a reversal of the position of the patient in his cabinet positive pressure could be produced, it would seem that the early pioneers in the field are to-day scarcely receiving the credit that is their due; and that we in this country at least should not forget that Fell, O'Dwyer, and Matas did yeoman's service in the introduction and development of what is as truly a positive pressure method as any of the forms of apparatus of which we hear so much to-day. A parent is naturally partial to his own child, and we find Fell<sup>12</sup> in a recent article again calling attention to the merits which his apparatus in its latest form possesses. In the earlier forms of negative and positive pressure cabinets the intrapulmonic pressure was static, and the respiratory movements were dependent upon the patient himself. While collapse of the lung was prevented, cessation of respiratory movements would quickly end fatally, and might easily result from paralysis of the respiratory centre, whether produced by poison or shock.

The ease with which Fell overcomes this danger by his method of forced respiration, varying at will the number of respirations from 5 to 50 per minute, following when desirable the autorespirations, and controlling the degree of collapse or inflation of the lung to suit the operator, makes him doubt the flexibility of the mechanism of the cabinets, or what Carrel calls the "classical" types of apparatus. But with the

improvements which have been already obtained in some of these wonderfully ingenious and (although it must be said cautiously to avoid Meyer's sharp criticism) complicated pieces of apparatus, rhythmic changes of pressure sufficient to aid the patient's flagging respiration and to effect exchange of the air in the lung by its alternate collapse and distention can be readily obtained.

To pass on from this reference to Fell's apparatus, which he has modified to meet the demands of both positive and negative pressure, to the consideration of the classical types of apparatus, the cabinets of Sauerbruch, Brauer and Peterson, and their followers, and the masks of Robinson and Tiegel, we find that the mechanical perfection of these forms of apparatus has made great progress since Sauerbruch's cabinet was presented in 1904. Meyer<sup>13</sup> and his brother have constructed a differential pressure cabinet which permits of the use of either positive or negative pressure, or a combination of the two, and which in the working out of details is the most perfect form of apparatus from a mechanical stand-point yet offered. Of course, the time required for knocking down and transporting such a piece of mechanism practically renders it available in only one institution. So, too, the positive pressure cabinet constructed under the supervision of Robinson<sup>9</sup> for the Massachusetts General Hospital, while less elaborate, and much less costly, is also open to this objection. But smaller and easily transportable devices are provided in the positive pressure cabinet of Green and Janeway, and the positive pressure masks of Robinson and Tiegel. The cabinet of Green and Janeway permits of a rhythmic rise and fall in the pressure of the inspired air and ether vapor, a true artificial respiration being carried on without any effort on the part of the patient, and it can be used for respiratory failure due to any cause. The inspired air is warmed, thus overcoming an objection which has been urged against positive pressure, and the ether vapor is diluted. The patient's head is under perfect control, and the positive pressure around the patient's head in the cabinet induces a degree of cerebral anæmia, which renders less ether necessary.

A more extensive description of these cabinets is superfluous, but the large cabinet of Robinson, where the etherizer sits in the cabinet, connected by megaphone with the outside world, administering the ether in the ordinary manner except for the fact that the pressure in the cabinet is elevated to 10, 15, or 20 mm. of mercury at will, the patient's air passages free and under perfect control and inspection, and the whole interior fed with air by noiseless motor and ventilating pumps, certainly appeals to the imagination at least, as a wholly practicable device.

The positive pressure masks are exemplified in Robinson's smaller apparatus and Tiegel's mask. The description of Tiegel's<sup>14</sup> apparatus and a citation of the results obtained by Tiegel in Henle's clinic<sup>10</sup> lead one to believe that the method he employs may yet be found the most practicable. The apparatus is comparatively simple. The mask is similar to that used in giving nitrous oxide, and can be quickly applied or removed. Tiegel finds that the use of oxygen instead of atmospheric air has certain advantages. It is not necessary to use the same amount of pressure as with air, 1 to 2 cm. of water being sufficient in most cases of unilateral pneumothorax, higher pressure being reserved for cases of tracheal stenosis, double pneumothorax, threatened aspiration of blood, and for fully distending the lung at the conclusion of the operation. The fact that the exposed lung is not fully distended under low pressure renders manipulation easier than in the Sauerbruch method, for example, where the lung is kept in contact with the chest wall. At the same time, while using oxygen, the breathing continues regular, and there is neither dyspnoea nor cyanosis. Distention of the stomach, which has occurred under the use of other forms of positive pressure, is avoided (he cites a fatal case of Küttner's). The pressure supplied from an ordinary oxygen cylinder takes the place of the pump with its complicated parts and liability to internal disorders. The fact that his apparatus has been freely tested, not only on animals but in pressure stenosis of the air-passages, and in stab wounds, rupture of the lung, and resection

of the chest wall, has proved its practical value. Experimental work on healthy dogs is, as Meyer says, different from operations on sick people, and he quotes Tiegel himself as reminding us that "dogs do not drink, smoke, or stay out late at night."

This brings us to the last of the four methods of obtaining differential pressure, viz., that of direct insufflation through the larynx and trachea. We have already alluded to the pioneer work of Fell, O'Dwyer, and Matas in this field. Kuhn of Cassel, with his peroral intubation method; Dorrance, with his intratracheal pressure bulb tube, used in combination with the Matas clinical respiratory apparatus; Volhard and Robinson, have all contributed something to this method, and in a measure paved the way for the reception of the method of Meltzer and Auer,<sup>15</sup> which comes to us with the stamp of approval of Carrel, and has been tested on the human subject by Elsberg and Lilienthal. It is based on the following facts: The exchange of gases in the lung is maintained by a system of ventilation. Internal respiration is the name applied to the exchange of oxygen and carbon dioxide in the tissues and the blood stream, and is dependent upon the flow of blood through the capillaries. In external respiration the movement of the air is accomplished by inspiration and expiration. Meltzer and Auer maintain an artificial respiration by imitating internal respiration, and supplying a constantly flowing stream of air under moderate pressure (15 to 20 mm. mercury) in one direction, which carries the air to a certain distance, the remainder of the distance being covered by diffusion aided by the currents excited. A tube two-thirds the diameter of the trachea is passed through the mouth, larynx, and trachea, down to the bifurcation, and then withdrawn a short distance. The pressure is supplied in the original apparatus by a foot-bellows; the air is passed through an ether bottle, and the pressure measured, of course, by a manometer. Like the masks, it is at once an artificial respiration and etherizing apparatus. There is a backward flowing stream of air which keeps the larynx and pharynx free, and anæsthesia is rapid and com-

plete; and strange to relate, overdosing with ether seems impossible. The lungs are distended, breathing is deep and regular, and interruptions of the current or reductions in pressure once or twice a minute permit temporary collapse of the lung, and aid in the diffusion of the gases.

With the aid of this simple apparatus Carrel<sup>16 17</sup> has done some of his most wonderful work on the lungs, the heart, and great vessels, and the œsophagus, and finds it perfectly satisfactory; while Elsberg<sup>18 19</sup> has modified and refined it by substituting an electric motor, blower, warming, and filtering apparatus, etc., to meet the exigencies of operations upon man, preserving, however, its principle. Both he<sup>19 20</sup> and Lillenthal<sup>21</sup> bear evidence to its satisfactory action in varied types of cases. It is perhaps but natural that this comparatively simple mechanism should excite the fine scorn of Meyer,<sup>22</sup> who, in the discussion following its presentation, contemptuously termed it the "blow-pipe method" and opposed its utility in anything but experimental work, viewing it as a backward step of fifteen years. Some of his objections seem valid, while others have been met by the modifications already mentioned, which, as Meyer prophesied, rob it of some of its simplicity. It is a true positive pressure method after all, as Janeway pointed out in discussion, due to obstruction to the backward flow of air. It is not easy to pass a rubber tube unaided into the larynx of an adult, even for one who has had considerable experience in intubation, as we can vouch, and Elsberg uses a Jackson speculum. The interference with the toilet of the mouth and with instrumentation on the œsophagus may also militate against it; as may also a deleterious action of the air and ether vapor on the bronchi, if such be proven (Janeway).

In closing the review of this part of the subject, it will be seen that, as said before, it is generally acknowledged that there is no great advantage of one form of differential pressure over the other, as far as our present knowledge goes. Expansion of the lung can be maintained, and natural or artificial respiration preserved or practised by both methods.

Mention might be made here of the practical application to many lesions of the thoracic viscera, including the oesophagus, of both forms of pressure. To which modification we will finally come, or whether one form will be found superior under certain conditions and another under other conditions, is still more or less an unsettled question; but that differential pressure has come to stay is certain. With Meyer's universal cabinet he claims that exploratory thoracotomy is as safe to-day as is exploratory laparotomy, thus gratifying Friedrich's wish, which statement, with certain limitations, now to be taken up, may be considered true.

#### TECHNIC IN THORACIC SURGERY.

The importance of a most rigid technic in all operations upon the pleura, and the direct influence of infection upon the operative results are now well recognized. In both experimental and clinical work infection shares in importance with and outclasses pneumothorax as a most dangerous complication. This has been strongly brought out in an analysis of the deaths after operation in cases of wounds of the heart, 45.4 per cent. of which, according to Guibal (Matas<sup>23</sup>), are directly due to septic infection of the pleura or pericardium or of both; in Stuckey's<sup>2</sup> series of cases of lung suture, infection was the most frequent cause of death. The well-known experiments of Notzel show greater susceptibility of the pleura to infection than is the case with the peritoneum, although less than that possessed by the synovia of the joints. The pleura possesses considerably more resistance when closed than in the presence of pneumothorax. The cessation of lung activity associated with pneumothorax means disturbance of the circulation in both the blood and lymph channels, and the resistance of the pleura at once collapses.

Carrel,<sup>17</sup> in a recent article on the experimental surgery of the thoracic aorta and the heart, reminds us again of the fact that we are in danger of forgetting, viz., that the bulk of so-called aseptic wounds are almost always slightly infected. What would be a negligible infection elsewhere, in the pleura

becomes an important and threatening condition. Among the measures which favor such infection, Carrell includes handling with forceps and retractors, sponging, walling off with gauze, and the exposure of large surfaces to the air. Hence the innovation he practises. These are: the covering of the lung with silk compresses impregnated with vaseline, to prevent evaporation and drying of the tissues, and these covered in turn with thick flannel to prevent cooling; the exclusion of blood from the pleural cavity, and the avoidance of handling and sponging. Moreover, the operating room is kept at a high temperature, and using these precautions, he operates successfully on the œsophagus, the lungs, and the pericardium, discarding many of the suggestions, appliances, and methods of technic found necessary by other experimenters in the same field.

The relationship of pneumothorax to infection, the loss of pleural resistance associated with its presence, and the added resistance afforded by complete closure and air exclusion, will be seen to be of prime importance in considering the whole question of operations on the lung, and more acutely, the question of drainage. From our own slender experience it has always seemed that while the pleura was easily infected, and while drainage was usually followed by infection, it was rather quickly thrown off if the drainage was adequate. But such a position is no longer tenable, if taken as an excuse for the use of drainage as a routine measure or even in cases of doubt. Nearly all the statistics quoted by Matas, in his masterly article on heart wounds in Keen's "Surgery," support the view that a patient's chances are better without pleural drainage; and a study of the more or less exhaustive papers on wounds of the lung, published within the last two years, from the clinics of Körte, Trendelenburg, and Brunner, confirm this opinion. Only by the restoration of the normal physiological conditions, in whole or in part, can infection be satisfactorily controlled.

The practical applications of these considerations in regard to technic leads us to the question of wounds of the pleura

and lung, and of these the latter are by far the most important.

WOUNDS OF THE PLEURA AND LUNG.—In another part of this paper we alluded to the views which were commonly accepted and those which were new some ten or twelve years ago. The conservative treatment of such wounds is familiar to every medical student. Rest, with sealing, suture, or tamponing of the external wound, strapping of the chest, cold externally, and morphia are routine, and for the attending surgeon, easily applied and satisfactory measures. What are the untoward consequences to the patient of a too universal application of such treatment? He may continue to bleed into his pleura, and a huge hæmothorax result. If a large bronchus be wounded, with each inspiration air will be pumped into that sac, and failing means of escape externally, compress first the wounded lung, and then by pushing over the mediastinum to the opposite side, displace the heart, press upon the sound lung, and cause kinking of the great vessels and the large bronchi, and result in suffocation from "pressure pneumothorax;" or emphysema may appear, in the presence of a wound in the chest wall, or extend through the mediastinum into the root of the neck and such escape give only temporary relief from pressure. If the patient survives or escapes these immediate dangers, infection frequently develops later, introduced from without through the chest wall or from within through an open bronchus, and empyema results; or secondary hemorrhage, the result of a wound from a small calibre jacketed bullet, may finally carry him to his grave, a complication especially noted during the Boer War. Even if he escapes these accidents, experience has shown that a patient who does well in the early period may be invalidated by the development of respiratory and circulatory crippling, the result of hæmothorax, as noted in the Russian-Japanese War (Küttner). Besides the conservative and expectant treatment, it behooves us to consider the other measures which have been recommended. Aspiration for the removal of blood and air from the pleura is the most frequent minor measure. The permanent insertion of a tube between the

ribs, either to favor collapse of the lung and thereby encourage hæmostasis (Le Conte), or to allow the escape of air under pressure, in the latter case providing it with some valve mechanism to prevent admission of air from without (Hopkins, Tiegel), have both been advocated. Thoracotomy, followed by evacuation of the blood from the pleura and direct control of hemorrhage, is the most recent and apparently the ideal method.

To Garré<sup>24</sup> of Königsberg is due much of the credit for pointing out the urgent necessity in a certain number of cases for the institution of active surgical measures for direct control of hemorrhage from a wounded lung. In this epoch-making article, read before the Thirty-fourth Congress of the Deutsches Gesellschaft für Chirurgie in 1905, he presented the results of a statistical study of 700 wounds in the lung treated conservatively, dwelt upon the high mortality under such methods of treatment, and exposed some of the fallacies which had long influenced the treatment of these lesions. He pointed out that the general mortality was over 40 per cent.; in ruptures of the lung, uncomplicated by other injury it exceeded 50 per cent.; while stab wounds and gunshot wounds in the antiseptic era exhibited a death-rate of 38 per cent. and 30 per cent. respectively. He also clearly demonstrated that antisepsis as ordinarily applied could not favorably influence the internal wound which opened the lung itself; that the small calibre jacketed bullet was as dangerous as the old-fashioned projectile; and also asserted that the often repeated view that bleeding spontaneously ceased in the collapsed lung had neither clinical nor experimental confirmation. The prime indications for operation, according to Garré, were hemorrhage, abundant, persisting, or recurring, and pressure pneumothorax not yielding to aspiration. While they were only present in 5 or 6 per cent. of cases of lung injury, they demanded prompt interference. He collected nine cases of suture of the lung, including one case of ruptured lung (his own) with six recoveries. The principles of treatment, as he laid them down, are not very different from those found useful by his followers; nor has

his technic been greatly modified, except as influenced by the facilities afforded by the development of differential pressure and a better understanding of the influences of pneumothorax and its relationship to drainage.

Since the appearance of Garré's article, a number of other important contributions have appeared, including those of Küttner, Sauerbruch, Hotz, Stuckey, V. Möller, Wolf, and Grassmann. The last three, coming from the clinics of Körte,<sup>25</sup> Trendelenburg,<sup>26</sup> and Brunner,<sup>8</sup> have appeared within a year or two, and set forth what may be accepted as the authoritative teaching at this time as contrasted with the extremely radical views advanced by Stuckey<sup>2</sup> of St. Petersburg, which have received wide publicity.

In determining the indications for operation in lung wounds, it would seem desirable to restore as completely as possible the normal physiological conditions of the pleura, to check hemorrhage, remove infection or the conditions favoring its development, and prevent absolutely all danger from those accidents which we have enumerated as possible sequels of such wounds. This would seem to be the ideal treatment, and it may be that in a short time we will resort to operation as promptly as we do in gunshot wounds of the abdomen. This is practically the ground taken by Stuckey, who reports from one hospital no less than 25 wounds of the lung subjected to operation and suture—an enormous number when contrasted with the sum total of those gathered from the literature by a number of investigators. Stuckey advises thoracotomy and suture in every stab wound of the chest seen within twelve hours of the time of its infliction. His cases showed a mortality of 36 per cent., and combining his cases with 7 cases of suture for stab wound from the literature, the series shows a mortality of 31.27 per cent., which he contrasts with the mortality of 38 per cent. in conservatively treated cases cited by Garré.

This paper led Körte to suggest a study of the cases in his clinic from 1891 to 1909, and V. Möller<sup>25</sup> reports them *in extenso*. This paper represents the more conservative attitude which would restrict operation to cases exhibiting

certain well-defined symptoms. In 48 gunshot wounds there was a mortality of only 14.6 per cent., while of 19 stab wounds the mortality was nil. Of 23 cases of subcutaneous rupture of the lung, 9 died, a mortality of 39 per cent. The operations included aspiration, the most frequent operative procedure; thoracotomy only twice; one suture of the lung; one tamponing of the pleura; and one or two laparotomies. V. Möller argues that in only two of the fatal cases of penetrating wounds could death have been prevented by prompt operative treatment, using our modern technic; nor was empyema more frequent than in Stuckey's series; and the lack of mortality and the much shorter period of healing in his stab wounds, is in striking contrast to Stuckey's results.

Grassmann<sup>26</sup> takes a view very similar to that of V. Möller, in restricting thoracotomy to certain rather sharply defined conditions.

The favorable outcome of some of the most desperate cases, without operation, is the stumbling block in determining when to interfere. Wolf<sup>8</sup> reports four cases recovering after suture of the lung—one of rupture, a very rare case, two cases of gunshot wounds, and one of stab wound, operated by Trendelenburg himself. Positive pressure was used in the first case throughout the operation, and in the last case to remove the air from the pleura and to distend the lung before closure of the chest wall. Drainage was dispensed with in all.

The binding indications for operation in penetrating wounds of the chest would seem to be as follows:

1. A wound which from its situation and direction would render likely a penetration of the heart, pericardium, or diaphragm.

2. Severe primary or recurring hemorrhage, as shown by the physical signs of hæmothorax or external bleeding, or by severe hæmoptysis with threatened aspiration of blood into the other lung.

3. Secondary hemorrhage, especially to be looked for in gunshot wounds.

4. Severe pneumothorax, especially when accompanied by symptoms of mediastinal and cardiac displacement, dyspnoea, cyanosis, and threatened suffocation, and which is not relieved by aspiration; also when extensive and increasing external emphysema is present.

5. Secondary pneumothorax, which is always due, according to V. Möller, to suppuration or sloughing of lung tissue.

#### 6. Empyema.

It seems certain that with the improvements in our technic, which include greater familiarity with methods of differential pressure, that these indications will increase in number rather than diminish, and that the ideal treatment, already mentioned, will in time become the accepted one; but a checking up of the results from time to time by our mortality and morbidity statistics should accompany the gradual adoption of more sweeping indications.

In a very limited series of chest wounds under our own observation, the following cases were operated:

1. A stab wound of the chest in the fifth interspace, anterior axillary line, left side, with free external and internal hemorrhage. Treated by prompt rib resection, suture of the wound in the lung, drainage of the thoracotomy wound, and posterior drainage, according to the method of Delageniere. Recovery.

2. A stab wound of the chest in the eighth interspace, anterior axillary line, left side, with moderate external bleeding and traumatopnoea. Treated within a few hours by enlargement of the wound, exploration of the pleura, lung, and diaphragm, cleansing of the pleura, and closure of the wound, with superficial drainage only. Recovery.

3. A stab wound of the chest in the second right interspace, two and a half inches from the sternum, which entered obliquely and divided the internal mammary artery. Operated for recurrent hemorrhage the same day. Ligation of the artery. Partial closure, with drainage. Death from hemorrhage.

4. A case of stab wound in the second interspace, left side. Admitted during Dr. Wharton's service, and treated at first by conservative measures, and later by aspiration on two occasions. Empyema developed, and we resected a rib five weeks after his admission. Recovery.

5. A stab wound of the chest penetrating the pleura between the scapula and the spinal column, and associated with multiple non-penetrating wounds of the back. Operated within a few hours for persisting hemorrhage and hæmothorax. Owing to the position of the wound exploration was unsatisfactory, and tamponing was resorted to. Infection of the pleura followed, and rib resection and drainage were finally necessary. Recovery.

6. A gunshot wound of the chest, self-inflicted, in the third interspace, left side, one and a quarter inches from the sternum. Operated the same day for suspected wound of the heart. Thoracotomy and formation of a quadrilateral chondroplastic flap. Pericardium uninjured. Temporary control of hemorrhage by insertion of large gauze laparotomy pads. Spontaneous cessation of hemorrhage, and closure of the wound with superficial drainage only. Death in four days from delirium tremens.

7. A gunshot wound of the chest below the precordial region on the left side, with penetration of the diaphragm, gastro-hepatic omentum, and kidney. Laparotomy performed the same day, stomach and intestines examined and found uninjured. Temporary improvement, interrupted by streptococcic throat infection, otitis media, and symptoms of lung infection on the right side, with sudden unexpected death several days later. No autopsy.

8. We have also operated upon one case of rupture of the lung, in which the most alarming thoracic shock was present for 36 hours, and which developed empyema later, for which rib resection was done. This patient recovered.

It seems to us that this list, small as it is, emphasizes some of the accidents, immediate and remote, which are frequently met with in chest wounds and injuries. It includes only one case of wound of the diaphragm, treatment of which by the transthoracic route has certain advantages which are now recognized. Nor does it include any well-defined case of "tension" or "pressure" pneumothorax so called (Spannungspneumothorax), which is one of the most urgent indications for operation, or any wounds of the pericardium or heart. But our experience has been sufficient to convince us that the too optimistic views often voiced in regard to chest wounds, and an over-conservative attitude in their treatment, will sooner or

later lead us all into trouble, and that the attitude which we are now forced to assume is one which is based not alone on physiological and experimental but on truly clinical grounds.

*Operative Technic.*—Where differential pressure is available, it will usually be employed; or if not used throughout the entire operation, it is useful at its termination before closure of the opening in the thorax, to distend the lung and abolish pneumothorax. It has been used in a number of cases of wound of the lung with the greatest satisfaction, five cases being collected by V. Möller.

Elsberg<sup>27, 28</sup> emphasizes the fact that both in experimental and clinical work the patient breathes better if lying in the prone position when the chest is opened, and he has recommended this position in operations on the lungs and pleura. The weak anterior mediastinum receives more support in this position, and coughing and respiratory disturbances were absent in empyema cases so operated, while the exposure was excellent. We have tried it in several cases with good results.

The remarks on the aseptic technic, already quoted, are to be borne steadfastly in mind. They need no repetition.

In the presence of a wound, the opening in the chest wall should usually be planned to include it, unless in operating late for infection alone, when the site for drainage is chosen according to the indications common to empyema cases of other origin. Resection of one or more ribs or the formation of an osteoplastic flap is advisable. Intercostal incision, with the use of a powerful rib spreader, is feasible. The lung is at once seized and pulled outward into the wound, using the hand and holding the lung with moist compresses, as Rehn recommends, or adopting the suggestion of covering the rubber glove with a cotton glove to obtain a firmer grasp. Instruments are prone to lacerate the lung tissue. Traction on the lung, drawing it into the wound, as recommended by Rehn, is especially useful when differential pressure is not used, as entrance of air into the pleura is in a measure prevented, while the traction on the mediastinum steadies it and helps to overcome the respiratory and circulatory dis-

turbances incident to pneumothorax. An examination of the surface is then made for wounds and lacerations. Wounds are sutured whether bleeding is present or if it has ceased, unless situated at the hilus and not accessible for suture, when tamponing may be necessary. In such cases Bramann recommends suturing the wound in the parietes around a large tube provided with a rubber tissue valve. In gunshot wounds the wound of exit from the lung must not be forgotten; failure to suture it may result fatally, as recorded in one case (Delbet).

Lacerated and badly soiled areas may call for excision, preferably wedge-shaped, while clots and foreign bodies are to be removed. The sutures, either of silk (as Talke prefers) or catgut, passed with a round pointed needle, are inserted near the edge of the wound, and penetrate the entire depth, being tied firmly enough to secure hæmostasis and occlusion, but not so tightly or so closely as to cause atelectasis. The visceral pleura may then be sutured over the wound to secure early occlusion. The lung tissue itself heals readily when the wound edges are neatly approximated. Broad lacerated surfaces may be sutured into the wound, shutting off the general pleural cavity (Jonnesku); especially if suturing fails to control hemorrhage (Brunswig). The pleura is cleansed of blood and clots, and preparations made for closure of the wound. Where differential pressure is not used to secure expansion of the lung, it is recommended by Bayer to suture it to the wound in the parietes before closure, as this favors expansion; otherwise it is released and the wound closed by layer suture with superficial drainage. Drainage of the pleura in primary cases is usually contraindicated for the reasons already given. Wolf's report of four successful cases, including one stab wound, two gunshot wounds, and one of rupture of the lung, all treated without drainage, is very convincing.

When packing is necessary in an inaccessible wound, or when gross infection is present, as shown by pleural exudate, and exceptionally under other circumstances, as when a large bronchus is wounded and cannot be sutured, drainage will be

necessary, and under such circumstances drainage posteriorly is preferable (Delagenieres' method).

Of 26 cases of gunshot wound collected by V. Möller, operated according to the usual indications of hemorrhage, pneumothorax, emphysema, or suspicion of heart injury, 11 died (42 per cent.); 20 were sutured with 7 deaths; 2 were sutured to the opening in the pleura, with 1 death; 2 in which the lung was resected died; and 1 in which the pleura was packed, recovered.

Of stab wounds he collected 10; 7 were sutured, with 1 death; and 3 were treated by tamponing the pleura, with no deaths. There were also 19 unclassified injuries to the lung, of which 18 were sutured, with 7 deaths; and 1 case treated by tampon, which recovered.

Stuckey's cases, operated without regard to the usual indications, are not included in these statistics, which are the most elaborate and most recent, although not complete as regards the American literature.

In *rupture* of the lung the question of operation is also to be carefully considered before interference is practised or discarded. The mortality is higher than in the case of penetrating wounds, being 50 per cent. after deducting all deaths due to accompanying injury to other organs (Richter-Wolf). If operation is to be of value, it must usually be practised early, as the lacerated lung, lying in a pleura filled with blood, soon becomes infiltrated and hepatized, as shown by Garré. The pneumothorax which is due to a limited laceration of the parenchyma, like that associated with small penetrating wounds, may be of trifling significance; but if a large bronchus be torn, air may be pumped into the pleura with each inspiration, and its exit hindered by a valve-like closure of the bronchus. Dangerous or fatal pressure on the heart and the opposite lung quickly results under these conditions. Profound shock is a familiar picture in these cases, and after it passes away, hæmothorax, pneumothorax, and wide-spread emphysema often develop. The cases associated with fracture of the ribs give the highest mortality. Wolf says that if, after

the period of initial shock has passed the patient's facies show an increasing paleness and cyanosis, or if signs of hæmothorax, with difficult breathing, small frequent pulse, and anxious expression are present, operation is indicated. Garré operated for rupture of the lung on the fourth day after the injury, too late to save his patient, but Wolf was more fortunate in his case. He operated under positive pressure, sutured a tear in the lower lobe 5 cm. in length (the site of active hemorrhage), cleansed the pleura, elevated a depressed and fractured rib, sutured it in place, and closed the pleura without drainage. The patient recovered, a triumph of surgery.

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