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PLEURISY AND PNEUMO-THORAX.

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*Reprint from Transactions of the Medical and Chirurgical Faculty of Maryland, 1884.*

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BALTIMORE:  
JOURNAL PUBLISHING COMPANY PRINT,  
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## THE INFLUENCE OF LUNG RETRACTILITY IN PLEURISY AND PNEUMO-THORAX.

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The application of the knowledge, acquired by physiological research, of the retractile force of the lungs, to the investigation of the pathological conditions of the chest, has been strangely overlooked. This fact has retarded, in no small degree, our thorough study of diseases of the chest.

*Marey*, long since, by his experiments, showed the negative force of the lungs in aspirating the blood from the large venous trunks into the right side of the heart, thereby assisting the whole venous circulation.

*Dr. John Hutchinson*, in 1846, drew attention to the antagonism existing between the expansion of the chest by muscular action, and the elasticity of the lungs and the chest walls.

*Dr. Hyde Salter* (1865) showed that at the commencement of inspiration thoracic elasticity was favorable to inspiration, but as it advanced, it became an expiratory force with lung tension against further expansion.

*Dr. R. Douglas Powell* (1870) drew further attention to these facts in connection with respiration and its modifications in disease.

*Mr. Le Gros Clarke* (1872) showed that atmospheric pressure over the abdomen kept up the diaphragm in a condition of

arched passive tension. He claimed, that this negative force resisted the elasticity of the lung and was the means of retaining the supplemental air in the lungs, and that it limited the encroachment of the abdominal organs. *Dr. Douglas Powell*, in 1876, in an elaborate and very suggestive paper, gave the practical bearing of these physiological facts in clinical medicine, as indicating a better insight as to the true mechanism and relative value in diagnosis of some signs of chest diseases, especially as to the importance of thoracic resilience as a conservator of force in respiration.

It was not, however, until 1877, that the amount of retractile force exerted by the lungs was ascertained, or indeed was more than guessed at. *Dr. W. H. Stone*, of London, then reported his experiments on sheep. He concluded that this retractile power was equal to from four to five inches of water. He also showed, that even when the effusion was considerable in the pleural cavity, that the lung still possessed contractile force sufficient to support two inches of water, so that to evacuate the fluid it was necessary to use external suction sufficient to overcome this lung traction. A few months subsequent to *Dr. Stone's* papers, *Dr. G. M. Garland*, of Boston, published his work on "Pneumo-Dynamics," giving in detail the results of his observations and experimental researches as to the manner in which the retractile force of the lungs was exerted in health and in disease. This author's conclusions gave an immense impetus to the study of the dynamics of the chest. English, French and German observers have been forced to acknowledge the results of his experiments as satisfactory in explaining some conditions especially found in pleurisies.

Previous to 1843, the authorities universally taught that the effused fluids in the pleural cavity obeyed the law of gravity as they would in an open vessel or in a vacuum. They never appeared to question, but that they would necessarily assume their hydrostatic level, and, consequently, that they would reach a horizontal line in all parts of the chest. As much stress as had been placed upon percussion as an element of physical diagnosis, the distinction between dulness as indicating impaired reson-

ance and flatness as indicating absence of all resonance had not been really recognized. If the percussion taps be carefully made by quick, slight motions of the percussor, the differential diagnosis ought always to be made. Over fluid contents of the pleural cavity there is perfect flatness, but where there are membranes, bands, œdematous or consolidated lung, there may be marked dullness, yet there is not absolutely flatness. There, however, is some resonance observed. Surely so accurate a percussor as Piorry should have discovered that the distribution of effused fluid in the pleural cavity did not assume, when the patient was in the erect position, a horizontal level as long as there was any expansive force in the lung itself. He should not have left it to Mr. Damoiseaux, in the year 1843, to be the first to call attention to the important fact that the line of distribution was not horizontal under such conditions, but irregular, taking more or less of the form of a parabola. Since Damoiseaux's first paper, the attention of the profession has been called to this subject and, with but few exceptions, it has been acknowledged that the line of flatness over the upper surface of the effused liquid, unless it fill the whole cavity up nearly to the clavicle, is not horizontal when the patient is sitting or in the erect posture. Time forbids my going into the differences of opinion among English and continental writers as to the exact modifications of the line of distribution, nor is it of importance for the purpose of this paper.

The views of Dr. Calvin Ellis, of Harvard University, published in 1874 and 1876, which were formed from the careful observation of a number of cases, have been confirmed by Dr. Garland and others, including myself. *Dr. Ellis* described the upper line of the effused fluid as beginning with medium effusion, relatively low down on the back, passing outward from the vertebral column, and turning upward and proceeding obliquely across the back to the axillary region where it reaches the highest point. Thence it advances in a straight line but with a slight descent to the sternum. This has been designated as the *Ellis curve*. Dr. Garland, in consequence of the resemblance of the curve to the italic letter S, has named it, very appropri-

ately, the *letter S curve*. According to his experience, this curve of Dr. Ellis's may be traced by proper percussion in any case of free, uncomplicated pleurisy when the patient's body is erect and the amount of fluid present is not excessive. As the effusion increases in amount, the course of the distribution gradually rises and tends to flatten out, so that it no longer presents its characteristic S feature after the fluid reaches the second rib. At this point, when the fluid occupies nearly the entire side, the curve comes quite near the horizontal, but if some of the fluid be withdrawn by aspiration or absorption, the letter S curve will re-appear and gradually retreat downwards. We consider that these modern views of the distribution of fluid in pleural cavities are well founded.

Neither Damoiseaux, Ferber, nor Ellis, ventured to explain the cause of the fluid not taking the horizontal level. Dr. Douglas Powell, in his article (1876) showed the influence of lung elasticity. *Dr. Garland by his elaborate and carefully conducted experiments, demonstrated that the lung, by virtue of the strength of its contractility, draws up the pleural effusion along with it, in its retraction.* Thus the liquid assumes a pneumo-dynamic instead of a hydrostatic level. *The physical cause of this condition is the retractile force of the lung.* This is aided by the elastic resistance of the thoracic walls and the negative pressure exercised by the effused liquid. It must be borne in mind, that the normal line on the right side of demarcation between lung and liver is the letter S curve drawn out, the summit being low and the anterior branch correspondingly depressed. The modification of this normal line in pleuritic effusions represents the effect of the negative pressure of the fluid; and the decline in the Ellis curve toward the sternum shows that the elastic energy of the anterior part of the lung is feeble, compared with that in the axillary region. The layer of liquid is of less thickness above than at the base of the lung against the diaphragm. The upper surface taking its shape from the lung which lifts it by its retractility, the effusion by its weight exerts a negative pressure upon the lung. The mass of the fluid is held, when in moderate quantity, in the



supplemental space between the lower border of lung and the diaphragm (Garland). The atmospheric pressure from the interior of the lungs and from the exterior of the chest wall keeping the costal and parietal surfaces together.

The line of the distribution of the pleural liquid, we conclude, shows a very important influence of lung retractility. This ought never to be lost sight of in studying diseases of the chest.

We next propose to call your attention to the effects of the retractility of the lungs in producing

#### DISPLACEMENTS OF ADJACENT ORGANS IN PLEURISIES.

The displacement of the heart as a physical sign indicating the presence of fluid in pleurisy, is one of great significance. It is indeed a cardinal sign, second only in value to percussion flatness. It is almost invariably met with. Stokes stated that it was observed at an early period, and was one of the very first signs of effusion; that it may exist even before the upper portions of the chest have become flat on percussion; and is a circumstance of constant occurrence, long before any yielding of the muscular portions of the thoracic walls. Dr. Douglas Powell states, that the heart is displaced at the very commencement of the effusion and that its dislocation increases *pari passu* with the effusion. He adds that the absence of this displacement, unless it can be explained by some special circumstance, which rarely occurs, such as the retention of the pericardium by old adhesions or by consolidation of the opposite lung, would negative the diagnosis of unilateral effusion. In this condition there is a marked contrast with the displacement and depression of the diaphragm and the resulting alteration of position of the liver, spleen and stomach. These only occur where the effusion is in great excess—when even the Skodaic resonance at apex has disappeared—and not until, from the large quantity of fluid, the retractility of the lung is overcome and is, consequently, unable to lift up the fluid and the diaphragm. This altered position of the diaphragm drags the heart downwards by means of the ligamentous attachment of the pericardial sac to its tendinous portion. The deviations from

the normal position of the heart in slight effusions can always be noticed, if the exact point of the apex beat is sought for by palpation and listened for with the stethoscope. Careful percussion will show the shifting area of the flatness.

Dr. Powell calls attention to a fallacy with reference to cardiac displacements in the earlier stages of effusion, namely, that as the base of the lung retracts, the left or the right margin of the heart as the case may be, becomes uncovered. This may lead to an apparent delay in the displacement of the organ, the more extreme left or right boundary being now within reach of palpation. The axis of the heart is not greatly changed by an ordinary degree of effusion. It becomes a little more vertical and in extreme cases it may become slightly twisted. Only in rare and extreme cases does the axis of the heart become altered in direction beyond the vertical line. Dr. Powell found at a post-mortem a heart that had become so twisted as to present itself obliquely edgeways to the view of the observer in front. Dr. Gibson had previously pointed out this disposition of the heart to turn over and to present its posterior surface forwards in cases of effusion.

There can be no question as to altered situation of the heart in pleurisy. How is this displacement effected and what is its significance? Until within a few years and indeed very generally now, it is believed that the sole cause is from the direct pressure of the fluid actually pushing the heart away from its normal position. Skoda, Traube, Stokes, Powell and Garland were, we believe, the first authors to show that such was not the case, certainly in moderate effusions. The *displacements take place when the amount is very small and no direct pressure is possible*. It is true that nature places the heart in such a position that it can yield readily to slight forces. It hangs in the pericardial sac which is suspended by the aorta and which is bound by ligaments to the body of the third dorsal vertebra. Every change of the position of the body causes certain physiological alterations of the heart's position.

Wintrich, Skoda and Braune think that the heart swings like a pendulum from its base and that its apex is therefore elevated with every deviation to the right or left. Lebert says the heart

is first depressed by the sinking of the diaphragm and then elevated by being pushed to the right. Fraentzel says, that in displacements to the right, the heart is simply pushed over and is never elevated as Wintrich describes it. Woillez maintains that the mediastinum offers but slight resistance and is very easily pushed to the right side, where there is no compact organ to resist and where the cavity is larger, whereas it is with more difficulty pushed to the left where the heart occupies so large a space.

*It has been satisfactorily demonstrated that until the pleura is about two thirds full of fluid, no positive pressure is exercised upon the lungs or heart.* According to Rokitansky, the lung cannot be compressed until seven-eighths of the pleural cavity is occupied by fluid. The fluid cannot be drawn off by a canula unless air enters to replace the fluid. Fraentzel states that unless the pressure on the fluid from within the cavity be greater than that of the atmosphere we cannot draw off a large quantity; if, however, the pressure balances that of the atmospheric air, only a few drops of fluid are discharged externally except by forced expirations and coughs. This he found was the case even when the quantity reached several litres. The feebler the expiratory force, the less fluid reached. Yet the heart is displaced as soon as the effusion appears, even in small quantity. *The significance of the displacement is that it shows us the presence of fluid, but does not give us the measure of intra-thoracic pressure* (Powell). Dr. Garland's explanation is, that the heart with the sac and its connections in health is placed between two highly elastic bodies (the lungs), which are striving to retract in opposite directions. The heart, therefore, being acted upon on both sides—by opposing forces, occupies a position where these forces just balance each other. This is the status of physiological repose, in the vertical position of the body. When an effusion is poured into either chest, the lung of that side contracts and thereby exhausts a certain amount of its retractile energy. The opposing lung, however, still remaining normal, immediately begins to draw the heart towards itself, and the degree of displacement thereby induced will be proportional to the diminution of energy in the compromised lung.

*Dr. Stokes* divided these displacements into *eccentric* and *concentric*. The former he considered were due to direct pressure of the fluid, and the latter existed where, from any cause, there was diminution of volume of one lung, the other lung by its increase of volume forcing it over. The concentric displacements, he thought, were generally the result of some chronic disease producing atrophy of the lung.

Thus, we see that displacements of the heart occur at three distinct periods in the course of pleurisy and from different causes in each case.

1st. As soon as fluid forms in the pleural sac. At this period the displacement is caused by the presence of the fluid which occupies part of the pleural cavity. The lung by its elasticity retracts. It is consequently of less volume and exerts less negative force upon the mediastinum and its contents than the healthy lung. The two lungs having by their equal tractile energy kept previously the heart in situ, the healthy lung draws the mediastinum out of its position in a transverse direction. Necessarily the displacement of the heart from this cause is in proportion to the amount of fluid effused. This is the most frequent mode of displacement of the heart. It can be said to be almost always present.

2d. When the quantity of fluid is great enough to overcome the retractility of the lung and exert intra-thoracic pressure it forcibly expels the air from the alveoli of the lung and by direct, positive pressure pushes the heart aside. The displacement of the heart in this case can only be produced when the pleural sac is two-thirds or more filled by fluid. When this condition is met with, the displacement is very great because the heart has been previously displaced by lung traction. Previous to Garland, Stone and Powell's researches, this was supposed to be the only manner of explaining the displacement of the heart from pleurisy.

3d. Is where, as illustrated by Stokes' and Hunt's cases, and the very interesting case of dextro-cardia reported last year by Professor Chew, the heart is displaced towards the diseased side. This occurs more as a sequel of pleurisy. It is met with in the course of the absorption of chronic or suppurative pleurisy where

by non-expansion of lung there is a partial vacuum produced. The external atmosphere presses in the thoracic walls of the diseased side, and the internal atmospheric pressure from the healthy side is exerted against the mediastinum and presses the heart in that direction. Marked displacements from this cause are rare, slight displacements are more frequent. Cicatrices from healing of large cavities would have this effect. Mere consolidation of lung could not cause it. Let us now look into the cause of the *Displacement of the Lung*. We have already shown that the lung, in cases of effusion, is drawn up by its own retractile energy. It has been demonstrated that this force is considerable (from 4 to 5 inches of water). As the effusion advances the lung recedes until a certain point, when the fluid, having overcome the retractility of the lung, and having a fixed point below, actually exerts positive pressure upon the lung (Garland), and compresses the air out of the alveoli and the compressible bronchi. This compression cannot take place until the diaphragm is no longer elevated into the thorax, but is bagged down by the excessive weight of the fluid. Jaccoud and Fraentzel both confirm this view, that there can be no compression of lung until its elasticity has been exhausted. The gradual effect of the continued contraction of the lung is to straighten out the letter S curve. The force of lung necessarily gradually diminishes as it contracts in volume. On the other hand, the immediate effect of compression would be to obliterate that curve. So long, therefore, as we are able to trace a well marked letter S on the chest, we may be certain that the lung is well out of reach of compression (Garland). M. Peyrot showed by plaster of Paris injections into the chests of cadavers and then making cross sections, that deformities of the chest are not due to a development of one side, the other remaining normal, but that they consist of a mutual adjustment of all parts. Fernet states that simultaneous movement of the sternum toward the left in left sided effusions, makes the displacement of the heart appear greater than it actually is. Let us study next the condition of *The Diaphragm and Intercostal Spaces*.—As shown by

Garland, the diaphragm is not depressed below the edge of the ribs, nor do the intercostal spaces bulge until the weight of the fluid exceeds the lifting force of the lung. Dr. W. H. Stone showed the same result from the admission of air into the pleural sac. Skoda says, "the depression of the diaphragm is due in part to the weight of the fluid, but chiefly to the diminished contractile energy of the retracted and diminished lung. The displacement of the mediastinum depends upon similar conditions. Since the traction of the lungs always affects both sides of the thorax, the movable mediastinum must follow the lung which is still capable of contracting, and therefore with right-sided exudations the left lung will draw the parts over to itself. Only with excessive effusions in the pleural cavity, does the pressure of the fluid come into activity.

*The Liver and Spleen* may be pushed below their normal position by excessive effusion, after the diaphragm yields to the weight of the fluid. Moillez found the liver displaced downwards in the abdominal cavity in one-fourth of the right pleurisies and only once in the left side pleurisies. The extent on right side was from two or three centimetres to three fingers breadth, even as far as umbilicus.

*The Stomach*, when the diaphragm sinks, may be pushed downward; thus the so-called semi-lunar space of Traube may be obliterated. Ferber noticed a peculiar displacement of the stomach in two cases where he had produced an artificial hydrothorax of the left side. The fundus was pushed to the right, and the stomach was folded over on itself to a certain extent. A second and marked folding in of the greater curvature occurred near the pylorus. Ferber says, that this condition of stomach, with left-side pleural exudations, has been hitherto entirely neglected by authors. He thinks that the vomiting which is often observed with excessive effusion and which has been attributed to violent acts of coughing, may be due to this doubling over of the stomach.

PNEUMO-THORAX.—Before concluding, gentlemen, let us see if the retractility of the lung is not a powerful influence in pneumothorax. The opening into the pleural cavity may be direct or

oblique. If direct it remains open, if it be oblique, it is generally more or less valvular. The symptoms, prognosis and treatment vary accordingly. Through a patent orifice the air enters in inspiration, and goes out with the expired air from the lungs. It cannot accumulate; consequently there can be no positive air-pressure within the pleura. If, however, the orifice be valvular, although the air enters it does not escape, for it presses upon the valve and closes it. If the valvular fold be perfect, the air soon becomes excessive in quantity and exerts dangerous pressure upon the lung and adjacent organs. By means of a trocar fitting by tubing to a water-pressure guage, Dr. Douglass Powell ascertained, post-mortem, the degree of intra-pleural pressure present in sixteen cases of pneumo-thorax. In four out of these cases, the pressure was *nil*. In twelve, there was more or less intra-pleural pressure present, varying in degree from one and three quarter inch to seven inches of water.

Unless the lung be mechanically prevented, the entrance of air into the pleural cavity at once produces a retraction of the lung owing to its elasticity. There will be no compression of the lung unless the air be increased in quantity by each inspiration, and having no exit, accumulates; then, the lung may be forced against the spinal column and the residual air actually forced out of the alveoli. Dr. Powell questions whether the intra-thoracic pressure excited in pneumo-thorax is ever equal to what is sometimes met with from pleurisy; the highest he had ever met with in pneumo-thorax was seven inches of water. Garland, in repeating Damoiseaux's experiments in testing the effects of the introduction of air into the pleural cavity, found that the air did not penetrate between the lung and the lateral chest walls until the lower border of the lung had retracted upwards the distance of several ribs.

One of the most pronounced effects, constantly observed in *pneumo-thorax*, is the immediate displacement of the heart to a greater extent than even in pleurisy. M. Gaide, as far back as 1828, described displacement of the heart as an important sign of pneumo-thorax. He related a case, where, at the moment of the perforation, the woman was conscious of the heart's beat, having

been transferred to the right of the sternum. Dr. Powell in 17 cases found it to have occurred in 16; in the 17th the unruptured lung was so consolidated that it could not collapse. In pneumothorax of the right side a careful examination is sometimes required to detect the displacement of the heart. The apex can be discovered at considerable distance to the left of the nipple, with the right ventricle drawn to the left edge of the sternum. It has been generally believed that the cause of this displacement was the intra-pleural pressure of the air, but this does not satisfactorily explain it, for there can be no pressure until the elasticity of the lung has been overcome. In thirteen of Dr. Powell's cases there was great displacement of the heart with different degrees of intra-pleural pressure. In three cases there was great displacement of the heart, no intra-pleural pressure. The same author showed, experimentally, that the elastic tension of one lung, when unopposed by that of the other, was sufficient to draw aside the mediastinum, and, with it, the heart.

He thus showed that these displacements are by no means necessarily a sign of intra-pleural pressure, since they may occur to the right of the sternum without there being any pressure. Clinically we know that the admission of air into the pleural cavity immediately and constantly displaces the heart, unless the opposite lung be consolidated or otherwise injured in its resiliency. This occurs even when the patent orifice of the perforation prevents the accumulation of any quantity of air. There is not enough air to produce direct pressure, but there is enough to impair the elastic traction of the lung of that side, and thus to destroy the equilibrium of traction which keeps the heart in its normal position. The healthy lung, by its unimpaired tractile force, immediately draws over the heart. Skoda maintains that "air does not enter the pleural cavity simply at the cost of the torn and retracted lung, but the sound lung also retracts to such a degree as the mediastinum is movable." Dr. Garland's experiments conclusively demonstrate that the air in pneumothorax is powerless to exert any appreciable lateral displacing force until the lung is completely collapsed, and this does not ordinarily occur. There can be, he says, but one cause of this constant and



early displacement of the heart, namely, the elastic force of the opposing lung which draws those parts over to itself.

He adds "that the explanation of the greater displacement of heart in pneumo-thorax is, because the air having practically no weight, cannot exert upon the heart the negative pressure which an effusion evidently would."

*We conclude, gentlemen, that lung retractility is not only a powerful physiological force in respiration, but that it also produces modifications of a decided character in diseases of the chest.*

The practical value of these facts consists,—in the aid they give us to the differential diagnosis of pleurisy and pneumo-thorax; the assistance they afford us in estimating the quantity of fluid in the pleural cavity; and the indications they furnish us as to the advisability of resorting to thoracentesis.





