PNEUMOTHORAX AND POSTURE.¹

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The danger from the sudden entrance of air into the normal pleural cavity has, more than anything else, impeded the progress of the surgery of the lungs and of the other intrathoracic viscera. Because of the importance of the subject, much careful experimental and clinical work has been done, and many investigations have been made to determine the cause of the dangerous respiratory embarrassment which is apt to ensue. Little or no attention has, however, been paid to the question whether posture has any influence upon the symptoms which appear when the normal pleural cavity is laid open. In fact, this phase of the subject is mentioned in only a few publications. In a discussion on the surgery of the lungs at the congress of the French surgeons in 1906, Dépage² stated that he thought it best to have the patients in whom the pleural cavity had to be opened during the course of an operation flat on the abdomen. He did not, however, give any reasons why he recommended this position. Kocher,³ in the last edition of his Operative Surgery, declares that, when the chest is to be opened, the patient should be placed on the side or abdomen, but he does not say whether he believes there is any advantage in the prone posture.

In this paper, experiments are described which were made with a view to determine what influence posture may have upon the symptoms of pneumothorax.

EXPERIMENTAL INVESTIGATIONS.

Open Pneumothorax.—The following experiments deal with the subject of pneumothorax caused by a free opening into one or both

¹ Received for publication January 8, 1909.
² Congrès de chirurgie, Transactions, 1906, xix, 387.
³ Chirurgische Operationslehre, 1907, p. 701.
pleural cavities. The method of operation for the open pneumothorax experiments was the following:

The animal was given a hypodermic injection of morphine several hours before the experiment was begun. Under ether anesthesia, tracheotomy was performed, a tracheal canula inserted, and the administration of ether continued through the canula. A large skin flap was then raised on one side of the chest and a subperiosteal resection of one or more ribs made. The intercostal muscles were carefully divided and the parietal pleura was exposed. While the animal was deeply under the influence of the anesthetic, a small opening was made in the pleura and the effect noted. The opening was then gradually enlarged. In a number of the animals, the pressure of the inspired and expired air was roughly measured by allowing the animal to breathe into a large bottle, the tube leading to the bottle from the tracheal canula being connected by means of a T-tube with a water manometer. During the entire time of observation the animals were kept deeply under the influence of the anesthetic, so that all of the reflexes were abolished.

The symptoms which ensued, in my observations, when an opening was made into one or the other pleural cavity will not be described in detail. For the purpose of this paper, the following facts will suffice. When a small opening is made into one pleural cavity of a dog, air enters the pleural cavity with a hissing noise and the lung collapses. For a moment respiration ceases, then the breathing becomes more rapid and deeper and the animal makes violent efforts at respiration. If the opening in the chest be a small one (1 to 5 mm.), one of the following several conditions will ensue: (1) After a few moments of violent respiration, expiration becomes prolonged and the heart suddenly stops beating; (2) more often the breathing will gradually return to the normal although the amount of inspired and expired air will be found to be considerably below the normal; (3) sometimes, after a few minutes, the breathing becomes irregular, violent inspiratory efforts alternate with prolonged slow expirations, the heart's action becomes slow and irregular until it ceases altogether.

Many dogs stand a small opening into the pleural cavity well. The larger the opening, however, the more likely is the occurrence
of serious interference with respiration. In almost all animals in which the size of the opening approached to or exceeded that of the diameter of the animal's trachea, dyspnea and death followed. No matter how slowly and cautiously the opening was made, typical dyspnea of a preponderant expiratory character ensued, the heart became irregular and weak, the pleural septum between the two sides bulged into the opening in the chest with each violent expiration, and rupture of the septum with double pneumothorax or sudden stoppage of the heart occurred.

The statements of most of the experimenters agree with those above given. Most of their animals died from the pneumothorax when a large opening was made in the chest. Thus Gluck lost all of the dogs he used; Biondi lost four of five; Block, Marcus, Schmidt, Pourrat and Rodet, Quenu and Longet, Sauerbruch, and many others had similar experiences. It should be mentioned that in the experiments of the above named authors the animals were operated upon in the supine position.

The Influence of Posture.—(a) Supine and Lateral Postures. Openings were made in the thorax, in various places on the right and left side, near the sternum, the vertebral column, the diaphragm or the clavicle. Here again the opening was at first of small size, then it was gradually enlarged. During the observations, the posture of the animal was frequently changed, so that the animal lay sometimes on its left side, on its right side, on its back, on its abdomen; sometimes its head was raised until the animal was almost suspended vertically, sometimes it was hung up by its hind legs. In all animals, excepting those that were kept on the belly, the symptoms which ensued when a small or large opening was made in the chest were those of open pneumothorax as described above. In the experiments, no differences were found between the symptoms produced by an opening in the right as compared with one in the left pleural cavity. Twenty dogs were used in these experiments; nineteen of the animals succumbed under the typical pneumothorax symptoms when a large opening into one pleural cavity was made. One dog, however, remained alive in spite of the

*A complete account of the work that has been done will be found in the paper of Sauerbruch, *Mitteil. aus den Grenzgebieten der Med. und Chir.*, 1904, xiii, 399.
fact that a large opening (6 cm. in diameter) had been made in the right chest. The animal presented many of the typical symptoms of pneumothorax, but its heart action remained regular, and respiration—though irregular and weak—continued. There are some few dogs that are apparently quite insensitive to the entrance of air into the pleural cavity.

The foregoing statements may be illustrated by the following two abbreviated protocols.

**EXPERIMENT I.—Large black male. On back; deep anaesthesia; canula in trachea connected with large bottle and by T-tube with water manometer. Inspiration 40–50 mm., expiration 50 mm. The animal was observed for five minutes, during which time the parietal pleura was exposed in the usual manner. With a small knife an opening 4 mm. in length is made in the right pleura. Inspiration and expiration at once become violent; inspiratory pressure 4–8 mm., expiratory pressure 15–25 mm. The breathing becomes more and more labored and expiration begins to be stronger than inspiration. After three minutes, inspiration 2–5 mm., expiration 25–40 mm., the animal presents all of the symptoms of pneumothorax dyspnea. Respiration irregular, expiration prolonged; heart irregular and slow, marked bulging of mediastinal septum at each expiration. The inspiratory oscillations of the manometer are almost nothing. The heart suddenly stops beating.

**EXPERIMENT 2.—Large male. On back; preparation as above in Experiment 1. The left pleura is exposed by resecting two ribs. Respiration 56; pulse 108. With a small knife, an opening measuring 3 mm. is now made. The animal stops breathing for 30 seconds, then breathing begins again at the same rate as before. Pulse now 136. Breathing is somewhat more labored. The animal is now turned on its right side; character and rate of respiration remains the same. No change is observed when the animal it turned on its left side or when turned on its back again. The opening in the pleura is now enlarged to 7 mm. Inspiration and expiration become deep and irregular; then inspiration becomes weak while expiration becomes more forcible and prolonged. With each violent expiratory effort the mediastinal septum bulges into the opening in the chest. Finally the septum ruptures and collapses, the heart then stops suddenly.

**Prone Posture.—**In the following experiments, the animals were operated upon in the prone position, or they were first on the back and were later turned on the belly.

When a small opening is made in the pleural cavity of a dog that is lying on its belly, the animal will, in most instances, continue to breathe quietly like a normal animal. Even a very large opening (2 to 6 cm. in diameter) can be made, and breathing go on regularly and quietly, almost if not quite like the normal. Even one-
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half of one chest wall can often be removed and the dog survive for hours. These statements are given after observations made in a large number of experiments, of which only the following few abbreviated protocols are given. It must be expressly stated that deep anesthesia is essential for the success of the experiments.

Experiment 3.—Large brown bitch. On belly; tracheotomy; usual preparation.
4:40 p. m. Deep anesthesia, inspiration 90 mm., expiration 70-90 mm.
4:50. Opening 3 mm. in diameter in left pleura, inspiration 40-60, expiration 50-70; animal is breathing quietly.
5:00. Opening enlarged to 2 cm., inspiration 25, expiration 30-40.
5:30. Opening enlarged to 6 cm., inspiration 30, expiration 40.
5:40. Inspiration 40, expiration 40.
During the entire time of observation the animal breathed quietly and there was no evidence of dyspnea, in spite of the fact that the amount of inspired and expired air was about one-half of the normal.

Experiment 4.—Small black female. Under artificial respiration a large opening 4.5 by 7 cm. was made in the right chest while the dog was on the belly. Artificial respiration then stopped. The animal continued to breathe quietly and the heart action remained strong and regular for 45 minutes, when the observation ended.

Experiment 5.—Large brown male. With the animal on the belly, an opening 6 by 4 cm. was made in the left pleural cavity under artificial respiration. The animal continued to breathe quietly and regularly for over an hour. It was then killed.

If a dog, on its back, with an opening in its chest and with typical dyspnea due to the pneumothorax, is turned on its belly, the breathing will often become regular and quiet again, and the pressure of air breathed in and out will be found to be several times as great as when the animal was on its back. On the other hand, a dog on its belly with a large opening in one pleural cavity and breathing quietly, can be brought into a condition of grave dyspnea and asphyxia by turning it on its back. Sometimes it is even possible to resuscitate an animal that has stopped breathing by thus turning it on its belly.

This is illustrated by the following protocols:

Experiment 6.—Large black male. After the usual preparation (tracheotomy, cannula connected with manometer, deep anesthesia) the animal is placed upon its back, and an opening 4 mm. in diameter is made in the right
pleural cavity at 3:15 p. m. Respiration at once becomes deeper and expiratory dyspnea begins. Inspiration 90, expiration 100.
3:18 p. m. Inspiration 50, expiration 80.
3:20. Inspiration 20, expiration 90; violent dyspnea.
3:21. Opening in chest enlarged to 1 cm.; inspiration 20, expiration 90; dyspnea very violent.
3:22. Opening enlarged to 3 cm., inspiration 20, expiration 30.
3:22½. Inspiration 5, expiration 10; heart action very irregular.
3:23. Inspiration 0, expiration 0; violent efforts at respiration, but manometer shows that no air is inhaled or exhaled. The heart suddenly stops beating. The animal is now quickly turned on its belly and artificial respiration given for one minute.
3:25. The animal is now breathing better again; inspiration 30 mm., expiration 40 mm., heart beating regularly.
3:26. The animal is now turned on its back. Dyspnea begins at once; inspiration 0-5, expiration 5-10.
3:27. Turned on belly; inspiration 30, expiration 40; breathing somewhat stertorous at first, but becomes gradually quiet and regular.
3:29. Animal has been breathing quietly for several minutes; it is now turned upon its back. Violent dyspnea begins at once, and continues until rupture of the mediastinal septum occurs two minutes later. The animal cannot be revived by artificial respiration.

EXPERIMENT 7.—Large dog. On back; canula in trachea connected with water manometer; deep anesthesia; inspiration 50 mm., expiration 40-50 mm. An opening 7 mm. in diameter is made in the left pleural cavity in the usual manner. The breathing becomes slightly labored and irregular. After 12 minutes the breathing is still good although there is now well marked expiratory dyspnea. Inspiration 20-35 mm., expiration 60-90 mm.

The board on which the animal is tied is now inverted so that the dog lies with its belly downward. The character of the breathing improves at once and the pressure of inspired and expired air is much greater; inspiration 130, expiration 140; at times inspiration 50-70, expiration 80-120; sometimes inspiration is more deep than expiration. Breathing good though somewhat labored. The board is now turned over so that the dog lies on its back again; violent dyspnea begins at once. The opening in the chest is now quickly enlarged to 3 cm.; inspiration and expiration are now almost nil although the animal makes violent expiratory efforts; pulse slow and weak. The board is now quickly turned over again so that the animal hangs belly downward; breathing becomes better and heart action stronger. Especially noticeable is the fact that the mediastinal septum no longer bulges on expiration. A few minutes later, the board is turned again so that the dog is again on its back; with one violent expiratory effort the mediastinal septum ruptures and the heart stops.

A dog on its back will sometimes stand a double pneumothorax when the opening in each pleura is a very small one—not more than 1 to 2 mm. in diameter—and made very slowly. But with the dog on its belly, an opening almost 1 cm. in diameter can sometimes be made, if cautiously done, and the animal may continue to breathe
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for a considerable time—sometimes for more than one hour. This was demonstrated by the following experiment:

**Experiment 8.**—Large brown male. *On back*; usual preparation; inspiration 140 mm., expiration 140 mm. Under deep anesthesia; inspiration 100–140, expiration 90–100 mm. An opening 3 mm. in diameter is now made in the left pleura; inspiration 90, expiration 90. Five minutes later; inspiration 70–85, expiration 80–90; there is slight dyspnea. An opening 3 mm. in diameter is now made in the right pleura; the dog awakes from the anesthesia and begins to struggle; inspiration 60–80 mm., expiration 100–130 mm. The animal is again deeply anesthetized; inspiration 50 mm., expiration 90 mm.; moderate expiratory dyspnea. The animal is now turned on its belly; inspiration remains the same, but the dyspnea is distinctly less marked. Five minutes later there is only slight expiratory dyspnea. The opening in the left pleura is now carefully enlarged to 1 cm. There is no essential change in the character of the respiration. The animal is now turned upon its back; expiratory dyspnea begins at once, heart action slow and irregular; inspiratory and expiratory pressures 0 mm. After three minutes of artificial respiration; inspiration 2–3 mm., expiration 5–15 mm. The animal is now quickly turned upon its belly; it is at once evident that there is much less dyspnea; inspiration 20–30 mm., expiration 30–40 mm. During the following thirty minutes the animal continues to breathe well without more than slight dyspnea.

**The Relation of the Position of the Heart to the Influence of Posture.**—It has been proved by the above experiments that there is a decided difference between the symptoms of pneumothorax in dogs operated upon in the prone as compared with those in the supine position. Not only did the animals present few changes in respiration and heart action when they were on the belly, if a small opening was made in the pleura, but very large openings could be made without causing serious symptoms, if the animals were kept on the belly or were turned into that position. The measurements of the pressure of inspired and expired air showed that decidedly more air was drawn in and exhaled when the animal was on its belly.

This is not due to the animal's lying on its chest, because if the animal is suspended with its belly downward (see Experiment 7) so that no pressure is made on the thorax, similar effects are to be observed. It might be due, however, to the change which occurs in the position of the heart in the thorax in the change from the supine to the prone position. When the animal lies on its back, the heart falls backward toward the vertebral column; when the animal lies upon its belly, the heart falls toward the anterior chest wall. In order to determine whether this change in the position of the heart...
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had anything to do with the difference in the pneumothorax symptoms, the organ was fixed to the anterior chest wall or to the vertebral column, and the effect of posture upon the symptoms in these animals was studied.

Under artificial respiration and ether anesthesia, a small opening was made in one pleural cavity, the pericardium grasped with a forceps and brought into the wound. If the animal was operated upon in the supine position the opening in the pleural cavity was made near the sternum. In this animal, the pericardium was attached to the anterior chest wall near the sternum by a suture which passed around a costal cartilage at the sternum. If the animal was operated upon in the prone position, the pericardium was attached to the vertebral column by a suture which passed from the pericardial sac through the muscles of the back near the vertebrae. The ends of the sutures in both cases were left long so that they could be easily cut when desired. In this manner, in the animals that were operated upon while on their back, the pericardial sac and heart were pulled forward against the anterior chest wall; in the animals operated upon while on their belly, the pericardial sac and heart were pulled toward the vertebral column. After the suture had been tied, artificial respiration was stopped, and the opening in the pleural cavity enlarged. The animal was observed for a time and then the suture which fixed the heart was cut. The results of these experiments can be summed up as follows:

In the case of the dog lying on its back with the heart attached to the anterior chest wall so that it could not fall backwards, a large opening could be made in one pleura—almost as large as in former animals lying on the belly—without the occurrence of serious respiratory difficulty. In other words, when the heart is fixed to the anterior chest wall, a fairly large opening can be made in the pleural cavity and breathing remain good no matter what the posture of the animal. The moment, however, that the stitch was cut and the heart allowed to drop backward, the typical pneumothorax symptoms occurred.

In the case of the dog on its belly with the pericardial sac attached to the posterior chest wall by a suture, no more than a very small opening could be made in one pleura without the immediate appearance of pneumothorax symptoms. In other words, if the
heart is fixed to the posterior chest wall, pneumothorax symptoms appear as soon as there is an opening into the pleural cavity no matter what the posture of the animal. If the dog is lying on its belly, and the stitch is cut so that the heart can fall toward the anterior chest wall, the symptoms disappear or are much relieved, and the animal then acts as would any dog lying on its belly with an opening in one pleural cavity. Although there were some exceptions, the experiments were successful in a sufficient number of cases to justify the conclusion that the position assumed by the heart, in the prone posture, is an important factor in the difference between the symptoms produced by an opening in the pleural cavity in the prone as compared with the supine animal.

**DISCUSSION AND SUMMARY.**

The last mentioned fact may perhaps find its explanation in the following statements: the two pleural cavities are separated by the layers of the anterior and posterior mediastinal septa. Between the two lies the heart. In the dog, the posterior seems to be somewhat tougher than the anterior septum, and somewhat more fixed and tense. With violent respiratory movements, it is the anterior septum which more especially flaps to and fro and bulges when an opening in the pleura has been made, and it is the anterior septum which is so apt to rupture and thus cause double pneumothorax and the death of the animal. When the dog is on its back, the heart falls backward and the bulging of the anterior mediastinal septum is made more easy. It is different when the animal is on its belly. The heart falls toward the anterior chest wall and thus supports the anterior septum; hence the flapping of the septum, the interference with the respiration of the lung on the sound side, the bulging on expiration on the open side, can not so readily occur.

The danger of the open pneumothorax is greatly lessened when the animal is in the prone position. In the supine position the danger of the pneumothorax is due to the falling back of the heart and thus facilitating the rupture of the fragile anterior mediastinal septum; the danger is therefore obviated by fixing the pericardium to the anterior wall of the thorax.

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