

AN EXPERIMENTAL STUDY OF THE QUESTION OF
ASPIRATION OF FOREIGN MATERIAL INTO THE
AIR PASSAGES DURING INTRATRACHEAL
INSUFFLATION.*

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Two years ago Meltzer and Auer¹ published experiments showing that by insufflation of a continuous stream of air through a tube reaching to the lowest part of the trachea, the life of curarized animals could be sustained for four hours or longer. In these experiments the tube was introduced through an incision in the trachea; and the diameter of the tube had to bear a definite relation to that of the trachea. Further experimentation upon the subject showed that similar results could be attained even when the tube was introduced into the intact trachea through the mouth and larynx. In this case, however, the tube had to be of a smaller caliber than when introduced through an incision in the trachea. Furthermore, to make the method safe with regard to a sufficient exchange of gases, it was arranged that the insufflation be interrupted, for a second or two, several times in a minute. This is the procedure now known under the name of "intratracheal insufflation"²—a practical, efficient method for intrathoracic surgery as well as for general anesthesia.

One of the possible dangers of this method is that of the entrance of foreign matter into the trachea, causing, possibly, an aspiration pneumonia. Since the tube keeps the glottis and epiglottis open, the secretions accumulating in the pharynx may conceivably enter alongside the tube into the trachea during an inspiration, or through an act of swallowing, or they may simply run into the

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¹ Meltzer and Auer, *Jour. Exper. Med.*, 1909, xi, 622.

² Meltzer, *Med. Record*, 1910, lxxvii, 477.

larynx and trachea while the animal (or human being) is under deep anesthesia. This danger may be especially great when vomiting occurs while the tube is in the trachea. The belief of some writers³ that vomiting can not take place while a tube keeps the glottis open, is, as we shall see later, not true, at least not to the extent assumed. We are not aware that this claim has ever been tested experimentally.

There is another assumption, which bears a special relation to this point, that has not been investigated experimentally; namely that aspiration into the trachea can not take place while the glottis is kept open by a tube. The rare occurrence of pneumonia in cases which have been intubated by the O'Dwyer method seems to support such an assumption. Kuhn,⁴ the originator of the method of the peroral intubation, thoroughly believes this and quotes in its behalf a statement of one of the present writers⁵ made in a discussion on intubation at the X International Congress held in Berlin in 1891. The remark reads as follows: "Sowohl Pneumonie, wie überhaupt alle Lungenerkrankungen, die durch Invasionen von infektiösen und indifferenten Fremdkörpern hervorgerufen werden, können bei offen stehender Glottis (wie bei der Intubation) gar nicht zustande kommen, weil das Hineingelangen von Fremdkörpern in die feinsten Bronchien nicht durch Aspiration, sondern durch einen rückläufigen Strom bewirkt wird, der entsteht, wenn bei geschlossener Glottis eine energische aktive Expiration ausgeführt wird, so z. B. beim Husten oder bei der Aktion der Bauchpresse." From the above quotation it is evident that the writer did not intend to imply that no aspiration can occur, that is, that no foreign matter can enter the trachea and the larger bronchi as long as the glottis is kept open. It is only claimed that no aspiration pneumonia can develop, that is, that the aspirated foreign material can not be driven into the finest bronchi and alveoli, as long as the glottis is kept open. Even this latter point is only an hypothesis, the validity of which, however, need not be discussed

³ Greene, *Med. News*, 1895, lxxvii, 9; *Med. Record*, 1897, li, 465. Hubbard, *Med. Record*, 1897, li, 213.

⁴ Kuhn, *Deutsch. Ztschr. f. Chir.*, 1905, lxxvi, 148.

⁵ Meltzer, *Verhandl. d. X. internat. Med. Congr.*, 1892, iv, Abt. xii, 107.

here. For even if the assumption be correct, as long as foreign material can get into the trachea and bronchi at all, the danger of pneumonia remains, because on the withdrawal of the tube the normal activity of the glottis returns. On the other hand, there seems to be no valid reason for assuming, as Kuhn does, that no foreign material can enter the trachea as long as a tube is present within the larynx. This conclusion had, at the time it was made, no practical importance, since by Kuhn's method measures were taken to prevent the entrance of foreign material into the larynx alongside the tube. In recent communications, however, Kuhn⁶ states expressly that such special measures are now omitted—"Es fällt jede Abdichtung weg." The question hence arises, by what mechanism, in the use of the method of peroral intubation, is the aspiration of foreign material prevented, and is it really prevented? For the method of intratracheal insufflation it is assumed that the practically continuous recurrent stream of air between the tube and the tracheo-laryngeal wall forms a safeguard against the entrance of foreign material into the respiratory tract. The numerous experiments on dogs, in which intratracheal insufflation was used, established the fact that such an invasion did not take place; the trachea was found in all cases examined to be perfectly free from extraneous material. However, the usual experience under normal conditions did not present a strong test since there was in the pharynx no unusual amount of foreign material; under intratracheal insufflation the animals never vomited. The same might be true also for the method of peroral intubation. However, some instances may present themselves in which there will be an unusual amount of mucus or blood, or the patient or the animal will vomit; the questions are then: What will happen to the respiratory tract under such circumstances? Will the return current of the insufflation method prove still to be a sufficient guard? And what guards against the invasion into the respiratory tract of these foreign materials in Kuhn's method of peroral intubation without the precautionary "Abdichtung"?

As regards intratracheal insufflation, some experiments, constituting severe tests, had already been made which were referred to very

⁶ Kuhn, *Centralbl. f. Chir.*, 1908, xxxv, 788.

briefly in a previous communication.⁷ But they were few in number and did not cover all the points concerned. The subject was therefore taken up again and a sufficient number of experiments made under various conditions to enable us to answer in a definite way the questions raised. The following is a brief account of these experiments.

INSUFFLATION AND EMESIS.

In one series of experiments the condition of the trachea and bronchi was studied after the animal was made to vomit. A few such experiments, as stated, had been made before with the insufflation method. This previous experience taught us a few facts, which now saved some preliminary work. It had been found previously that while the animal is receiving intratracheal insufflation it does not readily vomit, unless it has come entirely out of the anesthesia. Furthermore, in order to obtain a satisfactory result the stomach has to be filled first, preferably with an acid solution. Finally the vomiting has to be brought on by an active emetic, for instance by a subcutaneous injection of an effective dose of apomorphin. The present procedure of experimentation was as follows:

The animal was etherized, put on the board, the tube introduced into the trachea, and the ether continued by means of insufflation. Then a stomach tube was introduced and an acidulated solution, containing powdered charcoal in suspension, was poured into the stomach; whereupon the stomach tube was withdrawn. In some instances the stomach was filled before the insufflation tube was introduced. The ether was now discontinued (while the insufflation was continued with air), and apomorphin administered hypodermically. When vomiting occurred, the pharynx and mouth were not cleansed from the vomitus. Some time later ether was administered again, the trachea was exposed and clamped just beneath the larynx immediately on withdrawal of the insufflation tube, and the animal allowed to die from asphyxia. The trachea was now opened on the distal side of the clamp and examined for its contents and their reaction. The trachea should not be examined without previous clamping, because the very act of examination often causes an aspiration from the pharynx. For the same reason the findings above the clamp do not indicate the actual conditions prevailing before the opening of the trachea. In other experiments the animals were allowed to recover after the vomiting was over. They were killed later and the trachea and lungs were examined for the presence of charcoal.

We shall now present some abbreviated protocols illustrating the results of such experiments.

⁷ Meltzer, *loc. cit.*

630 *Aspiration of Foreign Material into the Air Passages.*

Experiment 1.—Yellow mongrel male dog; weight 10,000 grams. 11:10 a. m. Tube No. 17 (American) was introduced into the trachea, the end of the tube being half way between the larynx and sternum; insufflation started with ether. 11:20. The tube was introduced into the stomach and a suspension of charcoal in 250 c.c. of 0.7 per cent. hydrochloric acid was poured in. Ether was discontinued, and insufflation continued. 11:30. Animal coming out from anesthesia; 0.02 gram apomorphin injected subcutaneously. Vomiting promptly followed. 12 m. The trachea was clamped below the larynx. No particles of carbon were found; the reaction was faintly alkaline. There was a small amount of mucus in the bronchi.

Experiment 2.—Female mongrel; weight 6,800 grams. 2:45 p. m. Etherized, intubated, tube No. 15 (American), the end being just above the bifurcation; insufflation with ether. 2:55. 300 c.c. of a suspension of charcoal in water was introduced by stomach tube. Ether was stopped. 2:58. 0.017 gram apomorphin was given subcutaneously. 3:10. Animal vomiting, much retching. 3:15. Vomited a few c.c. 3:50. Animal killed by clamping trachea. No carbon was found in the trachea and bronchi. Pulmonary edema.

Experiment 3.—Black mongrel; weight 2,500 grams. 1:42 p. m. Ether, insufflation with ether. 100 c.c. of 0.7 per cent. hydrochloric acid with charcoal was poured into the stomach. 1:50. Ether was stopped, and insufflation continued. 1:54. Animal moving; 0.01 gram apomorphin was administered. Dog vomited. 2:35. The tube was removed and the dog released from the table; vomited twice later. Killed after 24 hours. Lungs and bronchi normal, no particles of coal.

In not a single instance in which insufflation was continued could the vomited material be discovered in the trachea. The animals which were permitted to survive remained well until they were subsequently killed.

TUBE IN TRACHEA WITHOUT INSUFFLATION.

In a number of experiments the insufflation was discontinued while the tube remained within the trachea, in order to ascertain whether the presence of the tube alone could prevent the entrance of the vomited material into the trachea, as is assumed by some writers.

Experiment 4.—Female dog; weight 4,000 grams. 1:21 p. m. Ether; tube No. 13 (American) was introduced into the trachea, the end being about 5 cm. below the larynx. 120 c.c. of 0.7 per cent. hydrochloric acid was introduced by tube into the stomach. 1:32. Ether and insufflation were stopped, the tube remaining in the trachea. 1:40. Animal moving; 0.015 gram apomorphin administered. 2:10. No vomiting yet; 0.015 gram apomorphin again administered. 2:15. Animal vomits dark brown acid liquid. 2:23. *Acid liquid comes from tracheal tube almost immediately after vomiting, and continues to come.* 2:40. The tube was removed and the dog released from the table; 5 c.c. of liquid obtained from the tube. Death occurred during the following night. The bronchi were partly filled with mucus and dark acid fluid. Areas of consolidation were present.

Experiment 5.—Female dog; weight 3,300 grams. 10:45 a. m. Ether, insufflation, the end of the tube being half way between the sternum and larynx; 90 c.c. acidulated suspension of charcoal was introduced by tube into the stomach. Ether and insufflation were stopped; the tube remained in place. 11:03. Dog moving; 0.01 gram apomorphin administered. 11:33. No vomiting yet; 0.01 gram apomorphin again administered. 11:37. Animal vomited *black fluid, 30 c.c. of which, mixed with particles of food and strongly acid, came from the tube.* 11:52. 7 c.c. of fluid of the same nature came in stream from the tube, although no fluid escaped from the mouth. 12:18. Animal died. Trachea and large bronchi contained vomitus with black particles; acid reaction. The left lower lobe showed pneumonic consolidation. The bronchi of this portion contained no charcoal.

Experiment 6.—Mongrel; weight 9,000 grams. 10:22 a. m. Ether; 250 c.c. aqueous suspension of charcoal introduced into the stomach by stomach tube, tracheal tube No. 11 (American), the end being midway between the sternum and larynx. 11:30. Ether and insufflation stopped, the tube remained in place. 10:37. 0.018 gram apomorphin given. 11:41. Animal vomited a large amount at once; 10 and 15 minutes later a few drops, not as acid as the vomitus, were obtained from the tube. 11:50. Animal killed by clamping trachea. Small specks of carbon found in trachea. Vomitus present in small amounts in bronchi of both lungs, and a good deal of carbon in the bronchi. Some pulmonary edema.

These experiments suffice to demonstrate unmistakably the fact that the simple presence of a tube within the trachea and the larynx does not prevent the entrance of foreign material into the respiratory tract. On the contrary, liquid may enter occasionally in such quantities as readily to escape again through the tube. Moreover, aspirated material may pass down into the bronchi and be the cause, either immediately or later, of serious consequences.

INSUFFLATION AND FILLING UP OF MOUTH AND PHARYNX.

In another series of experiments the test was made by filling up the mouth and pharynx with a suspension of charcoal, chiefly in an acid solution. The results were even more striking than in the previous experiments.

Experiment 7.—Brown and white dog; weight 6,100 grams. 11:15 a. m. Ether, intubation, tube No. 12 (American) inserted deeply in the trachea; insufflation and ether. 11:20. The mouth was filled with a suspension of charcoal in an acid solution. Until 12:10, the filling was repeated eight times. Insufflation continued during the entire experiment; the dog was out of ether for 22 minutes. 12:20. Trachea clamped. No black specks below the larynx.

Experiment 8.—Black and tan mongrel; weight 5,000 grams. 9:03. Intubation, tube No. 12 (American) inserted deeply; insufflation and ether. Until 10:25,

632 *Aspiration of Foreign Material into the Air Passages.*

the mouth was filled eight times with an acid suspension of charcoal. Animal swallowed with difficulty. Insufflation continued throughout the experiment; dog fairly under ether. 10:25. Animal killed by clamping trachea. No carbon below clamp.

Experiment 9.—Yellow dog; weight 5,100 grams. 2:15 p. m. Intubation, tube No. 14 (American); insufflation and full ether throughout experiment; the mouth was filled many times with a charcoal suspension. 3:30. Animal killed by clamping trachea. No speck of carbon was found in the entire respiratory tract.

TUBE IN TRACHEA WITHOUT INSUFFLATION.

Experiment 10.—Black and white dog; weight 4,850 grams. 1:40 p. m. Intubation, tube No. 13 (American) inserted deeply within the trachea. 1:45. The mouth was filled with a suspension of charcoal in acid solution (30 c.c.), the dog swallowing most of the fluid at once. 1:53. A few drops of clear fluid came out from the end of the tube. The mouth was filled three times more, each time with 10 c.c.; the animal struggled and swallowed; no more drops came from the tube. 2:05. Etherized by gauze around the mouth. 2:10. Mouth filled. 2:14. Dog died. The bronchi were full of black specks; acute pulmonary edema.

Experiment 11.—Young dog; weight 3,100 grams. 2:00 p. m. Intubation, tube No. 9 (American) inserted deeply. No insufflation, ether anesthesia by gauze around the mouth. 2:03. Mouth filled with charcoal suspension, acid; most of the liquid was swallowed at once. 11:08. Mouth refilled; respiration became shallow. 11:13. Respiration ceased; the trachea was clamped and the lungs were examined immediately. Particles of charcoal of all sizes filled some of the fine and most of the large bronchi; extensive pulmonary edema.

Experiment 12.—Black and white male dog; weight 5,600 grams. 4:00 p. m. Ether, intubation, tube No. 13 inserted deeply. 4:12. The mouth was filled with charcoal suspension in acid solution, which was swallowed at once. Until 4:55 the mouth refilled six times. Fluid escaped from the tube. No dyspnea. 5:00. Animal killed by clamping trachea. From the trachea down to the finest bronchi large masses of carbon were present. Moderate pulmonary edema.

While in the animals which had insufflation throughout the experiments not a particle of carbon could be found in the respiratory tract below the clamp, in all the animals that had no insufflation the trachea and bronchi were filled with the charcoal masses. It seems that the anesthesia was a fatal factor in these animals. When the anesthesia was not deep, swallowing seemed to exert a beneficial influence by removing a great deal of the threatening material from the pharynx into the stomach. In the animals under the control of insufflation, the anesthesia exerted not the slightest unfavorable influence, although deglutition in these animals was not prompt.

CONCLUSIONS.

The foregoing experiments clearly justify the following conclusions:—

Intratracheal insufflation protects the respiratory tract very efficiently against any invasion from the pharynx. The filling up of the pharynx with extraneous material, whether it be from the stomach or from the mouth, brings no danger to the trachea and bronchi. This holds true even if the animal is under deep anesthesia.

On the other hand, the presence of a tube in the trachea or larynx without the protection of an effective recurrent air stream, definitely facilitates the entrance of foreign material from the pharynx into the trachea. Anesthesia, which removes the protective action of deglutition, greatly increases the danger from aspiration in these cases.