THE INTRAVENOUS INJECTION OF MAGNESIUM SULPHATE FOR ANESTHESIA IN ANIMALS.

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(Received for publication, March 10, 1916.)

The effect on animals of intravenous injections of magnesium sulphate was investigated by us from a general experimental point of view about ten years ago.[1] The use of this salt for practical purposes of anesthesia in human beings was first studied by Haubold and Meltzer by the intraspinal method.[2] About two years ago a combination of subminimal doses of magnesium sulphate intramuscularly and ether by intratracheal insufflation was found by the present writers[3] to be effective in animals, and by Peck and Meltzer and also Elsberg and Meltzer in human beings. The use of magnesium sulphate by intravenous injection was in general discouraged by one of us.[4] However, a series of experiments made by the present writers with intravenous injection of magnesium sulphate in cases of experimental tetanus,[5] and the meager but satisfactory experience which Kohn[6] and Straub[7] had with the employment of this method in cases of tetanus in human beings, induced us to take up the experimental study in animals of the employment of magnesium sulphate by intravenous injection for the purpose of producing anesthesia. This was done as a preliminary test for the admissibility of

[1] Meltzer, S. J., and Auer, J., *Am. Jour. Physiol.*, 1905–06, xv, 387.

[2] Haubold, H. A., and Meltzer, S. J., *Jour. Am. Med. Assn.*, 1906, xlvi, 647.

[3] Meltzer, S. J., and Auer, J., *Proc. Soc. Exper. Biol. and Med.*, 1912–13, x, 159; *Zentralbl. f. Physiol.*, 1913–14, xxvii, 632.

[4] Meltzer, S. J., *Berl. klin. Wchnschr.*, 1915, lii, 261.

[5] To be published later.

[6] Kohn, H., *Berl. klin. Wchnschr.*, 1915, lii, 89.

[7] Straub, W., *München. med. Wchnschr.*, 1915, lxii, 341.

studying the exclusive use of intravenous injections of magnesium sulphate as a means of producing, or at least inducing, anesthesia in human beings. We wish to record a few abbreviated protocols of these experiments.

EXPERIMENTAL.

The experiments were made on dogs. The left external jugular vein was exposed under local anesthesia by ethyl chloride, a cannula introduced, and magnesium sulphate in an $\frac{M}{4}$ solution injected through the cannula from a burette. The reaction of the animals was tested in various ways, as indicated in the protocols. When the respiration appeared to be shallow, pharyngeal insufflation[8] was employed either temporarily or throughout the entire experiment. In some instances intratracheal insufflation was given, especially for the purpose of testing the possibility of introducing the intratracheal tube without using any other anesthetic and while the animal was still breathing spontaneously. At the end of the experiment either a small quantity of a calcium chloride or sodium sulphate solution was injected, or no further injection was given.

Experiment 1.—Black and white female fox-terrier; weight 4,600 gm.

10.20. On electric warming pad at medium. Clip hair of neck; used ethyl chloride as local anesthetic for exposing and inserting cannula in external jugular vein.

10.45. Rectal temperature 38.8°C.

10.50. Start infusion of $\frac{M}{4}$ magnesium sulphate into jugular vein.

10.55. Operation completed.

11.00. 5 cc. Lid reflex prompt and strong.

11.04. 14 cc. Slightly restless.

11.05½. Lid reflex prompt; active expiration, of good strength.

11.08. 20.5 cc. Lid reflex prompt and strong. Respiration good, fairly rapid, active expiration.

11.11. 26 cc. Respiration fairly rapid; quiet; lid reflex prompt and strong.

11.13. 33 cc. Respiration slower, with active expiration; no sound. Heart slow.

11.15. Catheter F. 19 inserted into trachea with ease; start air insufflation.

11.17. 40.5 cc. Lid reflex slight.

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[8] Meltzer, S. J., *Jour. Am. Med. Assn.*, 1913, lx, 1407; *Berl. klin. Wchnschr.*, 1915, lii, 425.

11.18. Very slight inspiration, slow rate; able to move head slightly.

11.20. 44.5 cc. Very shallow respiration on stopping insufflation.

11.22. 46.5 cc. Lid reflex fair.

11.23. Occasionally spontaneous, fair expirations during insufflation.

11.24. 50 cc. injected. Stop. Very slight spontaneous shallow respiration; slow rate. Lid reflex slight.

11.25. Injected through venous cannula 15 cc. $\frac{M}{8}$ calcium chloride into jugular vein. Respiration began promptly. Injection lasted about 1 minute. Suture wound after wiping with diluted tincture of iodine. Remove catheter. Animal trots away at once, slightly unsteady at first; wags tail, obeys command.

12.20. Runs about with ease.

2 days later, 10 a.m. Dog lively and active, jumps about, barks, behaves like a normal dog.

Next day. Good condition.

The intravenous injection of an $\frac{M}{4}$ solution of magnesium sulphate was given at a slow rate. After injecting 33 cc. in 23 minutes the intubation for intratracheal insufflation was performed with ease, while usually a great deal of ether has to be given to accomplish this purpose. A total of 50 cc. of magnesium was given in 34 minutes. The spontaneous respiration was then very shallow. After injecting 15 cc. of $\frac{M}{8}$ calcium chloride the respiration recovered promptly and the animal would execute satisfactory voluntary movements.

Experiment 2.—Black and white mongrel, male; weight 5,850 gm.

Preliminary preparations as in Experiment 1.

11.37. Start infusion of $\frac{M}{4}$ magnesium sulphate into jugular vein.

11.41. 9 cc.

11.44. 18 cc. Moves head, lid reflex strong. Barks sleepily.

11.46. 22 cc. Respiration more rapid, shallower; no reaction to pricking skin with needle; lid reflex strong.

11.50. 36 cc. Fair, slow respiration with active expiration. Lid reflex prompt. Occasional slight general motions. Heart slowed.

11.52. 39.5 cc. Respiration slow, moves head.

11.55. 46 cc. Very slow respiration, lid reflex fair; heart slow.

11.57. 50 cc. Respiration very slight; start pharyngeal insufflation. Pulse improved.

12.02. 54.5 cc. Stop insufflation to change stomach tube; no respiration seen.

12.04. 55.5 cc. Heart 24 to $\frac{1}{4}$ minute, small, regular, soft.

12.06. 56.5 cc. Breathes spontaneously; no reaction to pricking skin with needle.

12.09. 61 cc. Tracheal catheter inserted; slow spontaneous respiration, fair depth, some active expiration; lid reflex slight, moves head.

12.12. 64 cc. Legs relaxed; spontaneous respiration fair; lid reflex slight.

12.15. Pulse 27 to ¼, regular, strong (femoral); fair spontaneous respiration. Stop insufflation. 65.5 cc. injected. Respiration gradually improves and becomes good, deep. Respiration moderately slow; start air again.

12.16. Excellent respiration; no lid or corneal reflex. Tongue pink.

12.20. Respiration easy, more rapid; no lid or corneal reflex. 70 cc. injected.

12.22. Moves head; increase magnesium flow slightly.

12.23. 73 cc. Respiration slower, but good depth. Femoral pulse 22 to ¼, respiration good depth.

12.27. No reaction to pricking skin. 78.5 cc. Stop magnesium.

12.28. 8 cc. of $\frac{M}{8}$ calcium chloride into jugular vein. Respiration greatly improved and more rapid. Wound sutured. Placed on floor, holds head up; front legs spread, do not support body; licks jaws; moves tail on pressure. Pays attention to call and wags tail.

12.35. Able to walk about; tail erect.

2.10. Walks about normally.

Next day. Good condition.

The first 50 cc. injected in 20 minutes, about 2.5 cc. per minute, nearly completely abolished respiration. Pharyngeal insufflation was then started and exerted immediately a good effect. From 12.02 to 12.06 only 2 cc. were injected, equal to 0.5 cc. per minute; spontaneous respiration returned, but no reaction to pricking, and intubation of catheter was easily executed. Thereafter the rate of inflow was kept fairly low. Spontaneous respiration was continually present but was generally slow. There was no lid reflex and no reaction to pricking. After injecting about 78 cc. of magnesium in 50 minutes a quantity of 8 cc. of $\frac{M}{8}$ calcium chloride was injected; respiration improved at once. Voluntary movements, however, returned gradually.

Experiment 3.—Male; weight 7,500 gm.

Was fed previous to experiment. Preparation as in previous experiments.

2.27. Rectal temperature 38.7°. Femoral pulse 33 to ¼, regular.

2.33. Start $\frac{M}{4}$ magnesium sulphate into jugular vein.

2.37. 7 cc. Respiration deeper; swallows occasionally.

2.40. Pulse softer, 38 to ¼, regular; respiration more rapid with strong active expiration. 14 cc.

2.41. Vomited yellowish brown fluid.

2.43. Vomited large amount of yellow fluid with masses of meat.

2.44. 22 cc. Lid reflex prompt; occasional moderate struggle.

2.48. 32 cc. Moderate barks. Lid reflex strong.

2.49. 38.5 cc. Respiration chiefly expiratory. Tracheal catheter inserted; animal shows resistance. Catheter F. 21; constant air stream with remission. Lid reflex strong.

2.54. 44 cc. No reaction to pricking skin with needle.

2.55. 45 cc. Stop insufflation; practically only one inspiration and a number of weak abdominal contractions appeared during the intermission. Lid reflex strong. Able to move head moderately. Occasionally a sharp expiratory movement of abdomen. Started intratracheal insufflation again.

3.06. Remove tracheal catheter; start pharyngeal insufflation, tube in stomach.

3.10. 57 cc. Moves head vigorously; femoral pulse regular, soft.

3.13. 59.5 cc. Legs limp. Lid reflex good.

3.22. 73 cc. Open abdomen, rub peritoneum above liver; no motions.

3.23. 76 cc. Lid reflex fair.

3.26. 80 cc. Stop insufflation; no definite respiration, some expiratory contractions. Start insufflation. Abdomen closed.

3.31. 80 cc. No definite respiration on stopping insufflation. Good lid reflex. Pupils wide.

3.35. 90 cc. Stop magnesium. Lid reflex fair. Stop air; 3 slight respirations; start insufflation.

3.38. Slight, slow, shallow respiration on stopping pharyngeal insufflation. Femoral pulse 18 to $\frac{1}{4}$, regular, fair tension.

3.40. 10 cc. of $\frac{M}{8}$ calcium chloride into jugular vein. Deep, slow respirations begin.

3.43. Pulse 29 to $\frac{1}{4}$, regular, strong tension; no reaction to pricking skin with needle. Lid reflex strong; pupils wide. Neck wound closed. Placed on floor, attempts to get up.

3.44. Gets up after a few trials.

3.55. Lies on side; no response to pressure on toes; wags tail; tolerates probe in nose for a short time. When placed on feet walks away fairly steadily, then lies down again.

4.25. As before; no response to pressure on legs; lies on side usually. Raises head on call; walks when placed on feet. Lid reflex prompt; drinks some water. Killed later by chloroform.

This animal was fed about 3 hours before the experiment was started. After 14 cc. of the magnesium solution were injected (in 7 minutes) the animal vomited. This indicates the central action of magnesium sulphate. After 45 cc. were injected (in 22 minutes) there was practically no spontaneous respiration, although the lid reflex was strong and the animal was able to move its head. The failure of the respiration in this case was undoubtedly due to the in-

hibitory action of the magnesium sulphate upon the respiratory center, and not to a paralysis of the motor nerve endings of the respiratory muscles, which, as a rule, remain excitable longer than the other skeletal muscles. After 80 cc. of the magnesium solution (in 58 minutes) the abdomen was opened and the sensitive parts of the parietal peritoneum were rubbed without eliciting any reaction, although the lid reflex was still good. This animal received 90 cc. of the magnesium solution in 62 minutes. 3 minutes after stopping the injection the animal had only slow and shallow respirations. The injection of 10 cc. of $\frac{M}{8}$ calcium chloride deepened the respirations; it exerted also, fairly promptly, a favorable effect upon the general motility of the animal. But the return of reactions to a probe inserted into the nose and to other sensory stimuli was slow.

Experiment 4.—Wolf hound, female; weight 6,700 gm.

Preliminary preparations same as in Experiment 1.

2.42. Start $\frac{M}{4}$ magnesium sulphate into jugular vein.

2.43. 3 cc.

2.46. 10.5 cc. Lid reflex prompt, sustained. Respiration faster; pulse fuller, faster, 33 to $\frac{1}{4}$. Respiratory irregularity of pulse rhythm practically gone.

2.48. 16.5 cc. Respiration 18 to $\frac{1}{4}$, fair depth, slight active expiration.

2.50. 22 cc. Lid reflex prompt, but no longer sustained closure.

2.52. 28 cc. Respiration good, 14 to $\frac{1}{4}$; femoral pulse 30 to $\frac{1}{4}$, good volume and tension; no irregularity.

2.55. 36 cc. Respiration slower; pain sensation of skin abolished.

2.56. 39 cc. Respiration slower, but good depth; pulse irregular. Start pharyngeal insufflation. Stomach tube.

2.58. 46 cc. Lid reflex prompt but slight. Pupils wide.

3.00. 47 cc. Open abdomen and rub diaphragm; no motion of any kind.

3.02. Stop insufflation; very slight shallow respiration; start air; lid reflex a slight flick. Pulse 36 to $\frac{1}{4}$, regular, small volume and tension. Rub peritoneum; no sign of movement; legs limp.

3.07. 51 cc. Lid reflex slightly better; rubbing peritoneum causes no motion of any kind. No knee jerk.

3.08$\frac{1}{2}$ 52.5 cc. Stop insufflation; 16 very slight respirations per $\frac{1}{4}$. Rub diaphragm and parietal peritoneum: no motion. Legs limp. Lid reflex fairly sustained now (closure).

3.15. 56.5 cc. Femoral pulse 32 to $\frac{1}{4}$, regular, small, and soft.

3.17. 57 cc. Stop air; no respiration in 35 seconds. Start air. Lid reflex slight; pupils moderately contracted.

3.21. 58.5 cc. Rub peritoneum and diaphragm; slight motion of leg, but no other perceptible movement. Spontaneous respiration noticeable during insuffla-

tion. Stop air; 24 shallow respirations per ¼. Start air. Pulse 32 to ¼, fair volume and better tension now. Lid reflex prompt but weak.

3.25. 59.5 cc.

3.26. Moves leg slightly.

3.29. 61 cc. On rubbing peritoneum and diaphragm no motion, but later made vigorous movements with head and leg. (No apparent relation to stimulus; rubbing repeated; no motion.)

3.31. Some strong movements of head and legs. Lid reflex flick, not sustained. Stop air. Respiration spontaneous, 15 to ¼, good depth. Stop insufflation entirely.

3.33. 63 cc. of magnesium. Stop. Excellent respiration. Suture abdominal wound. Ligate jugular vein and suture wound in neck. No calcium chloride given.

3.36. Placed on floor; attempts to walk; hind legs spread; raises head and looks about.

3.43. Lying on side; placed on legs; walks about; lies down again shortly. Withdraws legs fairly promptly when pressed; walks away when tail is pressed; no sign of pain.

4.00. Walks about. Rectal temperature 36.4°; pulls away leg when toes are pressed.

4.38. Killed by chloroform.

During the first period of the experiment (about 18 minutes) the inflow of the magnesium solution occurred at a rate of about 2.9 cc. per minute. After the injection of 36 cc. (in 13 minutes) skin sensibility was abolished; the respiration, though slower, was good and there was even an occasional struggle. The pharyngeal insufflation was started before there was any necessity for it. After the injection of 47 cc. (in 18 minutes) the abdomen was opened and the peritoneum rubbed without any reaction. About this time, however, the spontaneous respiration was shallow, lid reflex slight, and the legs were limp. In the following half hour the rate of injection was considerably reduced—about 16 cc. in 33 minutes. The loss of sensibility lasted for about half an hour longer. The spontaneous respiration returned perceptibly sooner. Altogether 63 cc. of magnesium sulphate were injected in about 51 minutes. Then, when the magnesium sulphate injection was stopped and the insufflation discontinued, the spontaneous respiration immediately appeared to be excellent. No calcium chloride was given. After placing the animal on the floor, motility and sensibility returned fairly soon. The quan-

tity of magnesium given in this experiment was not large and the rate of injection slowed down considerably during the latter part of the experiment. The recovery here was prompt and without the aid of calcium chloride.

Experiment 5.—Bull terrier, female; weight 7,600 gm.

Preparation the same as in previous experiments.

Rectal temperature 40.2°. Femoral pulse 30 to ¼, small, regular, good tension. Respiration slow, 12 to ½, with active expiration.

10.58. Start $\frac{M}{4}$ magnesium sulphate into jugular vein.

11.04. 17 cc. Lid reflex prompt but not sustained; pupils wide. Respiration less deep, slow. Swallows occasionally.

11.06. 25 cc. 14 respirations to ½, good depth, moderate active expiration.

11.07. 29 cc. Lid reflex prompt and sustained. Quiet.

11.08. 35 cc. Pulse small, fairly soft, 38 to ¼, regular. Respiration good depth.

11.10. 43 cc. Respiration slow, less deep but still good, 7 to ¼. Slow magnesium inflow.

11.13. 50 cc. Respiration improved.

11.15. 53 cc. Magnesium inflow slowed. Lid reflex fairly prompt.

11.18. 56 cc. Open abdomen; rub peritoneum and diaphragm; no motion of any kind. Respiration good, more rapid than before.

11.20. 58.5 cc. Lid reflex slight; respiration rapid, 36 to ¼, next count 28 to ¼; legs relaxed. Expose left sciatic nerve; no motion at first, later moderate general movements.

11.25. 71 cc. Respiration excellent.

11.29. 86 cc. Respiration much shallower and slower. Start pharyngeal insufflation.

11.32. 98 cc. No lid reflex.

11.34. 102 cc. No definite respiration.

11.37. 104.5 cc. Stimulated left intact sciatic with Petzold inductorium. At coil distances of 200 and 120 mm. no reaction elicited. At 80 mm. respirations appeared during stimulation; left toes moved slightly; also weak general motions and movements of tail. Rub peritoneum and diaphragm; no response.

11.42. 107 cc. Stop pharyngeal insufflation; slight spontaneous respiration present; start pharyngeal insufflation; increase magnesium flow slightly. Limp. No lid reflex; pupils very wide.

11.47. Abdomen and thigh wound sutured. 116 cc. No lid reflex.

11.49. 117 cc. Stop magnesium. Spontaneous respiration very slight; pharyngeal insufflation necessary.

11.50. 60 cc. $\frac{M}{4}$ sodium sulphate into jugular vein. Respiration improved promptly. Stop pharyngeal insufflation.

11.53. Pulse good. Suture neck wound, lid reflex slight.

11.56. Placed on floor, holds head up for short time, then rests it on floor; cannot stand. Wags tail when called.

12.01. Pressure on tail and toes; moves head towards tail, draws away foot.

12.05. Lid reflex very slight, pupils wide. Able to get up but prefers to squat or lie down.

1.55. Walks about readily, keeping left hind leg lifted (left sciatic nerve had been exposed), no staggering; lid reflex prompt and sustained. Pupils well contracted. Urinated large amount; first time since injection.

4.45. Walks about easily when placed on feet (staid in one place since last note); no more urine passed. Killed by chloroform.

This dog had from the start a slow respiration although its temperature was higher than normal. During the first 10 minutes of the magnesium infusion 3.5 cc. per minute were injected, more than in any of the animals in previous experiments. There were no struggles. After injecting 56 cc. the abdomen was opened and the parietal peritoneum rubbed without any reaction, while the respiration was good and even more rapid than before. After 102 cc. no definite respirations were present, and after 104 cc. the motor nerve endings were affected. The inflow was then reduced—only 13 cc. in 12 minutes. Altogether 117 cc. were injected in 51 minutes. There was practically no spontaneous respiration when the infusion of the magnesium solution was discontinued. However, the respiration improved within 1 minute after the injection of 60 cc. of $\frac{M}{4}$ sodium sulphate. The general motor and sensory depression seemed also favorably affected by this injection.

Experiment 6.—Black male; weight 7,500 gm.

Preliminary preparation as in Experiment 1.

3.13. Start $\frac{M}{4}$ magnesium sulphate into jugular vein.

3.17. 12 cc. Respiration 8 to $\frac{1}{4}$. Good depth. Femoral pulse 29 to $\frac{1}{4}$, regular, good volume and tension.

3.18. 15 cc. Lid reflex prompt and strong, pupil moderately dilated. Dog quiet.

3.20. 25 cc. Good respiration, 12 to $\frac{1}{4}$, active expiration stronger. Femoral pulse 32 to $\frac{1}{4}$, regular, good tension. Barks.

3.22. 31 cc. Lid reflex prompt and sustained; pupils wider.

3.23. 34.5 cc. Pain abolished; opening of peritoneum; respiration easy, good depth and frequency. Abdomen relaxed.

3.25. 46 cc. Rub peritoneum and diaphragm; no movement. Lid reflex prompt and sustained; respiration slow, good depth, 11 to $\frac{1}{4}$.

3.27. 50 cc. Blood bright red. Slow magnesium inflow.

3.28. 51 cc. Rub peritoneum of diaphragm; no movement. Lid reflex weak.

3.30. Pulse 30 to $\frac{1}{4}$, regular, good volume and tension.

3.31. 53.5 cc. Slight knee jerk.

3.32. 55 cc. Moved legs; respiration faster and deeper. Rub peritoneum and diaphragm; no immediate effect, after a few seconds rapid respiration with moderate strength. Increase magnesium inflow.

3.34. 61 cc. Lid reflex a mere flick; rapid respiration with active expirations in short group, then easy respirations without active expirations.

3.39. Respiration slow, good depth with active expiration.

3.42. 85 cc. Blood a little darker; respiration shallower.

3.44. Start pharyngeal insufflation.

3.46. Pulse 20 to $\frac{1}{4}$, fair volume and tension, regular. No lid reflex. Rub peritoneum and diaphragm; no movement. Legs limp; no knee jerk.

3.52. No spontaneous respiration on stopping insufflation.

3.55. Pupils well dilated but not maximal; no lid reflex. 103 cc. Pulse small, 25 to $\frac{1}{4}$.

4.00. 104.5 cc. No lid reflex. Rub peritoneum; no movement; no knee jerk.

4.05. No spontaneous respiration on stopping insufflation; pulse weak. Start insufflation again.

4.07. No movement on rubbing peritoneum and diaphragm. 106 cc. Stop magnesium. No lid reflex. Injected 60 cc. $\frac{M}{4}$ sodium sulphate into jugular vein.

4.10. Femoral pulse 25 to $\frac{1}{4}$, small, regular, better tension. Rubbing peritoneum and diaphragm; no movement.

4.11. Stop insufflation; slow respiration, getting deeper; start insufflation again. No lid reflex; pupil wide.

4.13. Rub peritoneum; no movement. Legs limp; no knee jerk.

4.17. Suture abdomen and neck wound and stop insufflation. Pulse 27 to $\frac{1}{4}$, regular, good volume and tension; 4 respirations to $\frac{1}{4}$, good and deep, no active expiration; no lid reflex, pupils wide; 36.4°. Placed on floor; cannot stand, lies on side. Pain sensation fair; looks about and wags tail.

4.25. No lid or corneal reflex; wags tail when called; feeble knee jerk; on moderate pressure of toe pads, no movement. When lifted and placed on floor front legs bear body weight, but not the hind legs. Pupils widely dilated.

4.30. Respiration easy, good depth, 14 to $\frac{1}{2}$, no active expiration. Femoral pulse 29 to $\frac{1}{4}$, regular, good volume and tension. Lies on side, wags tail. Very slight lid reflex.

4.45. Sits up on haunches, but does not walk about; lid reflex fairly good. Passed small amount of urine.

5.00. Walks about, no weakness; lid reflex prompt and sustained; pupils still wide. Killed with chloroform.

This strong dog received in the first 10 minutes about 35 cc. of the magnesium solution. There was very little excitation, and at the

end of this period the skin of the abdomen could be incised to the peritoneum without any reaction. In the following 2 minutes 11 cc. were infused, and the sensitive parts of the parietal peritoneum were energetically rubbed without producing any reaction, while respiration was still good and the lid reflex prompt and sustained. The rate of injection was now reduced, and the spontaneous respiration kept up efficiently for some time. After 19 minutes during which time about 44 cc. were injected (a little less than 2.5 cc. per minute) pharyngeal insufflation was started. In the next 23 minutes only about 16 cc. were injected (about 0.7 cc. per minute). During this period there were no spontaneous respiration, no lid reflex, no knee jerk, and the legs were limp; finally the pulse became weaker. Altogether 106 cc. of the magnesium solution were injected in 54 minutes. At the end of the magnesium injection no calcium chloride was given, but, as in the previous experiment, 60 cc. of sodium sulphate in $\frac{1}{4}$ solution were injected intravenously. The effect of the injection in this experiment, however, was in no way striking. The respiration did not improve at once and the insufflation had to be continued for about 10 minutes longer. The fact should be borne in mind that in this experiment the rate of injection of the magnesium sulphate during the first half of the infusion period was considerably greater than in any of the other experiments.

In addition to the foregoing experiments we wish to record briefly the exceptional course of one of the experiments. This dog had an irregular heart beat and its extremities were rigid before the experiment was begun. There was no spontaneous respiration after injecting 44 cc. of magnesium solution (in 14 minutes), while the peritoneum remained sensitive and the lid reflex active during most of the injection period. The animal received 72 cc. in 57 minutes. The pulse was small and often weak during the last half hour. At the end of the magnesium injection 10 cc. of $\frac{M}{8}$ calcium chloride were injected without restoring the spontaneous respirations. A few minutes later 5 cc. more of the calcium chloride brought on some weak respirations, but the heart stopped soon after and the animal died.

Here was a case in which calcium did not restore the respiration which had been abolished by magnesium; on the contrary, it was perhaps instrumental in accelerating cardiac death.

SUMMARY AND CONCLUSIONS.

These experiments justify the following general conclusions.

By the intravenous injection of $\frac{M}{4}$ magnesium sulphate into dogs at a certain rate, a stage can be reached where the abdominal walls are completely relaxed and when section of the abdomen and stimulation of sensitive parts of the parietal peritoneum do not produce pain or elicit any reaction of the animal. At the same time spontaneous respiration may still be maintained within normal limits and the lid reflex be fair or even normal. In this stage intratracheal intubation for artificial respiration can be easily accomplished. This stage may be attained in 12 to 14 minutes when the rate of injection is about 3 cc. per minute. When this stage is once attained the rate of injection should gradually be reduced, otherwise, sooner or later, spontaneous respiration will be abolished, and by a further maintenance of the rate of injection all the skeletal muscles may become paralyzed.

When the injection of magnesium is continued for a longer period, the paralytic effects of the magnesium injection will set in, even when administered at a slow rate.

The paralysis of the respiratory function is readily met by intrapharyngeal insufflation, which is easily executed even without training in this procedure, or by the method of intratracheal insufflation, if executed by one trained in its management.

When the respiration of the animal is accomplished by insufflation, the paralytic effect of the magnesium may be abolished fairly rapidly by an intravenous injection of about 10 cc. of an $\frac{M}{8}$ calcium chloride solution; or it may disappear slowly, after the infusion of the magnesium solution is discontinued for some time. The latter mode of disappearance may be favorably accelerated by an intravenous infusion of 60 to 100 cc. of an $\frac{M}{4}$ solution of sodium sulphate.

The production of anesthesia by intravenous injection of magnesium sulphate should not be undertaken unless an apparatus for intrapharyngeal insufflation is at hand, because in exceptional cases the disappearance of spontaneous respiration may be one of the earliest consequences of the magnesium injection.

The injection of calcium chloride should not be employed in cases in which the subject shows cardiac insufficiency. In such instances, moreover, injections of magnesium should not be used for the purpose of anesthesia; at least not until greater experience has been acquired in the employment of this method.