

esthetic effect. Miller similarly suggested that structure I (such as xenon) and structure II (such as halothane) anesthetics might interact to produce a greater than additive effect. *Results.* We have tested this hypothesis with xenon and halothane. MAC (minimum alveolar anesthetic concentration) for xenon was found to be 71 per cent by administration of xenon and oxygen to 29 patients. MAC for halothane was originally found to be 0.74 per cent, and in three subsequent studies was found to range between 0.75 and 0.77 per cent. In another group of 12 patients the alveolar halothane concentration was held at  $2/3$  MAC, while xenon was administered at  $1/3$  MAC. The combination proved to be equivalent to the effect of either anesthetic given at 1 MAC. That is, we found no potentiation. This can be expressed mathematically as  $(C_{xe}/MAC_{xe}) + (C_h/MAC_h) = 1$  where  $C_{xe}$  and  $C_h$  are the concentrations of xenon and halothane which, when administered together, give the same anesthetic effect as  $MAC_{xe}$  or  $MAC_h$ .  $MAC_{xe}$  and  $MAC_h$  are the MAC values for xenon and halothane. *Summary:* Thus, our data do not support the Pauling-Miller thesis. Our data do support the concept that inhalation anesthesia in man using a combination of two agents is the result of simple addition of sufficient molecules of two dissimilar agents.

**Prolonged Sensory Block Using Ammonium Salts.** JOHN I. DAVIES, M.D., PAUL B. STEWART, M.D., and HOWARD P. FINK, M.D., *Departments of Anesthesia, Surgery and Pathology, Veterans Administration Hospital, Kansas City, Missouri and University of Kansas School of Medicine, Kansas City, Kansas.* The potential of ammonium salts to produce sensory, but not motor nerve block was first described in 1939 (Stewart, W., and others: *Amer. J. Physiol.* 129: 475, 1940). Following the work of Judovich and Bates who described somatic analgesia in over 5,000 cases using 0.75 per cent ammonium sulphate or chloride, attempts were made to confirm their favorable results (Bates, W., and Judovich, B. O.: *ANESTHESIOLOGY* 3: 663, 1943; Judovich, B. and Bates, W.: *Segmental Neuralgia in Painful Syndromes*, F. A. Davis, 1946). Bonica reported very disappointing results

with 0.75 per cent ammonium sulphate and stated that although Alexander has completely discarded using ammonium salts, Lundy believed that good results might be obtained by increasing the concentration of ammonium sulphate to 64 per cent. Bonica using 64 per cent ammonium sulphate stated that the results had been better (Bonica, J. J.: *The Management of Pain*, Lea and Febiger, 1953). Recently, some reports from Denmark claim favorable results in 970 blocks in 405 patients using 10 per cent ammonium sulphate with 1 per cent mepivacaine. This report describes the results of using ammonium sulphate or chloride in strengths of 5, 7.5, 10 and 15 in 1 per cent mepivacaine for 65 blocks in 21 patients. *Methods and Results:* Five patients suffered from bilateral ischemic leg pains and had 23 blocks of the nerve considered mainly responsible for the pain. The common peroneal nerve was blocked 13 times, the posterior tibial 7 times, the anterior tibial twice and the femoral nerve once. Following relief of pain and clinical analgesia with 2 per cent mepivacaine, block with 5, 7.5 or 10 per cent ammonium salt with 1 per cent mepivacaine was carried out using minimal volumes of the mixture (3-8 ml.) through the same needle. The addition of mepivacaine was necessary to minimize or avoid the initial hyperesthesia and pain of about 30 minutes duration, produced when the ammonium salts were used alone. In cases where the peroneal nerves were blocked with 2 per cent mepivacaine, transient foot drop resulted. Prolonged motor power seemed to be unaffected when the block was produced by concentrations of ammonium salts of 10 per cent or less. One block of a peroneal nerve using 15 per cent ammonium chloride produced prolonged foot drop. Good sensory analgesia over the nerve distribution blocked was obtained in every instance. No circulatory changes were observed although 2 per cent mepivacaine produced temporary changes in warmth and color in some instances. Sensory loss after 5 per cent ammonium salt (3 blocks) lasted about 2-3 weeks; 7.5 per cent ammonium salt (7 blocks) lasted 4-6 weeks; 10 per cent ammonium salts (12 blocks) lasted 6-16 weeks. In some limbs analgesia was still present at the time of amputation

and an end point of block effect could not be determined. Following amputation above the knee, 6 blocked nerves were available for microscopic examination and were compared with sections of unblocked nerves from the same patient. The pathological report indicated that the nerves at the site of, and slightly distal to the block showed acute degenerative neuropathy. It is apparently impossible with the material that has been submitted to differentiate between degeneration of motor and sensory fibers, though clinically the distinction can be readily made. No difference was observable clinically between ammonium sulphate or the chloride salt. Thirty-one intercostal nerve blocks were performed on 8 patients suffering from late "postthoracotomy neuralgia." Although clinical analgesia over the distribution of the blocked nerve was obtained following 28 blocks, only one patient considered symptomatic relief of pain satisfactory, the others continued to complain of "deep pain" and superficial numbness. Eight injections of areas of myositis or "trigger zones" in 5 patients with 1 per cent mepivacaine and 10 per cent ammonium chloride produced analgesia which lasted the duration of the mepivacaine block only. In 3 patients following successful lumbar sympathetic block with 1 per cent mepivacaine, the needles were left in place and 1 per cent mepivacaine and 10 per cent ammonium chloride was injected (3-8 ml.). Moderate pain was produced for about 10 minutes but the sympathetic block was not prolonged beyond that produced by the mepivacaine. **Conclusion:** Although this is a small series of cases and the results are of doubtful significance it seems likely that prolonged sensory block can be produced with 7.5 or 10 per cent ammonium salts without producing motor loss.

**Respiratory Effects of Anesthesia with Innovar and Nitrous Oxide in Man.** B. S. DUNBAR, M.D., A. OVASSAPIAN, M.D., and T. C. SMITH, M.D., *Department of Anesthesia, University of Pennsylvania, Philadelphia.* **Methods:** Respiratory response to carbon dioxide was studied in seven patients of physical status 1 and 2, anesthetized with innovar and nitrous oxide. Premedication con-

sisted of 1.0-2.0 ml. Innovar administered intramuscularly. Sixty minutes later anesthesia was induced with an intravenous infusion of 5.0 ml. Innovar in 100 ml. of 5 per cent glucose in water administered over a 5 minute period. Administration of nitrous oxide (4 liters/minute) and oxygen (2 liters/minute) was begun by mask 3-4 minutes after the infusion had been started. Succinylcholine was then given and the trachea was intubated. Spontaneous breathing resumed within the next 10 minutes and continued throughout the study while anesthesia was maintained with nitrous oxide and oxygen. Measurements of end-tidal  $\text{CO}_2$  tension and resting ventilation, as well as ventilatory response to  $\text{CO}_2$  inhalation, were made while the patient was awake and unpremedicated. The same measurements were repeated 30 minutes after premedication, and again 30 and 60 minutes after the induction of anesthesia. **Results:** Mean end-tidal  $\text{CO}_2$  tension during oxygen breathing was 42.0 Torr before premedication, and 39.9 Torr 30 minutes after premedication. Anesthesia with Innovar and nitrous oxide was associated with only moderate  $\text{CO}_2$  retention as shown by mean end-tidal  $\text{P}_{\text{CO}_2}$  of 46.5 Torr 30 minutes after induction; and 44.0 Torr 60 minutes after induction. However, by itself,  $\text{P}_{\text{CO}_2}$  is an insensitive index of respiratory depression. Neither  $\text{P}_{\text{CO}_2}$  tidal volume, respiratory frequency, nor minute ventilation are as revealing as carbon dioxide sensitivity curves, which can quantitate the response of respiration to a measurable challenge. Normal ventilatory response to elevated  $\text{P}_{\text{CO}_2}$  consisted of an increase in ventilation of 1.5 liters/minute for each unit rise in  $\text{P}_{\text{CO}_2}$ . The mean ventilatory response fell to 1.0 liter/minute/Torr 30 minutes after the intramuscular dose of Innovar. Thirty minutes after the induction of anesthesia the response fell further to 0.56 liters/minute/Torr. These values represent mean reductions in response to  $\text{CO}_2$  of 32, 63, and 54 per cent, respectively. **Conclusion:** In these studies Innovar premedication and Innovar with nitrous oxide anesthesia have been shown to be potent respiratory depressants with rapid onset and exhibiting peak duration of action in somewhat less than one hour. (Supported in part by U.S.P.H.S. Grant GM-09070-04.)