A STUDY OF TRAUMATIC SHOCK UNDER CERTAIN ANESTHETICS * †

JOHN W. PENDER, M.D.,‡ AND HIRAM E. ESSEX, PH.D.
Rochester, Minnesota

WITHIN recent years the ultra short-acting barbiturates, administered intravenously, have assumed an important role in the field of anesthesia. Their increasingly frequent use is evidence of their adaptability to the needs of civilian surgery. Because of the ease of administration, quick induction and recovery, few immediate or delayed complications, nonexplosibility, ease of transportation, and a minimum of necessary apparatus for administration, the intravenously administered barbiturates will probably be used more extensively in the future in military surgery. The extent of their use, however, will depend on the contraindications to their administration. Experimentally, little has been done to determine whether the intravenous use of thiobarbiturates in shock is contraindicated. In 1936 Seeley, one of us (Essex) and Mann (1) reported that when shock was produced in dogs by intestinal manipulation with the animals under sodium amytal anesthesia, the rate of concentration of hemoglobin and the fall of blood pressure were less rapid and the survival time was longer than when ether alone was used as the anesthetic agent. Using similar methods, Kendrick (2) obtained strikingly similar results in experiments with pentobarbital sodium anesthesia.

The object of this study was to compare the rate of concentration of hemoglobin, the rate of decrease of blood pressure and the survival time of dogs when shock was produced by intestinal manipulation with the animal under the following anesthetics: ether, ether and oxygen, pentothal sodium, pentothal sodium and oxygen, pentobarbital sodium, sodium n-butyl 1-methylallyl thiobarbiturate (an experimental drug), and sodium n-butyl 1-methylallyl thiobarbiturate and oxygen.

METHODS

Animals weighing 6.3 to 41 kg. were used in these experiments. Carotid blood pressure was taken by standard methods in which a mercury manometer and kymograph were used. Pulse rate was obtained

* From the Department of Anesthesiology and the Division of Experimental Medicine, Mayo Foundation, Rochester, Minn.

† Abridgment of thesis submitted by Dr. Pender to the Faculty of the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of M.S. in Anesthesiology.

‡ Now Lt., M.C., U. S. Naval Reserves.

by means of a cardiotachometer (an electrical device which when attached to leads on the chest indicated the pulse rate on a dial). Determinations of hemoglobin were made on the Cenco-Sheard-Sanford photelometer (3) and expressed in percentages of the original determination of hemoglobin taken before the dog was anesthetized. The control reading was taken arbitrarily as 100 per cent.

Ether anesthesia was induced in a closed ether chamber and in three experiments the ether anesthesia was maintained by autoinhalation (4). In three other experiments respiratory valves were placed in the circuit to prevent exhalation over the ether. The administration of ether and oxygen was accomplished by the Lundy-Heidbrink kinetometer gas machine with soda lime absorption chamber. The barbiturates were administered intravenously by the Lundy (5) intermittent technic in amounts sufficient to keep the animals in the second plane of third stage anesthesia. The corneal reflex was abolished and the wink reflex kept diminished but not eliminated in all experiments regardless of the type of anesthetic agent used. Pentothal sodium was given intravenously as a 2 per cent solution in distilled water, pentobarbital sodium as a 2.5 per cent solution and the sodium n-butyl 1-methylallyl thiobarbiturate as a 4 per cent solution. Whenever oxygen was given with one of the intravenously administered anesthetics, 100 per cent oxygen was delivered by the closed circuit gas machine to the intratracheal tube, which was used in all experiments to insure an adequate airway. Soda lime was used to absorb the carbon dioxide.

When the indicated level of anesthesia had been obtained, a midline incision was made and the small intestine, from the ligament of Treitz to the ileocecal junction, was delivered outside the peritoneal cavity onto a rubber sheet which had been sutured to the edges of the incision to form a hammock in which the intestines were laid. The intestine then was manipulated gently between the gloved fingers of the operator for thirty-five minutes while a continuous tracing of the blood pressure was recorded. Every thirty minutes after the completion of intestinal manipulation, observations were made on the following: mean blood pressure, pulse rate, respiratory rate, rectal temperature and the state of the wink reflex. Every thirty minutes the intestines were turned to prevent drying and the peritoneal fluid was collected from the rubber sheet and deposited in a graduated cylinder. Determinations of hemoglobin were made before anesthesia was induced, fifteen minutes after a state of surgical anesthesia was reached, after intestinal manipulation was completed, and at hourly intervals thereafter until death. All experiments were followed to the death of the animal.

RESULTS

Because of the frequent occurrence of respiratory failure before the development of shock under sodium n-butyl 1-methylallyl thiobarbiturate anesthesia, the use of this drug was discontinued and will not be discussed further.

In agreement with previous work in this laboratory, the average rate of concentration of hemoglobin was least rapid and the average survival time longest under pentobarbital sodium anesthesia. The most rapid concentration of hemoglobin and the earliest deaths occurred under ether anesthesia. The average rate of concentration of hemoglobin and average survival time under pentothal sodium were between the average findings under pentobarbital sodium and those under ether (table 1). As controls, 3 animals were kept anesthetized with ether and 2 with pentothal sodium for an average of six hours without any intestinal manipulation. After the initial effect of the anesthetic

TABLE 1

AVERAGE TIME FOR DEVELOPMENT OF SHOCK AND DEATH FOLLOWING INTESTINAL TRAUMA UNDER VARIOUS ANESTHETIC AGENTS

Anesthetic agent	Experiments	Time from beginning of stripping of intestine to produce			Remarks
		130 per cent hemoglobin	70 mm. Hg blood pressure	Death	
Ether *	3	1 hr. 43 min.	5 hr. 12 min.	6 hr. 35 min.	
Ether †	3	4 hr. 15 min.	6 hr. 25 min.	8 hr. 56 min.	
Ether-average		2 hr. 59 min.	5 hr. 48 min.	7 hr. 45 min.	
Ether + Oxygen	6	2 hr. 55 min.	5 hr. 28 min.	7 hr. 16 min.	
Sodium n-butyl l-methylallyl thiobarbiturate	5	4 hr. 58 min.	5 hr. 26 min.	6 hr. 43 min.	
Sodium n-butyl l-methylallyl thiobarbiturate + oxygen	3	5 hr. 5 min.	6 hr. 37 min.	7 hr. 10 min.	
Pentobarbital sodium	4	4 hr. 12 min.	12 hr. 17 min.	14 hr. 12 min.	
Pentothal sodium	6	4 hr. 5 min.	9 hr. 53 min.	10 hr. 36 min.	Normal initial hemoglobin
Pentothal sodium	4	3 hr. 20 min.	3 hr. 57 min.	7 hr. 42 min.	Low initial hemoglobin
Pentothal sodium-average		3 hr. 47 min.	7 hr. 30 min.	9 hr. 26 min.	
Pentothal sodium + oxygen	6	4 hr. 10 min.	7 hr. 22 min.	9 hr. 40 min.	Normal initial hemoglobin
Pentothal sodium + oxygen	4	2 hr. 20 min.	8 hr. 20 min.	9 hr. 40 min.	Low initial hemoglobin
Pentothal sodium	3	1 hr. 55 min.	6 hr. 5 min.	9 hr. 26 min.	Low initial hemoglobin induced by hemorrhage

* No respiratory valves.
† Respiratory valves in circuit preventing exhalation over ether.

TABLE 2

PERCENTAGE CONCENTRATION OF HEMOGLOBIN * IN CONTROL ANIMALS

Dog	15 min. after anesthesia	Hours after anesthesia induced							
		1	2	3	4	5	6	7	8
Ether									
48	113	117	113	110					
49	108	108	108	108	112	112	108	108	108
50	109	109	108	112	115	114	114	115	
Average	110	111	110	110	113	113	111	111	108
Pentothal sodium									
51	80	78	85	85	113	96			
52	85	83	91	92	100	100	105	100	
Average	83	81	88	88	106	98	105	100	

* Concentration of hemoglobin before the dog was anesthetized is taken as 100 per cent.

agent, little change of the concentration of hemoglobin occurred (table 2).

In accord with previous observations (1, 2), ether anesthesia caused an initial increase of concentration of hemoglobin before the production of shock began and barbiturate anesthesia caused an initial decrease of the hemoglobin concentration. This difference in the initial effect did not seem to affect the final concentration of hemoglobin. Four hours after intestinal manipulation had been completed, the concentration of hemoglobin was practically the same under each of the anesthetic agents.

The rate of the production of shock under each anesthetic agent was approximately the same whether a sustained depression of the blood pressure to 70 mm. of mercury or less (table 1) or concentration of the hemoglobin (table 3) was used as the criterion of the onset of shock.

The rate and the amount of output of peritoneal fluid seemed to be an individual characteristic not closely related to the rate of concentration of hemoglobin or the type of anesthetic agent used. For example, in dog 36, receiving pentothal sodium and oxygen, a concentration of hemoglobin of 130 per cent developed and the animal survived about eight hours, during which time 100 cc. of peritoneal fluid was collected from the rubber sheet. In dog 33, also receiving pentothal sodium and oxygen, a concentration of hemoglobin of 142 per cent developed and the animal survived about nine hours without enough peritoneal fluid being exuded to permit collection.

Under pentothal sodium anesthesia alone the average survival time was much shorter in 4 animals that had a low initial percentage of

TABLE 3

AVERAGE TEMPERATURE, CONCENTRATION OF HEMOGLOBIN AND BLOOD PRESSURE VALUES DURING THE DEVELOPMENT OF SHOCK UNDER THE DIFFERENT ANESTHETIC AGENTS

Anesthetic agent	Experiments	Initial rectal temperature, °C.	Blood pressure, mm. Hg, at time of hemoglobin concentration to 130%	At time of reduction of blood pressure to 70 mm. Hg		At time of death		Remarks
				Hemoglobin concentration, per cent *	Rectal temperature, °C.	Hemoglobin concentration, per cent *	Rectal temperature, °C.	
Ether	6	38.4	90	136	35.6	141	34.3	
Ether + oxygen	6	39.1	89	139	35.8	142	35.6	
Sodium n-butyl l-methylallyl thiobarbiturate	5	39.4	87	131	37.4	132	37.0	
Sodium n-butyl l-methylallyl thiobarbiturate + oxygen	3	38.7	120	134	34.5	134	34.3	
Pentobarbital sodium	4	38.7	117	152	33.6	156	32.9	
Pentothal sodium	6	38.7	128	145	35.8	148	35.7	Normal initial hemoglobin
Pentothal sodium	4	39.1	98	129	34.0	141	34.0	Low initial hemoglobin
Pentothal sodium + oxygen	6	39.6	105	141	36.6	142	36.3	Normal initial hemoglobin
Pentothal sodium + oxygen	4	38.4	82	155	32.8	156	32.5	Low initial hemoglobin
Pentothal sodium	3	38.1	100	155	32.3	160	30.9	Low initial hemoglobin induced by hemorrhage

* Concentration of hemoglobin before the dog was anesthetized is taken as 100 per cent.

hemoglobin than in 6 animals that had a normal initial hemoglobin value. This was true whether the lower percentage of hemoglobin was spontaneous or induced by repeated bleedings. Under pentothal sodium and oxygen anesthesia the average survival time was the same in the group that had a low initial value of hemoglobin as in the group that had a normal initial percentage of hemoglobin. In 6 animals that had a normal initial hemoglobin value the average survival time was slightly shorter under pentothal sodium and oxygen than in 6 animals under pentothal sodium alone. Likewise in animals that had a normal initial hemoglobin value the average survival time was slightly shorter under ether and oxygen anesthesia than under ether anesthesia alone.

Our observations on the effect of the administration of oxygen are in agreement with those of Beecher (6). Schnedorf and Orr (7) observed that oxygen prolonged the survival time 70 per cent in dogs in which shock was produced by trauma to a hind limb under pentobarbital sodium anesthesia. This difference in results might be due to the difference in the methods used in the production of shock by these investigators.

CONCLUSIONS

1. Shock and death after intestinal manipulation in dogs occurred most rapidly under ether anesthesia, less rapidly under pentothal sodium anesthesia, and least rapidly under pentobarbital sodium anesthesia.

2. The rate of production and the amount of peritoneal exudate in the present series of experiments appeared to be unrelated to any single factor studied, such as concentration of hemoglobin or type of anesthetic agent used.

3. Inhalation of high concentrations of oxygen during the production of shock did not prolong the survival time in dogs that had a normal initial percentage of hemoglobin but was of apparent benefit in dogs that had a low initial hemoglobin value.

REFERENCES

1. Seeley, S. N.; Essex, H. E., and Mann, F. C.: Comparative Studies on Traumatic Shock under Ether and under Sodium Amytal Anesthesia: an Experimental Research, Ann. Surg. 104: 332–338 (Sept.) 1936.
2. Kendrick, D. B., Jr.: Results of Intravenous and Intra-arterial Administration of Fluids in Traumatic Shock Produced Experimentally, Surgery 6: 520–523 (Oct.) 1939.
3. Sanford, A. H., and Sheard, Charles: The Determination of Hemoglobin with the Photoelectrometer, J. Lab. & Clin. Med. 15: 483–489 (Feb.) 1930.
4. Hardenbergh, J. G., and Mann, F. C.: The Auto-inhalation Method of Anesthesia in Canine Surgery, J. Am. Vet. M. A. 71: 493–501 (July) 1927.
5. Lundy, J. S.: Intravenous Anesthesia: Preliminary Report of the Use of Two New Thiobarbiturates, Proc. Staff Meet., Mayo Clin. 10: 536–543 (Aug. 21) 1935.
6. Beecher, H. K.; McCarrell, J. D., and Evans, E. J.: A Study of the "Shock Delaying" Action of the Barbiturates, Ann. Surg. 116: 658–667, 1942.
7. Schnedorf, J. G., and Orr, T. G.: Beneficial Effects of Oxygen Therapy in Experimental Traumatic Shock, Surg., Gynec. & Obst. 73: 79–83 (July) 1941.