

STUDIES ON THE PARENTERAL ADMINISTRATION OF HYDROGEN PEROXIDE * † ‡

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INTRODUCTION

At times the condition of the pulmonary system is such that the effective administration of oxygen to patients by inhalation methods is impossible. To combat oxygen-want under these circumstances, resort to other methods of administration has been attempted. Among these methods, the intravenous administration of oxygen has been used clinically on several occasions with reportedly good therapeutic results. In 1902, Mariani (1) injected oxygen intravenously into a patient dying of tuberculosis. The pulse and respiration improved. The treatment, however, was not repeated and the patient died the next day. Tunnicliffe and Stebbing (2) in 1916 treated 3 very ill patients with intravenous oxygen. They stated that 600 to 1,200 cc. per hour can be given, that dyspnea and cyanosis are rapidly relieved, and that the beneficial results of the intravenous injection of oxygen were certainly more lasting than could apparently be explained by the mere relieving of cyanosis. Singh and Shah (3) in 1940 gave intravenous oxygen to 6 patients with severe pulmonary disease. All 6 showed clinical improvement as was indicated by raised blood pressure and improved pulse. They concluded by stating, "In man about 10 to 20 cc. per minute of oxygen can be administered intravenously. . . . This amount of oxygen does not appear to be considerable, but still a distinct clinical improvement follows its administration."

Ziegler (4) in 1941 devised a more practical apparatus for the continuous administration of intravenous oxygen at rates varying from 200 to 1,000 cc. per hour for periods as long as nine hours. He observed that cyanosis cleared, the pulse rate decreased, blood pressure increased if hypotension was present, and the mental state improved. He also reported that in patients in shock or with heart failure the blood pressure increased and the pulse and respiratory rates decreased. One pa-

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tient with severe pulmonary edema was relieved after twelve hours following administration of intravenous oxygen for five hours. He also stated that the clinical improvement in patients, "seems to be all out of proportion to the small amount of oxygen administered." He never observed symptoms of gas embolism, and used the criteria of definite increases in pulse rate and respiration as indicative that too much oxygen was being given.

Recently Jacobi et al. (5) successfully treated 3 patients in severe progressive acute secondary traumatic shock by the method of Ziegler. They also induced irreversible toxic shock in dogs by the intravenous injection of a saline extract of dog muscle. Three untreated and 3 plasma treated control animals died, while 5 dogs given 100 cc. of oxygen per hour intravenously for ten to fifteen hours survived.

Experimental injection of oxygen intravenously in animals has been extensively studied by several investigators (6, 7, 8, 9). On the whole, however, results have not been encouraging because of marked embolic phenomena. Grodins, Ivy, and Adler (10) in 1943 gave oxygen intravenously to dogs under nembutal anesthesia at rates varying from 0.21 cc. to 3.2 cc. per kilogram per minute. They concluded that the anoxemia from the anesthesia was not corrected but actually aggravated by the treatment since the measured arterial oxygen in most animals was reduced. Reduction of blood pressure and increased respiratory rates were also noted. They suggested that the anoxemia was increased because of a reduction in the pulmonary capillary bed by multiple gas emboli, and concluded that intravenous oxygen in the form of gas bubbles is impractical from a therapeutic viewpoint.

The reasons for the disparity between the clinical and animal observations are not clear. Possibly the presence of terminal states or shock in the human cases is important. Also, the larger size of the human organism plus a factor of species difference in susceptibility to gas embolism may in part account for the difference.

The limiting factor in the administration of oxygen by vein is the formation of gas emboli. If the oxygen is administered as small bubbles, the tolerance is increased because the bubbles dissolve more rapidly. Hydrogen peroxide decomposes into water and gaseous oxygen, a reaction which is much hastened by the presence of catalase in human blood. Since the hydrogen peroxide is in solution, molecules of it are widely separated from each other by water. The gaseous oxygen produced by decomposition of the substance, therefore, should be in the form of minute bubbles. As a result of their small size, the oxygen bubbles should dissolve very rapidly and have less tendency to produce gas embolism. The experiments recorded in this paper were performed to test the validity of this premise, and to determine the value of hydrogen peroxide as an easily administered and controlled form of intravenous oxygen therapy.

The intravenous administration of hydrogen peroxide has been recorded in the literature on two occasions. In 1920, Oliver and Murphy (11), during an epidemic in Mesopotamia, treated 24 individuals with very severe influenzal pneumonia with intravenous hydrogen peroxide. They administered approximately 0.6 per cent hydrogen peroxide over fifteen-minute intervals, which is equivalent to intravenous oxygen given at a rate of about 600 cc. per hour. They noted slower, steadier and deeper respirations following the injections, and also a drop in pulse rate and marked general clinical improvement. The mortality in the series was 49 per cent as compared to 80 per cent in a similar untreated group. In the fatal cases autopsies failed to reveal any evidence of gas embolism. In the cases successfully treated the fever dropped by crisis a few hours after administration of intravenous hydrogen peroxide. The authors considered the beneficial results largely the result of oxidation of circulating toxins.

In 1944, Siderova (12) reported the use of intravenous hydrogen peroxide in animals as an antidote against potassium cyanide poisoning. He successfully administered doses of 1 to 3 cc. per kilogram of 1 to 2 per cent hydrogen peroxide against 2.4 times the lethal dose of potassium cyanide given subcutaneously in dogs. In general, the treatment was less effective in rabbits than in dogs. He concluded that the effect was owing in part to the oxidizing and methemoglobin-forming properties of hydrogen peroxide.

EXPERIMENTAL METHODS AND RESULTS

Preliminary experiments on the effect of hydrogen peroxide on blood were performed. Addition of an equal volume of 3 per cent hydrogen peroxide in normal saline solution to human blood was found not to alter the hematocrit, microscopic appearance or differential picture as compared with a similar sample to which only normal saline solution had been added. While human blood retained its bright red color and foamed vigorously on the addition of 3 per cent hydrogen peroxide, dog blood foamed less vigorously and rapidly turned a dark brown color. Even with very small amounts of hydrogen peroxide this color change was evident. Bloods from a few other animal species were similarly treated with hydrogen peroxide. Rabbit, cat, mouse, and rat bloods remained bright red like human blood while chicken blood turned dark, as did that of the dog. A mixture of half dog and half human blood remained bright red.

Determinations of quantitative catalase activity (Kat. f.) on various bloods were undertaken following a modification of von Euler and Josephson's procedure (13) suggested by DuBois (14).

Thirty-five cubic centimeters of 0.02 normal hydrogen peroxide, 10 cc. of M/15 sodium phosphate buffer pH 6.8, and 4 cc. of distilled water were mixed and placed in an ice water bath at 4 C. One cubic centi-

meter of a diluted blood sample (prepared by diluting 0.10 cc. of blood to 10 cc. with water) was then added to the mixture and allowed to react for two minutes. Five cubic centimeters of the mixture was then pipetted into 10 cc. of 1 normal sulfuric acid and the remaining hydrogen peroxide titrated with 0.002 normal potassium permanganate. Blank titrations were performed with 1 cc. of water substituted for the blood solution.

Calculations were based on the formula,

$$\text{Kat. f.} = \frac{K}{(\text{Gm. enzyme preparation})}$$

where K is the monomolecular reaction velocity constant,

$$K = (1/t) \log (C_0/C_t),$$

C_0 — initial hydrogen peroxide concentration,

C_t — hydrogen peroxide concentration at end of time t .

The ratio (C_0/C_t) in this case is equivalent to the ratio of the volumes of potassium permanganate solution in the blank over that in the unknown titrations. Duplicate determinations were done on each sample.

Results of these determinations are given in table 1 for oxalated blood samples not over seventy-two hours old. It is evident from this table that considerable individual and wide species variation in blood catalase activity exists. Becht (15), in 1919, first called attention to this fact through a rather crude method involving the determination of the total volume of oxygen liberated from a solution of hydrogen peroxide by measured quantities of various bloods. He noted that human, cat, and horse bloods have very much greater catalytic power than dog, goat, and sheep bloods. No mention, however, is made of the differential effect of hydrogen peroxide on the various bloods.

The catalase determinations provide the explanation for the different effects of hydrogen peroxide upon the blood of various animal species. If the catalase content of blood is high, hydrogen peroxide is rapidly decomposed to water and gaseous oxygen, which foams in the bright red blood. If the catalase content of blood is low, the peroxide decomposes slowly, changing hemoglobin into methemoglobin probably both directly and also through the action of nascent oxygen formed by the reaction between blood peroxidase and hydrogen peroxide.

An attempt was made to increase the catalase activity of the blood of a dog weighing 8 kg. by injecting intravenously 100 cc. of centrifuged human erythrocytes over a thirty-minute period. Blood samples were drawn before, and fifteen minutes after, the injection. The Kat. f. before injection was 0.3 and the hematocrit reading 33 per cent. After the injection the Kat. f. was 1.2 and the hematocrit reading 24 per cent, which indicates considerable hemolysis. When hydrogen peroxide was added to the latter sample only slight darkening occurred. Hence, the

critical Kat. f. level to protect blood against excessive formation of methemoglobin by hydrogen peroxide is somewhere around one. Incidentally, after two days the dog recovered entirely from the effects of the transfusion of human red cells even though extensive hematuria occurred during the first day.

TABLE 1
CATALASE ACTIVITY DETERMINATIONS ON VARIOUS BLOODS

Sample	Kat. f.	Av. Kat. f.
Human adult No. 1	25.4	26.0
	26.6	
Human adult No. 2	30.4	30.4
	30.3	
Human adult No. 3	35.9	36.1
	36.3	
Human adult No. 4	22.5	22.4
	22.3	
Human adult No. 5	24.6	24.7
	24.8	
Human infant—5 months	20.1	19.7
	19.2	
Cat. No. 1	27.0	27.0
	27.0	
Cat. No. 2	15.8	15.9
	16.0	
Rabbit No. 1	12.4	12.7
	13.0	
Rabbit No. 2	15.3	15.6
	15.8	
Rat	6.9	7.0
	7.1	
Mouse	6.9	6.9
	6.9	
Dog No. 1	0.3	0.3
	0.3	
Dog No. 2	0.3	0.3
	0.3	
Young rooster	0.02	0.02
	0.015	

Tolerance studies of intravenous administration of hydrogen peroxide in several animals were undertaken. Normal saline solutions of pure 30 per cent hydrogen peroxide (Superoxol) in various dilutions were used. The strengths of the solutions will be expressed in terms of the volume oxygen equivalent, keeping in mind that a 3 per cent solution of hydrogen peroxide yields approximately ten volumes of oxygen

per cubic centimeter. Light to moderate pentothal or nembutal anesthesia was used in almost all instances to keep the animals quiet.

In the dog, ten volume hydrogen peroxide injected intravenously at a rate approximately equivalent to 1 cc. of oxygen per kilogram per minute, within five minutes led to an intense brownish "cyanosis" without associated dyspnea or signs of gas embolism. This "cyanosis" slowly cleared over a three day period and undoubtedly represented methemoglobinemia.

In an unanesthetized young rooster (approximately 750 Gm.), 1.5 cc. of ten volume hydrogen peroxide given intravenously over a three-minute period led to deep brownish cyanosis and death. The oxygen capacity of the blood at death was measured as 5.9 volumes per cent, using the Van Slyke (16) manometric method.

In contrast to the hydrogen peroxide tolerance limitation based chiefly on methemoglobin formation in the dog and chicken, it was found that phenomena owing to gas embolism limited the tolerance in the rabbit and cat. The following sequence of events was quite regularly observed in these animals during progressive slow gas embolization, either from intravenous hydrogen peroxide or oxygen administration.

1. Tachypnea—ultimately reaching rates exceeding 100 per minute.
2. Pallor.
3. Accentuation of heart tones.
4. Early cyanosis.
5. Tinkling sound over precordium owing to the presence of tiny intracardiac gas bubbles.
6. Continuous loud rumbling to-and-fro murmur of intracardiac gas.
7. Development of slow, deep, irregular, gasping respiration rapidly leading to complete apnea in the inspiratory phase.
8. Sudden weakening of pulse and bradycardia.
9. Cardiac arrhythmias.
10. Severe cyanosis.
11. Sudden, rapid fall in blood pressure.
12. Pupillary dilatation and urinary and fecal incontinence.
13. Complete cessation of heart action and respiration.

The signs of gas embolism are classified as mild up to number five in sequence, as moderate between five and seven, and as severe after seven. A characteristic feature of the sequence was the sudden development of each additional symptom. It is also of interest to note that the blood pressure and pulse remained essentially unchanged until terminal stages were reached. Although in several animals the retinal vessels were observed for gas bubbles, none were ever seen. On autopsy at no time could gas be detected in the left side of the heart or systemic circulation despite the presence at times of tremendous amounts of gas in the right heart. The most remarkable feature of the

entire process, however, was the rapid and complete recovery of the animals even at near terminal stages when administration of either the hydrogen peroxide or oxygen was stopped.

Since posture and injection site are important factors in the tolerance to gas embolism as first emphasized by Van Allen, Hrdina and Clark (17), all injections were given in the femoral vein with the animals in a horizontal position.

In table 2 the results are summarized of tolerance studies of intravenous administration of hydrogen peroxide in rabbits and cats. For

TABLE 2
INTRAVENOUS HYDROGEN PEROXIDE TOLERANCES IN CAT AND RABBIT

Animal	Weight Kg.	Strength H ₂ O ₂ (cc. O ₂ liberated per cc. by an excess of blood)	Needle Gauge	Duration of Injection	Injection Rate (O ₂ equivalent as cc./Kg./min.)	Symptoms of Gas Embolism
Rabbit No. 1	4.0	0.2	26	30 min.	0.12	None
Rabbit No. 2	4.5	1.0	26	15 min.	0.15	Mild
Rabbit No. 1	4.0	1.0	26	6 min.	0.16	Mild
Rabbit No. 1	4.0	0.5	24	10 min.	0.32	Mild
Rabbit No. 1	4.0	1.0	24	13 min.	0.64	Moderate
Rabbit No. 3	4.8	5.0	25	3 min.	0.70	Severe—death
Rabbit No. 4	3.5	3.3	25	12 min.	1.0	Severe—death
Rabbit No. 5	3.5	1.7	25	1 min.	1.3	Severe
Rabbit No. 4	3.5	3.3	25	½ min.	2.0	Very severe
Cat No. 1	3.2	1.0	24	30 min.	0.34	None
Cat No. 1	3.2	1.0	24	30 min.	0.7	None
Cat No. 2	2.0	3.0	24	30 min.	1.5	Very mild
Cat No. 3	2.5	4.0	24	30 min.	1.6	Mild
Cat No. 4	2.5	5.0	24	30 min.	2.0	Moderate
Cat No. 5	3.3	4.0	24	6 min.	2.0	Severe—death
Cat No. 6	2.1	5.5	24	3 min.	2.6	Severe—death

purposes of comparison, a few tolerance measurements of intravenous oxygen gas were done in cats, with the results as given in table 3.

The data presented in these tables seem to indicate that: (1) a considerable species difference in susceptibility to gas embolism exists between the rabbit and cat; (2) considerable individual variation in susceptibility to gas embolism exists; (3) the more dilute solutions of hydrogen peroxide less readily cause severe signs of gas embolism; and (4) in the cat, oxygen can be administered intravenously in the form of hydrogen peroxide at least twice as fast as in the form of gaseous oxygen without producing severe embolic signs.

The animals surviving these experiments, after recovering from anesthesia, appeared normal in all respects and remained well during several weeks of observation. On autopsy, all animals dying during the experiments showed pale, emphysematous lungs and the presence of considerable amounts of gas in the great veins and right side of the heart only.

Chronic studies on the parenteral administration of hydrogen peroxide were carried out in mice. With lethal doses given subcutaneously (0.3 cc. of a 3 per cent solution per 25 Gm. mouse), death occurred from gas embolism as demonstrated by the symptomatic course and autopsy findings. Apparently a large part of the hydrogen peroxide enters the vascular system before being decomposed by catalase.

TABLE 3
INTRAVENOUS OXYGEN TOLERANCE IN THE CAT

Animal	Wgt. Kg.	Needle Gauge	Injection Rate of O ₂ (cc./Kg./min.)	Duration	Embolic Symptoms
Cat No. 7	3.3	24	0.3	30 min.	Mod. severe
Cat No. 8	1.9	27	0.52	30 min.	Mod. severe
Cat No. 4	2.5	26	0.6	15 min.	Moderate
Cat No. 4	2.5	26	0.8	13 min.	Severe
Cat No. 4	2.5	24	0.8	30 min.	Severe
Cat No. 4	2.5	24	1.2	4 min.	Severe—death

In a series of 30 young mice (approximately 15 Gm. each), maximum tolerated doses of 0.1 cc. of 1.5 per cent hydrogen peroxide in normal saline solution were given subcutaneously twice daily over a period of two weeks. Several animals showed brief embolic signs immediately after the injections. In addition to the general picture of gas embolism already discussed, another commonly observed sign was paraplegia lasting for a few minutes. An occasional animal also exhibited brief generalized convulsions. Five mice died with embolic symptoms at various times during the course of the experiments.

Locally, subcutaneous emphysema was present in all cases after the injections and small ulcers eventually developed at the injection sites in about 25 per cent of the animals. Aseptic technic, however, was not followed in making the injections. No further apparent ill effects, other than those temporarily caused by embolic phenomena, were observed as a result of the injections in the surviving mice. In a control group of 5 mice given similar injections of an equal volume of normal saline alone, however, ascites and omental edema were observed. Histologic sections were taken of various organs of some of these animals, including heart, lung, kidney, liver, spleen, gastrointestinal tract, pancreas, bone and mediastinal structures. No tissue differences between the hydrogen peroxide and the saline-treated mice were noted with the exception of the edema as mentioned previously and local superficial skin ulcerations at the injection sites in some of the peroxide treated animals. Histologically, however, the animals dying of gas embolism showed distended pulmonary alveoli and occasional small hemorrhagic areas in the lungs and brain.

Arterial analyses of blood gas, using the Van Slyke manometric apparatus and methods, were made on 2 cats under pentothal anes-

thetia, who were treated with intravenous hydrogen peroxide for hypoxia induced by administration of 90 per cent nitrous oxide and 10 per cent oxygen by means of a face mask. The results given in table 4 indicate that hypoxia, rather than being relieved by the administration of even relatively small amounts of hydrogen peroxide, is actually aggravated even though in interpreting the data one makes allowance for blood loss incident to sampling. Gas embolization of the pulmonary capillary bed, as suggested by the work of Grodins et al. (10), probably in large part accounts for these results.

TABLE 4
EFFECT OF I.V. HYDROGEN PEROXIDE ON ARTERIAL BLOOD GASES IN HYPOXIA

Cat	Wgt. Kg.	Treatment	Duration of Treatment	Blood Sample	Volumes Per Cent		Symptoms
					Oxygen	CO ₂	
I	1.5	90% N ₂ O and 10% oxygen inhalation	7 min.	7 cc.	14.55	56.40	Trace of cyanosis
		Above plus I.V. H ₂ O ₂ in 8.4 cc. N saline \approx 0.4 cc. of O ₂ /Kg./min.	21 min.	7 cc.	8.32	45.23	Cyanosis but no embolic signs
		I.V. H ₂ O ₂ discontinued	10 min.	7 cc.	9.53	33.74	Pallor and cyanosis
II	2.1	90% N ₂ O and 10% oxygen inhalation	16 min.	7 cc.	17.50	41.92	None
		Above plus I.V. H ₂ O ₂ in 8 cc. N saline \approx 0.4 cc. of O ₂ /Kg./min.	15 min.	7 cc.	16.20	43.17	None
		H ₂ O ₂ injection increased to be \approx 1 cc. of O ₂ /Kg./min.	15 min.	7 cc.	6.90	49.03	Cyanosis and mod. embolic signs

In two cats the effect of intravenous administration of hydrogen peroxide in carbon monoxide poisoning was studied. Illuminating gas was administered by means of a face mask until the respiratory rhythm changed, and then was discontinued. Arterial blood samples of 5 cc. were then taken at intervals before and after a period of intravenous administration of hydrogen peroxide. Analyses for oxygen, carbon monoxide and carbon dioxide were made on these samples by the Van Slyke manometric methods.

From the results given in the graphs in figures 1 and 2, it is evident that intravenous administration of hydrogen peroxide had but little effect in accelerating the elimination rate of carbon monoxide. Thus

in figure 1, during the thirty-five-minute period prior to the administration of hydrogen peroxide, the carbon monoxide of the arterial blood decreased from 10.49 to 5.85 volumes per cent and oxygen increased from 3.38 to 8.53 volumes per cent. Then in the ensuing thirty-five minutes during which the peroxide had been given, carbon monoxide dropped further to 3.21 and oxygen increased to 10.33 volumes per cent.

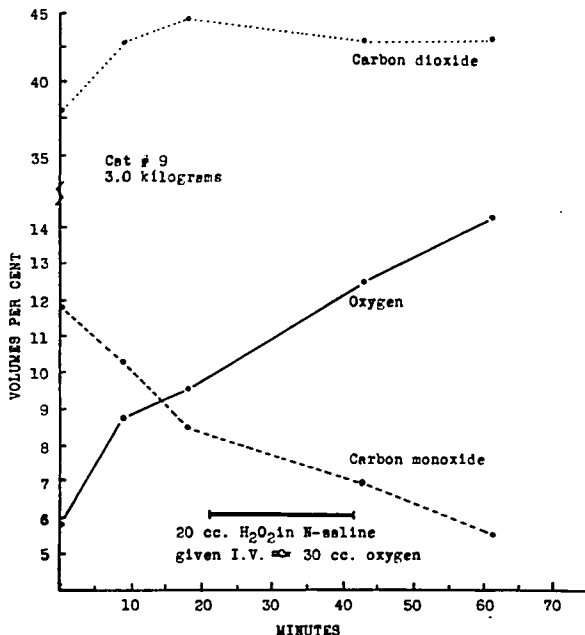


FIG. 1. Effect of intravenous hydrogen peroxide in carbon monoxide poisoning.

Similarly in figure 2, in the twenty minutes prior to intravenous injection of hydrogen peroxide, the carbon monoxide of the arterial blood dropped from 11.80 to 8.42 volumes per cent, and oxygen increased from 5.87 to 9.56 volumes per cent. In the following twenty minutes during which the peroxide was given, carbon monoxide fell further to 6.94 and oxygen increased to 12.54 volumes per cent. Then after another twenty-minute interval, carbon monoxide was 5.44 volumes per cent and oxygen was 14.24 volumes per cent.

In both animals during the administration of hydrogen peroxide, respiration became less labored. No signs of gas embolism occurred and both cats made an uneventful recovery from the experiments. It is perhaps significant that in these experiments the intravenous administration of hydrogen peroxide did not increase hypoxia as in the previous investigations.

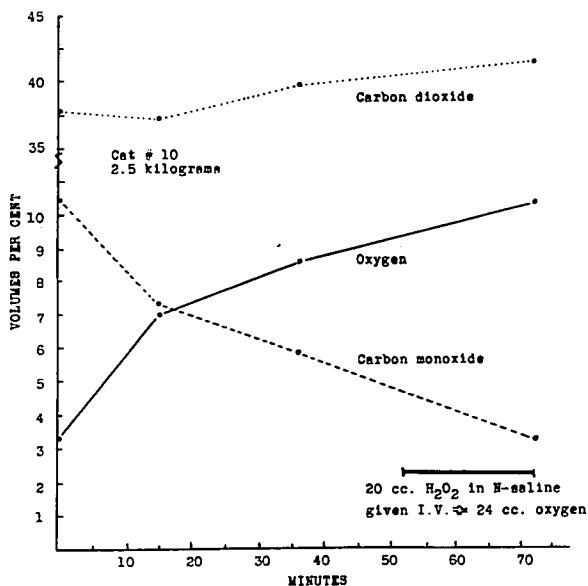


FIG. 2. Effect of intravenous hydrogen peroxide in carbon monoxide poisoning.

Finally, preliminary observations on the effects of intravenous administration of hydrogen peroxide in cats affected by several types of chemical toxic shock and hemorrhage were made. Five animals were used and shock was induced in one animal each by intravenous injections of peptone, histamine, procaine and sodium nitrite, and by sudden 30 per cent hemorrhage. Hydrogen peroxide was administered at rates equivalent to 1 cc. of oxygen per kilogram per minute. In all cases of chemical shock, after the administration of hydrogen peroxide the blood pressure rose about 20 mm. of mercury from previous systolic levels below 65 mm. of mercury. The effect, however, could not be sustained and lasted for only a very few minutes. In sodium nitrite shock the

administration of hydrogen peroxide led to increasing further methemoglobinemic "cyanosis." In the case of shock resulting from massive hemorrhage, the intravenous administration of hydrogen peroxide had no effect on the blood pressure, while later injection of the removed blood promptly restored the blood pressure to normal.

DISCUSSION

This investigation indicates that in animals with sufficient blood catalase, hydrogen peroxide can be given intravenously with effects similar to those following intravenous administration of oxygen. Significantly larger amounts of oxygen, however, are tolerated in the form of hydrogen peroxide. The method of administration of intravenous hydrogen peroxide is quite simple and can be readily controlled.

In animals very little therapeutic value could be found for intravenous treatment with hydrogen peroxide. It must be recalled, however, that in animals similar poor results are reported for intravenous administration of oxygen, while in man clinically beneficial results are recorded. It, therefore, seems indicated that further cautious clinical experiments might be carried out with intravenous administration of hydrogen peroxide substituted for intravenous administration of oxygen.

SUMMARY

The effect of hydrogen peroxide on the blood of various animals was observed and quantitative determinations of blood catalase activity were made. No deleterious effects were observed other than formation of methemoglobin in those species with very low blood catalase levels.

Tolerance observations on intravenous administration of hydrogen peroxide were made. In the dog and chicken, hydrogen peroxide tolerance was limited by formation of methemoglobin, while in the rabbit and cat by gas embolism. The rabbit was more susceptible to gas embolism than was the cat.

Oxygen in the form of hydrogen peroxide could be administered intravenously in cats twice as fast as in the form of oxygen gas without producing severe embolic signs.

Observations were made in mice on the chronic administration of hydrogen peroxide given subcutaneously twice daily for two weeks. Other than for immediate temporary embolic phenomena and an incidence of local skin ulcers in 25 per cent, essentially no deleterious effects were observed.

Hypoxia was induced in 2 cats by inhalation of 90 per cent nitrous oxide. Small amounts of hydrogen peroxide given intravenously aggravated rather than reduced the hypoxia as shown by arterial blood gas analyses.

Intravenous therapy with hydrogen peroxide for carbon monoxide poisoning, hemorrhage, and chemical toxic shock in 7 cats produced no noteworthy benefit.

Although hydrogen peroxide given intravenously has little or no value in the cat, further investigation of its use in the treatment of certain hypoxic and shock states in man may be indicated.

We wish to express our sincere appreciation for the encouragement and valuable guidance of Professor E. M. K. Geiling throughout the course of this investigation.

REFERENCES

1. Mariani, F.: Le iniezioni endovenose di ossigeno nell' uomo, *Riforma med.* **18**: 194, 1902.
2. Tomichliffe, F. W., and Stebbing, G. F.: The Intravenous Injection of Oxygen Gas as a Therapeutic Measure, *Lancet* **11**: 321-323 (Aug. 19) 1916.
3. Singh, L., and Shah, M. J.: Intravenous Injection of Oxygen under Normal Atmospheric Pressure, *Lancet* **1**: 922-923 (May 18) 1940.
4. Ziegler, E. E.: The Intravenous Administration of Oxygen, *J. Lab. & Clin. Med.* **27**: 223-232 (Nov.) 1941.
5. Jacobi, M.; Klein, B.; Rascoff, N.; Kogut, B.; Auerbach, R. W., and Jennings, J. E.: Effect of Intravenous Administration of Oxygen on Shock in Dogs and in Human Beings, *Arch. Surg.* **52**: 42-49 (Jan.) 1946.
6. Gaertner, G.: Ueber intravenöse Sauerstoffinfusionen, *Wien. klin. Wchnschr.* **15**: 691, 1902.
7. Stuertz, E.: Ueber intravenöse Sauerstoffinfusionen, *Ztschr. f. phys. u. diätet. Therap.* **7**: 67, 1904.
8. Bourne, G., and Smith, R. G.: The Value of Intravenous and Intraperitoneal Administration of Oxygen, *Am. J. Physiol.* **82**: 328-334 (Oct.) 1927.
9. Dick, M.: The Respiratory and Circulatory Responses to Intravenous Oxygen and Their Relation to Anoxemia, *Am. J. Physiol.* **127**: 228-231 (Sept.) 1939.
10. Grodins, F. S.; Ivy, A. D., and Adler, H. F.: Intravenous Administration of Oxygen. *J. Lab. & Clin. Med.* **28**: 1009-1014 (May) 1943.
11. Oliver, T. H., and Murphy, D. V.: Influenzal Pneumonia: The Intravenous Injection of Hydrogen Peroxide, *Lancet* **1**: 432-433 (Feb. 21) 1920.
12. Siderova, S. G.: *Farmakol. i Toksikol.* **7**: (no. 3) 39-43, 1944.
13. Sumner, J. B., and Somers, G. F.: *Chemistry and Methods of Enzymes*, New York, Academic Press, 1943, p. 11.
14. DuBois, K. P.: Personal Communication.
15. Becht, F. C.: Observations on the Catalytic Power of Blood and Solid Tissue, *Am. J. Physiol.* **48**: 171-191 (Mar.) 1919.
16. Peters, J. P., and Van Slyke, D. D.: *Quantitative Clinical Chemistry*, Baltimore, Williams and Wilkins Co., 1932, vol. 2.
17. Van Allen, C. M.; Hrdina, L. S., and Clark, J.: Air Embolism from the Pulmonary Vein. A Clinical and Experimental Study, *Arch. Surg.* **19**: 567-599 (Oct.) 1929.

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Monday, April 5, 1948.

8:00 a.m.—11:00 a.m. Hospital Clinics.

1. Providence Hospital, Kansas City, Kansas.
2. Research Hospital, Kansas City, Missouri.
3. St. Josephs Hospital, Kansas City, Missouri.
4. University of Kansas Medical Center, Kansas City, Kansas.

11:00 a.m.—12:00 Noon. Registration—Hotel President.

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