

the cortical hormone content of the blood of the adrenal veins of dogs rises within 15 minutes after an infusion of physiological amounts of epinephrine. Despite the prevention of further cortical hormone production by adrenalectomy approximately 10 minutes after epinephrine injection, the continued normal 4 hour fall in circulating eosinophiles takes place. This indicates that the progres-

sive eosinopenia occurring in normal rats need not depend on persistent or increasing elaboration and secretion of adrenal hormones.

Conclusions. 1. In rats, an eosinopenia follows stress even though adrenalectomy is completed within 10 minutes. 2. The progressive fall in circulating eosinophiles over a 4 hour period occurs even without the continued secretion of the adrenal cortex.

7. Vogt, M., *J. Physiol.*, 1944, v103, 317.

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Effect of Sinusoidal Stimulation upon Circulation Time.* (18291)

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The primary motivation for this work was the hope of Dr. V. L. Tichy, attending in Surgery, Crile V. A. Hospital, to cut down on the incidence of thrombosis and embolism, post-operatively. With this end in view, Dr. Tichy approached the author late in 1946 with the desire to stimulate electrically, with periodic stimulation, the calf muscles of post-operative and other patients confined to bed. Sinusoidal stimulation was suggested by the author as a likely possibility. A routine technic was then established for post-operative sinusoidal stimulation of the calves of both legs. A preliminary report of this work was given by Dr. Tichy and the author before the Cleveland Chapter of the American Society of Experimental Biology and Medicine in November, 1947. Since then two clinical reports have been given(1,2).

The present report deals with the investigative results on the effect of sinusoidal stimulation (such as in being used post-operatively) on circulation time. The effects of sinusoidal stimulation upon circulation time have not previously been reported. However, Gaskell(3) and Bulbring and Burn(4) more

recently, studied the blood flow during muscular contraction produced by faradic stimulation. As regards the effect of exercise, Smith, Allen, and Craig(5) have shown that lifting and dropping a leg, 40 times per minute, while wiggling the foot vigorously at the same time, reduced the circulation time in 4 patients by 24% to 40%.

Blood chemical changes. In order to ascertain the effect of sinusoidal stimulation upon circulation time, two types of examinations have been made. The first was suggested by Dr. J. R. Kahn, Director of Laboratories, Crile V. A. Hospital, and was performed by Leonard Skaggs, chemist at this hospital. Venous blood was drawn from the foot of stimulated as well as non-stimulated patients 24 hours post-operatively, and studies were made of the O₂ and CO₂ tensions, and CO₂ combining power of the specimens. These studies showed that sinusoidal stimulation has no definite effect on blood O₂, plasma CO₂, or the plasma CO₂ combining power.

Sodium cyanide test. In searching for a simple, accurate, yet comparatively safe method, the use of the sodium cyanide test as developed by Smith, Allen, and Craig(5) seemed the most feasible. This method is

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1. Tichy, V. L., *Surgery*, 1949, v26, 109.

2. Tichy, V. L., and Zankel, H. T., *Arch. Phys. Med.*, 1949, vXXX, 711.

3. Gaskell, W. H., *Art. a.d. Physiol. Inst., Leipzig*, 1877, v12, 45.

4. Bulbring, Edith, and Burn, J. H., *J. Physiol.*, 1939, v95, 203.

5. Smith, Lucian A., Allen, Edgar V., and Craig, W. McK., *Arch. Surg.*, 1940, v41, 1366.

objective because the end point consists of a gasp resulting from stimulation of the carotid sinus by sodium cyanide. Two percent freshly prepared sodium cyanide was injected into the dorsal vein of the foot anterior to the medial malleolus. The dose was 0.2 to 0.22 mg per kg of body weight. Two types of technics were used. The first consisted in rendering the vein prominent by the usual methods, inserting the needle into the vein, waiting 30 seconds, then injecting the solution as rapidly as possible, after which the needle was removed, and the whole procedure repeated as often as necessary. It was soon discovered however that foot veins are not as easy to get into as the antecubital vein of the forearm. Very often several attempts had to be made before entering the vein. It seemed to the author that if the patient could be spared this repeated needling, and if the needle could be inserted once and maintained in the same position for the duration of the test, the factors of trauma and compression could be eliminated even better than by the 30 second waiting period. Hence the second technic was adopted for most of the tests. This consisted in finding the vein as before, inserting a needle, and connecting it to a 5% saline solution[†] which was allowed to drip into the vein. We thus had a ready place for injecting our solution whenever we wished. The objection that the solution itself promoted blood flow is overcome by performing the test at variable intervals before, during, and after stimulation. Having inserted a needle (23 gauge)[†] into the vein and connected it to a solution of 5% sodium chloride in water, we allowed the saline to drip into the vein very slowly. After a variable interval, the syringe was removed from the needle, the sodium cyanide injected and the reaction timed with a stop watch. As soon as the sodium cyanide injection was completed, the saline was again allowed to flow at the same slow rate. After another variable rest period, the calf of each leg was gently stimulated by placing under it an electrode connected to the sinusoidal current

(22-24 stimulations per minute). The rest period before stimulation varied from one to 40 minutes. The actual time of stimulation varied between 9 and 30 minutes, after which, and while the calves were still stimulated, the circulation time test was repeated, using the same dose. The stimulation was then stopped but the drip resumed, and a final test was done after an interval of 15 to 30 minutes.

Table I shows the results of 24 tests on 9 patients. Patient 9 had a subjective, therefore questionable, endpoint, namely, a precordial pressure. All others had definite visible gasps. Where a blank was obtained, as in case 3, column G, and case 4, column J, the test was repeated after a suitable interval. Case 7, column J has 2 end points, 44 and 47 seconds. I feel that we ought to disregard the first because it was subjective, even though the patient was very definite that he recognized an odor or taste of sulfur 3 seconds before having to catch his breath.

Because of the questionable safety of sodium cyanide, an attempt was made to repeat these tests using 20% sodium dehydrocholate (Endo Products). This drug, when injected in upper extremity veins, produces a sharp end point. However, repeated attempts to test circulation time by injection into the veins of the foot were entirely unsatisfactory. In the first place, blanks (absent end points) occur too frequently. Furthermore, the amount of drug necessary (6 to 10 cc) is apt to produce chemical thrombosis. Hence this drug has been discarded for lower extremity circulation time testing.

The ether in saline circulation time test as developed by Hitzig(6) was found much more satisfactory than sodium cyanide or sodium dehydrocholate, and is the present method of choice. Tests with ether and saline confirm the above results with regularity. Hence, it can be concluded that sinusoidal stimulation, sufficient to produce a mild muscular contraction, causes a reduction in circulation time.

Time control. Soon after instituting sinusoidal stimulation, post-operatively, it became

[†] Normal saline is being used now, and 20 gauge needles.

TABLE I. Effect of Sinusoidal Stimulation on Circulation Time.

Drug, sodium cyanide 2%; dose, 0.2 to 0.22 mg/kg body wt; end point, deep gasp; site, dorsum of foot (saphenous vein); current, sinusoidal, 60 cycles/sec.; strength, enough for mild contraction; No. of contraction, 24/min.; site of stimulation, each calf.

Pt. No.	Diagnosis	Wt, lbs.	Dose, cc	Method	Int. min.	CT, sec.	Int. min.	Stim. min.	CT, sec.	Int. min.	CT, sec.	Remarks
1	Herniorrhaphy	160	.72	Drip	5	32	1	15	22	30	33	Very definite end point
2	Fissure in ano 22 hr post op.	137	.6	"	5	45	25	30	37	15	47	Test done while under stimulation
3	Renal stone, no operation	130	.6	"	85	B						Definite end point
4	Renal stone, no operation	160	.73	"	30	56	5	15	B	20	56	Definite end point
5	Subphrenic abscess, 1 mo. post oper.	120	.55	"	45	32	5	10	22			Needle fell out after J.
6	Ishio-rectal abscess	140	.65	"	50	80	5	25	35	10	B	Precordial pain.
7	CNS lues	155	.7	"	60	56	1	10	44			Patient noted sulfur odor before gasp. Needle out after J.
8	Hysteria	135	.6 .67	Drip- less		N 64	1	9	44			B. with 0.6 cc. Marked end point with 0.67 cc
9	Multiple sclerosis	145	.7 .75	Drip- less		N 34	15	10	22			B. with 0.7 cc. Good endpoint with 0.75 cc.

Code: Int.—Interval. CT—Circulation time. B—(blank) = No end point.

apparent that to take care of as few as 3 machines, there were required the full-time services of an attendant, day and night, 3 shifts, 7 days a week, or 4 attendants in all. Because of the shortage of qualified personnel, and to eliminate, if possible, the human factor of time control, it was felt that an automatic time control unit that would throw the current on and off at predetermined intervals might be a valuable adjunct in these cases. A machine was made to meet this need, (Teca Corp., N. Y. City). The principle is the use of a clock which instead of having one hour hand and one minute hand, has 2 minute hands, one of which is used to start the current, the other to interrupt it. It is thus possible to arrange any combination of time, within an hour, such as: 55 minutes-on, 5 minutes-off; 30-on, and 30-off; 40-on, and 20-off, etc. There are 2 pilot lights. One is 'on' at all times as long as the machine is connected to the house current. The other lights only with each stimulation.

To prevent a sudden stimulation after a period of rest, 2 thermistors are inserted into

the circuit. These are resistors which permit a slowly increasing current to pass as they are heated to a maximum, thus allowing for a slow rise of current to the patient at the beginning of each cycle of treatment. It takes between 3 and 4 minutes for the current to reach its maximum and about 5 minutes for the thermistors to cool off.

Summary and conclusions. 1. Experimental evidence is presented that mild sinusoidal stimulation decreases circulation time. 2. A new sinusoidal stimulator is introduced, using the principle of automatic time control at predetermined intervals of stimulation alternating with periods of rest during units of one hour, and allowing a slow rise in current at the beginning of each cycle.

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