

BLOOD FLOW AFTER GENERAL ANAESTHESIA IN SYMPATHECTOMIZED LIMBS * †

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INTRODUCTION

DURING general anaesthesia, the peripheral blood vessels dilate, producing a warmer, often flushed skin. This peripheral increase in blood flow returns to normal almost immediately after the end of the anaesthesia [Foster *et al* 1945 (1), Lynn and Shackman 1951 (2), Messent and Beaconsfield 1954 (3)]. The vasodilation present during anaesthesia is not accompanied, in most instances, by a fall in blood pressure or an increase in pulse rate. Shackman and his co-workers (1952) (4) have demonstrated that, under general anaesthesia, the cardiac output does not change—if anything, it falls slightly. They have concluded, therefore, that if there is a general peripheral vasodilatation, and the cardiac output, the blood pressure and the pulse do not change noticeably, there must be vasoconstriction in some other part of the body. By further investigations of the blood flow through the liver, Shackman *et al.* (1953) (11) (5) have found that the splanchnic flow is decreased.

What causes this peripheral vasodilatation under general anaesthesia? Is it of peripheral (local) or central origin? With our present knowledge of the facts, we can state that both peripheral and central influences operate. General anaesthesia has a direct effect on the vasomotor centers. Knoll (6) was the first to be interested in the physiology of anaesthesia; as long ago as 1878 he believed the vasodilatation and the fall in blood pressure observed during chloroform or other anaesthesia to be caused by a direct action on the vasomotor center. Sjostrand (1941) (7) showed that anaesthesia has a direct peripheral vasodilator effect, and proved this by perfusion experiments through the limb muscles. This vasodilatation was produced by both chloroform and ether, and by some of the barbiturate anaesthetics.

The effects of general anaesthesia on the blood circulation, peripheral as well as central, thus are well documented. We would like now briefly to analyze what happens to a sympathectomized limb during general anaesthesia.

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Kovalewsky in 1886 (8) and Langendorff in 1900 (9) showed that, under ether anaesthesia, a denervated pupil dilates to a greater extent with less anaesthesia, and remains dilated for a longer time than an undenervated pupil. This exaggerated pupillary vasodilatation could be due to the direct effect of the anaesthetic on the pupil, or perhaps to local tissue anoxia. Felder *et al.* (1951) (10) have shown that general ether anaesthesia will produce a fall in skin temperature of sympathectomized limbs; this could be due to the direct action of the anaesthetic agent on the limb vessels or to the effect of adrenalin[®] released from the adrenals as a result of anoxia, or to a combination of the two. We know [Fulton (11) 1949] that sympathectomized blood vessels are hypersensitive to adrenaline and other chemicals. This fits in very well with Cannon's law of denervation (12): (1939)—sympathectomized vessels are more susceptible than unsympathectomized to a number of hormones and metabolites.

METHOD AND MATERIAL

Patients who were to undergo bilateral cervical or lumbar sympathectomy were chosen for the investigation. The operation was performed on one side first and the maximum foot and blood flow during general anaesthesia was recorded plethysmographically before the resection of the sympathetic chain. An indirect heating test of 60 minutes' duration was performed to demonstrate the completeness of the sympathectomy two weeks later and during the same week infiltration with 5 ml. of 1 per cent procaine of the ulnar (upper extremity) or the posterior tibial nerve (lower extremity) was carried out with the same aim. In the few days that followed, the patient underwent sympathectomy on the contralateral side. During this second operation, hand or foot blood flow was measured by the plethysmograph in the already sympathectomized extremity. In all, 16 patients were investigated. Of these, 12 underwent a lumbar sympathectomy, 8 receiving cyclopropane and 4 ether anaesthesia, and of the 4 who had a cervicodorsal sympathectomy, 2 received cyclopropane and 2 ether. Throughout the experiment, arterial blood pressure and pulse rate were recorded.

RESULTS

1. Response of a Sympathectomized Limb to Cyclopropane

Eight feet and 2 hands were investigated (table 1, fig 1).

Lower Extremity. The mean foot blood flow before lumbar sympathectomy was 1.5 ml. per 100 ml. of tissue per minute. This increased under general anaesthesia before the chain was resected to 5.1 ml. Two weeks after the operation, the foot blood flow was 3.3 ml. After the indirect heating test, the blood flow gave a mean of 3.2 ml.

TABLE 1
BLOOD FLOW AFTER ANAESTHESIA IN SYMPHECTOMIZED LIMBS
(Blood flow measured in mls. per 100 ml. tissue per min.)

Case No.	Age	Sex	Before Operation	Maximum Blood Flow Before Chain Removed	2 wks. After Operation	After Indirect Heating Test	After Infiltration of Motor Nerve with 5 ml. of 1% Novocaine	During Anaesthesia	Anaesthetic Agent	Part of Limb Investigated
1	57	M	1.5	4.9	3.0	3.1	2.8	3.6	Cyclopropane	Foot
2	63	M	0.8	3.7	3.0	3.1	3.1	4.7	Cyclopropane	Foot
3	67	M	1.2	5.1	2.7	2.8	2.9	4.1	Cyclopropane	Foot
4	70	M	1.9	5.1	3.1	3.0	3.1	3.9	Cyclopropane	Foot
5	48	M	2.3	6.7	3.9	3.9	3.5	5.0	Cyclopropane	Foot
6	51	M	1.7	5.3	4.7	4.2	4.5	6.7	Cyclopropane	Foot
7	63	M	0.9	3.1	3.0	3.3	3.0	3.1	Cyclopropane	Foot
8	33	F	2.3	7.1	3.1	3.1	3.3	4.9	Cyclopropane	Foot
Mean			1.5	5.1	3.3	3.2	3.2	4.5*		
9	51	M	2.1	5.9	4.1	4.0	4.0	4.0	Ether	Foot
10	63	M	1.7	5.5	2.9	3.0	2.9	3.0	Ether	Foot
11	45	M	1.9	6.7	4.7	4.5	4.6	4.9	Ether	Foot
12	62	M	1.2	5.0	3.1	3.1	3.0	3.3	Ether	Foot
Mean			1.7	5.8	3.7	3.6	3.6	3.8†		
13	39	F	2.7	11.3	4.9	4.7	4.9	5.9	Cyclopropane	Hand
14	30	F	2.4	12.6	3.3	3.3	3.1	5.3	Cyclopropane	Hand
Mean			2.5	11.9	4.1	4.0	4.0	5.6		
15	27	F	1.9	11.2	5.0	5.1	5.0	4.9	Ether	Hand
16	32	M	3.1	15.3	6.1	6.0	6.1	5.7	Ether	Hand
Mean			2.5	13.3	5.5	5.5	5.5	5.1		

* The difference shown in the blood flow of the sympathectomized limb after cyclopropane anaesthesia was found to be statistically significant $P < .01$.

† Difference not statistically significant.

Procaine infiltration of the posterior tibial nerve produced no change in the flow, which remained at 3.2 ml.

During the operation on the second side, the blood flow increased in the limb already sympathectomized, reaching 4.5 ml. 20 minutes after the induction of anaesthesia. Statistical analysis showed that this increase in flow is significant $P < .01$.

Upper Extremity. The average hand flow before cervicodorsal sympathectomy was 2.5 ml. per 100 ml. of tissue per minute. This increased under general anaesthesia before the chain was resected to 11.9 ml.

Two weeks after the operation, the hand blood flow was 4.1 ml.

After the indirect heating test, the blood flow showed a mean of 4.0 ml.

Procaine infiltration of the ulnar nerve produced no change in the flow, which remained at 4.0 ml.

During the operation, the blood flow increased, reaching a mean of 5.6 20 minutes after the induction of anaesthesia.

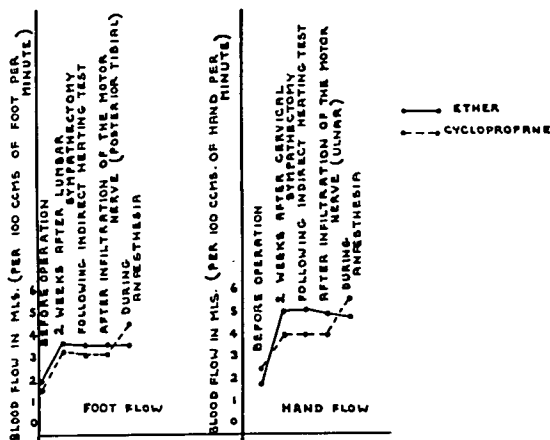


FIG. 1. Blood flow after anaesthesia in sympathetomized limbs.

To summarize, therefore, it was seen that, during the operation on the contralateral limb, the blood flow in the already sympathetomized limb showed an increase during cyclopropane anaesthesia, rising from a mean of 3.3 to 4.5 in the foot and from a mean of 4.1 to 5.6 in the hand, when no increase had been obtained by reflex heating of somatic nerve infiltration.

2. Response of a Sympathectomized Limb to Ether

Four feet and 2 hands were investigated (table 1 and fig. 1).

Lower Extremity. The mean foot blood flow before lumbar sympathectomy was 1.7 ml. per 100 ml. of tissue per minute. This increased under general anaesthesia before the chain was removed to 5.8 ml.

Two weeks after the operation, the foot blood flow was 3.7 ml.

After the indirect heating test, the blood flow remained unchanged, still showing an average of 3.6 ml.

Procaine infiltration of the posterior tibial nerve produced a mean blood flow of 3.6 ml.

During the operation on the second side, the blood flow in the foot already sympathetomized was recorded at 3.8 ml.; 20 minutes after the induction of anaesthesia there was a temporary vasoconstriction. The same holds true for the hand.

Upper Extremity. The hand blood flow before cervicodorsal sym-

pathectomy was 2.5 ml. This increased under general anaesthesia before the chain was resected to 13.3 ml.

Two weeks after sympathectomy, it was 5.5 ml.

After the indirect heating test, it remained unchanged at 5.5 ml.

After procaine infiltration of the ulnar nerve, the blood flow was 5.5 ml.

During the operation on the contralateral side, the blood flow was recorded as being 5.1 ml.

To summarize, therefore, it was observed that, during the operation on the contralateral limb, the blood flow in the already sympathectomized limb did not alter under ether anaesthesia; during the first 5 to 15 minutes after induction, the blood flow actually recorded values lower than seen before the operation; 30 minutes after induction, the blood flow was at the preoperative level, where it remained.

Throughout the second operation, blood pressure and pulse remained virtually unchanged. In only 1 case, patient No. 15, who underwent cervical sympathectomy under ether anaesthesia, did the blood pressure rise more than 15 mm. Hg (from 120/60 to 160/80) and the pulse more than 20 beats per minute (from 60 to 100).

SUMMARY AND CONCLUSIONS

Changes in peripheral blood flow under general anaesthesia (cyclopropane or ether) in previously completely sympathectomized limbs were studied. The results of the above investigation made the following conclusions possible:

1. The vasodilatation which occurs during cyclopropane anaesthesia in normal limbs also occurs in sympathectomized limbs, but to a much lesser degree. This would substantiate the hypothesis that cyclopropane anaesthesia has a dual action on the peripheral vascular system: (a) on the vasomotor centers directly where effect is greater and is abolished by sympathectomy and (b) by some other mechanism which acts locally on the blood-vessel wall and is not interrupted by sympathectomy. The data do not permit further analysis of this second mechanism.

2. Ether anaesthesia produced no increase in blood flow in the sympathectomized limb and it therefore can be stated that ether inhalation has a negligible effect on this second mechanism.

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