Quantitation of Cutaneous Blood Circulation in the Rhesus Monkey (*Macaca mulatta*)

Venous occlusion plethysmography, calorimetry, and thermal conductivity are the three usual methods of measuring the blood flow to the skin. Although these methods provide useful qualitative and quantitative information about circulation to the skin of the extremities, particularly of the digits, they have the obvious defect of only indirectly measuring the blood flow to the skin. For instance, measurement of the blood flow to the limbs includes the blood flow not only to the skin but to the skeletal muscles and the bones, and hence yields only indirect data on the skin. Moreover, information obtained from measuring the blood flow to the extremities cannot be applied to other areas of the body where the architecture of the dermal arterioles and capillaries is strikingly different[1].

The purpose of this paper is to report estimates of blood flow in the skin of nonhuman primates, using a method based upon the distribution of nuclide-labeled microspheres.

Materials and methods. We measured the blood flow to the skin of the rhesus monkey (*Macaca mulatta*) and the cardiac output, using an intracardiac injection of nuclide-labeled microspheres and endocyanine green dye respectively. From the ratio of the radioactivity in the skin to that of the whole body, we determined the proportion of the cardiac-output distributed to the skin:

$$\text{Skin blood flow (ml/min)} = \frac{\text{skin } \gamma \text{ activity}}{\text{total body } \gamma \text{ activity}} \times \text{cardiac output (ml/min)}$$

Five adult rhesus monkeys were used in this study. After anesthesia and tracheal intubation, the femoral and anterior neck areas of the animals were sterilely prepared and draped. A general anesthesia was maintained with halothane throughout the experiment. The femoral arteries, the carotid, and the pulmonary arteries were cannulated with soft polyvinyl tubing (Figure). One femoral artery catheter was used to monitor heart rate and blood pressure; the carotid artery catheter was used to determine the cardiac output. The other femoral artery catheter was advanced into the left ventricle and used to inject nuclide-labeled microspheres and endocyanine green dye. The location of the left ventricle and pulmonary artery catheters was ascertained by the character of the recorded pressure tracings and confirmed at the autopsy. Room temperature during the operations was 21°C.; skin temperature of the monkeys was 34–35°C., and rectal temperature was 37–38°C.

The cardiac-output was measured with a standard dye solution of endocyanine green by a method previously described[2,3]. After the cardiac-output was measured, nuclide-labeled microspheres were injected into the left ventricle over a 1-minute time period; a second cardiac output was determined after this injection. The calculation of cardiac output was based on the average of the two dye measurements.

The tissue distribution of the cardiac output was calculated from the measured distribution of activity from the nuclide-labeled microspheres. This technique[3,4], its validation, and the evidence that the injection of the number of microspheres used in these studies does not result in a measurable circulatory disturbance have been reported elsewhere[3,5].

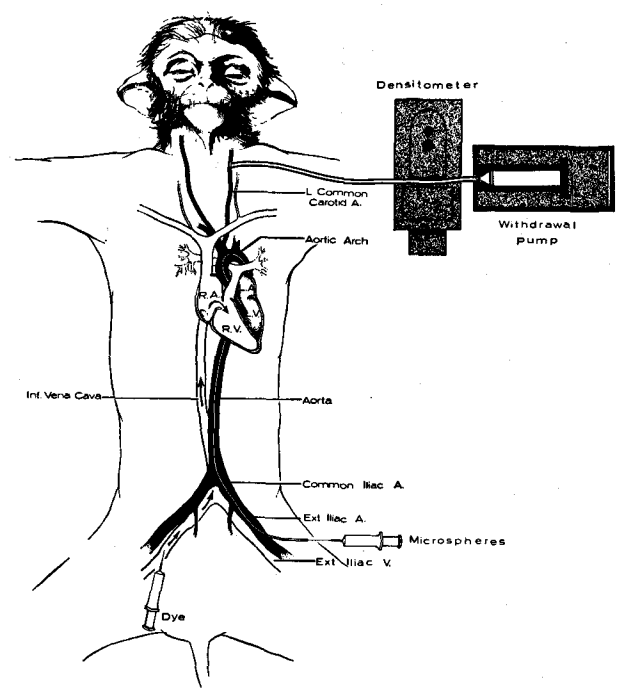

Diagram of the injection sites of the nuclide-labeled microspheres and endocyanine green dye. For description see text.

[1] W. MONTAGNA, *The Structure and Function of Skin*, 2nd edn. (Academic Press, New York, New York 1962).
[2] E. N. PETERSON and R. E. BEHRMAN, Am. J. Obstet. Gynec., in press.
[3] A. M. RUDOLPH and M. A. HEYMAN, Circulation Res. *21*, 163 (1967).
[4] R. H. PHIBBS, F. WYLER and J. NEUTZE, Nature *216*, 1339 (1967).
[5] J. M. NEUTZE, F. WYLER and A. M. RUDOLPH, Am. J. Physiol. *215*, 486 (1968).

Animal No.	Body wt. (kg)	Skin wt. (g)	Cardiac output (ml/min)	Total skin blood flow (ml/min)	Skin cardiac output (%)	Skin blood flow (ml/min/g skin)
190	6.7	646	825	30	3.6	0.1
2490	6.9	760	1150	90	7.8	0.1
1458	6.5	663	1071	135	12.6	0.2
2123	5.5	568	822	35	3.4	0.1
Means	6.4	659	967	73	6.9	0.1

The nuclide-labeled microspheres supplied by the Nuclear Products Division of Minnesota Mining and Manufacturing Company had an average diameter of 50 ± 5 µm. 75 to 90 µC, or approximately 40,000–50,000 spheres, were injected into the left ventricle of each animal used in this study. The animals were sacrificed with intro-arterial barbiturate immediately after these procedures. The skin was dissected from the carcass, weighed, and incinerated at 500°F for 4 h. The ashes were examined for radioactivity with a Nuclear-Chicago automatic gamma well-counter. The gamma counter was calibrated with cesium standard and with small aliquots of labeled-microspheres. Isotopes of strontium (85-Sr) and iodine (131-I) were used in this study. Standard arithmetical methods were used to obtain total activity and specific activity for the skin.

Results and comments. The results obtained are presented in the Table. The total body weights of the monkeys ranged from 5.5 to 6.9 kg. The dissected skin weight was between 568 and 760 g. The cardiac output varied from 822 to 1150 ml per min. The blood flow in the total skin showed considerable variation between individual animals and ranged from 30 ml to 135 ml per min, which represents 3.6 and 12.6% of the total cardiac output. Despite the differences between animals, there was a good agreement between estimations of blood flow per g of skin. The skin is only 10% of the body weight, but the blood flow is about 7.0% of the total cardiac output.

Zusammenfassung. Die Durchblutung der Haut von Rhesus-Affen (*Macaca mulatta*) wurde mittels Verteilung radioaktiver Kügelchen gemessen und beträgt etwa 7% des HerzMinutenvolumens.

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Complete Development of *Ancylostoma ceylanicum* (Looss, 1911) in Golden Hamsters, *Mesocricetus auratus*

The importance of the small laboratory animal adapted strain of hookworm has long been realized, especially so from the experimental chemotherapeutic point of view. The work of Sen and Seth[1] with human hookworm *Necator americanus* in golden hamsters demonstrate that such a host-parasite system is possible. It is the first time that the complete development of a species of the genus *Ancylostoma* is reported in golden hamsters. The existence of *Ancylostoma ceylanicum* in dogs and cats has been reported by several workers[2–5]. Lane[6] reported for the first time man as a host of this parasite in India. Ever since then it has been reported in man from several parts of the world[5,7–9]. The controversy with regard to the identity of the 2 different species, *Ancylostoma ceylanicum* and *Ancylostoma braziliense* has been well thrashed out by Biocca[10] and later confirmed by other workers[11–14]. It is now evident that the reports available up to date about *A. braziliense* being found in man, in fact relates to *A. ceylanicum*[15–16]. The object of our investigations was to determine whether hamsters could be a suitable host for dog hookworms.

The infective larvae were obtained from 10–12-day-old faecal culture prepared from pooled faeces of dogs naturally infected with *A. canium* and *A. ceylanicum* maintained in the animal house by methods described by Sen et al.[17].

Two experiments were conducted with 3-month-old female hamsters. Infection was given per os with a specially designed feeding needle. In Experiment No. 1 a single dose of 1000 mixed infective larvae was given to a batch of 34 hamsters and in Experiment No. 2, the same dose of infective larvae was given to a batch of 10 hamsters repeatedly at weekly intervals till the ova were seen in pooled faeces.

In Experiment No. 1 where single dose infection was given 4 animals were necropsied on day 12. The parasites found were all male adults of *A. ceylanicum* like 1, 0, 1 and 3 with one animal without worms. On days 16, 17 and 18 faecal examination of pooled faeces was found negative for ova. On day 18, 10 animals were necropsied but no worms could be recovered. On day 20 the remaining 20 animals after negative faecal examination were necropsied and only from two of them 1 adult male and 1 female of *A. ceylanicum* respectively could be recovered.

In Experiment No. 2, we were interested to see only the complete development of any one of the species of worms by the presence of ova in faeces; none of the animals were necropsied at any stage of the experiment, until any were found to have died naturally.

Examination of pooled faeces for the presence of ova started regularly from day 16 after the first infective dose. 3 animals died on day 22. On necropsy no worms could be recovered from them. Infertile eggs were first seen on day

[1] H. G. Sen and D. Seth, Nature, Lond. *214*, 609 (1967).
[2] A. C. Chandler, Ind. J. med. Res. *13*, 213 (1925).
[3] A. S. Dissainaike, Ceylon J. med. Sci. *10*, 1 (1961).
[4] A. J. Peter and E. R. Brygoo, Annls Parasit. hum. comp. *42*, 279 (1967).
[5] Y. Yoshida, K. Okamoto and J. K. Chiu, Am. J. trop. Med. Hyg. *17*, 378 (1968).
[6] C. Lane, Ind. med. Gaz. *48*, 217 (1913).
[7] R. T. Leiper, Jl. R. Army med. Corps *24* (1915).
[8] C. C. Velasquez and C. B. Cabrera, J. Parasit *54*, 430 (1968).
[9] S. Areekul, P. Radomyos and C. Viravan, J. med. Ass., Thailand, *53*, 315 (1970).
[10] E. Biocca, J. Helminth. *25*, 1 (1951).
[11] S. Yamaguti, *Systema Helminthum* (Interscience Publishers, New York 1961), vol. 3, p. 362.
[12] G. A. M. Haydon and A. J. Bearup, Trans. R. Soc. trop. Med. Hyg. *57*, 76 (1963).
[13] Y. Yoshida, J. Parasit. *51*, 631 (1965).
[14] B. H. Rep, J. C. M. Vetter and M. Eijsker, Trop. geogr. Med. *20*, 367 (1968).
[15] B. H. Rep, Trop. geogr. Med. *17*, 146 (1965).
[16] D. J. B. Wijers and A. M. Smit, Trop. geogr. Med. *18*, 48 (1966).
[17] H. G. Sen, U. N. Joshi and D. Seth, Trans. R. Soc. trop. Med. Hyg. *59*, 684 (1965).