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CARDIOPULMONARY MEASUREMENTS OBTAINED BY RIGHT AND LEFT CARDIAC CATHETERIZATION OF MACACA MULATTA

RALPH O. HAYDEN, CAPTAIN, USAF, MC

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RALPH O. HAYDEN, CAPTAIN, USAF, MC

FOREWORD

This report was prepared in support of Project No. 7222, "Biophysics of Flight," administered by the Multienvironment Division, Biophysics Laboratory of the Aerospace Medical Research Laboratories, Aerospace Medical Division, Wright-Patterson Air Force Base, Ohio. This work was accomplished in the Environmental Stress Branch of the Multienvironment Division during late 1963 and early 1964.

The author is indebted to Dr. Raymond H. Murray and the staff of the Indiana Cardiopulmonary Research Laboratory (Air Force Contract No. AF 33(616)-8378) for their invaluable advice and assistance with the procedures, and to Ralph F. Ziegler, Captain, USAF, VC, for preparation of the animals and follow-up care.

This technical report has been reviewed and is approved.

J. W. HEIM, PhD
Technical Director
Biophysics Laboratory

ABSTRACT

Eight normal Macaca mulatta anesthetized with pentobarbital were subjected to right and retrograde left heart catheterization and analysis of expired gas. Measurements were made of the aortic, left ventricular, pulmonary capillary, pulmonary arterial, right ventricular and right atrial pressures, heart rate, cardiac and stroke index, peripheral and pulmonary vascular resistance, tension-time index, systolic ejection period and rate index, left ventricular work and stroke index, minute respiratory volume and oxygen consumption index and arterial and mixed venous blood oxygen content and saturation. The data will serve as a baseline for cardiopulmonary studies with this species.

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INTRODUCTION

Scant data is available on the hemodynamics of the intact rhesus monkey (Macaca mulatta) (refs 1, 2, 3). The small fragile peripheral arteries and veins in this species, the largest of which approximates 2-3 mm in the adult, cause considerable technical difficulty in gathering such data.

MATERIALS AND METHODS

Eight healthy male monkeys (Macaca mulatta) were anesthetized with a 30 mg/kg intravenous injection of sodium pentobarbital. An inflatable cuffed endotracheal tube was then inserted. Supplemental injections of sodium pentobarbital were administered as required to maintain surgical anesthesia.

Following measurement of the rectal temperature, conventional electrocardiographic paste electrodes were attached to shaved areas on the extremities for continuous oscilloscopic monitoring throughout the experiment. A peripheral artery and vein, usually unilateral femoral vessels, were surgically exposed under aseptic conditions. A PE-160 polyethelene catheter with an indwelling Seldinger guidewire was inserted through an incision in the artery and introduced under fluoroscopic guidance to the left ventricle. The guidewire was then removed and the arterial catheter attached to a Statham P-23DB strain gauge at the right atrial level. Pressures were recorded on a Model DR-8 Electronics for Medicine recorder with a direct writing attachment in the left ventricle and during a pull-through to the ascending aorta. The arterial catheter was left in place in the central aorta and flushed periodically with a heparin-saline mixture, consisting of 100 mg of heparin per liter of normal saline.

The exposed vein was intubated with a 6-French, birdseye, catheter, which was manipulated to the pulmonary capillary (wedge) position under fluoroscopic guidance. Pressures were obtained throughout the lesser circulation as described above. Electronically integrated mean pressures were obtained from the central aorta, the pulmonary capillary position, pulmonary artery, right ventricle, and right atrium. Patency of the venous catheter was ensured by a continuous heparin-saline gravity drip. The total volume of infused saline was less than 50 ml during the time required for the procedure, approximately 1 hour.

Following pressure measurements, from 3- to 10-minute timed samples of expired gas were collected in a Douglas bag. The volume of the collection was determined in a Tissot spirometer and the percentage of oxygen in the expired gas measured with a Beckman Model E-2 oxygen analyzer considered to be accurate within ±0.5%. Blood samples were drawn rapidly from the aorta and pulmonary artery at the midpoint of the expired gas collection and analyzed for oxygen content and saturation with the Van Slyke apparatus. This permitted computation of the cardiac output by the direct Fick oxygen method.

Immediately after the expired gas collection, cardiac output was determined by the dye dilution technique. Cardio-Green (1.25 mg) was injected into the pulmonary artery, and central aortic blood was drawn through a Gilford densitometer with a Harvard Model 600-900 Infusion/Withdrawal Pump. The resulting dye curves were recorded on the Model DR-8 recorder and analyzed for flow by a method described by Lilienfeld and Kovach (ref 4). When the procedure was completed the vessels were doubly ligated and the wounds closed with silk sutures.

RESULTS AND DISCUSSION

Each animal was studied once, with the exception of animal 1. A repeat study was made on this subject 50 days after the procedure, an interval considered more than adequate for recovery.

Table 1 gives the various pressures measured and the weight and surface area of the eight animals. Body weight and surface area varied widely. The pressures were similar to those obtained in the normal human adult. Several of the monkeys demonstrated a sustained systolic and diastolic hypertension, which may have been a pentobarbital effect, as in canines. The marked difference in aortic and left ventricular systolic pressures in animal 8 are in part related to considerable respiratory variations in the left ventricular recording.

Table 2 gives further hemodynamic data including several of the conventional indices of myocardial function. The rather low values for the cardiac index and other indices employing the body surface area as a denominator probably reflect the high surface to volume ratio of Macaca mulatta related to its long, narrow extremities. Cardiac index was successfully determined on four animals by the Fick oxygen method and gave a mean value of 2.5 liters per minute per square meter with a standard deviation of 0.3. The small number of measurements is the only apparent explanation for the disparity with the dye-dilution method.

TABLE 1

PRESSURES (mm Hg)

Animal	Weight (kg)	Body* Surface Area (m^2)	Aortic Systolic	Aortic Diastolic	Aortic Mean	Left Ventricular Systolic	Left Ventricular End Diastolic	Pulmonary Capillary Mean	Pulmonary Arterial Systolic	Pulmonary Arterial Diastolic	Pulmonary Arterial Mean	Right Ventricular Systolic	Right Ventricular Diastolic	Right Atrial Mean
1	12.3	0.623	110	78	98	127	7	8	23	8	13	28	3	2
1 (50 days later)	11.4	0.591	159	92	120	156	9	8	23	11	16	23	3	2
2	6.1	0.392	95	64	80	100	4	4	27	5	12	25	3	1
3	7.3	0.440	137	100	117	143	4	2	12	5	8	13	-1	-2
4	5.9	0.383	112	84	96	107	3	7	17	9	12	19	2	2
5	10.2	0.552	99	73	84	102	1	3	14	8	11	12	2	2
6	7.7	0.457	103	74	87	103	3	5	16	9	12	17	2	3
7	3.6	0.278	104	70	86	113	3	7	18	10	13	21	0	2
8	3.5	0.272	164	122	141	141	6	10	39	16	23	49	6	4
Mean	7.6	0.443	120	84	101	121	4	6	21	9	13	23	2	2
Standard Deviation	3.2	0.131	26	12	21	21	3	3	8	4	4	11	2	2

* Computed from formula: Body Surface Area = 11.8 x weight in grams$^{\frac{2}{3}}$ x 10^{-4}

TABLE 2

HEMODYNAMICS

Animal	Heart Rate (beats/min)	Cardiac Index (L/min/m²)	Stroke Index (ml/beat/m²)	Peripheral Vascular Resistance (dyne-sec-cm⁻⁵)	Pulmonary Vascular Resistance (dyne-sec-cm⁻⁵)	Tension Time* Index (mmHg-systolic sec/min)	Systolic Ejection Period* (systolic sec/beat)	Systolic Ejection Rate Index (ml/systolic sec/m²)	Left Ventricular Work Index* (kg-meters/min/m²)	Left Ventricular Stroke Work Index* (gm-meters/beat/m²)
1	192	1.4	7.2	8,920	511	3,460	0.185	38.8	1.86	9.67
1 (50 days later)	147	1.2	7.9	13,700	985	5,100	0.245	32.3	2.17	14.80
2	150	2.7	15.1	5,960	716	1,990	0.172	87.5	2.60	14.40
3	190	1.5	8.4	14,900	749	4,550	0.203	41.4	2.32	13.30
4	145	2.6	15.1	7,480	356	3,380	0.233	65.0	3.45	19.80
5	133	1.0	8.0	12,300	1,200	2,680	0.212	37.7	1.11	9.10
6	145	1.5	10.7	9,930	881	3,340	0.237	45.3	1.71	12.30
7	190	2.4	12.2	9,870	646	3,480	0.205	59.7	2.77	13.90
8	220	2.3	11.4	17,400	1,600	4,060	0.130	87.5	4.30	20.90
Mean	168	1.8	10.7	11,200	849	3,560	0.202	55.0	2.48	14.30
Standard Deviation	30	0.7	3.0	3,700	376	930	0.036	21.2	0.96	4.00

*Determined from central aortic pressure tracing

Table 3 contains the mean values for minute respiratory volume, oxygen consumption, hemoglobin, hematocrit, blood oxygen analyses, and rectal temperature. The mean minute volume index of 3,860 ml per minute per square meter agreed with the work of Guyton (ref 5), who studied a group of smaller unanesthetized rhesus monkeys. He derived a value of 3,800 ml per minute per square meter. The mild arterial oxygen unsaturation is attributed to the respiratory depressant effect of pentobarbital.

TABLE 3
RESPIRATORY AND BLOOD

Determination	Number of Measurements	Mean Values	Range
Minute Volume Index	6	3,860 ml/min/M^2 (STPD)	2,860 - 4,960
Oxygen Consumption Index	4	94.2 ml O_2/min/M^2 (STPD)	78.8 - 104
Hemoglobin	5	12.7 gm %	11.2 - 14.6
Hematocrit	5	41%	38 - 45
Arterial Oxygen Capacity	5	18.5 vol %	16.0 - 21.3
Arterial Oxygen Content	5	16.2 vol %	14.1 - 18.1
Arterial Oxygen Saturation	5	87.8%	85.1 - 92.9%
Pulmonary Arterial Oxygen Content	5	11.9 vol %	10.8 - 13.9
Pulmonary Arterial Oxygen Saturation	5	64.7%	54.5 - 70.5%
Rectal Temperature	7	37.4°C	36.6 - 37.7

REFERENCES

1. Britton, S.W., V.A. Pertzoff, C.R. French, and R.F. Kline, "Circulatory and Cerebral Changes and Protective Aids during Exposure to Acceleratory Forces," Am. J. Physiol., 150: 7, 1947.

2. Rosenfeld, S., and C.F. Lombard, "Cardiovascular Pressor Reflex Mechanism and Cerebral Circulation under Negative G Head-to-Tail Acceleration," Aviat. Med., 21: 293, 1950

3. Duane, T.D., Lt., R.L. Wechsler, J.E. Ziegler, and E.L. Beckman, "Studies on Cerebral Physiology of Monkeys at 12 Negative G," J. Aviat. Med., 23: 479, 1952.

4. Lilienfeld, L.S., and R.D. Kovach, "Simplified Method for Calculating Flow, Mean Circulation Time and Downslope from Indicator-Dilution Curves," Proc. Soc. Exp. Biol. Med., 91: 595, 1956.

5. Guyton, A.C., "Measurement of the Respiratory Volumes of Laboratory Animals," Am. J. Physiol., 150: 70, 1947.

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