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Coronary Sinus Catheterization Technique for Studying Coronary Blood Flow and Myocardial Metabolism *in vivo*.

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Recent reviews stress the need for a method of studying the coronary circulation in intact animals, as well as in man.[1,2] Harrison and coworkers cannulated the coronary sinus of intact morphinized dogs,[3] with a modified Morawitz brass balloon cannula.[4] A less traumatic technique of intravenous catheterization of the coronary sinus of intact dogs is presented in this report, using the soft Forssman catheter,[5] as modified by Cournand.[6] Application of this method in studying myocardial metabolism *in vivo* will be reported elsewhere,[7,8] particularly the measurement of coronary blood flow by the nitrous oxide method, developed by Kety and Schmidt for measuring cerebral blood flow.[9]

The catheter,[6] (size 7-9, reasonably stiff but without stylet), is inserted through the dog's external jugular vein, under light nembutal anesthesia. Fluoroscopically, in the right anterior oblique position,* a triangular area of lung with the following boundaries is visible: (1) the anteromedial border of the inferior vena cava, (2) the posteroinferior cardiac border, and (3) the diaphragm. The coronary sinus ostium lies just anteromedial to the superior corner of this triangle which marks the junction of inferior cava and right auricle, posteroinferior to the tricuspid valve. The catheter is first passed into the inferior cava, then withdrawn just inside the auricle. As the tip is shifted anteromedially, with repeated gentle thrusts toward the ostium, the catheter will eventually enter the coronary sinus, (Fig. 1). The tip often passes further in the same direction, superiorly and to the left along the auriculo-ventricular groove, past a delicate valve into the great cardiac vein. Sometimes the catheter enters the middle cardiac vein, or more rarely the first posterior vein of the left ventricle, and passes along the posteroinferior septal surface toward the apex.

Evidence of successful coronary sinus catheterization includes: (1) the typical fluoroscopic position of the catheter,† (2) withdrawal of very dark venous blood which shows an extremely low oxygen content, markedly lower than in mixed venous blood, (Table I), and (3), in some cases, autopsy with the catheter still inserted in the sinus.

The coronary sinus of 30 dogs, weighing 28-75 lbs., has been successfully catheterized 55 times, with as many as 7 procedures on the same dog at monthly intervals. Three attempts in small dogs were failures. Postoperative recovery was prompt, except in those intentionally sacrificed. No post-

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3 Harrison, T. R., Friedman, B., and Resnick, H., Jr., *Arch. Int. Med.*, 1936, **57**, 927.

4 Morawitz, P., and Zahn, A., *Zentralbl. f. Physiol.*, 1912, **26**, 465.

5 Forssman, W., *Klin. Wchnschr.*, 1929, **8**, 2085.

6 Cournand, A., *Fed. Proc.*, 1945, 207.

7 Eckenhoff, J. E., Hafkenschiel, J. H., Harmel, M. H., Goodale, W. T., Lubin, M., Bing, R. J., and Kety, S. S., in press.

8 Goodale, W. T., Lubin, M., and Banfield, W. G., in press.

9 Kety, S. S., and Schmidt, C. F., *Am. J. Phys.*, 1945, **143**, 53.

* Terminology, as in *man*.

† Diodrast (3,5-diiodo-4-pyridone-N-acetic acid and diethanolamine) was occasionally injected forcibly to outline the coronary venous system fluoroscopically, but sometimes caused local myocardial necrosis and hemorrhage. Forcible injection of any fluid against the coronary venous stream may be hazardous.

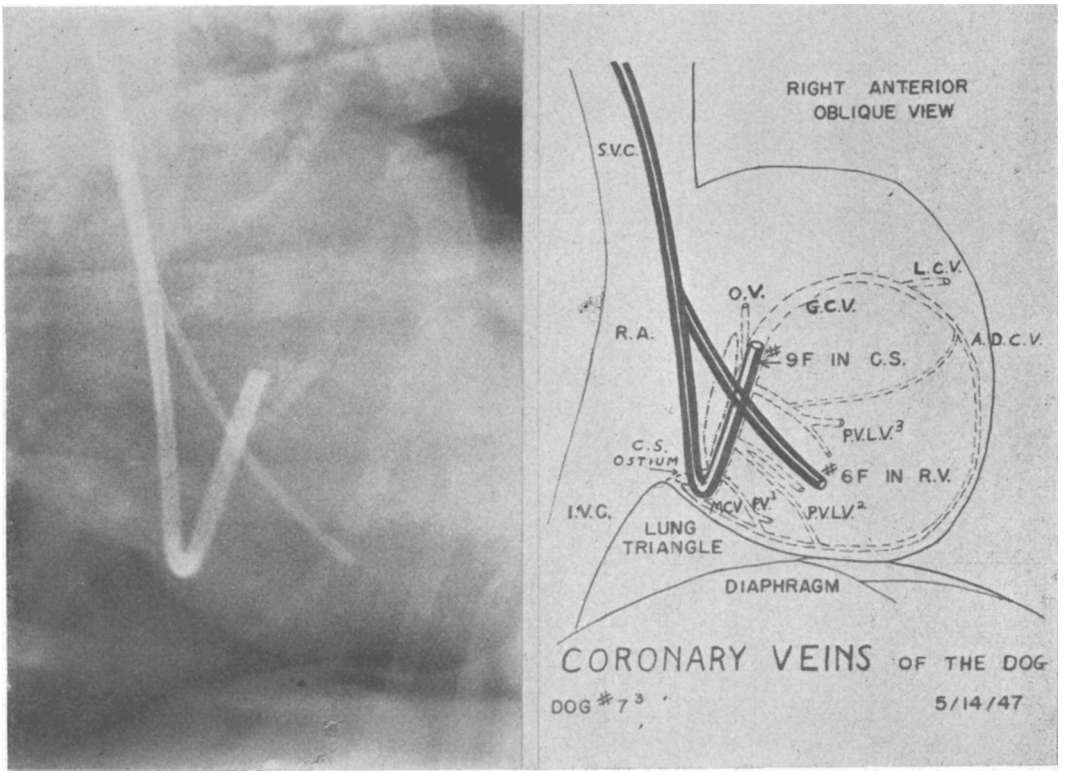

FIG. 1.

Large No. 9 catheter is inserted 3-4 cm into coronary sinus (C.S.), with small No. 6 catheter passing through tricuspid valve (— · — · —), into right ventricle (R.V.). The coronary sinus venous system, as found at autopsy, is sketched in as follows: middle cardiac vein, MCV; posterior veins of the left ventricle, PV_1, $PVLV_2$, and $PVLV_3$; oblique vein of Marshall, OV; great cardiac vein, GCV; left circumflex vein, LCV; anterior descending coronary vein, ADCV. The extensive veno-venous anastomoses between the major veins draining the left ventricle are illustrated. (The venous drainage of the right ventricle is largely independent of the coronary sinus system, through the Thebesian, anterior, and other small cardiac veins.)

Metabolic Observations: 19 Aug., 1947; Oxygen content of blood from coronary sinus, 3.7 vols. %; pulmonary artery, 14.8 vols. %; femoral artery, 18.2 vols. %, 94% saturated. Coronary flow, 71 cc/min/100 g of left ventricle. Myocardial oxygen consumption, 10.6 cc/min/100 g. Systemic blood flow, 168 cc/kg body wt/min. Weight of dog, 31 kg. Heart weight at autopsy, 240 g. Mean arterial blood pressure, 115 mm Hg. Work of heart, 7/6 · QR = 503 kg/hr. Cardiac efficiency, 16%.

Pathology: This dog was catheterized 7 times in 5 months, with a total of over 16 hours of actual insertion of the catheter in the coronary sinus, with a second catheter in the pulmonary artery or right ventricle. Autopsy 7 weeks after the last procedure showed a normal heart except for slight subendocardial fibrosis in the right auricle and medial tricuspid valve leaflet.

operative local or systemic infection, or other clinical complications attributable to catheterization, were encountered.

Thirty autopsies following coronary sinus catheterization often showed small mural thrombi and subendocardial hemorrhages in the coronary sinus and right auricle. Gross lesions were rarely found when the dog was sacrificed immediately after catheterization, but often when sacrificed at least 24 hours later. Minimal subendocardial fibrosis in the right auricle was the only finding in 4 of 5 dogs sacrificed 3 to 6 weeks after catheterization.

Mural thrombi and subendocardial hemorrhages, however, were also found in the right auricle, on the right ventricle and on the tricuspid and pulmonary valves after catheter-

TABLE I.
Oxygen Content of Blood Samples.[15]

	Oxygen content vol. %					
	No. of observations	Mean value	S.E.*	S.D.†	C.V.‡	Extreme range
Coronary sinus	44	3.8	.16	1.04	27.7	2.4- 8.3
Pulmonary artery or rt. ventricle	30	12.5	.72	3.89	31.5	9.5-15.3
Femoral artery	48	16.9	.25	1.75	10.3	14.5-22.6

* Standard error of the mean.
† Standard deviation.
‡ Coefficient of variation.

izing the pulmonary artery or right ventricle.‡ The auricular lesions were more frequent and more severe than those found after passing the catheter only into the coronary sinus.

In 3 cases, lesions obviously peculiar to coronary sinus catheterization were found: 2 of coronary venous thrombosis and one of gross hemorrhage into the myocardium drained by a catheterized vein. These were perhaps related to prolonged insertion of a large catheter beyond the sinus into the great cardiac vein, or to forceful reinjection of fluid through the catheter. Such lesions have not been found in 11 control experiments in which precautions were taken, including the gentle insertion of a No. 7-F catheter only 1-2 cm into the coronary sinus for only 60 minutes. With these precautions, coronary sinus catheterization appears to be actually less hazardous than catheterization of the right ventricle or pulmonary artery of the dog by our technique.

In man, several thousand well-controlled intracardiac catheterizations have been performed without cardiac damage apparent even in numerous autopsied cases.[6,10-14] Species peculiarities and differing techniques may well explain the occurrence of lesions in dogs, where none have so far been found in man. The present technique, however, is being applied to current studies of the coronary circulation in man only with the precautions which prevented significant myocardial and coronary venous damage in dogs.

Summary. Coronary sinus catheterization technique has been developed in intact dogs in order to study coronary blood flow and myocardial metabolism, and to evaluate the safety and practicality of a similar procedure in man. The pathological findings, among 30 autopsies following the procedure, have been discussed.

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‡The occurrence of endocardial lesions in dogs after catheterizing the pulmonary artery by this technique, has been recently confirmed, although with less frequency and severity than in the present series (Hellems, H. K., Haynes, F. W., Fanger, H., and Dexter, L., personal communication, 1947).

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