peated under constant conditions at the shortest possible intervals frequently vary by ±5% or more. The excellent agreement between the kymographic and the acetylene-rebreathing methods is remarkable in view of this. It would appear that the kymographic method provides an estimate of stroke output at least as accurate as the acetylene method within the limits of heart size and output studied by us.

It should be pointed out that the kymographic method requires practically no coöperation on the part of the subject; it is only necessary that the breath be held for about 3 seconds during the exposure. However, there is generally some apprehension or excitement involved in placing the subject in position and minimal cardiac output under basal conditions is not attained until several experiments have been made. This is similar to but less marked than in the acetylene rebreathing procedure.

10490 P

Quantitative Measurement of Valvular Efficiency of the Human Heart.

ANCEL KEYS AND H. L. FRIEDELL.

From the Laboratory of Physiological Hygiene and the Department of Radiology, University of Minnesota, Minneapolis, Minn.

In the preceding paper it was shown that the stroke output of the heart may be measured accurately by calculation from the diastolic and systolic areas traced on a roentgenkymogram. Actually, this is a measure of the amount of blood expelled from the heart; in the subject with normal valves it equals the net amount of blood *circulated* by the stroke. In the patient with aortic or mitral regurgitation, however, we should expect that such equality would not hold and the amount of blood circulated would be less than the amount expelled from the heart by the amount of regurgitation.

The net amount of blood circulated may be measured by the acetylene-rebreathing method. We have found it possible to make what are essentially simultaneous roentgenkymograms and acetylene cardiac output determinations. Comparison of the two results with this procedure should give an absolute quantitative measure of the extent of the back leakage (or the efficiency) of the mitral and aortic valves.

TABLE I.

Results from Simultaneous Roentgenkymography and Acetylene Rebreathing in a Case of Aortic Regurgitation (Moderate Leak) at Rest (but Not Basal). Areas in cm^2, volumes in cc.

		Corrected Frontal Area		Volume = $0.64(A)^{1.45}$		O_2 Uptake cc/min.	A.V. O_2 diff. cc/L	Cardiac Index L/min./m^2	Stroke Volume		Leak cc	Efficiency %
		Diast.	Syst.	Diast.	Syst.				Kymo.	Acet.		
2/8	I	148.5	136.5	902	798	250	39.9	3.4	104	75.4	28.1	72.5
	II	148.5	136.6	902	799				103			
3/1	I	146.7	138.0	885	811	232	50.2	2.1	74	50.2	23.8	67.8
	II	148.4	141.0	910	836				74			

The equation we have developed for the calculation of stroke volume gives, by definition, an average efficiency of the valves of 100% when subjects with normal valves are studied in this way with the two procedures used simultaneously. We have applied this procedure to a series of cases of aortic, mitral, and double aortic and mitral regurgitation and invariably have obtained results which differ from the normal subjects in the expected way.

The subjects were selected on the basis of a clearly defined clinical condition and ability to coöperate in the acetylene rebreathing. None of the subjects was decompensated, though several were on the verge of decompensation or had been decompensated at some time. The clinical evaluation of the lesions in the various patients differentiated 3 groups: (1) minimal leaks, (2) moderate leaks, (3) severe leaks. The leaks in the first group were such as might be missed in a hasty physical examination. Patients in the second group were able to carry on the ordinary routine of professional or clerical work but were restricted in their ability to indulge in exercise. The patients in the third group were marked examples of aortic or mitral regurgitation and were very much restricted in activity but not bedridden.

The summarized data on a patient with a "moderate leak" are given in Table I as an example of the results. This patient was apprehensive in the first experiment in spite of the fact a dummy trial had been made on the previous day. The results illustrate our constant finding that the cardiac output, measured by either method, is almost always considerably smaller in a second experiment.

Table II presents in condensed form the valvular efficiency found in 17 experiments with patients with aortic or mitral leaks. The absence of overlapping is probably fortuitous, but in any case the 3 groups are clearly differentiated from one another and from results in 22 experiments on subjects without valvular leaks.

It will be noted in Table I that, in this case, the efficiency of the

TABLE II.

Estimated Efficiency of Mitral and Aortic Valves in Subjects with Normal Valves and in Patients with Varying Degrees of Regurgitation. Constant resting condition in all cases.

No. of Experiments	Clinical Evaluation	% Efficiency	
		Mean	Range
18	Normal	99	*91-110
5	Minimal leak	87	82- 89
8	Moderate "	72	58- 78
5	Severe "	51	45- 54

* 16 of the 18 cases showed apparent efficiencies not less than 94%.

valves was somewhat greater at the smaller stroke volume. Similar results were obtained in second subject with a larger leak who was also studied on different occasions when the cardiac output differed markedly. This suggests that the percentage of leak is not independent of the total cardiac output but that the leak is relatively smaller at the higher level of output. Such a finding is in agreement with physiological expectations. The heart rate is generally faster when the stroke volume is increased and hence the duration of diastole, in which regurgitation occurs, is shorter. These studies are being continued on a larger scale, but it already appears that this method provides an acceptable quantitative measure of aortic or mitral regurgitation in man.

10491 P

Behavior of Dogs after Complete Temporary Arrest of the Cephalic Circulation.*

CLARENCE DENNIS AND HERMAN KABAT. (Introduced by M. B. Visscher.)

From the Department of Physiology, University of Minnesota, Minneapolis.

The authors have previously reported a method of decerebration of the dog by means of cephalic vascular stasis.[1] The emphasis at that time was upon the use of the procedure as a method for preparing decerebrate animals. Since that time our interest has shifted to the evidence that could be gained concerning the resistance of various cells in the brain to temporary cessation of blood flow and the correlation of these changes with changes in the behavior of the animal.

The technic has been modified to the following form: Two days after laminectomy at the second cervical level, the animal is atropinized, and a metal tracheal tube is inserted orally. A blood pressure cuff is wrapped about the neck, and the pressure is raised quickly to 700 mm Hg, at which level it is maintained as long as vascular arrest is desired, artificial respiration being administered through the tracheal tube. The completeness of circulatory

* Assistance in the preparation of these materials was furnished by the personnel of Works Progress Administration Official Project No. 665-71-3-69.

1 Kabat, Herman, and Dennis, Clarence, PROC. SOC. EXP. BIOL. AND MED., 1938, **38**, 864.