As the levels did not appreciably change the following procedures were undertaken. Blood samples were taken from very ill patients and the serum cholesterol levels estimated. If in any case death did not occur within 24 hours the blood was discarded and a fresh specimen taken. In one case blood was taken just after death.

Bodies were left at a temperature of $+5^{\circ}\text{C}$. in the post-mortem room and at varying times blood samples were taken. This sampling presented no difficulty: a 20-ml. syringe and a 5-in. (12.5 cm.) No. 14 gauge needle was used to take the blood from a femoral vein or artery, from the heart by substernal puncture, or direct from the heart at necropsy. There was usually a great deal of haemolysis, but by long centrifugation enough serum was always obtained.

The estimations were performed by the colorimetric method of Sackett (1925).

The results (Table III) in 26 cases show that up to 60 hours after death there is no large fluctuation in the cholesterol estimation, and in two cases at 90 hours after death the level was quite near that found before death.

TABLE III

Age	Disease or Injury	Hours before Death Sample Taken	Cholesterol (mg./100 ml.)	Cholesterol (mg./100 ml.) Hours after Death			
				0-30	30-60	60-90	90+
21	Subarachnoid haemorrhage	18	187	190			
60	Crush injuries	19	139	137	134		
51	Cerebral haemorrhage	22	362	348			
56	Bronchopneumonia	23	90		91		
50	Subarachnoid haemorrhage	16	221		250		
74	Steatorrhoea	12	37		48		
41	Chronic nephritis	12	113		112		
9	Influenza	1	82	81			
32	Cerebral haemorrhage with hypertension	8	231		214		
60	Neoplasm pancreas	12	89		80		
46	Subarachnoid haemorrhage	18	362	379			
28	Multiple injuries	1	146	148			
69	Influenza	7	208	218	187		195
39	Fractured skull	At death	116		125		
68	Pneumonia	"	53		58		
66	Influenza	"	76		76		
23	Carcinoma of bladder	At death	187				183
2	Carcinoma of prostate	2 hours after death	147		157		
68	Cerebral haemorrhage	8	234		241		
61	Pulmonary abscess	At death	42		46		
61	Cor pulmonale	"	88			96	
70	Mesenteric thrombosis	"	95		94		
38	Multiple injuries	1	110		108		
54	Cor pulmonale	9	83		86		
53	Cerebral haemorrhage	6	138	135	132		
60	Nephrotic nephritis	3	620	620			

Summary

The serum cholesterol was estimated on 26 patients shortly before and at varying times after death. The ante-mortem and post-mortem levels were close.

The post-mortem serum cholesterol may be taken as an indication of the level just before death.

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REFERENCES

- Dock, W. (1958). In *Principles of Internal Medicine*, edited by T. R. Harrison, 3rd ed., p. 1332. McGraw-Hill, New York.
 Oliver, M. F., and Boyd, G. S. (1953). *Brit. Heart J.*, **15**, 387.
 Sackett, G. E. (1925). *J. Biol. Chem.*, **64**, 203.

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RAPID METHOD FOR ESTIMATION OF CARBON MONOXIDE IN BLOOD

BY

MAUREEN HENDERSON,* M.B., B.S., D.P.H.
*M.R.C. Group for Research on Atmospheric Pollution,
 St. Bartholomew's Hospital, London*

AND

G. H. APTHORP,† M.B., M.R.C.P.
Medical Unit, St. Bartholomew's Hospital, London

A simple, rapid, and accurate method of measuring the carbon monoxide content of blood is required for investigation of subjects exposed to that gas. Analysis of alveolar gas which has reached equilibrium with the pulmonary capillary blood (Sjöstrand, 1948) is simple and accurate but time-consuming. This paper describes a rapid method based on Sjöstrand's method and compares its accuracy with the results of direct blood-gas analysis.

Method

The subjects were six healthy adults (five male and one female) aged 26 to 34 years, and the procedure was as follows:

Each subject washed out the nitrogen from his lungs by breathing 100% oxygen from a simple open circuit (Fig. 1) for a period of three minutes. At the end of this time he was instructed to take a maximum inspiration and hold his breath. The three-way tap (T) was then turned and he exhaled through a carbon dioxide absorber, previously washed out with oxygen, into an empty bag and rebreathed from this bag for a further three minutes. The contents of the bag were then analysed for oxygen by the Haldane method and for carbon monoxide, using an infra-red meter. From these figures the basal blood carboxyhaemoglobin saturation (COHb%) was calculated, using Dahlström's (1955) equation, namely:

$$\text{COHb}\% = \frac{M \times 100 \times p_{\text{CO}}}{p_{\text{O}_2} + (M \times p_{\text{CO}})}$$

where $M=231$ and p_{CO} and p_{O_2} are the partial pressures of carbon monoxide and oxygen in the equilibrated bag.

During the last minute of the rebreathing period 7 ml. of venous blood was withdrawn for the direct measurement of the carbon monoxide content of the blood by the method of Lawther and Apthorp (1955). The oxygen capacity of the blood of each subject was measured by the method of Van Slyke, and from these

*Present address: Department of Preventive Medicine, University Hospital, University of Maryland, Baltimore 1, Maryland, U.S.A.

†Cooper and Coventson Research Scholar, St. Bartholomew's Hospital, London.

FIG. 1.—Breathing circuit. The mouthpiece (M) is fixed to a three-way tap (T) which can be turned so that the subject first washes out his lungs with oxygen and then rebreathes from the 5-litre bag through the CO_2 absorber.

measurements the percentage of haemoglobin saturated with carbon monoxide was calculated.

Each subject was given carbon monoxide in air to breathe at approximately half-hourly intervals in quantities sufficient to raise the blood carbon monoxide level step-wise from the initial level to 20% saturation. At each level the carbon monoxide saturation was measured by the rebreathing method and by simultaneous direct blood-gas analysis.

Results and Discussion

A scatter diagram (Fig. 2) shows there is close agreement between the carbon monoxide saturation measured by both methods within the observed range of 0 to 20% saturation. All but two points fell within the lines which represent differences of $\pm 10\%$. In a subject whose haemoglobin concentration is normal (14.8 g./100 ml.) and is 20% saturation with carbon monoxide, these lines represent a difference of 0.4 volumes of carbon monoxide per 100 ml. of blood.

Analysis of the oxygen content of the rebreathed gas in the bag is the most time-consuming part of the estimation. The possibility that this analysis could be avoided by assuming the oxygen content of the bag was investigated. One hundred estimations of the COHb% of 14 normal subjects and 32 patients with cardiac or respiratory diseases were made by the method. The intrapulmonary gas-mixing efficiency was measured in all subjects by the helium closed-circuit method (Bates and Christie, 1950), as it is in patients with impairment of this function that variations in the oxygen content of the rebreathed bag are most likely to occur. The subjects were divided into three groups: normal subjects, patients with normal intrapulmonary gas-mixing (50 to 100%) (group 1), and patients with impairment of intrapulmonary gas-mixing (0 to 50%) (group 2). The results are shown in the accompanying Table. It will be seen that there was no significant difference in the oxygen content of the rebreathed bag in the three groups. The average oxygen content was 92.7% and the standard deviation of this figure was $\pm 3.4\%$.

FIG. 2.—The carboxyhaemoglobin saturation percentage found by the rebreathing method described is plotted against that found by direct blood-gas analysis. The solid line indicates equality and the interrupted lines a difference between the methods of $\pm 10\%$.

Mean Concentration of Oxygen in the Rebreathing Bag During 100 Estimations of Carboxyhaemoglobin by the Rebreathing Method

Group	No. of Subjects	Helium-mixing Efficiency		No. of Observations	Mean Oxygen %	Standard Deviation
		Range	Mean			
Normal subjects ..	14	50 to 100%	84%	62	92.4	$\pm 4.0\%$
Patients group 1 ..	22	50 to 100%	71%	22	93.6	$\pm 2.3\%$
" " 2 ..	10	0 to 50%	32%	16	92.6	$\pm 1.9\%$
All subjects ..	46	—	—	100	92.7	$\pm 3.4\%$

FIG. 3.—Scatter diagram identical to Fig. 2, except that the results of the rebreathing method have been recalculated, substituting a standard figure of 92% for the oxygen content of the rebreathed gas.

In view of these findings the 30 COHb saturations already described were recalculated, using in the equation a standard figure of 92% to represent the oxygen content of the rebreathed gas. On a similar scatter diagram (Fig. 3) these revised values all fell within the same limits as those originally described. It appears that the estimation of blood COHb% by the modified Sjöstrand method is as accurate as direct measurement of COHb in blood. For clinical and field studies it is apparently unnecessary to measure the oxygen content of the rebreathed gas. No patient experienced difficulty in carrying out the method.

Summary

A rapid modification of the Sjöstrand rebreathing method for the estimation of COHb% in blood is described and compared with direct blood analysis.

The modified rebreathing method gave results which agree well with those produced by direct blood analysis. Evidence is given which suggests that for routine purposes an assumed oxygen value can be used in Dahlström's equation.

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REFERENCES

- Bates, D. V., and Christie, R. V. (1950). *Clin. Sci.*, **9**, 17.
- Dahlström, H. (1955). *Acta physiol. scand.*, **33**, 296.
- Lawther, P. J., and Apthorp, G. H. (1955). *Brit. J. industr. Med.*, **12**, 326.
- Sjöstrand, T. (1948). *Acta physiol. scand.*, **16**, 201.