THE CEREBRAL CIRCULATION AND METABOLISM IN HYPERTHYROIDISM AND MYXEDEMA [1]

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In vitro studies (1–5) of the effect of variations in the functional activity of the thyroid gland upon cerebral metabolism have yielded conflicting results; some investigators have found the oxygen consumption of the brain to be increased in experimental hyperthyroidism, and diminished after thyroidectomy; others have not been able to demonstrate a change in the oxygen uptake of brain slices of either hyper- or hypothyroid animals. The introduction of the nitrous oxide method for the determination of cerebral blood flow provided a means of directly measuring cerebral circulatory and metabolic functions in man, and this technique was promptly applied to a study of these functions in human subjects with hyperthyroidism and myxedema. The initial studies in man, however, have also yielded conflicting results, especially with respect to the cerebral circulatory changes in thyroid disorders. Scheinberg (6), and Sokoloff, Wechsler, Balls, and Kety (7) found that the mean cerebral blood flow of a small series of subjects with hyperthyroidism was not significantly different from the mean CBF previously determined in a series of normal young men. Sokoloff, Wechsler, Mangold, Balls, and Kety (8) later reported that the CBF in hyperthyroidism was increased, but attributed this increase to anemia. Scheinberg, Stead, Brannon, and Warren (9) found the mean CBF in subjects with myxedema to be significantly lower than in young normal subjects, an observation in agreement with the findings of Himwich, Daly, Fazekas, and Herrlich (10) who studied the rate of blood flow in cretins by means of a thermostromuhr placed in an internal jugular vein. In 1951, Madison, Sensenbach, and Ochs (11) reported the results of a preliminary study of cerebral circulatory and metabolic functions in hyperthyroidism and myxedema, in which the values for these functions, obtained after euthyroidism had been achieved, served as controls for comparison with pre-treatment findings. Since then, the study has been enlarged to include observations in 22 subjects with hyperthyroidism and 11 with myxedema and forms the basis for the present report. Studies were repeated after euthyroidism had been achieved by treatment in 16 of the 22 hyperthyroid subjects and in 8 of the 11 subjects with myxedema.

CLINICAL MATERIAL AND METHODS

Twenty-two males with hyperthyroidism whose ages ranged from 24 to 64 years were studied. The diagnosis was established when the characteristic history, physical findings, and laboratory studies clearly indicated the existence of a hypermetabolic state due to overactivity of the thyroid gland. Prior to the institution of definitive therapy, there was a period of observation during which the patients were treated with bed rest, hyperalimentation, supplementary vitamins, and sedation as needed. Just prior to the institution of treatment the initial circulatory studies were made; sedative drugs were withheld for at least 24 hours prior to the studies. Five of the patients were treated surgically, 14 with I^{131} and 3 with propylthiouracil. Cerebral circulatory and metabolic studies were repeated in 16 of the subjects after a euthyroid state had been attained; in six subjects euthyroid studies were not done because of technical difficulties or failure of the patients to return to the hospital for follow-up examination.

Eleven male subjects with myxedema ranging in age from 24 to 68 years were studied. The etiology of the myxedema was post-thyroidectomy in five, post I^{131} in one, spontaneous in four, and secondary to hypopituitarism in one. The cerebral circulatory studies were performed just prior to treatment and were repeated after the administration of thyroid substance had restored the euthyroid state.

The functional status of the thyroid gland was evaluated on the basis of clinical findings, BMR, radioactive

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TABLE I

Cerebral circulatory and metabolic functions in hyperthyroidism, before and after treatment

Subject	Age	Treatment	BMR %		I^{131} Uptake %		Mean arterial blood pressure MABP *mm. Hg*		Cerebral blood flow CBF *cc./min./100 gm.*		Cerebral vascular resistance CVR *mm. Hg/cc./min./100 gm.*		Cerebral oxygen consumption $CMRO_2$ *cc./min./100 gm.*		Cerebral glucose consumption CMR_{glu} *mgm./min./100 gm.*	
			Hyperthyroid	Euthyroid	Hyperthyroid	Euthyroid	Hyperthyroid	Euthyroid	Hyperthyroid	Euthyroid	Hyperthyroid	Euthyroid	Hyperthyroid	Euthyroid	Hyperthyroid	Euthyroid
O. W.	64	I^{131} and propyl.	+47	+12	73		79	96	72	60	1.10	1.60	3.63	3.47	2.9	4.2
R. F. B.	59	I^{131} and propyl.	+59	+ 7	67		79	96	88	75	0.90	1.28	4.54	4.49	4.4	7.5
G. E.	59	I^{131}	+28	+ 7	66	33	85	97	85	44	1.00	2.20	3.96	2.60	4.3	2.6
C. W.	59	I^{131}	+23	− 4	79	12	95	101	64	48	1.48	2.10	4.49	4.50	5.1	4.3
R. K.	56	I^{131} and propyl.	+60	+13	62		100	94	130	60	0.77	1.57	5.59	3.49	7.8	2.4
R. H.	56	Propyl.	+39	− 4			95	102	103	69	0.92	1.48	5.86	5.00	6.2	7.6
J. R.	56	Propyl. and thyroidectomy	+39	+16	54		103	119	78	57	1.32	2.09	3.73	3.75		7.4
C. R.	49	Propyl. and thyroidectomy	+68	+11	67	14	97	109	91	68	1.07	1.60	5.26	3.36	7.3	
S. A.	43	I^{131}	+38		68		81		72		1.13		3.92		4.3	
H. E.	41	I^{131}	+43		67		68		73		0.93		4.41		6.6	
W. F.	40	I^{131}	+67	+16	73	42	76	84	70	53	1.09	1.58	4.00	3.61	5.1	6.4
R. Y.	37	I^{131}	+40	+ 9	74	5	96	91	68	56	1.41	1.63	4.70	4.00	2.0	5.6
G. S.	36	I^{131}	+48	+10	64	17	80	87	93	77	0.86	1.13	3.96	4.76	4.7	4.8
L. T.	34	I^{131} and propyl.	+44		67		91		120		0.76		7.12		8.4	
H. H.	33	Propyl. and thyroidectomy	+97	+ 5	58	16	78	81	63	55	1.24	1.47	3.87	3.94	5.0	2.8
R. S.	32	I^{131}	+32	−12	80		94	97	64	43	1.47	2.26	4.28	4.38	7.3	6.4
E. M.	31	Propyl.	+44	+11	60		78	80	92	72	0.85	1.11	4.63	4.54	7.4	5.0
J. B.	31	I^{131} and propyl.	+90	+19	79		78	80	98	65	0.80	1.23	4.00	4.08	2.9	6.5
L. S.	31	Thyroidectomy	+67	− 4	77		87	93	76	65	1.14	1.43	4.04	4.96	5.3	
L. B.	28	I^{131}	+53		78		93		83		1.12		5.57		3.3	
R. L. S.	26	Propyl.	+80		97		84		102		0.82		5.30		5.1	
R. B.	24	Thyroidectomy	+42		64		92		114		0.81		5.85		5.9	
Mean	42		+52	+ 5	70	20	87	94	86	60	1.05	1.61	4.67	4.06	5.3	5.3
P value				<.001		<.001		<.01		<.001		<.001		>.10		> .90

TABLE II

Blood constituents in hyperthyroidism, before and after treatment

Subject	Age	Arterial oxygen content vol. %		Cerebral venous oxygen content vol. %		Arterial-cerebral venous oxygen difference vol. %		Cerebral oxygen extraction ratio ERO_2 %		Arterial carbon dioxide content vol. %		Cerebral venous carbon dioxide content vol. %		Arterial pH		Hemoglobin gm. %	
		Hyperthyroid	Euthyroid	Hyperthyroid	Euthyroid	Hyperthyroid	Euthyroid	Hyperthyroid	Euthyroid	Hyperthyroid	Euthyroid	Hyperthyroid	Euthyroid	Hyperthyroid	Euthyroid	Hyperthyroid	Euthyroid
O. W.	64	13.60	15.97	8.56	10.19	5.04	5.78	37	36	52.27	51.70	56.73	56.63	7.41	7.37	11	12
R. F. B.	59	16.67	17.70	11.51	11.71	5.16	5.99	31	34	47.10	50.41	52.39	55.59	7.37	7.42	13	13
G. E.	59	19.29	21.07	14.63	15.16	4.66	5.91	24	28	51.09	43.82	56.21	49.10	7.36	7.44	15	15
G. W.	59	19.90	20.77	12.88	11.39	7.02	9.38	35	45	46.43	42.43	52.59	50.82	7.40	7.39	15	16
R. K.	56	15.89	18.00	11.59	12.18	4.30	5.82	27	32	47.81	45.31	52.00	50.78		7.45	11	
R. H.	56	17.22	20.74	11.53	13.50	5.69	7.24	33	35	49.38	45.58	55.05	52.96	7.35	7.37	13	13
J. R.	56	17.83	18.69	13.05	12.99	4.78	5.70	27	30	53.68	53.44	58.53	59.14			14	13
C. R.	49	19.60	16.34	13.82	11.40	5.78	4.94	29	30	45.21	48.55	50.86	53.19			16	15
S. A.	43	16.42		10.97		5.45		33		46.42		51.38		7.37		14	
H. E.	41	16.17		10.13		6.04		37		51.67		57.92		7.43			
W. F.	40	16.84	19.60	11.12	12.78	5.72	6.82	34	35	47.65	47.16	52.53	53.21		7.39	12	14
R. Y.	37	20.53	21.87	13.62	14.72	6.91	7.15	34	33	48.96	44.93	56.54	51.83	7.41		15	15
G. S.	36	14.96	19.49	10.70	13.28	4.26	6.18	28	32	52.18	46.95	55.59	52.84			13	14
L. T.	34	17.21		11.28		5.93		34		43.39		48.73		7.31		15	
H. H.	33	18.07	18.20	11.93	11.03	6.14	7.17	34	39	39.04	45.06	45.27	51.88	7.35	7.36	15	14
R. S.	32	18.99	21.20	12.30	11.03	6.69	10.19	35	47	47.85	47.68	53.57	56.86			16	16
E. M.	31	17.85	18.08	12.82	11.77	5.03	6.31	28	35	49.42	46.17	54.67	52.42	7.41		14	14
J. B.	31	16.75	19.81	12.67	13.53	4.09	6.28	24	32	53.44	42.23	57.74	49.68			14	16
L. S.	31	17.97	20.34	12.66	12.71	5.31	7.63	30	38	47.34	45.04	51.98	52.63			15	16
L. B.	28	21.17		14.46		6.71		32		48.79		55.54				15	
R. L. S.	26	17.17		11.97		5.20		30		47.48		52.87		7.37		13	
R. B.	24	19.28		14.15		5.13		27		50.23		54.38				15	
Mean	42	17.70	19.24	12.20	12.46	5.50	6.78	31	35	48.49	46.65	53.78	53.10	7.38	7.40	14.0	14.4
P value			<.01		>.8		<.001		<.001		>.05		>.4		>.10		>.9

TABLE III

Cerebral circulatory and metabolic functions in myxedema, before and after treatment

Subject	Age	Diagnosis	BMR %		I^{131} Uptake %		Mean arterial blood pressure MABP *mm. Hg*		Cerebral blood flow CBF *cc./min./100 gm.*		Cerebral vascular resistance CVR *mm. Hg/cc./100 gm./min.*		Cerebral oxygen consumption $CMRO_2$ *cc./min./100 gm.*		Cerebral glucose consumption CMR_{glu} *mgm./min./100 gm.*	
			Hypothyroid	Euthyroid	Hypothyroid	Euthyroid	Hypothyroid	Euthyroid	Hypothyroid	Euthyroid	Hypothyroid	Euthyroid	Hypothyroid	Euthyroid	Hypothyroid	Euthyroid
F. E.	68	Spontaneous myxedema	−21	+ 1	0.9		95	87	46	51	2.07	1.71	4.23	3.32	5.1	
J. S.	61	Spontaneous myxedema	−32	+ 4	1.3		78	69	43	57	1.81	1.21	3.03	3.16	4.3	3.4
B. H.	56	Pituitary myxedema	−27	+ 1	9.8		62	62	46	56	1.35	1.11	3.60	3.17	5.5	5.6
D. B.	56	Spontaneous myxedema	−26		3.3		92		42		2.19		2.98		3.8	
A. B. B.	55	Postoperative myxedema	−28	− 7	1.5		109	90	31	50	3.52	1.80	2.64	3.99	3.7	7.5
H. C.	44	Spontaneous myxedema	−29	− 1	5.5		80	63	40	55	2.00	1.15	2.84	3.90	2.4	4.4
A. B.	32	Postoperative myxedema	−23		5.0		88		58		1.52		4.30		5.2	
L. S.	31	Postoperative myxedema	−29	+ 1	5.0		92	75	50	60	1.84	1.25	3.62	3.64	4.0	3.0
J. B.	31	Post I^{131} myxedema	−22	+19	3.8		68	80	49	65	1.39	1.23	3.61	4.08	5.4	6.5
C. L.	30	Postoperative myxedema	−24	+ 2	2.0		96	71	60	84	1.60	0.85	3.85	4.62	7.2	7.6
R. B.	24	Postoperative myxedema	−31		3.3		97		55		1.76		3.75		5.8	
Mean	44		−27	+ 3	3.8		87	75	47	60	1.91	1.29	3.50	3.74	4.8	5.4
P value				<.001				<.05		<.001		<.01		>.10		> .20

TABLE IV

Blood constituents in myxedema, before and after treatment

Subject	Age	Arterial oxygen content *vol. %*		Cerebral venous oxygen content *vol. %*		Arterial-cerebral venous oxygen difference *vol. %*		Cerebral oxygen extraction ratio ERO_2 %		Arterial carbon dioxide content *vol. %*		Cerebral venous carbon dioxide content *vol. %*		Arterial pH		Hemoglobin *gm. %*	
		Hypothyroid	Euthyroid	Hypothyroid	Euthyroid	Hypothyroid	Euthyroid	Hypothyroid	Euthyroid	Hypothyroid	Euthyroid	Hypothyroid	Euthyroid	Hypothyroid	Euthyroid	Hypothyroid	Euthyroid
F. E.	68	18.07	17.05	8.88	10.55	9.19	6.50	51	38	46.76	50.33	54.23	56.24			14.0	13.0
J. S.	61	15.24	15.54	8.19	9.98	7.05	5.56	46	37	45.62	46.02	52.85	51.23			12.0	13.2
B. H.	56	14.74	14.63	6.91	8.97	7.83	5.66	53	39	45.54	51.36	54.49	57.97	7.41	7.42	11.2	10.5
D. B.	56	16.62		9.52		7.10		43		42.30		50.06		7.51			
A. B. B.	55	19.22	19.34	10.71	11.37	8.51	7.97	44	41	43.92	43.88	53.46	52.14			15.4	14.4
H. C.	44	13.83	16.89	6.74	9.80	7.09	7.09	51	42	47.97	43.44	54.42	49.45	7.37	7.33	10.6	13.7
A. B.	32	19.88		12.47		7.41		37		43.33		50.90		7.38		15.5	
L. S.	31	19.34	19.40	12.11	13.33	7.23	6.07	37	31	50.95	49.05	57.27	55.18			15.0	15.8
J. B.	31	17.73	19.81	10.37	13.53	7.36	6.28	42	32	45.17	42.23	52.33	49.68	7.38		15.8	15.5
C. L.	30	17.76	17.08	11.35	11.58	6.41	5.50	36	32	50.02	46.10	55.49	51.93	7.39		13.7	12.8
R. B.	24	17.36		10.54		6.82		39		52.60		58.83				14.0	
Mean	44	17.25	17.47	9.80	11.14	7.45	6.33	44	37	46.74	46.55	54.03	52.98	7.41	7.38	13.7	13.6
P value			>.30		<.01		<.01		<.001		>.7		>.2				>.8

iodine uptake, and serum protein bound iodine; subjects exhibiting borderline or equivocal findings were excluded from the study.

The cerebral blood flow (CBF) was determined by the nitrous oxide method of Kety and Schmidt (12), as modified by Scheinberg and Stead (13). Cerebral oxygen consumption ($CMRO_2$) was calculated from the CBF and the arterio-cerebral venous oxygen difference, cerebral glucose consumption (CMR_{glu}) from the CBF and the arterio-cerebral venous glucose difference, and cerebral vascular resistance (CVR) from the CBF and the mean arterial blood pressure (MABP). MABP was measured directly from a peripheral artery with a damped mercury manometer. Blood oxygen content and carbon dioxide content were determined manometrically. Blood sugar was determined by Nelson's modification of the Somogyi method (14). Blood samples for pH determination were drawn anerobically and the pH immediately determined at 37° by means of a Cambridge Research Model pH Meter. The cerebral blood flow determinations were done on recumbent subjects in the post-absorptive state.

The data were analyzed statistically by the method of paired observations; the pertinent difference between values obtained before and after treatment were calculated for each subject. The mean of these differences together with its standard error was then calculated from the individual differences. P values so determined are recorded in Tables I to IV.

RESULTS

Hyperthyroidism

The results of cerebral circulatory and metabolic studies in 22 subjects with hyperthyroidism are summarized in Tables I and II. These tables also include results obtained in 16 of 22 subjects when the studies were repeated after successful treatment of the hyperthyroidism. Comparison of the pre-treatment observations with control or euthyroid values reveals that hyperthyroidism is associated with a 42 per cent increase in CBF (60 to 86 cc. per min. per 100 gm.) ($P = < .001$); a 35 per cent decrease in CVR (1.61 to 1.05 mm. Hg per cc. per min. per 100 gm.) ($P = < .001$), and a 7 per cent decrease in MABP (94 to 87 mm. Hg) ($P = < .01$). These circulatory changes, however, are not accompanied by changes in cerebral oxygen utilization, for the increase in CBF is associated with a decrease in cerebral O_2 extraction (35 to 31 per cent) ($P = < .001$) and a decline in arteriocerebral venous oxygen difference (6.78 to 5.50 vols. per cent) ($P = < .001$). Cerebral glucose consumption is likewise unchanged. The only significant change observed in the blood constituents measured is the decline in arterial O_2 content (19.24 to 17.70 vols. per cent) ($P = < .01$). This change may be related to the alterations in pulmonary ventilation and gas exchange which occur in hyperkinetic states (15, 16).

Myxedema

The results of studies in 11 subjects with myxedema, and the findings obtained in 8 of these subjects after a euthyroid state had been established by adequate substitution therapy are summarized in Tables III and IV. These data reveal changes in cerebral hemodynamics opposite to those observed in hyperthyroidism. There is a 22 per cent reduction in CBF (60 to 47 cc. per min. per 100 gm.) ($P = < .001$), a 48 per cent increase in CVR (1.29 to 1.91 mm. Hg per cc. per min. per 100 gm.) ($P = < .01$), and a 16 per cent increase in MABP (75 to 87 mm. Hg) ($P = < .05$) in myxedema, as compared to the euthyroid control values in these subjects.

As in the case of hyperthyroidism, however, the circulatory changes are not associated with changes in the rate of cerebral oxygen utilization, the reduction in CBF being accompanied by increased cerebral oxygen extraction (19 per cent) ($P = < .001$) and an increase in arterio-cerebral venous oxygen difference (6.33 to 7.45 vols. per cent) ($P = < .01$). Cerebral glucose consumption is also unaltered. Reduction in cerebral venous oxygen content (11.41 to 9.80 vols. per cent) ($P = < .01$) is the only significant change to occur in the blood constituents.

The difference in mean $CMRO_2$ between euthyroid subjects who had been treated for hyperthyroidism (4.06 cc. per min. per 100 gm.) and those who had been treated for hypothyroidism (3.74 cc. per min. per 100 gm.) is not statistically significant ($P = > .2$).

DISCUSSION

These studies indicate that the cerebral circulation shares in the over-all hemodynamic alterations that occur as a consequence of an excess or deficiency of the thyroid hormone. They provide no evidence to indicate that the thyroid hormone exerts a specific effect upon the cerebral circulation, for the changes occur in the absence of alterations in the constituents of the blood that are known to be of importance in the specific regu-

lation of the cerebral vascular tone and of cerebral blood flow. They are, rather, changes which quantitatively and qualitatively parallel the variations in cardiac output and total peripheral vascular resistance that accompany hyperthyroidism and myxedema. Nor does it appear that the thyroid hormone exerts an influence upon the rate of cerebral oxygen or glucose utilization, for the data show that these functions are normal in both hyperthyroidism and myxedema, and they remain unchanged when euthyroidism is restored by appropriate treatment. This failure to demonstrate a relationship between blood flow and metabolic activity of the brain casts doubt, as Scheinberg (6) has previously indicated, upon the generally accepted concept that changes in the general circulation in thyroid disease occur in response to alterations in metabolic demands of the tissues. It indicates rather, at least as far as the brain is concerned, that they occur as a simple consequence of an effect of the thyroid hormone upon the heart and peripheral blood vessels.

The discrepancies which exist between the results of this investigation and the cerebral circulatory changes reported by others in hyperthyroidism are probably best accounted for by the different means by which these studies were controlled. Scheinberg (6) and Sokoloff, Wechsler, Balls, and Kety (7) compared the cerebral circulatory and metabolic functions in a small series of patients with hyperthyroidism with mean values for these functions previously determined in normal young males. In the present study and in the report by Sokoloff, Wechsler, Mangold, Balls, and Kety (8) a more valid basis for comparison of the results was obtained by repeating the measurements after euthyroidism had been achieved by treatment. Although Scheinberg (6) found the mean CBF in hyperthyroidism to be unchanged as compared with normal young men, the mean arterio-cerebral venous oxygen difference of his subjects was 5.50 vols. per cent, a value identical to that of this present study. Scheinberg attributed this low A–V oxygen difference to extracerebral contamination of cerebral venous blood but suggested that further study might reveal it to be a reflection of increased CBF. When Sokoloff, Wechsler, Mangold, Balls, and Kety (8) later employed the values of post-treatment studies as controls, they found the CBF in hyperthyroidism to be increased, but the decline in CBF which they observed after treatment was not statistically significant, and they attributed the increase in CBF to the presence of anemia in their subjects. However, a review of their data casts doubt upon the validity of their "controls." Three of the seven post-treatment studies were done when the BMR was + 25 per cent or more; in one instance there was no change in BMR (+ 30 to + 28 per cent) after treatment; and in another the BMR was − 35 per cent when the control studies were done. It is unlikely, therefore, that these values are accurately representative of the "normal" or euthyroid state.

The increased CVR and reduced CBF in myxedema is in agreement with the results of Himwich, Daly, Fazekas, and Herrlich (10) in cretins and of Scheinberg, Stead, Brannon, and Warren (9) in adult hypothyroidism. In contrast to the present studies, however, these investigators found evidence of depressed cerebral metabolism in hypothyroidism. Himwich, Daly, Fazekas, and Herrlich observed that the treatment of cretinism was accompanied by an increase in CBF and a decrease in arterio-cerebral venous oxygen difference. They "corrected" the measured fall in arteriocerebral venous oxygen difference for the observed increase in CBF and in this manner estimated that the rate of cerebral oxygen uptake was increased after the institution of treatment. Our findings in adult hypothyroidism indicate that this "correction" is invalid, for the arterio-cerebral venous oxygen difference after treatment changes in a reciprocal fashion to the changes in CBF, cerebral O_2 utilization remaining unaltered. Scheinberg, Stead, Brannon, and Warren (9), using methods similar to our own, also found evidence of depression of cerebral metabolism in myxedema. The mean arterio-cerebral venous oxygen difference reported by these authors (6.48 vols. per cent) did not significantly differ from their normal subjects. However, when their data are recalculated and four observations that were made 6 to 15 months after treatment are excluded, a mean arterio-cerebral venous oxygen difference of 7.23 vols. per cent is obtained; a value which closely approximates the significantly increased mean arterio-cerebral venous oxygen difference (7.45 vols. per cent) found in untreated myxedema in the present study.

The absence of change in cerebral metabolism following the successful treatment of either hypo- or hyperthyroidism, and the fact that the rate of cerebral oxygen and glucose uptake in subjects made euthyroid after the treatment of hyperthyroidism does not significantly differ from the rate of uptake of these substances in subjects made euthyroid after treatment of myxedema, in our opinion, constitutes strong evidence that the rate of cerebral metabolism is uninfluenced by the thyroid hormone.

CONCLUSIONS

1. Cerebral circulatory and metabolic functions have been measured before and after treatment in 16 of 22 subjects with hyperthyroidism and in 8 of 11 subjects with myxedema. Hyperthyroidism was found to be accompanied by diminished cerebral vascular resistance and increased blood flow; myxedema by increased cerebral vascular resistance and reduced blood flow. The cerebral circulation is restored to normal in both instances when euthyroidism is achieved by appropriate treatment.

2. The rate of cerebral oxygen consumption and glucose consumption is normal in hyperthyroidism and myxedema and is unaltered by the treatment of either.

3. The cerebral circulation apparently shares equally in the general circulatory changes incident to alterations in thyroid function. Oxygen and glucose consumption of the brain is not influenced by thyroid hormone.

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