Effects of high spinal cord transection on serum lipid levels

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SUMMARY The effect of the central nervous system on regulation of serum lipid, glucose, and protein levels under basal conditions and after excitement, or cold exposure, was studied in 11 normal dogs and in 4 of the 11 after spinal cord transection at level C-6.

Serum total cholesterol, "β-" ($-$S 20–40), and "high-density α-" ($-$S 1–5) lipoprotein concentrations determined weekly for 5 months in two normal dogs varied little; $-$S 5–10 and $-$S 10–20 lipoproteins were less stable. For 1–3 weeks after cord transection, serum cholesterol and α-lipoprotein concentrations decreased along with weight loss. After weight stabilization they returned to near control levels and remained there.

Levels of plasma free fatty acids (FFA) were low and of glucose were normal for several weeks after cord section; after several months the levels of FFA were consistently high and glucose became progressively lower than normal.

Short periods of excitement caused increased plasma FFA and glucose levels in normal dogs, but only slightly increased FFA in spinal cord-transected animals. Two hours of cold exposure caused the same response in normal dogs as did excitement; in cord-transected dogs both plasma FFA and plasma glucose decreased.

The concentrations of serum lipids are regulated by an interplay of chemical (1) and neural factors. Levy and Ramey (2) noted that rats with spinal cords transected at level T-2 and T-4 failed to mobilize fat from epididymal fat depots when subjected to the stress of restraint. Transection of the cord in rabbits at level T-5, or above, prevented the secondary rise in serum lipid levels following Tween 80 (polyoxyethylene sorbitan monooleate) administration (3).

Injection of epinephrine into human beings was found by Dole (4) to result in greatly increased levels of plasma FFA. The release of free fatty acids (FFA) by incubated epididymal adipose tissue was augmented when its nerves were stimulated (5); this effect was prevented by sympathetic denervation. Previously, Schotz and Page (6) had observed increased release of FFA from rat adipose tissue after addition of an adrenergic blocking agent to the medium and suggested that mobilization of fatty acids from fat depots was at least partly neurogenically mediated.

Since energy requirements are provided by glucose as well as by FFA, glucose concentration may influence that of FFA. Release of FFA from adipose tissue is accelerated when plasma glucose is low. Epinephrine and norepinephrine stimulate FFA release and this effect is blocked by injection of glucose (7). Mobilization of FFA following epinephrine injection is not affected by basal FFA concentrations; similar responses to epinephrine occurred in dogs with elevated FFA concentrations and hyperlipemia produced by Triton WR 1339 as in normal dogs (8).

Dogs receiving subcutaneous injections of epinephrine in oil showed a prompt but transient elevation in plasma FFA, and a delayed increase in serum cholesterol and lipoprotein levels which was evident after 24 hr (7).

To differentiate more clearly the respective roles of chemical and neural factors in regulation of serum lipid levels, the two mechanisms have been partially separated in dogs by cutting the spinal cord at the level of C-6. Since the only region for outlet of sympathetic impulses is below the level of transection, all sympathetic stimulation from higher centers is lacking in these animals. Serum cholesterol, lipoproteins, total protein, plasma FFA, and glucose levels were measured in the dogs before and for many months after operation. Changes in the plasma FFA and glucose concentrations after short periods of excitement or of cold exposure have also been determined.

METHODS

Chemical Analyses of Serum or Plasma

Determinations of plasma FFA (9), serum total cholesterol (10), lipoproteins (11), total proteins (12), and glucose (13), were made on samples collected from dogs in the post-absorptive state before, and at weekly intervals after spinal cord transection, and after short periods of stress.

Treatment and Care of the Dogs

Eleven adult male mongrel dogs ranging in weight from 7 to 12 kg were used. Four of them were studied for periods of 98 to 515 days after spinal cord transection (which was performed under Nembutal anesthesia). Food was provided daily in amounts adequate to maintain body weight and contained 32% protein, 7% fat, and 61% carbohydrate.[1] As soon as weight was stacle, control blood studies were performed, and the effects of short periods of excitement determined. Then the spinal cord was cut at C-6. The dogs were kept in a constantly warm room (26–28°) after operation, and additional radiant heat was applied if necessary to maintain normal body temperature. An indwelling urethral catheter was left in place for 3 or 4 days. Food and water were offered frequently. When the animals' appetites had returned to normal, feeding once daily was resumed. To prevent pressure sores, the animals were turned four or more times daily and were bedded on sponge rubber mattresses. To delay the onset of muscular atrophy, each time the dogs were turned the scratch reflex was stimulated for a minute or two by scratching the skin of the side and back slightly caudal to the ribs, and flexion and crossed-extensor reflexes were elicited by pinching the paws. Dog 1 (see Results) was not subjected to this treatment.

The effects of short-term excitement were measured before operation and several times after the dogs had recovered from the operation and were eating normally. Blood samples were drawn before and after 4–60 min of excitement produced by placing a cat near the dog in a small room, care being taken to prevent any injury to the animals. If this proved ineffective, an extremely active and playful dog was placed in the room with the test animal. The degree of excitement was judged by changes in respiratory rate and the appearance of alertness.

Cold was also used to stimulate 2 normal dogs and 3 experimental dogs several months after cord transection. They were placed in a cold room (2°) for 2 hr. Blood samples were taken immediately before and after the period in the cold room, and after 1 and 3 hr in a room at 23°.

The effect of reflex activity on FFA mobilization was studied in operated dogs by stimulation of sensory areas of the foot. The stimulus, which consisted of pricking with a needle once a second, was applied for 10–15 min.

[1]The diet was prepared by mixing 2 parts of Kibbled biscuits (Central Kennel Supply, Dayton, Ohio) and 1 part of beef (Fromm Dog Food, Federal Foods, Inc., Thiensville, Wis.).

RESULTS

Pathological Changes after Spinal Cord Transection (Level C-6)

For 3 or 4 days after operation, the dogs ate little and lost approximately 5–8% of their body weight. After about 1 week their appetites returned to normal, but they continued to lose weight, the total decrease averaging 9.5% of the initial weight. By increasing their food intake 50% above the preoperative maintenance ration there was usually a return of body weight to near normal levels within 3 or 4 weeks. Subsequently body weight remained stable when the animals received the preoperative ration, except when infections developed.

Within 2 weeks after cord transection the scratch and crossed-extensor reflexes had attained a high degree of activity and remained active throughout the study period.

In the first dog (No. 1) muscular atrophy was evident within a month after operation, while the other three developed atrophy less rapidly and less extensively, possibly because of more frequent stimulation of reflex activity. Despite turning of the dogs four times daily, small pressure sores occasionally developed. With more frequent turning, careful placing of sponge rubber pads at pressure sites, and local treatment with antibiotics, the areas healed promptly.

These dogs tolerated exitement, or cold, poorly. Two of them, for example, were disturbed by a cat meowing in an adjacent room. The next day they refused food, were listless and unresponsive. They were similarly affected when the temperature of their room fell from 26–28° to 19°.

Dog 1 lived 98 days after cord transection and died the day after a "1 hr stress" study. The adrenal glands appeared to be normal on histologic examination. Spermatozoa and spermatids were absent from the testes and there was reduction of mitotic activity in the gametogenic elements. The liver, spleen, and kidneys showed only acute congestion.

Dog 2 died 243 days after cord transection, after receiving 5 mg/kg of guanethidine daily for 4 days. The day before death, when the dog refused food and was listless, the drug was discontinued. Nothing abnormal was found at autopsy except atrophy of the adrenal

TABLE 1 Serum Cholesterol and Lipoprotein Concentration of Normal Dogs Determined Weekly for 5 Months

Dog No.		Cholesterol	Lipoproteins -S 20–40	-S 10–20	-S 5–10	-S 1–5
		mg/100 ml	*mg/100 ml*			
5	Mean ± SD	135 ± 13.8	37 ± 6.3	0	60 ± 33.7	403 ± 63.2
	(Range)	(114–156)	(26–49)	0	(15–120)	(349–480)
6	Mean ± SD	141 ± 14.7	35 ± 6.1	10 ± 7.0	39 ± 36.0	464 ± 57.8
	(Range)	(107–167)	(24–27)	(0–19)	(10–140)	(405–530)
5	Coefficient of variation, %	10.2	17.0	—	56.1	15.7
6	Coefficient of variation, %	10.1	17.3	70.0	92.3	14.0

glands and severe lipid depletion of the cortices. The cellular elements of the testes appeared normal.

Dog 3 died 395 days following spinal cord transection, after passage of a stomach tube and administration of 100 ml of water. Post-mortem examination did not reveal the cause for death. The adrenals were of normal size and histologic examination demonstrated a normal lipid content.

Dog 4 is still alive 2 years after spinal cord transection.

Long-Term Variations in Concentration of Serum Constituents before and after Cord Transection

Serum Cholesterol and Lipoproteins

The serum cholesterol levels of two normal dogs receiving the standard diet were studied weekly for 5 months (June to November) and showed little variation as judged by the standard deviation (Table 1). The range of values showed, however, that occasional large fluctuations occurred. These variations were not associated with change in body weight or season.

TABLE 2 Plasma FFA and Glucose Changes in Dogs Following Transection of the Spinal Cord at Level C-6

Dog No.	Months before or after Transection	No. of Samples	Plasma FFA Mean	Plasma FFA Range	Plasma Glucose Mean	Plasma Glucose Range
			μEq/liter		*mg/100 ml*	
2	−1 −0	2	730	670–790	74	67–81
	0–1	2	497	480–515	70	67–74
	2–5	3	992	780–1290	73	62–94
	6–10	5	1286	1000–1760	64	62–68
3	−1 −0	2	795	640–950	81	80–82
	0–1	5	592	500–780	88	60–105
	2–5	4	992	770–1220	70	63–82
	6–10	8	1876	1230–2580	64	58–81
	11–14	9	947	680–1220	60	59–62
	15	2	460	400–520	51	48–54
4	−5 −0	5	604	500–680	78	76–82
	0–1	2	310	250–370	67	65–70
	2–5	7	827	522–1410	61	58–62
	6–10	3	1837	1380–2970	58	55–62
Normal Dogs (10)		34	639.6	340–840	79	65–90

The serum lipoprotein pattern of normal dogs is characterized by high concentrations of α-lipoproteins and relatively small amounts of β-lipoproteins (3). The "α-lipoproteins," -S 1–20, are usually resolved as two clearly defined peaks when studied at a density of 1.21 in the analytical ultracentrifuge. The larger peak, -S 1–5, has a maximum deflection at -S 4; the smaller peak, -S 5–10, at -S 7. A less clearly resolved fraction of low concentration, with flotation rate -S 10–20, is sometimes present. The "β-lipoproteins" with flotation rate -S 20–40 may be resolved into one or two peaks with maximum deflection at -S 25 and -S 32.

During the 5 month study of the two normal dogs, the concentrations of the highest density, -S 1–5, lipoprotein showed small variability (Table 1). The lower density, -S 5–10, lipoprotein fraction showed greater variation, while in dog 6 the concentrations of -S 10–20 lipoprotein also showed wide variations. The variability of the lighter lipoproteins, -S 20–40, was relatively small.

For 1–3 weeks after operation, when the spinal cord-sectioned dogs lost weight, the concentrations of serum cholesterol and -S 1–20 lipoproteins decreased 20–30% and there was little change in concentrations of -S 20–40 lipoproteins. The changes found in spinal cord-transected dog 1 are presented in Fig. 1, and are typical of those found in the other three dogs. When the body weight had stabilized after operation, serum cholesterol concentration returned toward normal and the lipoprotein pattern became much less abnormal, although the concentration of high density -S 5–10 and -S 10–20 did not always attain the preoperative levels. The weekly variations in the concentrations were similar to those of normal dogs.

The effect of repeated bleeding on serum lipid levels was studied in two of the dogs (Nos. 2 & 3), 6 and 7 weeks, respectively after spinal cord transection. A week after they were bled 60 ml/day on 3 successive days, the serum cholesterol concentrations had increased 18 and 20%, and the serum total protein had decreased

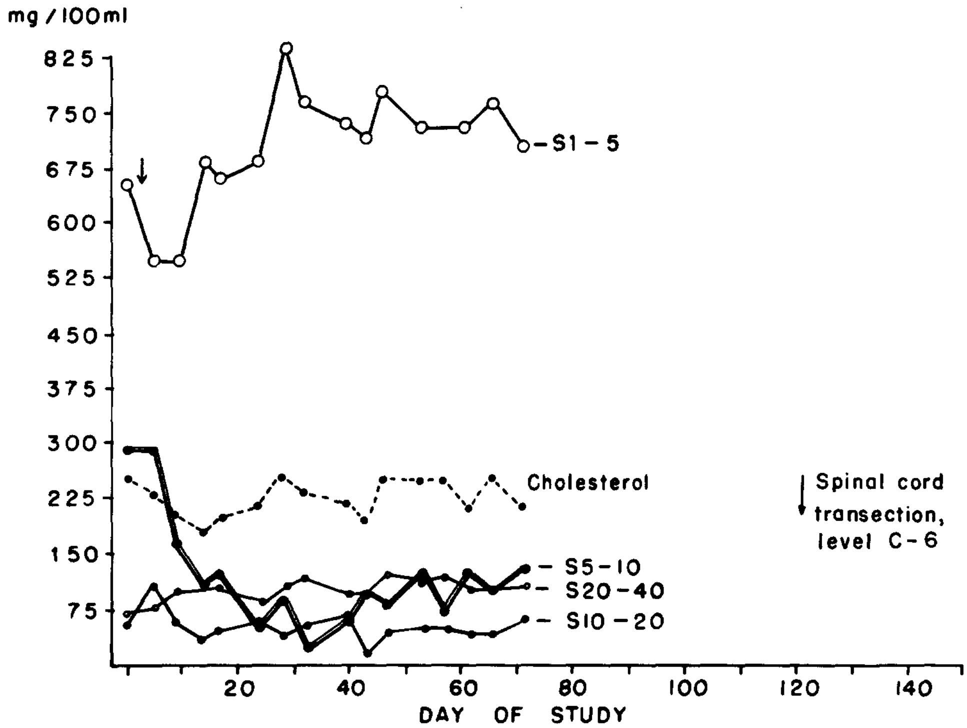

FIG. 1. Serum cholesterol and lipoprotein pattern of dog 1 before and after spinal cord transection at level C-6. Lipoproteins were determined ultracentrifugally at d 1.21, using NaCl–KBr to adjust density.

16 and 25%. There were 60 and 69% increases in concentration of -S 5–10, and 60 and 35% increases in -S 10–20 lipoprotein. The concentrations of these fractions and of cholesterol also increased when pressure sores developed in the operated dogs. Normal dogs when bled 60 ml daily for 3 days showed no significant change in cholesterol or lipoprotein concentration, but when two normal dogs were subjected to more extensive phlebotomy (150 to 200 ml/day for 5 days) serum cholesterol concentrations increased 25 and 29%, respectively and the lipoprotein patterns showed changes similar to those of the spinal cord-transected dogs after less extensive bleeding.

Plasma Free Fatty Acids and Glucose

Three measurements of FFA in three dogs, 16 hr after feeding, during the first month after cord transection, averaged 25, 33, and 49% lower than the control levels (dogs 3, 2, and 4, respectively, Table 2). After this the FFA concentrations gradually increased until the average was usually at least double the normal. The variability also became greater than normal.

Plasma glucose levels (Table 2) were normal (65–90 mg/100 ml) for several weeks after operation and decreased very slowly thereafter to levels of (for instance) 50–60 mg/100 ml 9–12 months after operation and 45–50 mg/100 ml after a year and a half.

After repeated bleedings the plasma FFA concentrations (Table 3) of the spinal cord-transected dogs were much reduced (61 and 71%) and the lower levels persisted for at least 2 weeks, while no significant change occurred in normal animals (Table 3).

Changes in Serum Lipid and Protein Concentrations after Short Periods of Excitement or Exposure to Cold

Excitement

The concentrations of FFA in plasma of normal and of operated dogs after 4–6 min of excitement were 10–100% higher (Table 4) than control values obtained when the dogs were relaxed, as judged by pulse and respiration rates.

If excitement was continued for 10 min, FFA concentrations decreased in both the experimental and normal animals. After 1 hr of excitement they were still decreased in the normal dogs, but in three cord-sectioned animals, the FFA concentrations were elevated. The latter animals were more fatigued and less alert than the others after 1 hr of excitement. One of the spinal cord-transected animals died the next day. Autopsy showed no cause for the sudden death.

After either short or long periods of excitement plasma glucose concentrations increased in normal dogs while

TABLE 3 Changes in Plasma FFA Concentration of Operated and Normal Dogs after Removal of 60 ml of Blood Per Day on 3 Successive Days

Dog No.	Bled* on Day	FFA on Day	Plasma FFA
			μEq/liter
Operated			
2		1	908
		9	1220
		23	1100
	23, 24, 25	28	420
		42	470
		49	950
3		1	780
		40	770
		42	1220
		46	843
	46, 47, 48	49	200
		60	370
		65	320
		100	1000
Normal			
7		1	860
	2, 3, 4†	8	810
8		1	660
	1	2	520
	2	3	550
	3	4	600
		8	480
9		1	750
	1	2	650
	2	3	840
	3	6	700

* 60 ml/day except where otherwise stated.
† 55 ml/day.

in cord-sectioned animals glucose concentrations decreased (Table 4).

Changes in serum cholesterol concentrations of normal and of experimental dogs as a result of short or long periods of excitement were similar to those observed from hour to hour in diurnal variation studies (to be reported separately) when the dogs were not subjected to excitement.

Exposure to Cold

During exposure of two normal, unrestrained dogs to a temperature of 2° for 2 hr, their body temperature was unchanged. The concentrations of plasma FFA increased 25–150%, serum glucose and total protein remained unchanged, and serum cholesterol decreased 15% (Fig. 2). After return of the dogs to a room at 23°, FFA concentrations remained high for 2 or more hours.

When spinal cord-transected dogs were similarly exposed, body temperature decreased 2–3°, plasma FFA concentration decreased approximately 60%, and serum glucose 40% (Fig. 2). Serum total protein concentrations (not shown) decreased 5% in dog 3, 20% in dog 2, and 8% in dog 4. When these animals returned to a room at 23°, body temperature rose to normal within 1–2 hr. After 3 hr the FFA concentrations had risen to initial levels, or higher, but serum glucose and total protein concentrations remained low.

Reflex Stimulation

The effect of reflex stimulation on mobilization of FFA was studied in dog 4 about 1 year after spinal cord transection and when reflex response was highly developed. After 15 min of stimulation by pricking with a needle the sensory area of the hind foot once per second, widespread contraction of the flexor muscles occurred and plasma FFA concentrations increased 33–35% in two studies (Table 5). When the dog had been treated with the ganglion blocking agent hexamethonium, there was a 21% decrease in FFA concentration after 7 min, and a 50% decrease after 20 min of stimulation; in a second study, not shown in the table, there was no change after 5 min of stimulation and 5% decrease after 10 min. The plasma glucose concentration was unchanged in all of the studies after reflex stimulation.

As controls, two dogs in which reflex activity had not had time to develop (1 week after cord transection) were used; after 10 min of stimulation there was no change in their plasma FFA concentrations (Table 5).

DISCUSSION

During periods of weight loss in man, decrease in plasma cholesterol levels occurs (14); similar changes were noted in our dogs (Fig. 1). The return of the body weight of the spinal cord-transected dogs to nearly normal levels several weeks after cord transection may be due in part to increase in body fat, since some atrophy of muscle occurred. The amount of muscular atrophy in dog 1 was more extensive than in the others in which reflexes were stimulated more frequently.

The variations in serum cholesterol levels (Table 1) of two normal dogs studied weekly for 5 months were similar to those of many human beings (15). The importance of nervous control in causing these variations has been suggested by the correlation between level of serum cholesterol and emotional stress in human beings (16–18). Since these variations were similar in both normal dogs and in spinal cord-transected dogs after recovery from the immediate effects of the operation, it seems unlikely that they were exclusively mediated in the dog by sympathetic nervous activity. In cholesterol-fed cockerels studied for 7 months, Joyner et al. (19) found that a conditioned emotional reaction had no influence on serum cholesterol levels or development of atherosclerosis.

In normal dogs' serum most of the cholesterol is in α-lipoproteins (20) which are resolved into three fractions by ultracentrifugation at d 1.21, namely -S 1–5, 5–10, and 10–20. The -S 1–5 component is usually present in greatest amount. The concentration of the "β-lipoprotein," -S 20–40, is low, and the low-density lipoproteins are not detectable by the method used. The concentrations of -S 20–40 lipoproteins, and of -S 1–5 lipoproteins, are relatively stable as shown by the small coefficients of variation (Table 1). In contrast to the stability of these fractions, fluctuations in concentration of -S 5–10 and -S 10–20 lipoproteins were large. Large increments in concentration of these lipoproteins, independent of variation in level of other lipoprotein fractions, have been observed in dogs after thermal injury (21). Increased concentration of lower density lipoprotein (corresponding to -S 10–40) has also been observed after X-irradiation (22). Studies of nephrectomized dogs maintained by peritoneal dialysis (23) and of protein-depleted dogs showed a greater percentage increase of -S 5–10 and -S 10–20 lipoproteins than of -S 1–5 or -S 20–40, when serum cholesterol concentrations rose above normal.

In the spinal cord-transected dogs, as in normal animals, variation in concentration of -S 5–20 lipoproteins was greater than in -S 1–5 and -S 20–40 lipoproteins. When serum cholesterol concentrations increase, a greater percentage increase occurs in -S 5–10 and -S 10–20 than in -S 1–5 lipoproteins (23).

The decreased plasma FFA concentrations observed for 2–3 weeks after spinal cord transection may possibly have resulted from low levels of plasma catecholamines (24). Ganglion blockade with hexamethonium also results in a prompt fall in plasma FFA levels (25). It would be helpful to know the dynamics of FFA turnover in our cord-transected animals; however, in the absence of such information the basal plasma FFA levels can give some insight into the changes resulting after cord transection. Two or three months after operation the basal plasma FFA levels of the dogs had returned

TABLE 4 Effect of Excitement on Concentration of Plasma FFA and Glucose of Normal and of Spinal Dogs

No. of Dog	Plasma FFA: Basal	Plasma FFA: Min of Excitement, Change from Basal: 4	10	30–60	Plasma Glucose: Basal	Plasma Glucose: Min of Excitement, Change from Basal: 4	10	30–60
	μEq/liter	%	%	%	*mg/100 ml*	%	%	%
Normal dogs								
5	790	+18			—	—		
	770	+36			70	+16		
	830	+42		—50	64	+65		+80
6	780	+10			—			
	890	+10		—26	—			
7	632	+100	—15	—48	64	+25	+18	
	860			—36	75			+16
8	780	+21			75	+30		
	850			—27	80			+46
9	520		—16		88		+18	
10	790	+10		—32				
11	840			—21	70			+30
				—29				+36
1	790			—25				
2	670	+15		—25	67	+10		+15
	790			—13	81			+21
3	640		—36	—30	62			+35
Average change, 10 normal dogs		+26.9	—22.3	—29.8		+29.2	+18.0	+34.9
Spinal cord-transected dogs								
1	999	+13		+50*	75	—26		—33*
2	480	+8						
	590	+10						
	908		—25	+40*	62		—9	—18*
3	640	+16			80	—8		
	590	+50			82	—20		
	1030	+10	—15		60	—8	—14	
	770		—16	+32*	78		—20	—24*
Average change, 3 operated dogs		+17.8	—18.7	+40.6		—20.6	—14.3	—25.0

* Animal noticeably fatigued.

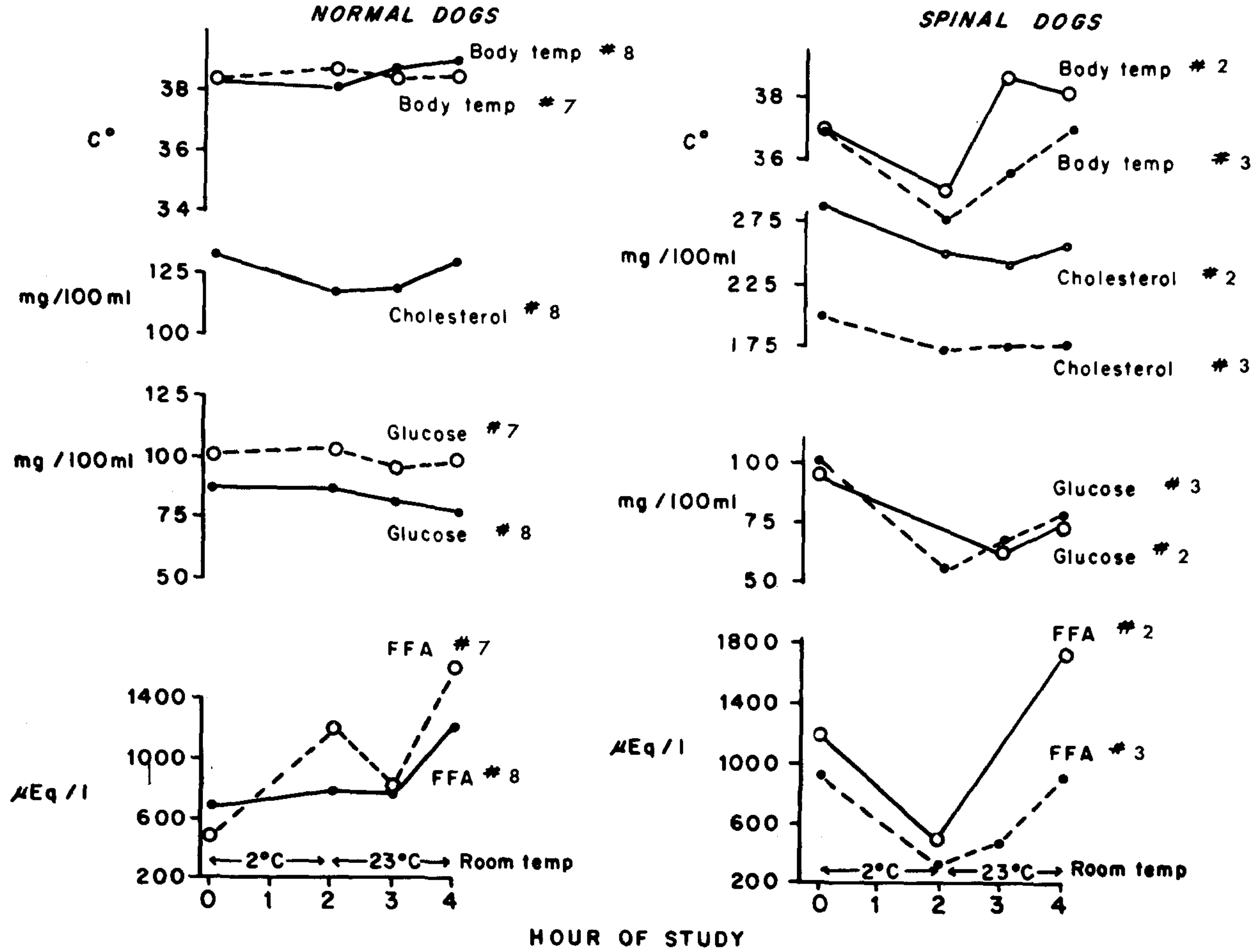

FIG. 2. Change in concentration of plasma FFA and glucose of normal dogs (Nos. 7 and 8) and spinal cord-transected dogs (Nos. 2 and 3) when exposed to a temperature of 2° for 2 hr.

to the normal preoperative level; subsequently the concentrations gradually increased until after 6 months they were usually double the normal level; fluctuations from week to week also were greater than normal. Glucose concentration, on the contrary, was slightly decreased (Table 2). In normal human beings hypoglycemia produces an abrupt and sustained rise in levels of growth hormone in plasma (26). Injection of growth hormone in dogs results in greatly elevated concentration of plasma FFA (27). Since the experimental dogs, 4 or more months after cord transection, had low fasting plasma glucose levels, their elevated plasma FFA concentrations may have been partially mediated by increased levels of growth hormone. In the operated animal, FFA seems to be the more available energy source.

The decrease in plasma FFA concentration (Table 3) of the cord-transected dogs after 60 ml bleeding on 3 successive days indicates the decreased ability of the cord-transected animal to mobilize fat after blood loss. Mill (28) in 1929 had observed that rabbits after high spinal cord section failed to develop hyperlipemia as a result of bleeding, while normal animals and those with section at 12th thoracic level consistently showed extensive hyperlipemia.

Excitement of short duration in our normal dogs was regularly associated with a rise in plasma FFA and glucose (Table 4). Others have found the same in human beings (29). Ganglionic or peripheral adrenergic blockade abolishes the effect (25). When excitement is prolonged, as for example for 1 hr, plasma FFA decreases and glucose increases, as though glucose were the energy source of choice when increased need is prolonged.

Exposure to cold (2° for 2 hr) in cord-transected dogs resulted in decrease in FFA and glucose. The decrease in FFA was unexpected because after excitement it increases. In normal animals, both increase. Possibly the difference between excitement and cold exposure is due to the longer period of cold exposure. Since the spinal cord-transected dog cannot shiver, the body temperature decreases significantly while that of the normal animal does not. There may have also been inadequate secretion of epinephrine to stimulate release of FFA from fat depots and to increase glycogenolysis.

Stimulation of the dog's paw is used as a means of eliciting muscular reflex action. During the first several weeks after cord section, the response is absent but gradually returns. How much this increased spinal reflex activity influences the energy requirements of the spinal animals is unknown. Along with the head and neck movements, it provides the only skeletal muscular action in these animals.

In 1931 Koskoff and deBarenne (30) reported that "reflex-hyperlipemia" occurred in cats, anesthetized with chloralose, following electrical stimulation of the sciatic nerve. The increase in plasma FFA which occurred in our experimental dogs following reflex stimulation by pricking sensory areas of the foot (Table 5) was probably mediated by release of norepinephrine, since prior treatment of the dog with the ganglioplegic hexamethonium inhibited the increase. While sympathetic ganglia are not usually considered to be reflex centers, there are autonomic vasomotor, pilomotor, and sweat centers in the thoracic spinal cord, through all of which simple reflexes involving only the spinal cord may be obtained. For example, rise of blood pressure of the spinal cord-transected cat occurs when the central end of the splanchnic nerve is stimulated (31).

TABLE 5 Changes in Plasma FFA and Glucose Concentrations of Spinal Cord Transected Dogs after Sensory Stimulation

Dog No.	Period after Operation	Experimental Condition	Time	Plasma FFA	Plasma Glucose	Plasma Cholesterol
	weeks		*min*	*μEq/l*	*mg/100 ml*	*mg/100 ml*
4	56	Basal	0	800	68	207
			10	750	68	200
			15	670	68	196
		Pin prick Stimulation	18–28			
			23	1000	66	206
			29	990	66	197
			34	830	66	206
			43	850	69	206
	$56^1/_2$	Basal	0	870	68	182
			5	890	67	177
		Pin prick Stimulation	10–20			
			12	1120	71	188
			16	1420	68	198
			21	1240	66	186
	59	Basal	0	1010	63	—
		Blocked with hexamethonium, 5 mg/-kg, iv	1–6			
		Basal	7	964	62	212
			16	949	61	212
			22	995	—	—
		Pin prick Stimulation	23–25			
			30	765	56	—
			36	551	59	220
			50	965	61	214
M	1	Basal	0	101	—	—
			3	130	—	—
			10	130	—	—
		Pin prick Stimulation	12–22			
			20	140	—	—
			25	158	—	—
			31	130	—	—
			41	72	—	—
N	1	Basal	0	375	72	—
		Pin prick Stimulation	11–19			
			19	396	76	—

Brooks (32) demonstrated in spinal cord-transected cats that nociceptive stimuli produced activity of spinal sympathetic outflow in absence of higher centers; this suggested the presence of a spinal mechanism making possible reflex excitation of pregnanglionic neurons of the sympathico-adrenal system. Additional reflexes (33) not usually present may be highly developed in spinal cord-transected dogs maintained for months, if efforts are made to preserve and develop them. The reflex activity of dog 4 had been developed to a high level at the time of the reflex stimulation studies. In cord-sectioned dogs in which no change in plasma FFA occurred as a result of stimulation, reflex activity was also lacking. Wertheimer (34) observed that phlorhizin diabetic animals after cord transection were unable to mobilize fat. The studies were made within a few days after operation, when reflex activity must have been absent or poorly developed.

The increase in plasma FFA observed in our cord-transected dogs after excitement may have resulted in part from reflex stimulation, since during the period of excitement active movement of the head and neck frequently caused change of body position and active movement of the legs, similar to that resulting from reflex stimulation.

CONCLUSIONS

Under basal conditions, central nervous or sympathetic control is not required for maintenance of normal serum cholesterol and lipoprotein concentrations in dogs. The levels of readily available energy sources, glucose, and free fatty acids, differed from normal in that glucose concentration was lower and free fatty acids higher in the cord-transected dogs. Further, after prolonged excitement or cold exposure the normal rise in these levels was not found; more usually, in fact, a decrease occurred.

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