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Research Article

MYOCARDIAL METABOLISM OF FATTY ACIDS *

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The myocardium is able to utilize both carbohydrates and noncarbohydrates for the performance of its work (1). Extraction of an individual substrate is usually determined by its arterial level. Thus, after a carbohydrate meal the heart derives much of its energy from the metabolism of carbohydrates; however, in the fasting state myocardial energy production is dependent upon noncarbohydrates, primarily fatty acids (1).

Recent studies (2, 3) have shown that the principal lipid fraction of plasma concerned with the transport and metabolism of fatty acids is the plasma nonesterified or free fatty acid (FFA) fraction. Previous studies have already demonstrated that the heart uses a considerable amount of FFA (3). The present study was undertaken to determine further the role of fatty acids in myocardial metabolism.

MATERIALS AND METHODS

Most of the methods used in this investigation have been described in detail in previous studies from this laboratory. Coronary sinus blood was obtained from a catheter placed in the coronary sinus, and blood samples from metabolic studies were simultaneously obtained from arterial and coronary sinus blood (1). The coronary blood flow was determined with the nitrous oxide desaturation method (4). Blood glucose was determined by the method of Hagedorn and Jensen (5) using Somogyi's method to prepare the blood filtrate (6). The manometric method of Van Slyke and Neill was used for blood oxygen analyses (7). Total fatty acids (TFA) were determined according to the method of Man and Gildea (8) based on the Stoddard and Drury method (9). According to these investigators, the error of this method is ± 5 per cent. However, modification of their original procedure developed by Siegel (10) resulted in the variance of the difference between two observations of only 0.000232 and a standard error of the difference of 0.015 (Table I). In the procedure employed in this laboratory the entire filtrate resulting from the extraction and deproteinization of 2.0 ml of plasma was used for subsequent hydrolysis. This provided a larger volume used for titration; it also removed possible errors in measurements arising from working with a volatile solution which must be made to a certain volume and from which an aliquot must be taken for subsequent analyses. In addition, all titrations were performed under nitrogen, as originally described by Man and Gildea (8). This resulted in sharper end-points and eliminated the fading effect resulting from exposure to atmospheric carbon dioxide. The data in Table I were obtained prior to the analyses carried out in this modification, in order to insure that the determinations described in this report were truly significant. FFA were determined in duplicate with the recently modified technique of Gordon, Cherkes and Gates (11). Recovery experiments in this laboratory with this technique for stearic, palmitic and oleic acids added to plasma in the concentration of 1 mEq per L indicate 96 to 102 per cent

TABLE I

Plasma fatty acids; agreement of duplicate determinations

Plasma fatty acids		Per cent diff.
Aver.	Diff.	
mEq/100 ml		
0.880	0.010	1.14
0.850	0.010	1.19
0.530	0.000	0.00
0.522	0.002	0.40
1.078	0.008	0.73
0.940	0.020	2.13
0.818	0.020	2.40
0.860	0.010	1.16
1.602	0.002	0.12
1.810	0.010	0.76
1.645	0.005	0.30
1.855	0.025	1.33
1.875	0.005	0.27
0.880	0.010	1.13
0.985	0.005	0.55
0.899	0.010	1.12
1.400	0.020	1.43
0.795	0.005	0.63
0.965	0.005	0.52
0.880	0.010	1.10
	Mean	0.91
	SD	0.61
	SE	0.14

* Supported by United States Public Health Service Grant H-2678, the Life Insurance Medical Research Fund, the American Heart Association, and the Tobacco Industry Research Fund.

TABLE II

Results on fasting patients

Patient	N_2O CBF	Myocardial extractions							Mycardial usage		O_2 extraction ratio†	
		ΔO_2*	Art. TFA	Δ TFA	Art. FFA	Δ FFA	Art. iod. number	Cor. sin. iod. number	TFA	FFA	TFA	FFA
	ml/100 g LV/min	*vol %*	*mEq/ 100 ml plasma*	*mEq/ 100 ml plasma*	*mEq/ 100 ml plasma*	*mEq/ 100 ml plasma*			*mEq/100 g/min*		%	%
FT	65	10.9	0.989		0.1096							
BB	60	10.7	1.263	0.107	0.1090	0.0060			0.0056	0.0021	50	18
EM	63	14.5	1.052	0.082	0.0913	0.0348			0.0301	0.0128	187	79
WB	84	9.3	1.263	0.056	0.0870	0.0216			0.0261	0.0101	187	72
LL	53	10.1	1.290	0.020	0.0610	0.0190	112	112	0.0059	0.0056	61	59
SL		10.5	2.010	0.083	0.0140	0.0262	114	118				
Mean	65	11.0	1.311	0.0515	0.0780	0.0215	112	115	0.0169	0.0076	145.2	57.2
					Effect of heparin							
JV‡	91	10.8	1.304	0.141	0.0668	0.0198	138	155	0.0836	0.0117	482	67
§			1.175	0.076	0.1370	0.0240	174	195	0.0450	0.0142	260	82
JH‡	46	13.4	1.090	0.019	0.0835	0.0249			0.0052	0.0068	48	63
§			1.033	0.078	0.1207	0.0351	143	159	0.0212	0.0095	195	88
RD‡	(diabetic)		1.101	0.044	0.0780	0.0158	140	144				
§			0.975	0.075	0.1010							
Mean‡			1.165	0.068	0.0761	0.0223	139	149	0.0444	0.0093	264.8	65.15
§			1.061	0.076	0.1195	0.0295	155	172	0.0331	0.0119	227.5	85

* Δ Mycardial extraction, i.e., coronary sinus arteriovenous difference.
† See Footnote 1 in text.
‡ Before heparin.
§ After heparin.

recovery. The blood samples for FFA were drawn into chilled tubes and refrigerated until the determinations were performed, in no case longer than 4 hours after sampling. A modification of the method of Yasuda was used for the iodine number determinations (12). Optical density was measured at 700 mμ with a Coleman junior spectrophotometer.

The usage of fatty acids (milliequivalents per 100 g of heart muscle per minute) was calculated as the product of coronary plasma flow (milliliters per 100 g heart muscle per minute) times the myocardial extraction of fatty acid (milliequivalents per 100 ml plasma). The oxygen extraction ratios of fatty acids were calculated as the ratios of their oxygen equivalent to the myocardial extraction.[1] The oxygen extraction ratio represents the contribution of the aerobic catabolism of fatty acids to the total myocardial oxygen extraction.

The patients listed in Table II had hypertensive, rheumatic or arteriosclerotic heart disease but were not in congestive heart failure. The first group deals with fasting individuals. In the second group, the fasting patients were given orally 2 ounces of a fat emulsion[2] containing 19 per cent saturated and 81 per cent unsaturated fatty acids. However, the metabolic studies reported here were not carried out until 3 to 4 hours after ingestion of this preparation when little or no lipemia remained (Table II). After blood sampling from the initial studies, 10 mg of aqueous heparin was given intravenously and blood was drawn again 20 minutes later for repeat metabolic studies (Table II). The coronary blood flow was determined in the interval between the two sets of blood samples, since studies on dogs, as reported in this paper, indicate that heparin does not alter the coronary blood flow despite the fact that it diminishes lactescence.

Two sets of animal experiments were performed (Tables III and IV). In the first group, myocardial utilization of fatty acids was determined in fasting dogs before and 20 minutes following the intravenous injection of 50 mg of aqueous heparin (Table III). The second group of animals was given 60 ml of Lipomul; 3 hours later the animals were anesthetized and samples were taken before and 1 hour after intravenous injection of 50 mg of heparin (Table IV). In this group, coronary blood flow was measured during lactescence and after clearing of the plasma with heparin (Table IV).

RESULTS

Myocardial fat metabolism in the postabsorptive state. Table II contains the results obtained in a group of six fasting patients. Results of similar studies in a series of 34 fasting dogs are given in Table III. In patients in the postabsorptive state, the range of the arterial levels of total fatty acids was from 0.989 to 2.010 mEq per 100 ml plasma

[1] Oxygen extraction ratio per cent =

$$\frac{O^2 \text{ equivalent of extracted fat}}{\text{myocardial oxygen extraction}} \times 100.$$

Oxygen equivalent of fatty acids = 570 × milliequivalents of myocardial fatty acid extraction.

[2] Lipomul, Upjohn Company.

with a mean value of 1.311 mEq per 100 ml of plasma. The range of myocardial extraction of total fatty acids in these individuals was from 0.017 to 0.083 mEq per 100 ml plasma, while the mean oxygen extraction ratio for TFA ranged from 50 to 187 per cent. In the same group, the arterial levels of FFA varied from 0.014 to 0.1096 mEq per 100 ml of plasma with a mean value of 0.0780 mEq per 100 ml plasma. The mean myocardial extraction of FFA was 0.0215 mEq per 100 ml plasma with a range of from 0.006 to 0.0348 mEq per 100 ml plasma; the mean oxygen extraction ratio was 57.2 per cent ranging from 18 to 79 per cent. Gordon and co-workers found similar values for FFA in their studies on humans (3, 11). The iodine number of TFA was determined in five patients; the coronary sinus levels were consistently higher than arterial levels. The figures in arterial blood as represented in Table II agree with those of Caren and Corbo in venous blood of normal individuals and patients with coronary artery disease (13).

In the studies performed upon fasting dogs (Table III) mean values for arterial levels, myocardial extractions, and oxygen extraction ratios of TFA were 0.956 mEq per 100 ml plasma, 0.042 mEq per 100 ml, and 123 per cent, respectively (range, 0.366 to 1.710 mEq per 100 ml plasma; 0.007 to 0.200 mEq per 100 ml; and 27 to 373 per cent). The arterial FFA concentrations

TABLE III

Results on fasting dogs

Dog no.	N_2O CBF	Myocardial extractions					Myocardial usage		O_2 extraction ratio†	
		Δ O_2*	Art. TFA	Δ TFA	Art. FFA	Δ FFA	TFA	FFA	TFA	FFA
	ml/100 g LV/min	*vol %*	*mEq/ 100 ml plasma*	*mEq/ 100 ml plasma*	*mEq/ 100 ml plasma*	*mEq/ 100 ml plasma*	*mEq/100 g/min*		*%*	*%*
1			0.698	0.0260	0.0584	0.0260				
2	333	5.7	1.152	0.0460	0.0251	0.0042	0.100	0.0091	297	27
3		11.9	1.010	0.0270	0.0215	0.0051			84	15
4	304	8.2	1.210	0.0790	0.0528	0.0057	0.156	0.0113	353	25
5	138	11.6	0.738	0.0160	0.0530	0.0219	0.0141	0.0193	50	68
6	187	7.6	0.990	0.0310	0.0378	0.0045	0.0446	0.0065	179	25
7	88	13.2	0.765	0.0100	0.0366	0.0094	0.0056	0.0053	27	25
8	222	14.0	0.568	0.0126	0.0405	0.0081	0.0182	0.0117	33	21
9	62	5.6	0.752	0.0177	0.0200	0.0026	0.0072	0.0011	118	17
10	60	6.9	0.875	0.0270	0.0274	0.0020	0.0090	0.0006	123	9
11	92	13.2	0.579	0.0154	0.0189	0.0092	0.0079	0.0047	36	21
12	85	16.2	0.865	0.0177	0.0336	0.0112	0.0099	0.0060	38	24
13	92	15.9	0.814	0.0295	0.0299	0.0102	0.0168	0.0058	65	22
14	88	12.2	0.366	0.0142	0.0243	0.0103	0.0082	0.0059	43	21
15	101	15.1	1.492	0.0212	0.0274	0.0140	0.0124	0.0082	46	30
16	87	14.0			0.0364	0.0006		0.0004		1
17	155	6.9	0.848	0.0280	0.0226	0.0096	0.0239	0.0082	125	43
18	124	14.0			0.0270	0.0126		0.0102		33
19	57	16.0	1.049	0.0240	0.0279	0.0105	0.0089	0.0039	55	23
20	93	11.3								
21	89	12.8	1.132	0.0630	0.1177	0.0095	0.0395	0.0060	195	29
22	90	13.2	1.070	0.0120	0.0332	0.0140	0.0071	0.0082	33	39
23	103	14.5	0.750	0.0980	0.0133	0.0076	0.059	0.0046	223	17
24	247	13.5	1.805	0.0900	0.0403	0.0203	0.129	0.0291	220	49
25	105	17.6	1.035	0.0680	0.0200	0.0033	0.0395	0.0019	121	5
26	185	8.9	0.787	0.049	0.0374	0.0098	0.0564	0.0113	193	38
27	174	10.8	0.666	0.016	0.0176	0.0113	0.0162	0.0114	48	34
28	160	12.0	1.174	0.059	0.0223	0.0068	0.0620	0.0072	183	21
29		5.4	0.634	0.007						
30	82	11.7	0.864	0.117	0.0164	0.0031	0.0637	0.00169	373	9
31	49	14.3	1.710	0.031	0.0265	0.0118	0.0085	0.00324	67	25
32	86	14.9	1.290	0.200	0.0189	0.0092	0.1015	0.00467	44	20
33	74	13.5	1.000	0.024	0.0364	0.0164	0.0107	0.00728	60	41
34	71	10.1								
Mean	125	11.9	0.956	0.0420	0.0329	0.0097	0.0384	0.0074	123	26

* Δ Myocardial extraction, i.e., coronary sinus arteriovenous difference.
† See Footnote 1 in text.

TABLE IV

Effect of heparin on dogs

Dog no.	N_2O CBF	Myocardial extractions					Myocardial usage		O_2 extraction ratio†	
		Δ O_2*	Art. TFA	Δ TFA	Art. FFA	Δ FFA	TFA	FFA	TFA	FFA
	ml/100 g LV/min	*vol %*	*mEq/ 100 ml plasma*	*mEq/ 100 ml plasma*	*mEq/ 100 ml plasma*	*mEq/ 100 ml plasma*	*mEq/100 g/min*		%	%
Fasting dogs										
14‡	88	12.2	0.3658	0.0142	0.0243	0.0103	0.00816	0.0059	43	31
§			0.3469	0.0141	0.0400	0.0108	0.00810	0.0062	42	32
17‡	155	6.9	0.8480	0.0280	0.0226	0.0096	0.02387	0.0082	127	43
§			0.8440	0.0160	0.0425	0.0058	0.01364	0.0050	72	26
23‡	103	14.5	0.7500	0.0980	0.0133	0.0076	0.05882	0.0046	223	17
§			0.7400	—0.0240	0.0244	0.0132	−0.01441	0.0079	−54	30
24‡	247	13.5	1.8050	0.0900	0.0403	0.0203	0.12893	0.0291	219	49
§			1.7390	0.0440	0.0380	0.0185	0.06303	0.0265	107	45
25‡	105	17.6	1.0350	0.0680	0.0200	0.0033	0.03949	0.0019	121	5
§			0.9540	0.0240	0.0445	0.0309	0.01394	0.0180	42	55
26‡	185	8.9	0.7870	0.0490	0.0374	0.0098	0.05639	0.0113	193	38
§			0.7870	0.0110	0.0367	0.0125	0.01266	0.0144	42	49
27‡	174	10.8	0.6660	0.0160	0.0176	0.0113	0.01619	0.0114	48	34
§			0.5670	0.0230	0.0147	0.0053	0.02328	0.0054	70	16
28‡	160	12.0	1.1740	0.0590	0.0223	0.0068	0.06230	0.0072	183	21
§			0.9990	0.1340	0.0205	0.0074	0.14150	0.0078	416	23
Lipemic dogs										
35‡	55	12.3			0.0735	−0.0021		0.00074		6
§	58	11.9			0.0880	0.0190		0.00727		59
36‡	67	13.4			0.0311	0.0111		0.00450		28
§	68	11.5			0.0311	0.0054		0.00256		18
37‡	92	11.5			0.0576	0.0217		0.01358		72
§	82	14.2			0.0227	0.0136		0.00691		33
38‡	50	15.2			0.0266	0.0134		0.00389		29
§	63	16.0			0.0312	0.0161		0.00588		33
39‡	96	16.6			0.0422	0.0222		0.01215		43
§	97	14.4			0.0395	0.0153		0.00980		39
40‡	79	15.2			0.0440	0.0084		0.00385		18
§	47	15.5			0.0507	0.0310		0.00918		71
41‡	65	16.4			0.0843	0.0343		0.01315		70
§	81	17.5			0.0460	0.0032		0.00151		6
42‡	138	14.1			0.0555	0.0243		0.01710		49
Mean of‡	152	12.0	0.9288	0.0527	0.02473	0.0098		0.0099	145	30
fasting dogs§			0.8721	0.0302	0.0326	0.0130		0.0114	92	34
Mean of‡	80.25	14.3			0.0518	0.0166		0.0086		39
lipemic dogs§	73.59	14.4			0.0445	0.0160		0.0068		39

* Δ Myocardial extraction, i.e., coronary sinus arteriovenous difference.
† See Footnote 1 in text.
‡ Before heparin.
§ After heparin.

ranged from 0.0133 to 0.1177 mEq per 100 ml plasma and the myocardial extractions from 0.0006 to 0.0260 mEq per 100 ml plasma. The oxygen extraction ratio of FFA varied from 1 to 68 per cent. In the average dog the extraction of FFA by the heart accounted for only 23 per cent of the total fatty acid extraction.

The effect of alimentary fat and of heparin. Three to four hours after ingestion of a fat meal (Table II), the mean arterial levels of TFA and FFA in patients were, respectively, 1.165 and 0.0761 mEq per 100 ml plasma. Plasma arterial levels of TFA varied from 1.090 to 1.304 mEq per 100 ml plasma, while FFA plasma levels ranged from 0.0668 to 0.0835 mEq per 100 ml plasma. The mean myocardial extraction of TFA was 0.068 and of FFA 0.0201 mEq per 100 ml plasma. These values are comparable with those obtained in fasting patients. The oxygen extraction ratios were 264 and 65 per cent, respectively.

The effect of heparin on fatty acid metabolism

was studied in a limited number of human subjects (Table II). In three individuals, heparin produced a slight fall in the average arterial concentration of TFA from 1.165 to 1.061 mEq per 100 ml plasma and resulted in a marked increase in the arterial concentration of FFA (from 0.0761 to 0.1195 mEq per 100 ml plasma); the myocardial extraction of FFA increased from 0.0201 to 0.0225 mEq per 100 ml plasma. In fasting dogs, similar changes were found 20 minutes after heparin injections. The arterial TFA concentration decreased from a mean of 0.9288 to 0.8721 mEq per 100 ml plasma, that of FFA rose from 0.0247 to 0.0326 mEq per 100 ml plasma. Myocardial extraction of TFA fell from 0.0527 to 0.0302 mEq per 100 ml plasma, while that of FFA rose from 0.0098 to 0.0130 mEq per 100 ml plasma (Table IV). Comparing results obtained on fasting dogs with another group in which Lipomul was given, it may be seen that the fat meal resulted in an elevation of the arterial FFA concentration of from 0.0247 to 0.0518 mEq per 100 ml plasma. The myocardial extraction of FFA also was higher (0.0098 to 0.0166 mEq per 100 ml plasma). The usage of FFA by the heart rose slightly (from 0.0074 to 0.0086 mEq per 100 g per left ventricle per minute; (Tables III and IV). TFA levels were not measured in these dogs, but all had lipemic plasma, and in all the plasma optical densities were higher than any found in fasting animals. In the seven lipemic dogs studied following heparin administration, the arterial levels of FFA rose in three, fell in three, and remained constant in one animal (Table IV). Here, too, the myocardial extraction and usage of FFA varied with their arterial concentration. The TFA concentration in fasting dogs declined slightly with heparin in seven out of eight animals (from a mean of 0.9288 to 0.8721 mEq per 100 ml plasma); however, there was a marked decrease in myocardial extraction (mean of 0.0527 to 0.0302 mEq per 100 ml plasma) and usage of TFA (mean of 0.0492 to 0.0327 mEq per 100 g per left ventricle per minute) in most dogs. In contrast to results obtained on patients with artificially induced hyperlipemia in whom the injection of heparin resulted in a rise in coronary blood flow (14), heparin did not alter the coronary flow in seven hyperlipemic dogs (Table IV).

DISCUSSION

The data on myocardial metabolism of fatty acids by fasting man and dog reveal that FFA average 6 per cent of the mean arterial level of TFA in the human, while in the dog this figure is approximately 3 per cent. In the fasting human the mean myocardial extraction of FFA accounts for 42 per cent of the TFA extraction while the esterified fraction makes up the other 58 per cent. In the fasting dog, the FFA fraction accounts for only 23 per cent of the total fatty acids extracted. The high oxygen extraction ratios for fatty acids confirm previously published experiments in which it could be shown that in the fasting state most of the energy in the heart is derived from fat metabolism (1).

Dole, as well as Gordon and Cherkes have developed the concept that FFA are the blood lipid fraction primarily concerned with the supply of fats to tissues for oxidative metabolism (2, 3). The concentration of the circulating FFA is in some way related to the nutritional state of the subject. If the energy requirements are satisfied by carbohydrates, the FFA level drops to a low value and the myocardial extraction of FFA decreases (3, 11). However, in the fasting state the heart derives only a small part of the energy from carbohydrate substances (15).

Gordon and Cherkes as well as Olson have calculated that the heart can extract fairly large amounts of FFA (3, 15). The results reported here confirm this ability but demonstrate that even in the fasting state, FFA account for less than half of the myocardial extraction of TFA. The likelihood exists that a large fraction of TFA removed by the heart is not immediately oxidized to CO_2 and water. Two of the four fasting patients (Table II) and 13 of 28 dogs in the postabsorptive state (Table III) show oxygen extraction ratios above 100 per cent.

Large myocardial extraction of esterified fatty acids is in line with the finding that over half of the chylomicron triglycerides are directly oxidized (16). These substances may be removed directly by the same tissue sites oxidizing plasma FFA, or lipoprotein lipase present within or on the surface of the myocardial cell may hydrolyze the triglycerides at the site of their oxidation (17). It is unlikely that phospholipids or cholesterol

esters are metabolized by the heart (17). Recently published studies have pointed out the great importance of the plasma FFA fraction in providing readily available foodstuffs to meet metabolic demands throughout the body. The results reported here have demonstrated that the esterified fatty acids account for most of the total fats extracted by the myocardium.

It has been demonstrated that the availability of glucose to the adipose tissue controls the release of FFA into the blood. With depletion of carbohydrate and greater utilization of fat for energy, triglycerides in adipose tissue are hydrolyzed and yield fatty acids to be discharged as FFA into the blood stream (18). Gordon, Cherkes and Gates have found that the myocardial oxygen extraction ratio of FFA decreases from a fasting level of 42 to 0 per cent after an infusion of glucose and insulin (11). The studies reported here were performed either on fasting subjects or after a meal containing only fat. Consequently, a wide range of arterial glucose levels was not present in these patients and animals and the effect of glucose on myocardial utilization of fatty acids could not be ascertained (Tables II and III).

In eight dogs which received a fatty meal, the mean arterial FFA concentration was 0.0518 mEq per 100 ml plasma, while in 34 fasting dogs it was 0.0329 mEq per 100 ml plasma (Tables III and IV). Concomitantly, there was an increase in their myocardial extraction, but the usage of FFA by the heart rose slightly (0.0086 as compared with 0.0074 mEq per 100 ml plasma). This finding illustrates that in the experiments of this series ingestion of enough fat to cause lipemia with a marked increase in optical density of blood increased FFA concentration in plasma. This is in contrast to the findings of Dole, and Gordon and Cherkes, who reported that ingestion of fats to cause lipemia had no effect on FFA concentration in plasma (2, 3). Apparently, as Fredrickson and Gordon have stated, changes in FFA concentration depend upon many factors, including the rate of absorption, rate of transfer of triglycerides from the blood, rate of hydrolysis of triglycerides, rate of utilization of FFA, and the responsiveness of adipose tissue to exogenous fat (17).

Heparin, in the three patients in whom data are available, results in a decline in the arterial concentration of TFA, and in a rise in the concentration of FFA. There is a slight increase in myocardial utilization and extraction of FFA (Table II). In eight fasting dogs, heparin had a similar effect on FFA blood levels and the myocardial extraction and usages increased in most instances concomitantly with the blood levels (Table IV). The effect of heparin in increasing the FFA blood levels of fasting man and dog is in agreement with results of previous investigators (17, 18). Following injection of heparin into seven lipemic animals the arterial levels of FFA rose in three, fell in three, and remained constant in one animal (Table IV). These fluctuations may be the result of changes in blood concentration of fats due to varying rates of absorption. As was found previously, the myocardial extraction and usage of FFA vary with their arterial concentrations. After heparin, the TFA concentration in the blood plasma of fasting dogs declines slightly; however, there is a marked decrease in myocardial extraction and usage of TFA in most of these animals. The finding of a relationship between plasma concentrations and myocardial usage and extraction of FFA is consistent with either active transport or passive diffusion of fatty acids into the cell.

It had been previously found that the injection of heparin into patients with induced hyperlipemia results in an increase in coronary flow (14). In the experiments reported here, heparin had no influence on the coronary flow of hyperlipemic dogs. It is possible that this discrepancy is the result of species differences.

Iodine numbers of the isolated TFA fraction of the plasma were obtained in five patients. The values in coronary sinus blood consistently exceeded those in arterial blood. This suggests that the relative concentration of saturated fatty acids is less in coronary sinus than in arterial blood as a result of greater myocardial usage of saturated fatty acids. Further identification of these saturated fatty acids must await the results of more refined analytical techniques.

SUMMARY

The myocardial extraction and usage of total and free fatty acids (FFA) have been determined in patients and in dogs.

In the postabsorptive state significant amounts of both esterified and free fatty acids were extracted by the myocardium.

The determination of the iodine numbers in plasma revealed that there was proportionately greater usage of saturated than of unsaturated fatty acids by the heart.

The ingestion of a fat meal increased both plasma concentration and myocardial extraction of FFA.

Heparin induced in man and in fasting dogs a fall in the plasma concentration of total fatty acids and an increase in the concentration of FFA.

These studies demonstrate that esterified fatty acids account for more than half of the total fats extracted by the myocardium. Under the experimental conditions reported here, the myocardial extraction of free fatty acids in given patients and animals is usually dependent upon their respective arterial concentrations.

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