Studies on Turnover Rate of Cardiac Glycogen In Vivo and In Vitro by Single Injection of C^{14}-glucose

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Glycogen is the most important storage form of carbohydrate in the heart as in other tissues. Therefore, the participation of this substance in metabolic processes, the mode of its synthesis and the mechanism of its degradation are of importance to the understanding of biochemistry of carbohydrate fuels and their utilization by animal tissues.

Over the recent years, a number of studies have provided data on metabolic and kinetic problems of glycogen turnover employing isotopic tracer techniques.

Cavert et al[1,2] found, working on isolated blood-perfused and non working heart preparation, that there was negligible or no incorporation into cardiac glycogen of isotopes from certain administered carbon labeled substrates such as pyruvate, short chain fatty acid and lactate. These authors postulated, as had Lorber et al[3] earlier, that blood sugar must be the principal precursor for cardiac glycogen synthesis and that incorporation of labeled carbon into cardiac glycogen in the intact animal must be secondary to the formation by the liver of blood glucose from the administered labeled compounds. Lorber et al[4] also found that an appreciable amount of labeled CO_2 was incorporated into glycogen obtained from the blood-perfused "working" cat heart. This finding apparently indicated that glycogen synthesis could occur in the cat heart by the way of some CO_2 fixation reaction, presumably involving a three carbon compound such as pyruvate. Since Cavert et al[1,2] were unable to confirm the CO_2 incorporation in the isolated dog heart, the discrepancy between the two findings could be attributed to a species variation in metabolism or to some differences in experimental approach. Cavert et al[5], however, using carbon by carbon degradation of glycogen obtained from dog heart and gastrocnemius muscle, that glycogen synthesis in these isolated organs occurred via reversal of the Embden Meyerhof pathway.

Stetten et al have reported studies on the mechanism of glycogen "turnover" in the tissues of the intact animal in a series of experiments.

In their earlier study[6], they estimated turnover rates of liver and carcass glycogen by measuring the stably-bound deuterium which was incorporated into glycogen while body water was maintained enriched with D_2O. In this experiment, they calculated turnover rates of 68% per day for liver glycogen and 19% per day for carcass glycogen. They also found that these fractions of glycogen turned over represented only 3% of the total glucose intake during the period of experimentation. Therefore, they proposed that glycogen represents a quantitatively minor pathway of glucose metabolism.

Recently Stetten and Stetten[7,8] have found, comparing the radioactivity of the peripheral tier and of the limit dextrin of glycogen, which were obtained by enzymatic degradation of glycogen isolated at various interval after single injection of C^{14}-glucose, that the peripheral tiers of glycogen is metabolically more active than the central core. Stetten discussed the implication and possible importance of the inhomogeneity of glycogen.

As described above, kinetic and metabolic characteristics of glycogen turnover were qualitatively evaluated by many authors with either the single or constant infusion method of various tracers. Rhee et al. reported quantitative measurements of turnover rate of glycogen isolated from blood-perfused dog heart by constant infusion of C^{14}-glucose in the heart-oxygenator Langendorff system[9]. In this experiment plasma glucose specific activity and blood glucose level were maintained

constant throughout the experimental period, there was relatively constant values for glycogen level before and after the experimental period. They assumed a steady state of glycogen turnover. If we make the assumption that glycogen is metabolically homogeneous and that the mode of turnover of glucose follows first order reaction kinetics, then the turnover rate of glycogen can be calculated quantitatively by obtaining the ratio of specific activity of the plasma glucose to glycogen. This technique requires determination of the characteristic disappearance of a single injection of the tracer to calculate the regulation of the infusion so as to maintain a constant concentration of the tracer during the experiment. Even so, it is difficult to maintain a constant concentration. In order to remove such difficulties in the experimental approach, we also introduced "The C^{14}-glucose dilution method" for quantitative determination of turnover rate of glycogen by single injection of C^{14}-glucose on in vivo study of the intact dog[10].

The calculation by "C^{14}-glucose dilution method" for the determination of turnover rate of glycogen is based on many assumptions and it can not be proved in vivo study. This paper efforts to prove the validity of assumptions required to calculate the turnover rate of glycogen by the "C^{14}-glucose dilution method" in the isolated dog heart and to compare the data from **in vivo** experiment to that from **in vitro.**

Experimental methods

A. Preparation of the isolated heart

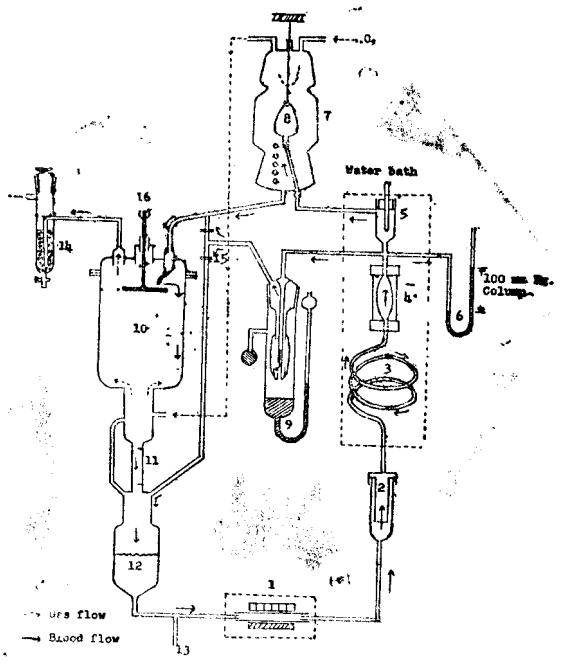
A modification of the perfusion method of Langendorff[11] was employed. The Langendorff preparation performed work only to the extent to which its muscle mass and the coronary blood collecting in the right ventricle were lifted against gravity with each contraction.

In this preparation, blood was perfused through the coronary arteries of the isolated dog heart via aortic arch by canulation of the brachiocephalic artery. Since the aortic semilunar valves remained closed under sufficient perfusion pressure arterial blood flow was directed only to the coronary system. Venous coronary blood collected on the right side of the heart was drained through incisions in the right auricle and pulmon ary artery. To prevent pooling of blood in the left ventricle, the mitral valve was rendered incompetent by cutting its chordae tendinae.

The procedure of isolating heart preparation required approximately one hour from the time of anesthesia with nembutal to commencement of independent perfusion.

B. Perfusion apparatus

Perfusion apparatus, as presented in Figure 1. consisted essentially of a thermostated closed circuit containing a glass chamber for oxygenating a film of coronary venous blood.



1. Sigmamotor pump. 2. Fine mesh filter.
3. Coil for warming. 4. Depulsator.
5. Thermometer chamber.
6. Macury manometer. 7. Heart chamber.
8. Isolated heart. 9. Starling's resistance.
10. Hooker-type oxygenator chamber.
11. Blood flow meter. 12. Blood reservior.
13. T-tube(blood drain).
14. CO_2 absorber. 15. Cramp.
16. Spinning disc,

[Fig. 1] Isolated Heart Perfusion Appratus.

1) Blood circuit

Blood flow through the coronary vessels was maintained by a perfusion pump(sigmamotor) and

a starling's resistance set to hold mean arterial pressure constant at about 100 mm Hg, Most of the inter glass connections in the blood circuit were joined by polyethylene tubing with an internal diameter of 3/16 or 1/4 inches. Glass joints were rendered completly air tight by application of a thin coat of lubricating greese.

Constant temperature was maintained by immersing the arterial inflow portion of the circuit in a controlled water bath at 37°C. The outer wall of the heart chamber was also circulated with warm water to provide a warm environment. Blood in this system was filtered by a fine mesh filter (Baxter) before circulating through the coronary vessels.

Venous blood collected from the right heart was oxygenated by a Hooker-type oxygenator[12] which provided a large diffusion surface (approximately 800 cm^2) for respiratory gas exchange. After passage through a simple calibrated tube as flowmeter, blood was collected in a reservoir before circulating through the pump. Measurements made every 30 minutes through-out the experiment included arterial perfusion pressure, coronary outflow rate, temperature and gas flow.

2) Respiratory system

Compressed oxygen was introduced at rate of approximately 500 cc/min. into the perfusion system. The oxygen was passed through a flowmeter at the bottom of the oxygenator and a carbon dioxide absorbing material (soda lime) before entering the system.

C. Experimental procedure

1) in vivo study; Dogs were lightly anesthetized with nembutal (20-30 mg/kg) before injection of C^{14}-glucose injecting solution, For blood sampling, the jugular vein was canulated. After a single injection of C^{14}-glucose (20 uc). hourly blood samples were collected for plasma glucose level and specific activity of plasma glucose determinations for a period of 5-6 hours. At the end of the experiment, cardiac muscle was quickly excised for glycogen determination.

2) in vitro study; The general procedures followed in this series of experiments has been well outlined by Cavert et al.[1,2]. Certain aspects of procedures and equipments were modified from perfusion studies reported by Lorber et al[13].

After positioning the isolated heart in glass chamber(Fig. 1), the entire perfusion system was allowed to stabilize for a period of more than 30 minutes, following which a control blood sample was drawn. A prepared solution of C^{14}-glucose was then slowly injected into the blood reservoir. Blood samples were withdrawn periodically for analysis of blood glucose, lactate, pyruvate and specific activity of plasma glucose.

In all experiments, after a single injection of C^{14}-glucose solution (10 uc) in the perfusion system, blood sugar concentration of perfused blood was maintained at a normal level throughout the experiment by additional injection of non radioisotope glucose solution at the rate of 50 mg of glucose per 10 minutes. This average rate of glucose utilization by the blood perfused isolated heart in this system had been determined from an earlier series of experiments employing the single injection method of substrate addition.

To minimize dilution of the injected radioactive glucose, an attempt was made to reduce the endogeneous glucose of circulating blood before the radioactive material was added. This was accomplished in part by drawing blood only from donor dogs previously fasted for 18 to 24 hours. When this blood was allowed to stand or to circulate slowly in the perfusion apparatus for approximately an hour, the control glucose level of circulating blood prior to the injection of C^{14}-glucose was approximately 60 mg/100 ml.

D. Analytical method

The following chemical procedures were employed. For blood glucose, the combined method of Somogyi;[14] and Nelson[15]; for blood lactate, the colorimetric method of Barker and Summerson[16]; for pyruvate, the method of Friedman and Haugen[17]; for estimation of tissue glycogen, a modification of the procedure of Good, Kramer, and Somogyi[18]; for isolation of glycogen, the method of Stetten and Boxer[6]; for total carbon, the method of Van Slyke and Folch[19] were employed.

When glycogen was determined on ventricular

biopsy samples of heart tissue, the procedure of Stadie, Haugaad and Marsh[20] was used.

E. Radioactivity measurements

1) C^{14}-glucose; The solution of C^{14}-glucose (universally labeled, Tracerlab, Inc.) for single injection was prepared by diluting the radioactive glucose with non radioactive glucose to obtain 0,2N glucose solution.

Specific activity of C^{14}-glucose injecting solution was determined from $BaCO_3$ plates prepared after completely oxydizing a sample of solution to carbon dioxide by the Van Slyke-Folch method.

2) Measurements of radioactivity of plasma glucose and cardiac glycogen. The plasma filtrate obtained by Somogyi's procedure was passed through cation and anion exchange columns in order to remove residual substances which might otherwise interfere with chemical manipulations and osazone formation. Plasma glucose was isolated as the phenylglucosazonn after concentrating the eluate to a small volume[21].

The osazone sample was burned to CO_2 by Van Slyke-Folch method. Alkaline carbonate sample was then mounted on filter paper as $BaCO_3$ and its radioactivity was counted as infinitely thin samples with an end window Geiger-Müller counter (Tracer lab. Inc.).

The same procedure was used for determination of specific activity of glycogen.

F. Method of calculation

Since single injection of C^{14}-glucose solution was administered and maintained relatively constant glucose pool in this series of experiments.

Specific activities of plasma glucose following single injection of C^{14}-glucose showed a linear relationship with time on a semilogarithmic scale, showing an exponential disappearance of C^{14}-glucose in the single homogeneous glucose pool(Fig. 2). If there are steady incorporation of plasma glucose into cardiac glycogen, the following calculation is available to determine the turnover rate of cardiac glycogen as described in our earlier paper[10].

$$K_I = \frac{n}{\int_0^t (SA)_{PG}\,dt} \quad \cdots\cdots(1)$$

Ki; % turnover rate of cardiac glycogen.

n: total counts incorporated into cardiac glycogen from plasma C^{14}-glucose.

$(S.A)_{PG}$: Specific activity of plasma C^{14}-glucose.

t: time.

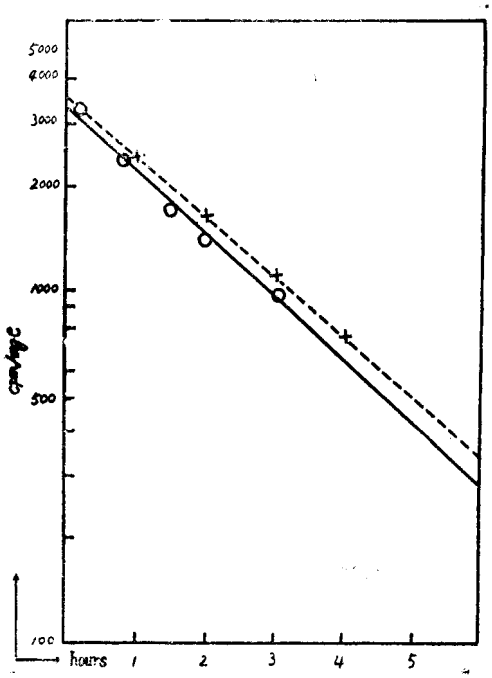
The numerator of the equation (1) is customally obtained as total counts incorporated in 100 mg of cardiac glycogen by equation (2).

$$n = \text{SA of glycogen(cpm/mgc)} \times 100 \times \frac{72}{162} \quad \cdots\cdots(2)$$

Since the denominator of the equation (1) corresponds to the area under the SA-time curve of plasma glucose as shown in the (Fig. 3), it can be easily measured by planimetry. The planimetry was done by weighing method[22].

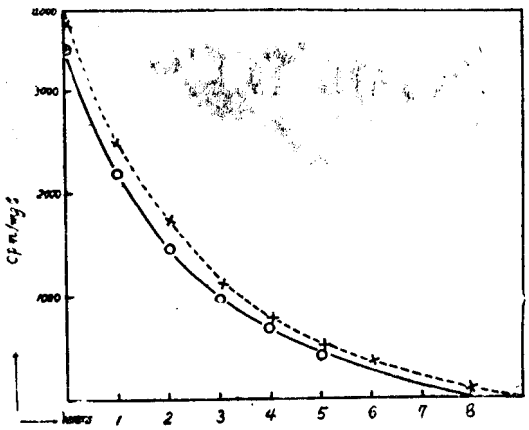
If we express the unit of numerator cpm/100 mg glycogen and that of denominator cpm/mg glucose-x hrs, the calculated data by equation (1) directly showed fraction of cardiac glycogen turned over per hour.

In the perfusion experiments, where plasma glucose level of the perfusion system was maintained relatively constant by secondary infusion of non radioglucose at the rate of glucose consumpt-



×·····× Theoretical curve.
○———○ Actual measured curve.

[Fig. 2] SA-time curve of plasma glucose on the semilogarithmic paper in the perfusion experiment. (Dog. No. 5)



×·····× Theoretical curve.
○———○ Actual measured curve.

[Fg. 3] SA-time curve of plasma glucose on the normal section paper in the perfusion experiment. (Dog. No.5)

ion by the heart following single injection of the C^{14}-glucose, theoretical SA of plasma glucose can be calculated by the following equation(Fig. 2, 3).

$$\frac{d(SA)}{dt} - = -K(SA)_{t=0} \cdots\cdots (3)$$

$$\log(SA) = \frac{-Kt}{2.3} + \log(SA)_{t=0} \cdots\cdots (4)$$

Where

(SA): specific activity of plasma glucose after single injection of C^{14}-glucose.

$(SA)_{t=0}$: specific activity of plasma glucose at $t=0$.

K: turnover rate of glucose pool in the perfusion system.

The $(SA)_{t=0}$ in the above eq ıation was obtained by total counts injected divided by total glucose pool in the perfusion system and K is obtained by secondary infusion rate of glucose divided by total glucose pool in the system.

If these values are substituted in the equation (4), specific activity of plasma glucose at any given time can be calculated.

Experimental Results

Mean value of glycogen concentration of hearts in vitro (table 1) was 516 mg/100 gm wet weight. This value was taken as the relative constant level of heart glycogen. The identity of glycogen concentration in biopsy sample and final tissue sample was confirmed by comparing the glycogen concentrations in biopsy samples removed before and after the perfusion. The net change in glycogen concentration showed less than 10% in the biopsy samples.

SA-time curve of plasma glcuose after single injection of C^{14}-glucose is shown in figure 2. SA of plasma glucose decreased exponentially with time. This relationship was obtained **in vitro** and **in vivo.** This means, in both groups, there was a steady state turnover of a single homogeneous glucose pool in the system over the experimental period. When the theoretical specific activity of plasma glucose at any given time is calculated by equation (4), it was almost same as the observed value.

This fact would mean a kinetic characteristics of a steady state turnover of single homogeneous glucose pool in the system over the experimental period.

Since we found relatively constant values for glycogen level before and after the experiment, and since glucose level were maintained constant throughout the perfusion experiment, it seems plausible to assume a steady state of cardiac glycogen turnover. If we make the assumption that glycogen is metabolically homogeneous and that the mode of turnover of glycogen by glucose

<Table 1> **Concentration of glucose, lactate, pyruvate and tissue glycogen in vitro study.**

	plasma glucose level(mg%)					glycogen level (mg/100gm)		pyruvate (mg%)		lactate (mg%)	
time / Dog No.	0.10 hr	1 hr	2 hrs.	3 hrs.	4 hrs.	before*	after	before	after	before	after
I	282	290	274	211	203	503	552	3.5	2.8	23	60
2	252	263	230	238	—	678	592	4.8	4.8	45	59
3	165	137	136	141	—	572	495	3.6	3.5	45	79
4	139	146	144	144	126	425	407	2.6	3.2	40	50
5	213	220	230	230	—	522	536	5.5	6.7	27	40
mean	—	—	—	—	—	554	516	4.0	4.2	36	58

* biopsy data.

follows the first order reaction kinetics, then the turnover rate of cardiac glycogen can be calculated by "C^{14}-glucose dilution method" stated in the method.

The figures in table 2. present the data for each experiment on the turnover rate of cardiac glycogen in the isolated dog heart. Amount of glycogen from isolated heart replaced by perfused plasma glucose, calculated by "C^{14}-glucose dilution method", was mean of 6.3 mg of glycogen per hour per 100 mg cardiac glycogen. Therefore, turnover rate of cardiac glycogen **in vitro** was a mean of 6.3% per hour. Since theoretical dilution area of SA-time curve **in vitro**, as shown in the Figure 3. was slightly higher than actually measured dilution area, the theoretical turnover rate, which is calculated by total counts incorporated in 100 mg of glycogen divided by theoretical dilution area, was always less than actual turnover rate(table 2).

However, this difference in values between actual and theoretical turnover rate was negligible to the order of their magnitude. The time for turnover of half of cardiac glycogen which is referred as to the half time ($t\frac{1}{2}$) was calculated

<Table 2> **Turnover rate of cardiac glycogen in the isolated dog heart.**

Dog No.	SA of glycogen	total cts in(100)mg glycogen	dilution area *		amount glucose turnovered△		turn over-rate	$t\frac{1}{2}$ ○
			actual	theoretical	actual	theoretical		
	cpm/mg C	cpm	cpm/mgC×hr.		mg/hr/100mg glycogen		%/hr.	hr.
1	308	16.900	6930	6250	6.4	6.1	6.4	10.3
2	415	18.450	6590	6850	6.3	6.1	6.3	11.0
3	375	16.890	6350	6730	5.9	5.6	5.9	11.7
4	453	20.100	7250	7800	6.2	5.8	6.2	11.2
5	588	23.600	7600	8600	7.0	6.1	7.2	1.0
mean	—	—	—	—	6.3	5.9	6.3	10.9

*: Area under the SA-time curve of plasma glucose.

△: Amount of turnoverd glycogen was calculated as follow

$$\frac{\text{Third column}}{\text{4th or 5th column}} \times \frac{162}{72}$$

○: $t\frac{1}{2} = \frac{0.693}{k}$

<Table 3> **turnover rate of cardiac glycogen in vivo Study**

Dog No.	Plasma glucose level	Cardiac glycogen level	S.A. of glycogen	tatal. cts in 100 mg glycogen ○	dilution area ×	amount of glucose △ turnovered	turnover rate (K)	$t\frac{1}{2}$ *
Unit	mg%	mg/100gm	cpm/mgC	cpm	cpm/mgC ×hr	mg/hr 100mg	%hr.	hr.
6	62	440	29	1290	430	6.75	6.75	
7	109	430	110	3990	1990	5.51	5.51	I2.6
8	98	667	90	4889	1750	5.10	5.10	13.6
9	96	530	88	3910	1820	4.84	4.84	14.3
10	101	667	79	3510	1820	4.34	4.34	16.0
11	87	307	67	2980	1500	4.47	4.47	15.5
12	78	488	103	4570	1980	5.20	5.20	13.3
	85	500	124	5510	2025	6.12	6.12	11.3
mean	90	504	—	—		5.29	5.29	13.4

×: Area of SA-time curve of plasma glucose.

○: S'A of glycogen$\times 100 \times \frac{72}{162}$

△: $\frac{\text{5th column}}{\text{6th column}} \times \frac{162}{72}$

*: $t\frac{1}{2} = \frac{0.693}{K}$

by substituting turnover rate of cardiac glycogen from the isolated dog heart to the first order kinetic equation. An average of 10.9 hr. was found.

On the basis of findings in the **in vitro** experiment, we proceeded to determine turnover rate of cardiac glycogen in the postabsorptive intact dog.

Table 3. summarizes the experimental data for the the turnover rate of cardiac glycogen in the intact dog.

Mean value of glycogen concentration of hearts **in vivo** was 504 mg/100 gm wet weight. Turnover rate of cardiac glycogen was an average of 5.3% per hour and its half time was 13.4 hours. These value are identical with those of **in vitro** values.

DISCUSSION

The determination of the glycogen turnover rate employing whether the single injection method or constant infusion method of C^{14}-glucose[9] as in the series of experiment presented by the author is based on the following assumptions.

1) principal precursor for cardiac glycogen is plasma glucose and plasma glucose level is constant.

2) glycogen pool is constant over the experimental period.

3) glycogen turnover is metabolically homogeneous.

It is worthy of note that glycogen concentration remained essentially constant **in vivo** experiments where plasma glucose was remained relatively constant. It has been found that the heart glycogen level is reduced by lowering the blood sugar and lactate concentraitons during an increase work load imposed on the working isolated heart. When either blood glucose or lactate concentration were maintained at normal levels, there was a prevention of a substantial glycogen loss[23]. Recently Bloom et al.[21] also observed glycogen levels of hearts from the anoxic rats and found that hearts beating against large work loads showed a rapid decrease in glycogen concentration was observed in the non working anoxic heart. In our non working heart preparation, pyruvate concentration was maintained relatively constant and blood lactate was increased a mean of 60% at the end of experiment(table 1), and also found that there are no net change in cardiac glycogen before and after the experiments. These fingings comfirm the view that cardiac glycogen level would be constant in the postabsorptive intact dog where blood sugar was remarkably maintained constant. Therefore, conditions in both **in vitro** and **in vivo** experiments agreed with the first and second assumptions which is necessary for steady state glycogen turnover in the calculation by "C^{14}-glucose dilution method".

There are some controversy to apply the third assumption described above in the determination of glycogen turnover with either the single injection method or constant infusion method of C^{14}-glucose[9] proposed by the author. These results on the turnover rate of glycogen indicate much more rapid replacement of dog heart glycogen both **in vitro** and **in vivo** than are reported on intact rats by Stetten and Boxer[6], in which D_2O was employed as a tracer. In the Stetten's work, the half time($t\frac{1}{2}$) of liver glycogen was found to be one day while that of carcass glycogen was 3.6 days. As shown in table 4, however turnover rates of the cardiac glycogen by single injection method referred to as C^{14}-glucose dilution method and constant infusion method reported earlier by author[10] were a mean of 6.3% per hour and 6.4% per hour, respectively, in the isolated dog heart. We also obtained very close agreement with these data in the intact dog heart(table 4).

<Table 4> Comparison of data of turnover rate of the cardiac glycogen by single and constant infusion method of C^{14}-glucose.

	unit	isolated heart		intact heart
		constant injecton method of C^{14}-glucose	Single injetion of C^{14}-glusruc	
turnover rate	%/hr	6.4	6.3	5.3
t 2/1	hr	11.3	10.9	13.4

Since the work of Stetten and Boxer was performed on intact rats under widely different experimental conditions from ours and since they did not isolate cardiac glycogen, quantitative comparison is almost impossible between their data and ours on turnover rate of cardiac glycogen of dog.

Recently, in the Stetten experiments[7,8], gly-

cogen samples were obtained from carcass and livers of rats from 3 to 48 hours after intraperitoneal injection of C^{14}-glycose. Each glycogen sample was digested with various enzymes such as β-amylase or phosphorylase and distribution of isotope between peripheral maltose or glucose unit and limit dextrin was determined. Their results showed that radioactivity of the peripheral tier of carcass glycogen was always higher than that of limit dextrin within 6 hours period. By the 12 th hour, this relationship is reversed, higher specific activity being found in the limit dextrin than in the peripheral glucose. In our series of experiments, in each case, cardiac glycogen was isolated within 4 to 6 hours after the single or constant infusion of C^{14}-glucose was commenced. Therefore, Stetten's data for carcass glycogen can be considered at least qualitatively applicable to heart glycogen, it would seem reasonable to suppose that turnover was occurring primarily within the more metabolically active peripheral tiers of cardiac glycogen during our experimental period. If this reasoning is correct, our values reported here for glycogen turnover probably apply to some average for total glycogen, containing both peripheral layers and limit dextrin, with rapid turnover being principally restricted to the former.

Since the Stetten's work indicates that it is probably an over-simplification to assume complete homogeneity of liver and carcass glycogen, interpretation of data based on the usual assumptions in turnover calculations must be modified. However, half times and turnover rates calculated from the above equations seems at least valid in indicating an order of magnitude for cardiac glycogen replacement from blood glucose.

Furthermore, we have provided here direct isotopic evidence that cardiac glycogen, at least under the conditions of our perfusion experiments, cannot be considered a metabolically inert and insulated material unable to participate in the chemical conversions of heart muscle. Indeed, our results suggest that a rather rapid interchange may occur between plasma glucose and cardiac glycogen. Thus the work presented here leads one to believe that cardiac glycogen may be a much more labile metabolic commodity that had previously been supposed by earlier students of heart metabolism[25].

SUMMARY

The turnover rates of glycogen isolated from **in vitro** and **in vivo** were measured by single injection method of C^{14}-glucose, referred to as "the C^{14}-glucose dilution method", in 13 dogs. In the Langendorff perfusion experiments, glyogen levels of the isolated heart were maintained relatively constant during the experiment, showing a mean of 554 mg and 516 mg per 100 gm of cardiac tussue before and after the experiments. These value were in fair agreement with those of in the intact heart. The specific activity of plasma glucose after single injection of C^{14}-glucose showed an exponential decrease with time both **in vivo** and in **vitro** experiments.

in vitro case, the calculated theoretical specific activity of plasma glucose was very close with the actually measured specific activity. Calculation made for the turnover rate of cardiac glycogen yielded values ranging from 5.9% to 7% of glycogen replaced per hour by labeled glucose with a mean of 6.3% per hour in 5 **in vitro** experiments. In 8 **in vivo** experiments the values ranged between 4.3% and 6.8% with a mean of 5.3% per hour.

Calculations of the half time ($t\frac{1}{2}$) for cardiac glycogen turn over gave values of a mean of 10.9 hr. **in vitro** and 13.4 hr. **in vivo,** respectively.

These data **in vivo** and **in vitro** for the cardiac glycogen turnover, including data obtained by constant infusion method of C^{14}-glucose in our earlier study, were in close agreement each other.

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—국문초록—

C^{14}-포도당 단일 주입법으로 측정한 정상생체내 및 적출한 심장의 glycogen 교체율에 관한 실험

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C^{14}-포도당의 단일 주입을 한후 "C^{14}-포도당 희석법"에 의거하여 8마리의 정상한 개의 심장 및 5마리의 적출한 개의 심장에서 분리한 glycogen의 교체율을 측정하여 다음과 같은 성적을 얻었다.

1) 정상견의 심장 glycogen의 조직 농도는 평균 504 mg/100 gm 심장근이고 적출한 개 심장의 glycogen농도는 평균 516 mg/100 gm 심장근이었다. 특히 후자에

서는 실험 전후에 glycogen 농도를 측정한 결과 별 변동이 없이 비교적 일정하였다.

2) 정상견 및 적출한 개 심장의 Langendorff 관류계내의 혈장 C^{14}-포도당의 specifie activity는 시간에 따라지수적으로 저하하였고 적출한 개 심장의 관류계에서 측정한 값은 이론값과 근사하였다.

3) 위와 같은 실험성적을 기준으로 하여 "C^{14}-포도당 희석법"으로 심장의 glycogen 교체율을 측정한 즉 정상견의 심장에서 평균 5.3%/hour이고 반주기($t_{\frac{1}{2}}$)는 13.4시간이었으며, 적출한 개 심장의 glycogen 교체율은 평균 6.4%/hour이고, 반주기는 10.9신간임을 계산하였다,

4) "C^{14}-포도당 희석법"으로 계산한 심장 glycogen의 교체율 성적은 본교실에서 C^{14}-포도당의 계속주입법으로 측정하여 적출한 개 심장의 glycogen 교체율성적과 비등하였음으로 "C^{14}-포도당 희석법으로 인한 glycogen 교체율 측정의 간편성 및 정확성을 재 확인 하였다.