Differences in Concentration of Galactose in Arterial, Capillary, and Venous Blood Following a Single Intravenous Injection

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Galactose concentration was studied in simultaneously removed samples of arterial, venous, and capillary blood following a single intravenous injection. The venous concentrations were for a period higher than the arterial ones. The capillary concentrations were not different. Galactose elimination capacity for arterial blood did not differ significantly from that for venous or capillary blood, while galactose half-time for arterial blood differed from that for venous blood but not from that for capillary blood. It is concluded that for theoretical studies arterial blood is to be preferred.

Key-words: Galactose differences; galactose elimination; liver

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During recent years interest has been centred, especially in Scandinavia, on intravenous galactose tolerance as a quantitative test of liver function (5, 6, 10).

At present there are two fundamentally different methods for assessing the galactose elimination of the liver. In one method, described by Tygstrup (7), arterial blood is used for the analyses, and the galactose elimination is calculated from a linear elimination curve following a single intravenous injection of 2.78 mmol (500 mg) galactose per kg body weight. In the other method, described by Tengström (6), capillary blood is used, and the half-time is calculated from a semilogarithmic curve following a single intravenous injection of 1.94 mmol (350 mg) galactose per kg body weight.

The object of the present study was to decide whether differences are demonstrable, after a single intravenous injection of galactose, in the concentrations found in simultaneously taken specimens of arterial, venous, and capillary blood, and the influence, if any, of these differences upon the determination of the galactose turnover in terms of the galactose elimination capacity (GE) and the half-time (T/2) in order to determine which form of blood sampling is most expedient.

MATERIAL AND METHODS

The material comprised eight in-patients aged 40-72 years, average age 58 years, of whom five had no diseases of the liver or biliary tract, and three had cirrhosis of the liver. All the cirrhotics had ascites and oedema. The criteria of normal liver function were: a history negative for diseases of the liver or biliary tract as well as a normal haemoglobin level, erythrocyte sedimentation rate, alkaline phosphatases, serum glutamic oxalacetic transaminase, serum paper electrophoresis, and a normal 45-minute bromsulphalein retention test. In all the cirrhotics the diagnosis had been confirmed histologically.

After fasting for 14 hours the patient had

2.78 mmol galactose per kg body weight injected intravenously in the course of 3 minutes. By an indwelling arterial and venous needle and by puncture of the earlobe, blood samples were drawn simultaneously at 5-minute intervals (except the first sample, which was taken 10 minutes after the start of injection) for a period of 90 minutes.

The arterial needle was inserted into the femoral artery after local anaesthesia and connected to a polyethylene tube with a three-way stop-cock. The system, volume 1.5 ml, was filled with heparinized saline (20,000 i.u. per litre of isotonic saline). Prior to each blood sampling, the heparinized saline and 5 ml blood were removed by a syringe. Immediately thereafter, the sample was drawn, average sampling period 3 seconds.

The venous needle was placed into the brachial vein after local anaesthesia and connected to a polyethylene tube, with a three-way stop-cock, of the same length and type as used for the arterial needle. To puncture the earlobe we used a disposable lancet; the puncture wound was 4 mm deep and 1 mm wide. The period for removing the capillary blood averaged 45 seconds, but the mid-points of the periods required for taking arterial, venous and capillary blood were made to coincide.

The blood was collected into test tubes containing 7.4 μmol potassium oxalate and 238 μmol sodium fluoride.

The whole blood was analysed for galactose by the galactose oxidase method described by Hjelm (2). Duplicate analyses were done on all blood samples. On the basis of the duplicate analyses, the standard deviations for capillary, venous, and arterial blood were found to be 0.227, 0.127, and 0.156 mmol/l, respectively. The standard deviation for capillary blood is significantly greater than that for the other two, which do not differ significantly from each other. The standard deviation calculated from the duplicate analyses was independent of the concentration within the range studied (1.39-13.88 mmol/l).

During the 24 hours after the study all urine was collected and analysed in the dilution 1:25, in the same way as the blood.

GE was calculated from the formula

$$GE = \frac{M - U}{tc=o + 7 \text{ min}}$$

where M is amount injected, U excreted amount in urine, tc = 0 time to concentration zero calculated from the slope of the elimination curve in the interval 20 minutes after the injection to a concentration of 2.22 mmol/l. Seven minutes are the empirically found correction for uneven distribution of galactose in the arterial blood (7). In calculating GE for capillary blood the same correction of 7 minutes is applied, but in calculating GE for venous blood a correction of 4 minutes is used (9).

T/2 is the galactose half-time calculated from a semilogarithmic plot of the whole elimination curve.

In a separate experiment haematocrit values were determined in 10 samples of arterial and 10 of capillary blood drawn simultaneously at 5-minute intervals after a single intravenous injection of galactose. The investigation was carried out in heparinized capillary tubes centrifuged for 5 minutes at 12,000 rpm.

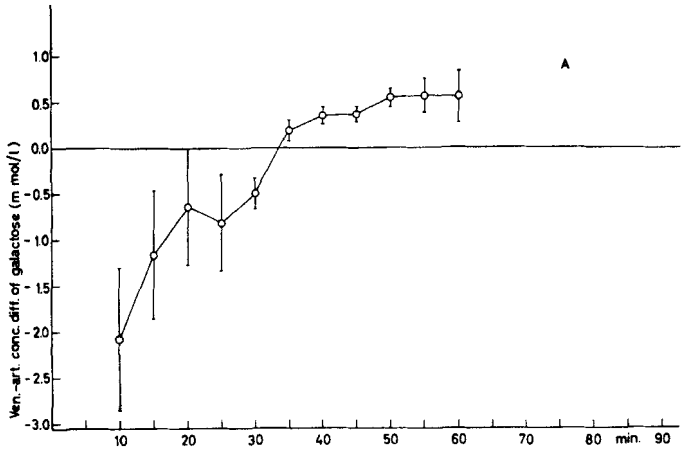
RESULTS

Fig. 1A shows the mean veno-arterial concentration differences in three normals, two having been excluded because of difficulties in keeping the venous needle patent. The mean differences at each point differ significantly from 0 ($P < 0.05$) in the interval 40-55 minutes while outside this interval they do not.

Fig. 1B shows the mean capillary arterial differences from all five normals. The mean difference at each point does not differ significantly from 0. The mean difference from all experimental points is significant ($P < 0.01$).

Fig. 2A illustrates the mean veno-arterial concentration differences from the three cirrhotics. The mean difference at each point differs significantly from 0 ($P < 0.05$) in the interval 45-55 minutes, while outside this interval they do not.

Fig. 2B shows the mean capillary arterial concentration differences from the three cir-



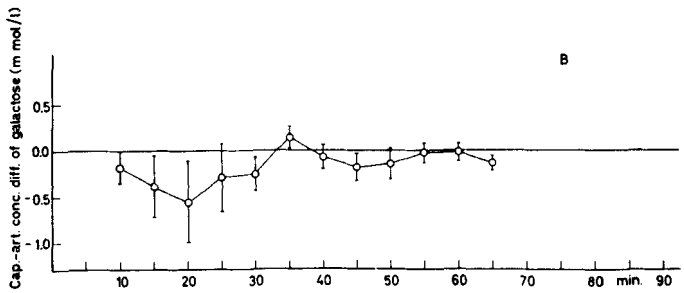
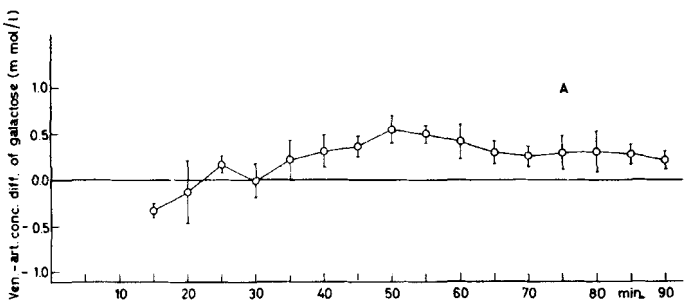


Fig. 1. A. Mean differences in galactose concentration between venous and arterial blood after single intravenous injections in 3 normal subjects. The standard error of the mean is marked by vertical lines. B. Mean differences in galactose concentration between capillary and arterial blood after single intravenous injections in 5 normal subjects.



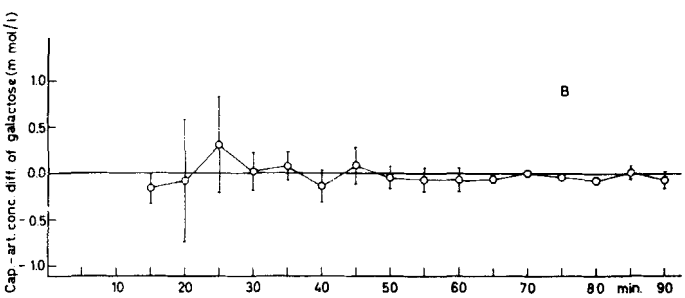


Fig. 2. A. Mean differences in galactose concentration between venous and arterial blood after single intravenous injections in 3 cirrhotic subjects. The standard error of the mean is marked by vertical lines. B. Mean differences in galactose concentration between capillary and arterial blood after single intravenous injections in 3 cirrhotic subjects.

Table I. Galactose elimination capacity (GE) calculated from arterial and capillary blood in 5 normal and 3 cirrhotic subjects and from venous blood in 3 normal and 3 cirrhotic subjects after single intravenous injections

No.	Sex	Diagnosis	GEart. mmol/min	GEcap. mmol/min	GEven. mmol/min
1	f	normal	2.20	2.01	
2	m	normal	2.86	2.96	2.73
3	f	normal	2.46	2.44	2.40
4	m	normal	2.02	1.89	
5	m	normal	2.39	2.36	1.98
6	m	cirrhosis	2.49	2.47	2.39
7	m	cirrhosis	0.87	0.91	0.79
8	f	cirrhosis	1.34	1.40	1.35

rhotics. The mean difference in each point does not differ significantly from 0. The mean difference from all experimental points is not significant ($P > 0.10$).

Table I gives the values for galactose elimination capacity (GE) calculated by the method of Tygstrup (7) from the concentrations in the arterial, capillary, and venous blood. The GE for arterial blood was, on the average, 6 per cent higher than the GE for venous blood. This difference is on the borderline of significance ($0.05 < P < 0.10$). GE for arterial blood was, on the average, 1 per cent higher than GE for capillary blood. This difference is not significant ($P > 0.4$).

Table II gives the T/2 calculated by the method of Tengström (6) for arterial, capillary, and venous blood. T/2 for arterial blood was, on the average, 18 per cent shorter than for venous blood. The difference is significant ($P < 0.05$). T/2 for arterial blood was, on the average, 6 per cent longer than for capillary blood. The difference is not significant ($P > 0.10$).

The haematocrit values proved to be, on the average, 1.1 vol per cent higher in capillary than in arterial blood. The difference is significant ($P < 0.02$).

DISCUSSION

The differences found between the levels of galactose in venous and arterial blood must be taken to indicate that during the time immediately following upon the injection, the galactose diffuses from the arterial blood to the extravascular space and later back to the blood. In the curves illustrating the mean veno-arterial differences (Figs. 1A and 2A) the time until the difference 0 can be estimated at 33 minutes in normals and 22 minutes in cirrhotics. An assessment from a single case with respect to this time is not possible. If the times 33 and 22 minutes indicate the time elapsing

Table II. Half time of galactose (T/2) calculated from arterial and capillary blood in 5 normal and 3 cirrhotic subjects and from venous blood in 3 normal and 3 cirrhotic subjects after single intravenous injections

No.	Sex	Diagnosis	T/2art. (min)	T/2cap. (min)	T/2ven. (min)
1	f	normal	22.5	17.9	
2	m	normal	16.5	16.3	19.2
3	f	normal	13.7	13.6	18.5
4	m	normal	25.3	25.5	
5	m	normal	19.4	18.9	29.2
6	m	cirrhosis	20.4	20.1	22.8
7	m	cirrhosis	65.5	57.9	77.2
8	f	cirrhosis	33.4	32.0	35.4

until diffusion equilibrium, it is longer than the period of 15-20 minutes stated by Tygstrup (8). It seems peculiar that in our experiments the time until diffusion equilibrium is longer in normals than in cirrhotics, but as the calculation of the times is very questionable, and the materials are small, it might be a coincidence. Tygstrup states that the time to diffusion equilibrium in cirrhotics is frequently longer than in normals (8). Incidentally, the time found seems to correspond well to the equilibration time for substances of a molecular weight in the same range as that of galactose. For instance Newman, Bordley, & Winternitz (3) have reported approx. 20 minutes and Elkinton (1) some 30 minutes for mannitol, Raisz, Young & Stinson (4) approx. 30 minutes and White & Rolf (11) approx. 30 minutes for sucrose.

In the curves illustrating the mean capillary-arterial differences the time until the difference 0 can be estimated from the graphs at 33 minutes in normals and 21 minutes in cirrhotics. The times do not differ from those found from the venous-arterial differences. It is strange that the capillary-arterial differences in both curves after the difference zero have a tendency to be negative.

Part of the explanation might be a possible admixture of blood from the arterial part of the capillary, which will give a smaller concentration difference, while an admixture of blood from the venous part of the capillary will give a larger concentration difference. A possible admixture of interstitial fluid will also give a larger concentration difference. Another part of the explanation might be the significantly larger haematocrit values in capillary blood than in arterial blood. If this difference is due to the erythrocytes being larger in capillary blood than in arterial blood, the concentration of galactose will not change, provided the galactose distributes evenly in the water compartment of the red cells. On the other hand, if the difference is due to a larger number of red cells in the capillary blood because of the sample technique, the content of dry matter in the samples will be increased, and thereby the concentration of galactose determined from capillary whole blood will be reduced.

Theoretically, the use of arterial blood would appear to be the best choice, since in the divisions of the vascular system the galactose concentration is best defined in the arterial blood. In practice, however, the removal of arterial blood is sometimes rather cumbersome and may be accompanied by disadvantages such as vaso-vagal attacks and formation of haematoma at the site of the puncture. The sampling of capillary blood is easier and does not carry any major disadvantages. However, the concentration of galactose in the samples will depend upon a number of partially uncontrollable factors. The use of venous blood is not well suited to studies of the galactose elimination, inter alia because the veno-arterial differences will presumably vary in different venous areas and will depend also upon the circulation time.

For clinical use it is presumably immaterial whether arterial or capillary blood is used, but for theoretical investigations on the galactose elimination arterial blood is preferable.

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