2012 International Conference on Nutrition and Food Sciences
IPCBEE vol. 39 (2012) © (2012) IACSIT Press, Singapore

A Comparison between Venous and Finger-Prick Blood Sampling on Values of Blood Glucose

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Abstract. It is important for people and especially diabetes patients to monitor their blood glucose concentrations which may obviously fluctuate from time to time due to various factors such as daily activity, mental status, diet component, and environmental change. The purpose of this study is to investigate changes in fasting and postprandial blood glucose values of 12 healthy voluntary subjects, who were asked to take 50g glucose solution, during 2 hours and compare correlations and differences based on two types of blood samplings, venous blood sampling and finger-prick blood sampling. It can be seen from experimental results that (1) there is no significant difference between the fasting venous blood glucose value (87.4±0.4 mg/dL) and the fasting capillary blood glucose (91.6±4.4 mg/dL) (0 min); (2) there is significant difference between the postprandial venous blood glucose concentration and the postprandial capillary blood glucose concentration, both of which reach the maximum levels at 30 min (postprandial venous blood glucose value=122.0±1.2 mg/dL; postprandial capillary blood glucose value=163.8±1.3 mg/dL), with glucose solution ingested by subjects; (3) the mean capillary blood glucose concentration is higher than the mean venous blood glucose concentration by 35%; (4) the correlation coefficient $r=0.875$($p<0.001$) suggests statistical discrepancy and positive correlation between two groups of blood glucose concentrations which imply the venous blood glucose concentration is a better indicator to clinically test blood glucose due to higher stability and fewer interference factors.

Keywords: Glucose solution, Blood glucose, Venous blood sampling, Finger-prick capillary blood sampling

1. Introduction

As a base of diabetes treatment, blood glucose monitoring contributes to clinically determining the level of carbohydrate metabolism, formulating therapeutic measures, evaluating effects, and realizing optimal blood glucose control. Intensive blood glucose monitoring and strict blood glucose control significantly eliminate or postpone occurrence or development of chronic diabetic complications. It is important to monitor accurate blood glucose concentrations which may obviously fluctuate from time to time due to various factors such as daily activity, mental status, diet component, environmental change. Blood glucose monitoring is also a necessary method adopted by many food nutrition experts to investigate the carbohydrate-induced glycemic reaction in addition to its clinic applications to diabetes patients. The common practice to control diabetes patients' diets focuses on weight of carbohydrate ingested rather than categories of carbohydrate diets which have different physiological effects on blood glucose concentrations. To properly control blood glucose and reduce incidence of diabetes patients' metabolic syndrome, coronary artery diseases and cancers, Jenkins *et al*. who depended on status of carbohydrate assimilated in human bodies offered the concept of Glycemic Index (GI) and the theoretical relationships between GIs and diseases in 1981 and classified GI values of various foods as one guideline to choose diets for diabetes patients (Jenkins, 1981). In contrast to the blood glucose value for diagnosis of diabetes referring to venous plasma

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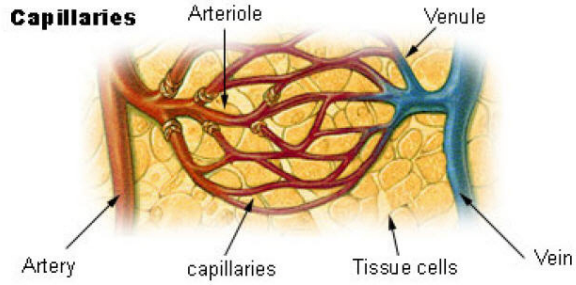
glucose based on the criteria of the World Health Organization (WHO), the measurement of a GI value for food is available in both finger-prick blood sampling and venous blood sampling according to the Food and Agriculture Organization (FAO) and the World Health Organization (WHO). The finger-prick blood sampling is to collect blood in peripheral capillaries and the blood glucose concentration approximates to the level of arterial blood glucose (Rasaiah, 1985). Despite few differences between fasting capillary blood glucose and fasting venous blood glucose, postprandial venous blood glucose is lower than postprandial capillary blood glucose by 7% because glucose absorbed by the human body is sequentially conveyed into arteries and tissue cells via diffusion in peripheral capillaries and some remaining glucose returns to veins.. Accordingly, the level of arterial blood glucose or postprandial capillary blood glucose is higher than that of postprandial venous blood glucose due to capillaries close to an artery (Figure 1).



(Burtis, 1994)

Figure 1: Schematic illustration of an artery, a vein and capillaries

2. Materials and methods

2.1. Subjects

The subjects selected in the study were twelve healthy adults, five females and seven males whose ages were between 18 and 26. These subjects' detailed characteristics are listed in Table 1. Subjects recruited were based on the following criteria: 1) healthy and stable weight prior to the study; 2) not dieters; 3) not smokers; 4) not taking prescription medication; 5) normal fasting glucose (Brand-Miller, 2004). All twelve subjects were asked to avoid alcohol, legumes and fried foods and eat a regular meal the night before test (Brand-Miller, 2005). The procedures of the study were explained to the subjects verbally and by a written notification. Informed consent was obtained from each subject before the enrollment. The study was approved by the Institutional Review Board of the Pingtung Christian Medical Hospital.

Table 1: Characteristics of subjects

Gender	Participants	Age	Weight (kg)	Height	BMI (kg/m^2)
Females	5	23.8±2.2	54.6±5.2	159.6±7.9	21.4±1.5
Males	7	20.4±2.3	67.83±3.8	174.4±6.3	22±1.3

2.2. Experimental Procedures

In this study, the paired samples such as finger-prick blood sample and venous blood sample were collected. The subjects who arrived at the laboratory at eight to nine o'clock in the morning had experienced 10/12-hour overnight fast. Each subject was fed 50 g glucose solution served with 220 ml of water. A venous blood sample (1.5 ml) was collected by one professional nurse who placed a scalp needle on one subject's forearm; a finger-prick capillary blood sample (1.5 ml) was gathered in an automatic lancet device (Safe- T-Pro; Roche Diagnostics GmbH Mannheim, Germany). All blood samples were taken immediately according to the rules: before eating (0 min) and every 15, 30, 45, 60, 90, and 120min after eating. The collected blood samples were injected in heparinized tubes and centrifuged for 3 min at 12500 x g and 4^{0}C to obtain plasma. Plasma was spotted onto a slide which contained a reagent layer (glucose oxidase and peroxidase (YSI 7100 Multiparameter Bioanalytical System)) for glucose concentrations.

2.3. Statistical Analysis

The statistical significance of differences between values was assessed by a paired *t* test and repeated-measures analysis of variance (ANOVA). Data were analyzed by SPSS Windows Release 15.0 (Standard Version, Germany) to determine significant differences. A value of $p<0.01$ was considered as significance.

3. Results

The comparisons of 12 subjects' capillary blood glucose concentrations and venous blood glucose concentrations based on two types of blood samplings are presented in Table 2 and Figure 2. As shown in Figure 2, both the peak value of venous blood glucose concentrations (115.5±1.3) and the peak value of capillary blood glucose concentrations (163.8±1.3) are observed at 30 min and the later is significantly higher than the former. The data regarding differences and mean percentages for blood glucose concentrations based on two blood samplings are shown in Table 3 and Figures 3 & 4. The data, for instance, the differences between postprandial venous blood glucose concentrations and postprandial capillary blood glucose concentrations (41.8% at 30 min; 49.5% (maximum) at 90 min) and the difference in fasting blood glucose concentrations for two blood samplings (4.8% (minimum)), imply the significant difference due to glycemic reaction with glucose solution ingested by subjects: (1) postprandial capillary blood glucose significantly higher than postprandial venous blood glucose; (2) blood glucose concentrations in each of both groups of data gradually descending over time and reaching the lowest level at 120 min; (3) smallest difference observed between fasting venous blood glucose and fasting capillary blood glucose. The correlation coefficient of 0.87 ($p<0.01$) between two groups of postprandial glucose concentrations suggests significantly positive correlation between capillary blood glucose and venous blood glucose.

Table 2: Venous and capillary blood glucose concentrations at different time points

time	0	15	30	45	60	90	120
V	87.4±4.3	105.6±0.4	115.5±1.3	116.4±0.6	101.4±1.8	84.4±1.3	72.0±1.5
F	91.6±4.4	139.7±3.1	163.8±1.3	153.4±0.9	141.7±0.8	126.2±1.2	102.0±1.7

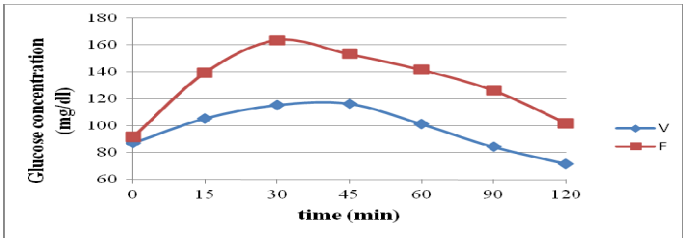


Fig. 2: Comparisons between capillary and venous blood glucose concentrations at different time points

Table 3 Venous and capillary blood glucose concentrations at different time points

	0	15	30	45	60	90	120
V	87.4	105.6	115.5	116.4	101.4	84.4	72
F	91.6	139.7	163.8	153.4	141.7	126.2	102
diff	4.2	34.1	48.3	37	40.3	41.8	30
diff %	4.8%	32.3%	41.8%	31.8%	39.7%	49.5%	41.7%

4. Discussion

It can be seen from blood glucose concentrations based on two types of blood samplings, venous blood sampling and finger-prick blood sampling, in this study that the mean capillary blood glucose concentration is higher than the mean venous blood glucose concentration by 35% and the phenomenon of capillary blood glucose concentrations greater than venous blood glucose concentrations is common at all time points. Furthermore, the minimum difference between the fasting capillary blood glucose concentration and the fasting venous blood glucose concentration is similar to the literature (Katja, 2006).

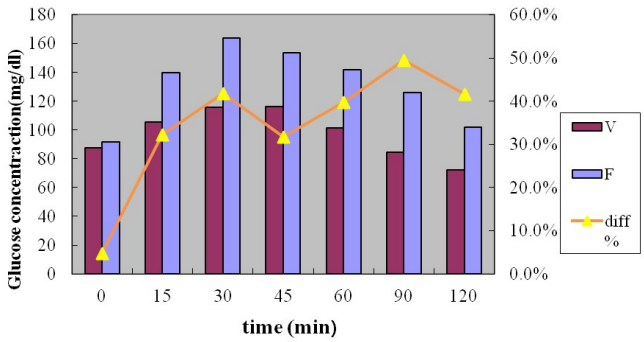


Fig. 3: Mean percentages of glucose concentrations based on two types of blood samplings at different time points: difference of 41.8% at 30 min; maximum difference at 90 min; minimum difference in fast status.

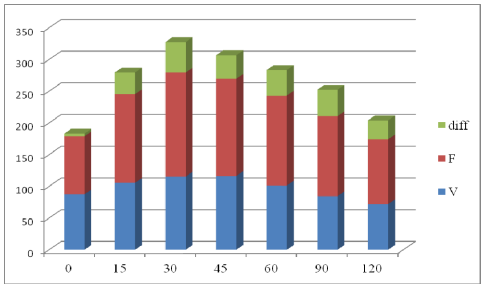


Fig. 4: Differences between glucose concentrations based on two types of blood samplings at different time points: maximum difference of 48.3 at 30 min; minimum difference in fast status.

The argument of capillary blood glucose concentrations inaccurate is disputable. The blood glucose is defined as venous plasma glucose according to the criteria of WHO to diagnose diabetes but the whole blood glucose on the peripheral capillary basis is available in a glucose meter. As one simple and convenient tool, the glucose meter is applicable to self-monitoring of blood glucose values which are accurate enough but proportional to venous plasma glucose values by a stable factor of 1.12 due to a different numerical benchmark rather than an error. The normal ranges of fasting blood glucose concentrations and postprandial blood glucose concentrations at 120 min are 70-110 mg/dL and ≤140 mg/dL, respectively. Referring to the World Health Organization and the International Diabetes Federation, the criteria to diagnose diabetes are the fasting plasma glucose concentration (antecibum, AC) ≥ 126 mg/dL or the 2-hour postprandial blood sugar concentration ≥ 200 mg/dL. In addition to the above descriptions, the criteria to diagnose diabetes formulated by the World Health Organization and the American Diabetes Association (ADA) in 2005 include the blood glucose concentration ≥ 200 mg/dL anytime or the 2-hour postprandial blood sugar concentration ≥ 200 mg/dL with 75g glucose ingested by one patient in an Oral Glucose Tolerance Test (OGTT) (ADA, 2006). It is very important to clinically test an accurate blood glucose value and immediately find out symptoms of diabetes without further deterioration.

In our experiments, the finger-prick blood samplings are different from general self-monitoring finger-prick blood samplings collecting whole blood and feature blood gathered from finger pulps which are centrifuged to obtain plasma and further blood glucose values for analyses. Furthermore, our finger-prick blood samplings are to collect peripheral capillary blood in which blood glucose concentrations approximate to arterial blood glucose concentrations (Rasaiah 1985) because glucose assimilated by the human body is sequentially conveyed into arteries and tissue cells via diffusion in peripheral capillaries and some remaining glucose returns to veins. Accordingly, both arterial blood glucose concentrations and postprandial capillary blood glucose concentrations are higher than venous blood glucose concentrations in virtue of capillaries close to an artery (Burtis, 1994). The similar results are also presented in our experiments. The postprandial capillary blood glucose concentrations detected at different time points with 50g glucose solution taken by subjects and the fasting capillary plasma glucose concentration are higher than the postprandial venous blood glucose concentrations and the fasting venous blood glucose concentration, respectively; the differences between postprandial capillary blood glucose values and postprandial venous blood glucose values are 41.8% (at 30 min) and 49.5% (at 90 min), respectively.

The correlation coefficient of 0.87 (p<0.01) due to the positive correlation between postprandial venous blood glucose and postprandial capillary blood glucose with 50g glucose solution taken by subjects suggests two isometric-ascending or isometric-descending blood glucose concentrations at all time points except two fasting blood glucose concentrations which are slightly different. In this regard, the glucose regulation mechanism which is naturally developed in the human body having experienced fast overnight causes arterial blood glucose, venous blood glucose and capillary blood glucose concentrations almost the same due to blood glucose concentrations regulated by two endocrine hormones such as insulin and glucagon: (1) Insulin secreted by pancreatic β-cells with blood glucose concentrations ascending facilitates blood glucose absorbed by liver, muscles and adipose tissues but reduces blood glucose concentrations; (2) Glucagon with features opposite to insulin facilitates glycogenolysis, decomposition of triglycerides, and gluconeogenesis (a process of amino acid synthesized to carbohydrate) and promotes lowered blood glucose concentrations and glucose balance (Philip L, 2007). Thus, there is no significant difference between fasting venous blood glucose and fasting capillary blood glucose.

Despite the glucose value for diagnosis of diabetes referring to venous plasma glucose based on the criteria of the World Health Organization (WHO), GIs for foods can be available in both finger-prick blood samplings and venous blood samplings according to the Food and Agriculture Organization (FAO) and the World Health Organization (WHO). The progressive development of food science in GIs for foods recently contribute to controlling diabetes patients' symptoms or obese people's diets wherein finger-prick blood samplings used to test blood glucose concentrations by lots of labs are also favorable to good experimental results.

5. Acknowledgements

Authors would like to acknowledge the financial support of this study by the National Science Council of ROC (Taiwan) under the project number of NSC 100-2221-E-020-002.

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