Glucose measure in arterial or in venous blood

Abstract
In current medical practice glycaemia is measured in blood collected from vein or capillaries.

In Intensive Care Units or during surgery, blood glucose is measured by pH meter from arterial catheters. Does a difference exist between the results of both measures? What might be its signification and consequences? The aim of this work was to give a beginning of answer to these questions.

Experiments conducted on 26 rats and analysis of 69 reports of Intensive Care Unit patients have shown that a significant difference in glycaemia depending on the origin of the collected blood (from arteries or from veins) may be observed mainly in pathological conditions or at the end of life.

Interpretation, possible explanations and consequences of this phenomenon are discussed and a hypothesis is proposed. The use of simultaneous double glucose determination in clinics is suggested.

Keywords: glucose metabolism, blood glucose measure, glycaemia, intensive care

Materials and methods
Experiments were conducted on 26 Wistar and Fisher rats, 21 males and 5 females, body weight 292-400 g under Nembutal anaesthesia (0.075 mg/kg). (Ethic Committee approbations N° 414N and 606N). In the first group (16 animals) only anaesthesia was performed and death was caused by anaesthetic drug overdose. In the second group (10 animals) after anaesthesia laparotomy was performed, ligatures were placed on ligamentum hepatoduodenale first (to avoid engorgement of the liver), then, on hepatic veins, in order to stop the outflow of the liver in direction of the heart. Blood collection was performed by puncture of the heart in the first hour after anaesthesia. Later the venous glycaemia had a tendency to diminish with time, especially after death (Figure 1).

In rats glycaemia was determined once an hour by strips method only (glucometer One Touch, Switzerland or Accutrend, USA). In clinics, blood glucose was measured with the use of the “ADL-90 Flex” gasometer.

Taking into account the reliability of glucometers (±2% of the measured ciphers) we took in consideration as significant a difference no less than 5 mg/dl between the results of different measures when glycaemia < 200 mg/dl, and no less than 10 mg/dl when glycaemia was > 200 mg/dl.

Statistic evaluation was performed by Mean values ± Standard Deviation calculation and Student criterion Td versus Tst was applied for determination of liability (p).

Results
In experiments on anaesthetized rats, considering each animal glucose measures at every moment, absence of difference between “venous” and “arterial” glycaemia was rather rare; 7.5% before death, none after it (Table 1). In the majority of the cases arterial glycaemia was higher than venous one and this tendency increased with the observation delay (53.8% frequency soon after anaesthesia, 83%-before death, 91.3% after it). A venous glycaemia value higher than arterial one was observed in 23% of the cases soon after anaesthesia; in 8% within 1 hour and 0% 30 min and later after death. Considering the mean values at consecutive observation moments the difference between arterial and venous glycaemia was not significant in the first hour after anaesthesia. Later the venous glycaemia had a tendency to diminish with time, especially after death (Figure 1).

Collecting of blood directly from the hepatic veins has shown a significant glycaemia increase relatively to values obtained in the “peripheral” venous blood, especially soon before and after death.

To verify the role of the liver in this phenomenon, the ligature of the liver veins was performed and, as shown in Table 2, the heart glycaemia has remained low.
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In clinics the retrospective analysis of the laboratory reports of the selected 69 patients has shown that in 52% of the cases, there was a significant difference (from 11 to >200 mg/dl) between glycaemia determined in peripheral (venous) blood and the one from central (arterial or heart) blood. In 1/3 of the cases central glycaemia was higher than venous, more often (2/3 of the cases) it was the contrary (Table 1). The link with pathology causing the acute distress was not examined yet but in the studied cohort 5 out the 6 patients with lethal issue showed a marked difference, venous glycaemia being higher than central one. Anyway other patients with such a difference were successfully transferred to other hospital units.

**Discussion**

In their work concerning glucose assimilation and turn over physiologists, mainly in animal experiments, have already shown that glucose levels are not the same depending from the vessels where the blood was obtained and others. Diabetes specialists have always been aware of the difficulty of liable glycaemia evaluation and continue to improve their method of punctual or continuous recording glucose levels in blood or even in subcutaneous tissues. But the simultaneous registration of glucose levels in different places of the body is rather difficult to imagine in humans, except in ICU or surgery when it may be required.

Our data have confirmed that the results of simultaneous glycaemia determination could be different in values at different moments and conditions depending on the vessel which blood was collected from, either in experiments or in clinics. In experiments our results has shown that in healthy anaesthesitized rats at the beginning of the observation heart blood glycaemia (when it was measured) was the same as or a little higher than peripheral one. This seems logical, as far as the liver is considered as the main place of glucose stocking and neo genesis and liver blood outflow reaches directly the heart. Blood collecting from the hepatic veins has confirmed the hypothesis.

It also seems logical that blood contents in peripheral veins may be lower than in arteriae, because blood has passed through organs and tissues which have utilized the glucose. So no difference or a mild difference between both kinds of values with eventual prevalence of arterial glycaemia could be a sign of the glucose metabolism equilibrium.

At the end of life caused by overdosing the anaesthetics-, venous glycaemia significantly diminished. This could be a sign either of increased needs of the organism, or of a decrease of glucose neo genesis and glycogen reserves. In the last case central glycaemia must be falling at the same time and this might be an alarm signal.

A second complementary explanation has to be considered. At the end of life, when blood circulation was failing, decreasing of the venous (peripheral) glycaemia was understandable due to blood supply decrease, but not the increase of the central one. Our results allow supposing the phenomenon linked with the beginning lysis of the hypoxic liver and the liberation of glucose from protein and other metabolite degradation. In these conditions clamping the hepatic veins ought to stop the increase of glucose contents in the heart blood. That was observed in the second group of experiments (Table 2). Such a brutal important increase of central glycaemia could be a sign of severe liver deficiency or even necrosis.

**Table 1** Incidence of difference between glycaemia values in arterial and venous blood in ICU humans and in experiences on rats

| Series       | Moment | Total Number/% | A = V | A > V | A < V | Total differences |
|--------------|--------|----------------|-------|-------|-------|------------------|
| **RATS**     | Before † | 13/100         | 1/7.5 | 9/53.8| 3/23  | 12 /29.5         |
|              | After †  | 12/100         | 0/0   | 10/83 | 1/8.3 | 11/91.3          |
| **HUMANS**   | Admission | 69 /100       | 32/48 | 13/18.2| 24/34.8| 37/52            |

ICU Intensive Care Unit. †- death

**Table 2** Measured differences between glycaemia values in arterial and venous blood in anaesthetized rats

| Series           | Tail vein Glycaemia (Initial)—mg/dl | Heart glycaemia (Initial)—mg/dl | Tail vein glycaemia ( †)—mg/dl | Heart glycaemia ( †)—mg/dl |
|------------------|-------------------------------------|---------------------------------|--------------------------------|-----------------------------|
| Anaesthesia only | 152.3 ± 13.0                        | 150.83±13                       | 73.3 ± 28 *                    | 312 ± 108 **                |
| N = 10           |                                     |                                 |                                |                             |
| LHD & HV clamp   | 134.11 ± 14                         | 203 ± 47 *                      | 81.6 ± 64 *                    | 148.1 ± 84                  |
| N = 10           |                                     |                                 |                                |                             |

*p < 0.05 relatively to tail vein glycaemia initial values, **p<0.01 relatively to initial tail vein glycaemia

N, number; LHD, hepatoduodenal ligamentum; HV, hepatic vein.

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The main consequence of these observations is the hypothesis that central/arterial glycaemia reflects the glucose amount accessible for the organism use, whereas peripheral/venous one represents the remaining free glucose after utilization by organs and tissues. In normal conditions the difference was minimal because of a quick mobilization of compensator mechanisms. Marked differences in the values of glucose contents in simultaneously collected central and peripheral blood could be an indication of more or less severe alterations of the glucose metabolism: either production or utilization of glucose or both, depending on the sign of the difference observed and on the absolute values obtained.

In clinics the observed tendencies were the same. Though a little less expressed, differences were detected in 52 % of the critically ill patients and arterial glycaemia was low in 5 out of the 6 pre mortem patients that give a beginning confirmation to the above mentioned hypothesis.

Nevertheless the recorded frequency of A>V (18%) was twice less than A<V (34%) that differs from experimental observations and may be due to the specific influence of the patients pathologies Taking into account the relatively limited number of observations and relatively high variety of pathologies present in ICU, the question could not be envisaged in the present study but remains a challenge for further investigations.

We can imagine different approaches of hyperglycaemia in these patients depending of the respective levels of central and peripheral glycaemia. Venous hyperglycaemia may be the consequence of different alterations of insulin production/utilization but also of other mechanisms and factors influencing the glucose metabolism. In such patients insulin administration would not be always pertinent: as already noted, observation of a too strict glycaemia regimen is known to be sometimes dangerous. The levels of central glycaemia and their evolution could be an indicator of the liver function as well, at least partly. For instance poor arterial glycaemia, or too high one, may be one of the markers indicating a liver insufficiency, respectively at its beginning when neo glycogenesis diminishes, or at its end, when lysis has begun. But the very causes of these organ or system pathologies leading to the observed glycaemia disturbances are still poorly known.

Anyway the simultaneous determination of central and peripheral blood glucose seems to be promising and deserves further investigations and studies for verification and possible development.

Conclusion

I. The differences between simultaneously recorded arterial (central) and venous (peripheral) glycaemia and their evolution probably reflect metabolic processes which we are not always aware of,

II. The presence of the absence of these differences can have an importance for understanding not only the physiology but also the disorders of glucose metabolism in different pathologies, as well as for a correct evaluation of the patient’s condition

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Conflict of interest

The author declares there is no conflict of interest.

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