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OSMOTICALLY VOLUMETRIC URINE INDEX IN EARLY RECOGNITION AND EVALUATION OF THE CENTRAL DIABETES INSIPIDUS CORRECTION EFFICIENCY

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Abstract

Purpose of the work: to develop an information criterion for early recognition and evaluation of the homeostasis correction efficiency in central diabetes insipidus.

Materials and methods. 48 neurosurgical patients who underwent traumatic brain injury (21), surgery for a brain tumor (14) and stroke (13), whose course of the disease was complicated by central diabetes insipidus, have been examined. The diuresis rate and urine density (refractometrically) were studied in each of its portions excreted out of the body within an hour. According to the indicator of osmotic density and the range of urine output, an information criterion for the diagnosis of diabetes insipidus and the dynamics of its course was developed – the osmotically volumetric urine index (OVUI).

Results and discussion. With physiological water input, 0.8-1.0 $ml \cdot kg^{-1}$of urine is usually excreted from the human body within an hour. Concurrently, its specific gravity (urine density, UD) is 1012-1025. In 12 patients of the comparison group without diabetes insipidus, the OVUI index was 8.0-12.0. Central diabetes insipidus is characterized by significant homeostasis disorders: blood hypohydration and hyperosmolarity due to violation of hypothalamic-pituitary regulation of antidiuretic hormone secretion. In these conditions the osmotically volumetric urine index decreases to indicators < 1.0. The criterion for the intensive therapy efficiency for homeostasis disorders in diabetes insipidus is OVUI increase above 1.0. The article presents a clinical case of timely recognition and successful correction of homeostasis in a patient with traumatic brain injury complicated by central diabetes insipidus.

Conclusions. The osmotically volumetric urine index – is an indicator that allows diagnosing diabetes insipidus in its early manifestations and timely preventing a violation of homeostasis. With the norm of OVUI at 8.0-12.0, its decrease to < 1.0 indicates the presence of diabetes insipidus in the patient. Timely and adequate correction of disorders of hydration, blood osmolarity and the use of desmopressin lead to the OVUI normalization, which is a dynamic marker of the efficiency of intensive therapy of diabetes insipidus. The simplicity of the study (the possibility of carrying it out directly at the patient's bedside), as well as the informativeness of the OVUI diagnostic and prognostic values deserve to be used in clinical practice.

Key words: central diabetes insipidus; homeostasis; osmolarity; urine density; diuresis rate; osmotically volumetric urine index.

Introduction

In neurosurgical patients with lesions of the hypothalamic-pituitary region, a syndrome of blood osmolarity disorders occurs in 30% of cases. Damage (as a result of craniocerebral trauma and surgical interventions), tumors (craniopharyngeoma, germinoma, glioma, etc.) and severe hypoxic or ischemic brain lesions can be the etiological factors of such disorders.

The so-called central (hypothalamic, pituitary) diabetes insipidus develops (CDI) [1, 2].

The pathogenesis of diabetes insipidus is due to impaired secretion or effect of arginine-vasopressin, which regulates water-electrolyte balance in response to changes in osmolarity and circulating blood volume. With disorders of this mechanism, water is lost in large volumes in urine; dehydration of all body sectors, hypernatremia and thirst occur [3].

Characteristically, in CDI, this hypohydration is accompanied by hypostenuria. The authors [4] note a significant decrease in the urine salt content, the osmotic density of which is < 1005. The osmotic pressure of blood plasma, on the contrary, increases. One of the basic laws of homeostasis is violated – the law of isoosmolarity, leading to general and especially intracellular hypohydration and organ damage.

In their studies, the researchers state [2, 5] that the personnel of neurosurgical clinics and intensive care units still do not pay enough attention to the early manifestations of sodium and water metabolism disorders in patients with cerebral coma; there is no vigilance regarding the development of critical osmolarity disorders in such conditions.

However, monitoring of osmotic parameters of blood, urine and hydration levels in patients with cerebral coma plays an important role in the treatment of acute injuries and brain diseases [6].

Purpose of the work: to develop an information criterion for early recognition and evaluation of the central diabetes insipidus correction efficiency.

Materials and methods

In CH "Feofania", during 2016-2021, 48 neurosurgical patients who underwent traumatic brain injury (21), surgery for a brain tumor (14) and stroke (13), whose course of the disease was complicated by central diabetes insipidus, were examined. 12 patients from the comparison group did not have diabetes insipidus.

Care and intensive care of patients was performed according to the recommended clinical guidelines [7].

Against the background of standard examinations (clinical and biochemical) used in ICU, the patients were specifically examined for the rate of diuresis, urine density and in the blood – the level of basic electrolytes, protein, glucose and urea; the osmolarity of the blood was calculated.

Patients diagnosed with diabetes insipidus were usually in a coma; they are characterized by polyuria (during the day from 4000 to 11000 ml of urine were excreted), hypostenuria and an increase in blood plasma osmolarity.

For the early CDI diagnosis and the prevention of the development of plasma osmolarity disorders, it is important to evaluate both the amount of urine excreted from the body over a certain time (diuresis rate) and to measure the concentration of salts in the urine. Normally, the daily requirement of sodium ions (the main cation of osmolarity) for the human body is 2 millimoles per kilogram of body weight. Accordingly, within an hour, about 0.08 $mmol \cdot kg^{-1}$ of Na^+ ions are excreted from the body with urine. In diabetes insipidus, the excretion of salts from the body, especially sodium, sharply decreases.

When studying the efficiency of renal functions in patients requiring intensive care, the total amount of urine excreted during the day is not of such an informational value as the diuresis rate. It is generally believed that in the normal condition a healthy person excretes urine from the body at the rate of 0.8-1.0 ml/kg body weight within an hour. A diuresis decrease to 0.5 ml kg^{-1} h^{-1} indicates oligoanuria and is an alarming sign of acute kidney damage [8].

In diabetes insipidus there is a diuresis increase above normal: mild – 4-6, moderate – 8-12, and severe – up to 16 l/day [9].

We propose a method for early detection of central diabetes insipidus syndrome based on the simultaneous evaluation of both urinary osmolarity disorders and the hourly urine diuresis rate. This ratio is called osmotically volumetric urine index (OVUI).

The formula is as follows:

$$\mathbf{OVUI = \frac{(UD - 1000) \cdot 100}{3 \cdot Vhour}}$$

where OVUI – osmotically volumetric urine index,

UD – urine density, g/l

Vhour – diuresis rate (volume of urine, in ml, excreted per hour)

Method of OVUI calculation

1. Diuresis rate is measured (volume of urine excreted by the kidneys per hour). Usually in intensive care units, monitoring the diuresis rate in patients with a urinary catheter is a routine examination performed by junior medical staff and supervised by a duty anesthesiologist.

2. In each of the portions of urine excreted from the body per hour, its specific gravity is measured (urine density, UD), which depends on the amount of substances dissolved in it: salts, uric acid, urea, creatinine. UD normally reaches from 1012 to 1025.

Typically, the relative urine density is measured in a clinical laboratory using an urometer (hydrometer scaled from 1000 to 1050). To do this, urine is poured into a 50 or 100 ml narrow cylinder, into which the urometer is lowered and the density is determined along the lower meniscus (the urometer must float freely in the cylinder and not touch its walls) [10].

However, it is much easier to measure its density by a refractometric method. This requires only a few drops of urine and a few seconds for examination.

The Abbe refractometer (or laboratory refractometer) is a visual optical device that allows determining the refractive index of liquids. The principle of refractometer operation is to measure the limiting angle of refraction at the flat interface of two transparent media (investigated and known) when light passes from a medium with a lower refractive index into a medium with a higher index [11].

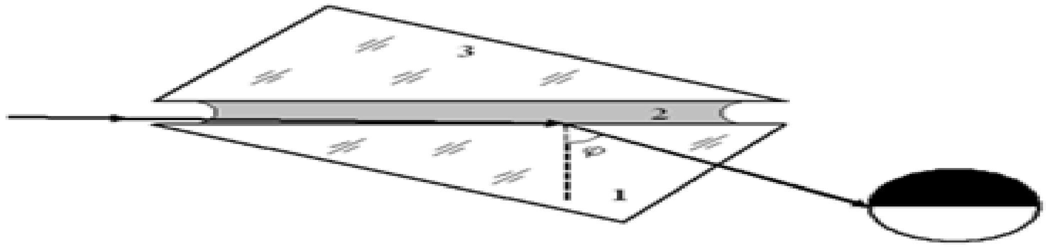

Fig. 1. The principle of refractometric measurement of fluid density

A portable medical refractometer (similar to the Abbe refractometer), which is commercially available, can be used at the clinic to measure a patient's urine density.

Fig. 2. Portable medical refractometer for measuring the urine specific gravity, blood plasma and serum protein

Characteristics of the refractometer.

Refractive index: range: 1.3330 - 1.3600 RI with a resolution of 0.00025 RI and an accuracy of ± 0.00025 RI.

The urine specific gravity (density) can be measured by refractometry in the range: 1.000-1.050 SG (urine specific gravity) with a resolution of 0.002 SG and an accuracy of ± 0.002 SG.

It is also possible to detect serum proteins in the range of 0-12 g/dL with a resolution of 0.2 g/dL and an accuracy of ± 0.20 g/dL.

When carrying out measurements there is an automatic temperature compensation in the range from 10 to 30 °C.

Method of measurement. Urine (2-3 drops) is pipetted onto the prism of the refractometer and covered with a hinged transparent (so-called day) lid, which ensures the spread of liquid on the surface of the prism in a thin layer. By directing the prism to the light source, observation is done through the eyepiece. Light passing through a prism is refracted in an aqueous solution. In the round field of the eyepiece there is a clear boundary between light and dark areas, located opposite the graduated scale. According to the location of this boundary in relation to the scale, the indicator of urine density is read.

It is important that no clinical laboratory is required to obtain the test result; refractometric examination of urine density can be performed directly at the patient's bedside, spending a minimum of time.

Using the calculator, the OVUI calculation according to this formula does not pose any difficulties.

Research results and discussion

In neurosurgical patients of the comparison group who did not have diabetes insipidus, plasma osmolarity was within the normal range. Throughout the observation period, the hourly diuresis rate in them was 60-80 ml, and its density in each portion of urine – 1020-1024 g/l.

Example of OVUI calculation in a patient from the comparison group:

UD = 1024, Vhour = 80 ml/hour

$$OVUI = \frac{(1024-1000) \cdot 100}{3 \cdot 80} = \frac{2400}{240} = 10,0$$

It was found that in all patients of the comparison group OVUI was in the range of 8.0-12.0 (10.0 ± 0.5).

In patients with diabetes insipidus, due to impaired secretion or the effect of antidiuretic hormone, an increase in volume of urine (diuresis rate) occurs with a simultaneous decrease in its osmolarity. We have found that the osmotically volumetric urine index decreases sharply, reaching values of < 1.0.

Clinical example. Patient J., 57 years old, was treated in the intensive care unit after suffering a traumatic brain injury in a coma (the Glasgow coma scale – 7 points). He had no respiratory or hemodynamic disorders. Through an indwelling catheter, 80-100 ml of urine was excreted hourly, the density of which was 1012-1014

Starting from the 12^{th} hour of observations, the diuresis rate increased to 150 ml/h. Refractometric examination of urine revealed that its density was 1003. The calculation was made:

$$OVUI = \frac{(1003-1000) \cdot 100}{3 \cdot 150} = 0,67$$

The obtained result (OVUI < 1.0) caused concern about the development of diabetes insipidus in the patient.

Despite the fact that there were no violations of homeostasis in the study of the patient's blood at present (the osmolarity of the blood plasma was 298 mmol/l), it was decided to use a salt-free liquid (water). It was administered orally through a gastric catheter based on the correction of hydration from the position of zero water balance against the background of hourly OVUI monitoring.

With further intensive care preforming, the following results were obtained:

During the second hour of observations:

Vhour = 180 ml, UD = 1002; OVUI = 0,37. Blood osmolarity – 304 mosm/l.

During the third hour of observations:

Vhour = 160 ml, UD = 1002; OVUI = 0,41. Blood osmolarity – 306 mosm/l.

Over the next six hours, the osmotically volumetric urine index did not rise above 1.0.

The research results showed that the patient developed a complication against the background of a closed traumatic brain injury: central diabetes insipidus. The patient underwent an effective correction of hydremia: within 8 hours he lost 1700 ml of urine, with oral rehydration he was administered with the same volume of water.

During this period, there were no violations of blood plasma osmolarity: the measurement results (308-311 mosm/l) indicated that its osmolarity did not exceed the upper limit of the norm. The highest rate of sodium was 146 mmol/l. However, to prevent further possible disorders of homeostasis, it was decided to supplement the treatment with pathogenetically reasonable therapy – to use a synthetic analogue of the antidiuretic hormone desmopressin. [12].

After endonasal administration, the following result was obtained:

Vhour = 75 ml, UD = 1012; OVUI = 5,33.

At the subsequent therapy to the patient for the indications (criterion of what was decrease in OVUI < 01,0) desmopressin was applied several more times. Rehydration was performed orally with salt-free solutions and with crystalloids – intravenously.

On the 3rd day of treatment, the patient regained consciousness. At this time OVUI was 9.4, plasma osmolarity – 307 mosm/l. There were no indications to use desmopressin. The patient was transferred to the neurosurgical department.

In this case, timely diagnosis of central diabetes insipidus, the use of adequate rehydration and pathogenetic replacement therapy made it possible to prevent the occurrence of an osmotic imbalance in the blood, severe hydration disorders and organ disorders in the patient.

After studying the diuresis rate and urine density in neurosurgical patients, we found that in diabetes insipidus, the the osmotically volumetric urine index in all cases falls below 1.0.

The high accuracy of the research results is due to the multidirectional shifts of pathological changes in diabetes insipidus: a decrease in urine density – in the formula it is reflected in the numeral, and an increase in the volume of urine excreted within an hour, which is reflected in the denominator.

The sensitivity of the central diabetes insipidus diagnosis according to the proposed formula is 100%, the specificity is 100%, and the accuracy is 100%.

When conducting corrective pathogenetically grounded intensive therapy of diabetes insipidus, an increase in the osmotically volumetric urine index of more than 1.0 is observed. The evidence of such therapy efficiency is OVUI increase above 1.0 and the restoration of this indicator to normal (8.0-12.0).

Conclusions

1. The osmotically volumetric urine index – an indicator that allows diagnosing central diabetes insipidus in its early manifestations and promptly preventing a violation of homeostasis.

2. Normally, OVUI is in the range of 8.0-12.0. Its decrease to < 1.0 indicates the presence of diabetes insipidus in the patient.

3. Timely and adequate correction of hydration disorders, blood osmolarity and the use of desmopressin lead to the OVUI normalization, which is a dynamic marker of the efficiency of diabetes insipidus intensive care.

4. The simplicity of the study (the possibility of carrying out many measurements directly at the patient’s bedside), its non-invasiveness, as well as the informativeness of the OVUI diagnostic and prognostic values deserve the introduction of this marker into clinical practice.

There is no conflict of interests.

Conflicts of interest: author have no conflict of interest to declare.

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