Vyšetření moči/Fyzikální

Physical examination consists of assessing **the color** of urine, its **odor** , **foam** and **turbidity** . An important part of the physical examination is the determination of **pH** , **density** and **osmolality** . For the purpose of functional examinations, it is necessary to measure the **volume** of urine for a precisely defined period of time.

Volume

Daily urine volume is significantly affected by fluid and dietary intake. Volumes less than 400 ml / 24 hours and greater than 2500 ml / 24 hours are considered pathological.

Oliguria and anuria

Oliguria is indicated for urine volume <400 ml / 24 hours and **anuria** for urine volume <100 ml / 24 hours.

Oliguria and anuria are the basic symptoms of **kidney failure**. The cause may be dehydration from insufficient fluid intake or increased fluid loss (diarrhea, sweating). Decreased urine volume may be due to primary damage to the renal parenchyma or due to fluid retention (edema, effusions in body cavities).

Oliguria and anuria can also be caused by mechanical obstruction in the urinary tract (prostatic hypertrophy, wedged stone, tumors in the small pelvis). If the obstruction is located below the bladder, we speak of **urinary retention** .

Polyuria

By polyuria we mean an increase in daily diuresis above 2500 ml.

There are two types of polyurethane states:

Polyuria caused by so-called water diuresis .

Water diuresis is due to a **reduction in tubular water resorption** in the distal part of the nephron. Tubular resorption and excretion of osmotically active substances is within normal limits. Urine osmolality is lower than serum osmolality. It is always less than 250 mmol / kg H_2O. Water diuresis is encountered physiologically when a larger volume of water is ingested or, for example, when there is insufficient secretion of antidiuretin (diabetes insipidus).

Polyuria caused by so-called osmotic diuresis .

It is caused either by increased filtration of osmotically active substances due to their increased osmotic concentration in the ECT (eg hyperglycemia) or by their reduced tubular resorption. Unabsorbed osmotically active substances "bind" water to each other and the result is a reduction in their tubular resorption. Urine osmolality is higher than 250 mmol / kg H_2O. Osmotic diuresis is characteristic, for example, of diabetes mellitus or polyuric phase of kidney failure or is result of diuretics.

Color

Fresh urine is amber in color, which is attributed to some bilirubinoids, especially urobilin . The intensity of the coloration depends on the concentration and amount of urine, which is determined by fluid intake and extrarenal output. The first morning urine, which is more concentrated, tends to be darker. Some pathological conditions or ingestion of certain exogenous substances may cause discoloration (eg beetroot, rhubarb). Selected characteristic changes in urine color are listed in the table:

Characteristic changes in urine color:

Color	Causing substance	Occurrence
yellow to colorless		▪ increased diuresis with excessive fluid intake ▪ diuretics ▪ diabetes mellitus ▪ diabetes insipidus ▪ polyuric phase of renal failure
Brown	bilirubin	▪ liver and biliary tract diseases
green-brown	biliverdin - is formed from bilirubin by oxidation in air	▪ old urine ▪ liver and biliary tract diseases
yellow-orange	carotenoids , riboflavin	▪ exogenous income
pink to fleshy red (*without haze*)	hemoglobin myoglobin porfyriny beetroot	▪ intravascular hemolysis ▪ burns ▪ muscle necrosis ▪ muscle inflammation ▪ porphyry ▪ exogenous income
pink to fleshy red *with haze*	blood in the urine - hematuria (microscopic hematuria, which can only be detected by chemical or microscopic examination, does not affect the color of the urine)	▪ kidney disease ▪ urinary tract disease ▪ bleeding conditions
Dark brown (standing in the air deepens the color to black)	melanin homogentisic acid	▪ melanoma ▪ alkaptonurie
Light red	urates	▪ hyperurikosurie

Odor

We judge it in fresh urine, because by standing in the light, some parts of the urine decompose and the odor changes. The characteristic odor is caused by some of the diseases listed in the table:

The smell of urine

The nature of the smell	Cause	Occurrence
Ammonia	the presence of urease-producing bacteria that catalyze the decomposition of urea to ammonia and carbon dioxide	▪ old urine ▪ urinary tract infections ▪ diseases with chronic urinary retention (eg benign prostatic hyperplasia)
Acetone *(overripe apples)*	urinary acetone excretion in ketoacidosis	▪ diabetes mellitus ▪ starvation
Maple syrup or maggi spice	branched chain carboxylic oxoacids (especially 2-oxoisocaproic acid , 2-oxoisovaleric acid)	▪ leucinosis (maple syrup disease)
hydrogen sulfide to putrefactive	bacterial breakdown of proteins releases H_2S from sulfur-containing amino acids	▪ urinary tract infection associated with proteinuria ▪ cystinurie
Mouse	phenylacetate	▪ fenylketonurie

Foam

Normal urine foams little, the foam is white and quickly disappears. The more abundant, colorless, more persistent foam occurs in proteinuria. In the presence of bilirubin , the urine foam turns yellow to yellow-brown.

Turbidity

Fresh urine is usually clear. Turbidity, which occurs after prolonged standing, causes epithelium and has no pathological significance. Turbidity in fresh urine can be caused by the presence of bacteria, leukocytes, lipids, phosphates, carbonates, uric acid, leucine, tyrosine a oxalates. It can be distinguished chemically or microscopically.

Density

Also **specific weight** in the literature .

Relative density (also *relative specific gravity*) is given by the **mass concentration of all solutes** excreted in the urine. In contrast to osmolality in addition to the number of dissolved particles, it also depends on their molecular weight. High molecular weight substances affect density to a greater extent than electrolytes. In the case of more pronounced glucosuria or proteinuria, the relative specific gravity increases. A protein concentration of 10 g / l increases the relative specific gravity of urine by 0.003 and a glucose concentration of 10 g / l by 0.004. The relative specific gravity of urine depends significantly on temperature.

By relative urine density we mean the ratio of urine density to water density. The density of water is practically equal to 1 kg / l, so the difference between the density of water (in kg / l) and the relative density of urine is negligible. The density in the SI system is $kg \cdot m^{-3}$. The density of the sample relative to the density of water is a relative quantity and is therefore given by a dimensionless number.

Determination of urine density

Urine density is estimated indirectly from cation concentrations using diagnostic strips. The indicator zone of the strip contains a suitable polyelectrolyte as an ion exchanger and the acid-base indicator bromothymol blue. The principle of diagnostic strips is based on the exchange of cations from urine, especially Na^+ , K^+ , NH_4^+ , for H^+ polyelectrolyte ions in the indication zone. The released H^+ acidifies the weakly buffered acid-base indicator, which is in alkaline form. Acidification is accompanied by a change in the color of bromothymol blue. The disadvantage is that the examination with diagnostic strips does not take into account non-electrolyte substances such as glucose , proteins, urea ,creatinine and some others.

Under physiological conditions, urine density ranges from 1,015 to 1,025. Extreme values of 1,003-1,040 can be reached in the dilution and concentration experiment .

As a rule, the larger the volume of urine, the lower its density (diluted urine) and, conversely, the smaller the volume of urine (concentrated urine), the higher. Conditions in which osmotic diuresis deviates from this rule : for example, in diabetes mellitus , the volume of urine is larger with a higher specific weight.

Density determination allows an approximate estimation of renal concentration. Values above 1,020 and higher are indicative of good renal function and the ability of the kidneys to excrete excess solutes. Highly concentrated urine indicates a significant reduction in circulating plasma volume.

When the kidneys are unable to concentrate urine, low-concentrated urine of low specific gravity is excreted; we are talking about **hypostenuria** . The patient excretes the same amount of solids with higher water consumption. Extremely diluted urine may be a symptom of impaired renal concentration, such as **diabetes insipidus** , or due to the side effects of some medications. The combination of hypostenuria with polyuria indicates damage to the renal tubular system.

Isostenuria is a serious symptom of kidney damage . The kidneys lose the ability to concentrate (and dilute) urine and excrete urine with the same density as the glomerular filtrate. The relative density of urine remains consistently low, at about 1,010. The current finding of isostenuria with oliguria is an indicator of severe renal insufficiency.

Dehydration , **proteinuria** or **glycosuria** contribute to the increase in relative density - **hyperstenuria** .

Changes in relative urine density

Designation	Relative density	Causes
Eustenuria	1,020-1,040	
Hyperstenurie	> 1,040	▪ dehydration ▪ glycosuria ▪ proteinurie
Hypostenurie	<1,020	▪ diabetes insipidus ▪ hyperhydratace ▪ kidney failure ▪ diuretics
isosthenuria	1,010 th most common	▪ kidney damage

Osmolality

Urine osmolality depends on the **amount of osmotically active particles** excreted in the urine, regardless of their weight, size or electric charge. Osmolality is expressed in mmol/kg. It is only approximately dependent on urine density. Its measurement is more accurate compared to density, has a greater informative value and is preferred.

If we compare the two quantities, the osmolality reflects **the total mass concentration of all solutes**, while the density reflects their total mass concentration. Therefore, we can simply say that osmolality will be more affected by changes in the concentration of low molecular weight substances (in practice, especially sodium, glucose and urea), while density will be more significantly affected by the presence of protein in the urine.

Normal osmolality values at normal fluid intake are 300-900 mmol / kg. Urine osmolality depends on the dilution and concentration of the kidneys. The extreme values of osmolality at maximum dilution or maximum concentration are in the range of 50-1200 mmol / kg. If the osmolality of the urine is approximately the same as the osmolality of the blood, it is **isoosmolar** urine. **Hypoosmolar** urine has a lower osmolality than blood, i.e. less than about 290 mmol/kg. **Hyperosmolar** urine is urine with a higher osmolality than blood.

Theoretically, we can imagine that definitive urine arises from isoosmolar glomerular filtrate, to which pure, so-called solvent-free water is added or resorbed in the renal tubules.

The transport of solute-free water expresses its clearance. We will explain what this quantity means using the following considerations: First, let us define the **clearance of osmotically active substances**. It is a quantity analogous to the commonly used clearance of endogenous creatinine: the clearance of osmotically active substances represents the theoretical volume of blood plasma, which is completely deprived of all osmotically active particles in the kidneys per unit time. The following will apply (derivation is similar to endogenous creatinine clearance):

$$Cl_{osm} = \frac{U_{osm} \cdot V}{P_{osm}},$$

where Cl_{osm} is the osmolar clearence in ml/s,
V is diuresis in ml/s
U_{osm} is the osmolar urine concentration in mmol/kg of water,
P_{osm} is the osmolar plasma concentration v mmol/kg of water.

If the primitive urine has the same osmolality as the plasma and we neglect the contribution of proteins to the total osmolality of the plasma, the volume of filtered primitive urine must be the same as the clearance of the osmotically active Cl particles .

Solvent-free water clearance is the difference between the actual volume of definitive urine excreted per unit time and osmolar clearance:

$$Cl_{H_2O} = V - Cl_{osm}$$

where Cl_{H_2O} is the clearence of solute-free water in ml/s,
Cl_{osm} is the osmolar clearence in ml/s,
V is diuresis in ml/s.

If the clearance of solute-free water is **negative**, it means that part of the solute-free water has been resorbed from the primitive urine, so that the definitive urine is more osmotically concentrated. Conversely, if the clearance of solute-free water were **positive**, hypoosmolar urine would form, against blood plasma diluted with solute-free water. Physiological values range between ,00.027 and ,000.007 ml / s.

The kidneys are able to excrete large amounts of solute-free water to prevent hyponatremia. Conversely, in the absence of water, its excretion is limited and particles are excreted in a smaller volume of water.

Determination of the urine osmolality

With osmometer

Osmometers are used to accurately determine osmolality. They take advantage of the fact that dissolved particles affect some properties of the solution:

- they reduce the freezing point of the solution (**cryoscopic** principle);
- they increase the boiling point of the solution (**ebulioscopic** principle);
- they reduce the solvent vapor pressure above the solution.

The magnitude of the change in the above quantities depends on the concentration of osmotically active substances in the measured solution, and osmometers record these changes with great accuracy. A lowering of the freezing point is usually detected. It is true that 1 mol of particles of a substance dissolved in 1 kg of water lowers its freezing point by 1.86 °C.

Roughly by calculation based on the substance concentration values of Na^+, K^+, NH_4^+ and urea in urine

$$\text{Urine osmolality} = 2([Na^+] + [K^+] + [NH_4^+]) + [\text{urea}]$$

This calculation fails if the urine contains a high concentration of other substances, which are physiologically present in orders of magnitude lower amounts - for example, with significant glycosuria or ketonuria.

Roughly calculated from the relative density value

If the urine does not contain protein or sugar

we multiply the last two digits of the relative density value by a factor of 33.

Relative density of urine = 1,019 → Estimation of osmolalit: 19 · 33 = 627 mmol/kg.

If the urine contains protein or sugar

we must first correct the relative density value

- in the presence of protein, we subtract 0.003 from the relative density value for every 10 g/l;
- in the presence of glucose, we subtract 0.004 from the relative density value for every 10 g/l.

Examination of kidne concenration

Impaired renal impairment is one of the first signs of renal disease. We proceed with its investigation as follows:

- We first examine the **osmolality** in the morning urine **sample** . A healthy person should produce urine with an osmolality of **about 600 mmol / kg** after taking fluids at night . This value indicates good renal concentration and, if achieved, we do not proceed with further investigation.
- **The adiuretin test** reflects the ability of the distal tubule and collecting duct to respond to adiuretin (vasopressin) by producing concentrated urine. The patient is administered 10 µg (2 drops) of 1-deamino-8-D-arginine vasopressin (DDAV), a synthetic analogue of adiuretin, to each nostril after nocturnal withdrawal . It is characterized by an enhanced antidiuretic effect, while other pharmacological effects are suppressed. The patient collects urine at four one-hour intervals and the osmolality of individual urine samples is measured. If it exceeds the value given in the table, this indicates good renal concentration and we will terminate the experiment. At the same time as the urine, blood is collected and the serum osmolality is examined. From the values of osmolality in urine and serum, we calculate the osmotic index (U osm(S eight), which more

accurately reflects the concentration capacity of the kidneys.

Physiological values of urine osmolality and osmotic index after adiuretin administration

Věk	$U_{mmol/kg\ H_2O}$	U_{osm}/S_{osm}
15–20	970	3,34
21–50	940	3,24
51–60	830	2,86
61–70	790	2,72
71–80	780	2,69

Another possibility is to evaluate urine osmolality under conditions of varying lengths of fluid withdrawal, which are currently rarely performed.

The concentration ability of the kidneys is impaired mainly in diseases affecting the renal tubules and interstitium, where the countercurrent concentration gradient is disturbed.

It is also possible to examine the **dilution ability of the kidneys** after exposure to distilled water. The test reflects the ability to produce urine whose osmolality is significantly lower than the osmolality of the serum.

pH

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The kidneys are the organ where the acid-base balance is adjusted by eliminating (or retaining) H + . The pH in the glomerular filtrate is the same as in plasma. As it passes through the renal tubular system, urinary acidification occurs.

The concentration of free protons in the urine is negligible compared to other ions; we can therefore say that H + is eliminated by the kidneys in two forms:

- bound to the anions present, eg to phosphates (conversion of hydrogen phosphate to dihydrogen phosphate)

  $H^+ + HPO_4^{2-} \rightarrow H_2PO_4^-$

  or to the anions of certain organic acids. This proportion is called the so-called titratable acidity, which under normal conditions is 10-30 mmol / 24 hours. It can be determined by titration with sodium hydroxide.

- as the ammonium cation, which is the most important system.

  $H^+ + NH_3 \rightarrow NH_4^+$

  The amount of NH_4^+ excreted in the urine is between 30-50 mmol / 24 hours.

Urine pH depends on:

on the composition of the diet
In a healthy person, urinary pH is most affected by the composition of the diet. Lactovegetarian diet causes alkalization of urine. In contrast, a diet rich in protein (meat) is accompanied by acidification.

on the state of acid-base equilibrium
Under pathological circumstances, urine pH reflects acid-base imbalances. Changes in urine pH are a manifestation of the compensatory and corrective activity of the kidneys. Aciduria is the result of correction of metabolic and correction of respiratory acidosis, alkaliuria is at the beginning of compensation of respiratory and correction of metabolic alkalosis. However, the excretion of acidic urine in acidosis and alkaline urination in alkalosis only applies to mild disorders and well-functioning kidneys. The current finding of aciduria and ketonuria indicates starvation. A combination of aciduria, ketonuria and glycosuria is common in the decompensation of diabetes mellitus.

The most common factors affecting urine pH

Acidic pH	Alkaline pH
protein diet	vegetarian food
protein diet	vegetarian food
dehydration	renal tubular acidosis
diabetická ketoacidóza	respiratory and metabolic alkalosis
metabolic and respiratory acidosis	bacterial urinary tract infections
starvation	

Permanently **alkaline** urine pH may indicate:

- **Infection** of the kidneys or urinary tract with urease-producing bacteria. Enzymatic hydrolysis of urea produces ammonia, which alkalizes the urine. The situation is similar for bacterially contaminated urine, in which the bacteria multiplied during a longer period of storage.

  $H_2N\text{-}CO\text{-}NH_2 + H_2O 2NH_3 + CO_2$
  $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

- **Distal renal tubular acidosis** , which is a disorder of the renal tubular cells characterized by the inability of the distal tubule to secrete H^+ .

The main benefit of urine pH testing is in the **diagnosis and treatment of urinary tract infections and urolithiasis** . Permanent variations in urine pH may be one of the factors contributing to the formation of urinary stones.

- Calcium oxalate stones are common in **acidic urine**. At acidic pH, uric acid stones are also easily formed. Alkalization of urine above pH 7.0 can, under favorable circumstances, lead to the slow dissolution of uric acid stones and the prevention of their formation. Cystine also precipitates more easily in acidic urine.
- Phosphates are poorly soluble in **alkaline** urine and at pH above 7 ammonium magnesium phosphate (struvite - $MgNH_4PO_4 \cdot 6H_2O$) and a mixture of phosphate and calcium carbonate ["carbonate capatite" - $Ca_{10}(PO_4CO_3OH)_3(OH)_3$].

Determination of urinary pH

Urine pH should always be tested in **fresh** urine. It is usually determined by **diagnostic strips** . Accurate pH determination can be performed with a pH meter .

The physiological pH of urine is in the range of 5.0–6.5, the extreme values are 4.5–8.0. Extreme values in the acidic or alkaline range suggest that urine collection instructions are not followed.

Examination of renal acidification

The basic examination to assess the acidifying activity of the kidneys is to examine **the pH of a morning urine sample** . The pH determination must be performed immediately and the use of a pH meter is recommended . In a healthy adult, the pH of the morning sample is less than 6.0. At higher values, there is a suspicion of impaired acidification, and if there are no contraindications (eg significant reduction in renal function), it is possible to perform an **acidification test** after NH_4Cl or $CaCl_2$(in patients with hepatic impairment). The patient is given ammonium chloride (2 mmol per kg body weight). 3 hours after ingestion of the test substance, urine is collected at 3-hour intervals and immediately after collection, the acidity of the urine samples is measured with a pH meter. With intact renal acidification, urine pH should fall below 5.5.

Acidifying ability is impaired in patients with renal tubular acidosis of the distal type.

In the case of an ambiguous result of the acidification test, the alkalizing ability of the kidneys after oral or intravenous exposure to sodium bicarbonate is examined.