

Densitometry

Densitometry is a method that determines the density of minerals in the bone (Bone mineral density-BMD) and the density of bone tissue. Everything is evaluated mainly on the basis of the amount of calcium in the bones. The examination method is fast, does not burden the patient and is painless. Thanks to the densitometric examination, the doctor is able to estimate the risk of fractures associated with osteoporosis.

Physical principle of X-ray bone densitometry

Absorption of EM radiation

When X-Ray, a type of electromagnetic radiation with wavelengths between 10 nm and 1 pm, interact with tissue, two phenomena occur that reduce the intensity of the transmitted radiation. The first of these is photoelectric absorption. During this phenomenon, the entire energy of the X-ray photon is transferred to the electron of the atom in the tissue. The second phenomenon that occurs is Compton scattering. Here, only part of the kinetic energy of the electron is transferred, and the photon changes its direction and has a lower energy due to this.

There is a relationship for the intensity of monoenergetic radiation passing through the material (in our case tissue).

$$I_r = I_i(-vx),$$

where I_r is the intensity of transmitted radiation, I_i is the intensity of radiation before passing through (incident), v is the characteristic of the material, the so-called linear absorption coefficient, and x is the thickness of the tissue.

The linear absorption coefficient is dependent on the density of the material, on the number of electrons in the shell of individual atoms (i.e. on the chemical composition) and also on the original energy of the photons. It is important to realize that there are several types of tissues in the body that have different characteristics. Most soft tissues have a similar absorption coefficient. The mineral component of bone is made up of hydroxyapatite, which has a significantly different absorption coefficient (phosphorus and calcium atoms). The organic component of bone such as the marrow and collagen network are considered soft tissue.

Therefore, if we take into account the difference in the coefficients of the soft tissue and the mineral component of the bone, we can create a relationship for the intensity of the passing radiation

$$I_r = I_i(-v_b x_b - v_s x_s),$$

where the index b indicates the bone mineral component and the index s indicates soft tissue.

The thickness x can be replaced by the so-called surface density, if we proceed from the relationship

$$x = \frac{1}{\rho} \frac{m}{A},$$

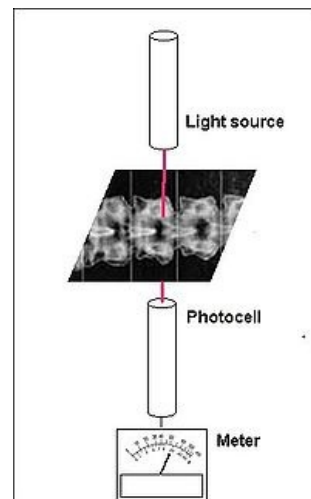
where ρ is the density, m is the tissue mass, and A is the area of the beam. Thanks to this, the product vx can be replaced by the product μM , where μ (v/ρ) is the mass absorption coefficient and M (m/A) is the already mentioned area density.

Single-energy densitometry

when using photons of one energy, there still remains the problem of one equation and two unknowns (the areal density of the mineral component of bone and soft tissue). When using single energy, the measured part of the body is immersed in water in a container with precisely known dimensions. This leaves one unknown out of the equation because the absorption coefficient of water and soft tissue is almost identical and thus we know the exact dimension x_s .

The areal density of the mineral component of the bone is determined by taking the first measurement through water, soft tissue and bone, and the second measurement right next to the bone. As a result, we are able to compare the difference and thus find out the required parameters of the bone (surface density of the mineral component of the bone, possibly also the linear density of the mineral component of the bone).

Dual-energy densitometry



Principle of densitometry:
point measurement of optical
density

When using photons of two different energies, there is no need to submerge part of the body in water. By measuring twice at two radiation energies, the results can be compared, using a modified equation for the intensity of the passing radiation, and thanks to this the required bone parameters can be determined again. In the beginning, natural radioactive emitters emitting two discrete energies (e.g. ^{153}Gd , photons of 44 keV and 103 keV) were used for dual-energy densitometry. However, due to time, financial and (above all) safety requirements, they switched to generating photons using an X-ray tube.

Quantitative Computed Tomography

Quantitative computed tomography combines the possibilities of modern imaging techniques (CT, possibly also MRI) and the techniques and principles of classic X-ray densitometry. Thanks to this, the measurement is more accurate, because the bone can be examined as a whole and thanks to this, some local phenomena can be detected, or an error can be avoided, because we are able to find out exactly where we are measuring. Within one bone, the characteristics of the mineral component change due to the anatomical structure (difference between compact and cancellous, etc.).

Densitometric methods

X-ray densitometry

Dual-emission X-ray absorptiometry, or DXA (dual-emission X-ray absorptiometry), is standard for the examination and monitoring of osteoporosis. An X-ray densitometer uses weak X-rays of two energies. Each radiation energy is absorbed differently by bone and differently by muscle and fat. This rule ensures accurate differentiation of the bone from the surrounding soft tissue. In practice, bone mass density is usually measured in two places, usually the lumbar spine and the upper part of the femur.

This examination takes a few minutes - the patient, is dressed, lies on a special bed and the scanner captures one or more areas of the bone.

QCT Quantitative Computed Tomography

This method allows measuring the volume of bone mass and is evaluated in the area of the head of the femoral or lumbar spine. On the contrary is more expensive and represents a higher radiation burden for the examinee.

Ultrasound densitometry

Quantitative ultrasonometry, or QUS (quantitative ultrasound), is based on the measurement of ultrasound waves after passing through the examined area, so the body is not exposed to radiation. It provides information about the amount of bone mass, but also about the quality and structure of the bone. This examination is not sufficient to diagnose osteoporosis or to monitor the effectiveness of treatment. The method must always be evaluated in combination with X-ray densitometry..

Examination with a densitometer does not burden the examinee. Patient can eat normally on the day of the examination, but he should not take food supplements or medicines containing calcium. Before the examination, put away jewelry, metal objects and glasses so that the result of the examination is not distorted. A densitometric examination cannot be performed during pregnancy.

The data obtained from the examination will be assessed by a radiologist (a doctor specialized in performing and evaluating X-ray examinations). He then sends the results to the doctor who prescribed the examination.

Densitometer

This examination is always performed by a doctor at a specialized radiology department in a larger hospital. There are two types of densitometers:

The central densitometer consists of a large flat plate and a movable arm that sits above it. The bone density of the spine and pelvic girdle is monitored.

A peripheral densitometer is a smaller device. Here, the patient places their hand in a device the size of a small box. The bone density of the wrist, heel or fingers is measured. Although the device works on the basis of X-ray radiation, the doses are very low and the device does not need to be placed in a specially protected room.

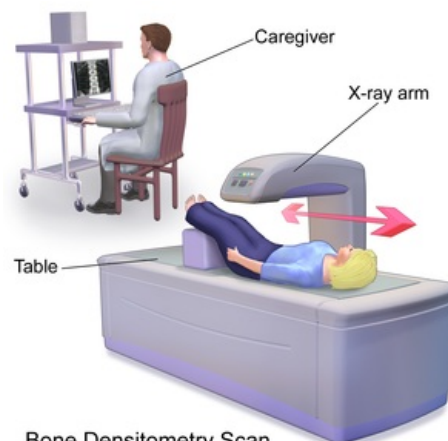
T-score and Z-score examination results

Two results called T-score and Z-score tell about bone density. The deviation of the result of your examination from the table value of bone mineral density is determined by the T-score. The table value refers to the results of healthy young individuals of the same sex. The resulting value determines the condition of our bones. If the value is greater than -1 (eg -0.2), this is a normal result. In the range of -1 to -2.5 we are talking about so-called osteopenia (= degree of osteoporosis), which is the first stage of bone thinning. About osteoporosis (= a disease of bone tissue that leads to increased bone fragility. As a result of this phenomenon, people suffering from this disease have more fractures.) we are talking if we find a T-score value lower than -2.5. Each decrease in this value by 1 standard deviation doubles the risk of fracture. The so-called Z-score is used to compare your bone density test result with the average values of people of the same age and sex.

These results allow the doctor to make an accurate diagnosis. He can then recommend regimen measures to the patient and start treatment. If the examination is prescribed by the attending physician who is treating the patient for a bone disease, in accordance with the existing List of medical procedures, then it is fully covered by the public health insurance. Here are the specialties of doctors who can prescribe this examination: rheumatology, pediatric rheumatology, orthopedics, traumatology, internal medicine, gynecology and obstetrics, pediatric gynecology, endocrinology. In certain circumstances, it can also be a general practitioner. You can also undergo an examination at your own expense. Whole-body densitometry is performed at specialized workplaces and its price is around 500 CZK.

Indications for examination

- Patients with osteoporosis.
- Patients with a history of fracture caused by an inadequately small force of injury.
- Patients with non-traumatic vertebral fracture.
- Patients with long-term treatment with corticoids or other drugs that reduce the amount of bone mass.
- Patients with increased function of parathyroid glands (hyperparathyroidism) or other diseases associated with bone loss.
- Women after menopause - especially if they have another risk factor such as smoking, heredity, women over 65, back pain, immobilization, thyroid disorders, etc.
- Women after hormonal treatment.



Bone Densitometry Scan
central X-ray densitometer

Sources

- NAVRÁTIL, Leoš – ROSINA, Josef. *Medicínská biofyzika*. 1. edition. Praha : Grada, 2005. pp. 524. ISBN 978-802-4711-522.
- REDAKCE ORDINACE.CZ,. *Ordinace.cz : vyšetření kvality kostí* [online]. ©2015. [cit. 2015-11-26]. <<http://www.ordinace.cz/clanek/denzitometrie/>>.
- Kostní denzitometrie – kdo by ji měl podstoupit. ULékaře.cz [online]. 2011, 2011-12-27 [cit. 2015-11-26]. Dostupné z: <https://www.ulekare.cz/clanek/kostni-denzitometrie-kdo-by-ji-mel-podstoupit-15133>
- Denzitometrie. Wikipedia: the free encyclopedia [online]. San Francisco (CA): Wikimedia Foundation, 2013, 2013-10-6 [cit. 2015-11-27]. Dostupné z: <https://cs.wikipedia.org/wiki/Denzitometrie>
- Physical Principles and Measurement Accuracy of Bone Densitometry. National Osteoporosis Society [online]. 2014 [cit. 2015-11-29]. Dostupné z: <https://nos.org.uk/document.doc?id=653>
- IAEA Human health series No.15. 2010. Austria: IAEA, 2010. ISBN 978-92-0-110610-0.
- WEBER, Collin E.. Photon absorptiometry, bone densitometry and the challenge of osteoporosis. *Physics in Medicine and Biology* [online] [online]. 2006, vol. 51, p. 13, Available from <[https://www.sprmn.pt/pdf/pmb6_13_r11_Bone_Densitometry_\(CEWebber\).pdf](https://www.sprmn.pt/pdf/pmb6_13_r11_Bone_Densitometry_(CEWebber).pdf)>. ISSN 00319155. DOI: 10.1088/0031-9155/51/13/R11 (<http://dx.doi.org/10.1088%2F0031-9155%2F51%2F13%2FR11>).
- FOGELMAN, Ignac – M. BLAKE, Glen. Different Approaches to Bone Densitometry. *The Journal of Nuclear Medicine* [online] [online]. 2000, y. 2000, vol. 41, p. 12, Available from <<http://jnm.snmjournals.org/content/41/12/2015.full>>. ISSN 2159-662X.