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INTRACRANIAL PRESSURE EVALUATION BY OPHTHALMOLOGIST

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SUMMARY:
The value of ICT is important in diagnosis of the diseases of the eye and orbit Methods for direct measurement of intracranial pressure (ICT) are exact, but they are invasive and there is some risk of infection and damage of the tissue. Currently there are 2 valid indirect methods of mesurement of IKT. Digital Ophthalmodynamometry (D-ODM) and Transcranial Doppler ultrasonography (TDU). D-ODM is a non-invasive method for measuring of the Pulsating Venous Pressure (VPT). We can measure VPT by the pulse phenomena. Physiologically (to be maintained blood flow) VPT not be less than the ICT and intraorbital pressure (IorbitT). If we raise the VPT to compensate the current IKT (or IorbitT) - there is a pulsation VCR. We can calculate aproxymative IKT with the formula: IKT = 0.903 - (VPT) - 8.87, or IKT = 0.29 + 0.74 (VOT / PI (AO)). [VOT = intraocular pressure. PI – pulsatility index arteriae ophthalmic from Color Doppler ultrasonography.] IKT can be approximate calculate with mathematical formulas: IKT = 0:55 × BMI (kg / m^2) + 0.16 × KT_D (mmHg) - 0:18 x age (years) - 1.91. [KT_D - diastolic blood pressure, BMI - Body master index] or: IKT = 16.95 x 0.39 x OSASW09 + BMI + 0.14 + TK_S - 20.90. [OSASW095: width of the orbital arachnoid space at a distance of 9 mm behind the eyeball (nuclear magnetic resonance). BMI: Body Mass Index. TK_S: mean arterial pressure]. Normal values of VPT are under 15 torr. The risk of increased intracranial pressure is above 20 torr. Under physiological conditions, there is intraocular pressure lower in about 5 torr than VPT. Conclusion: D-ODM is a useful screening method in the evaluation of IKT for hydrocephalus, brain tumors, cerebral hemorrhage after brain trauma and also in ocular diseases: Glaucoma, Ocular hypertension, orbitopathy (endocrine orbitopathy), ischemic / non -ischemic occlusion of blood vessels of the eye, indirect detection ICT carotid artery-cavernous fistula, amaurosis fugax, optic neuropathy. D-ODM is suitable for immediate evaluation of IKT, but is not suitable for continuous monitoring. As it can be repeated, it is useful for a patient suspected of having an increased ICT.

Key words: central retinal artery, central retinal vein, colour Doppler ultrasonography, digital ophthalmodynamometry, intracranial pressure, pressure of cerebrospinal fluid, transcranial Doppler ultrasonography, intraocular pressure, venous pulsation pressure, venous outflow pressure, retinal venous pressure

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Summary overview

Intracranial pressure (ICP) is hydrostatic pressure of the coelilymph. ICP is the result of active secretion and passive resorption of the cerebrospinal fluid into the venous system (22). Similarly to intraocular pressure (IOP), ICP also has a certain daily rhythm. Unlike IOP, ICP is markedly dependent upon the position of the body, or the head. The value of ICP in adults in lying position is within the range of 5-15 torr. In sitting position ICP is -10 to 0 torr (13). With age ICP slightly decreases physiologically. ICP may increase upon a higher degree of obesity (1). However, ICP is mostly increased in the case of various pathological intracranial conditions (brain edema, haemorrhage into brain, brain tumours, hydrocephalus etc.).

The standard diagnostic methods for clinical observation of ICP are invasive: Pressure sensor placed into the brain parenchyma or chamber space of the brain. These methods are exact, but are invasive and carry a certain risk of infection and damage to tissues. The majority of available studies compare the approximate values of ICP with the values of ICP obtained from lumbar puncture. Lumbar puncture is “more accessible” than a catheter into the intracranial space. However, it does not give such precise values as an intracranial catheter/probe, and furthermore represents a risk in the case of excessively raised ICP (risk of brain herniation). As a result, there is an endeavour to develop indirect measurement of ICP (table 1). The majority of the attempts to date have not demonstrated sufficient validity, and as a result are not used in clinical practice. At present 2 methods are proven on the basis of a number of experimental and clinical trials: Digital ophthalmodynamometry (D-ODM) and Transcranial Doppler ultrasonography (TDU) (6, 8, 14, 15, 17). D-ODM is a non-invasive method for measuring pulsating venous pressure (PVP).

The digital ophthalmodynamometer Meditron is composed of a 3-mirror Goldman lens, which has a fine pressure sensor on the outer edge. This pressure sensor measures the pressure which acts on the anterior segment of the eye. The pressure sensor is connected with an electronic unit with an LCD display, where the measured pressure is shown in the given blood vessel.

Measurement procedure: After the administration of local anaesthesia, an ophthalmodynamometric 3-mirror lens with sensor is applied to the cornea (similarly as upon examination of the anterior chamber angle). Attention is focused on the blood vessels of the disc of the optic nerve. During fine continual compression on the eyeball (in the anterior-posterior axis) it is possible to observe the occurrence of pulsation phenomena: pulsation of vena centralis retinae (VCR), pulsation and eventually collapse of arteria centralis retinae (ACR). The beginning of venous pulsations signals

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that IOP is higher (equal to) pressure in the VCR in the region of the papilla of the optic nerve. This value is referred to as pulsating venous pressure (PVP). Synonyms for PVP are: venous outflow pressure (6, 14), retinal venous pressure or venous occlusion pressure (20). Pulsation of ACR indicates that IOP is higher than diastolic pressure in the ACR. If pulsation of the ACR subsides (ACR ophthalmoscopically collapses), IOP is higher than systolic pressure in the ACR. After conversion in the formula PVP enables us to calculate approximate ICP.

The ICP value is significant in the diagnosis of certain pathologies of the eye and orbit. These are glaucoma, vascular occlusion of the eye, amaurosis fugax, differential diagnosis of edema of the disc of the optic nerve and others. Calculation and measurement of ICP from an ophthalmological perspective is illustrated in table 2.

PVP in the vena centralis retinae was evaluated previously by Baurmann in 1925 with the aid of ophthalmodynamonetry. Pulsation phenomena were observed in the ACR and VCR on the papilla of the optic nerve. The principle of evaluation of PVP with the aid of pulsation phenomena has remained unchanged to this day. At present an innovated ophthalmodynamometer is used, with which the obtained values are statistically significant. The mechanism, precision of measurement and the evaluation of ICP, as well as the intraorbital pressure, were convincingly demonstrated by Meyer-Schwickerat et al. (14).

On the level of the lamina cribriformis of the eye, two pressure systems meet: IOP and ICP. The VCR anatomically passes across the lamina cribriformis (threshold of intra and retrobulbar space) and into the optic nerve. The optic nerve is fenced in by the pia mater and dura mater. Between them is the subarachnoid space, filled with trabeculae and the cerebrospinal fluid. If the vena centralis retinae passes across the optic nerve, it is mechanically influenced not only by intraocular pressure but also by intracranial pressure from the cerebrospinal fluid. It subsequently passes across the orbit, into the vena ophthalmica superior and across the sinus cavernosus into the jugular vein.

Under physiological conditions (in order to maintain through-flow of blood), PVP cannot be lower than ICP an

Table 1. Indirect measurement of intracranial pressure

1. Ultrasound measurement:
   a. certain parameters of skull,
   b. mater dura,
   c. size of brain chambers,
   d. quantitative parameters of brain tissue.
2. **Transcranial Doppler ultrasonography.**
3. Evaluation of mechanical changes of skull bone.
4. ORL methods:
   a. Evaluation of tympanic membrane,
   b. Otoacoustic emissions: measurement of oscillations in endolymph and perilymph in inner ear.
5. Ophthalmological measurement:
   a. Measurement of optic nerve sheats
   b. Digital ophthalmodynamometry

Table 2. Ophthalmological possibilities of evaluating intracranial pressure

- Digital ophthalmodynamometry. Calculation of approximate intracranial pressure via formula:
  - ICP é 0.903 – (PVP) – 8.87. Correlation is statistically significant (r = 0.983; p-0.001) (3). (ICP: intracranial pressure, PVP: pulsating venous pressure).
  - ICP = 0.29 + 0.74 (IOP / PI (AO)) (17). (IOP: intraocular pressure, PI: pulsatility index from arteria ophthalmica)
- Transcranial duplex ultrasonography.
- Monitoring of parameters of retinal veins.
- Calculation of approximate ICP according to mathematical formulae:
  - ICP = 0.55 x BMI index (kg/m2) + 0.16 x BPD (mmHg) – 0.18 x age (years) – 1.91 (10) (BPD - diastolic blood pressure, BMI – body master index)
  - ICP = 16.95 OSASW09 + 0.39 x BMI + 0.14 + BPM – 20.90 (OSASW095: width of orbital subarachnoid space at distance of 9 mm behind eyeball (examination of nuclear magnetic resonance), BMI: body mass index, BPM: median arterial pressure (20)).

intraorbital pressure (IorbitP). If we intentionally increase PVP so as to be equal to current ICP or IorbitP, VCR pulsation occurs. This pulsation phenomenon, following calculation in the formula, enables us to indirectly determine ICP. It has been demonstrated experimentally that with the aid of D-ODM we can measure PVP in the VCR in the place where the VCR leaves the eyeball (6). Pulsating venous pressure is present independently of blood pressure. A statistically significant relationship between ICP and PVP has been demonstrated by a number of studies (12,15, 17, 19, 21, 23, 24).

Evaluation of the relation between IOP and ICP is not simple. It is necessary to be aware that within the retrolaminar region there are several locations with various types of hydrostatic pressure. These are retrolaminar tissue pressure, pressure in the subarachnoid space, pressure of the orbital tissue and intracranial pressure itself. It is pressure of the orbital tissue that fills the pressure difference between pressure in the subarachnoid space and the retrolaminar tissue pressure (15). An important experimental finding was the demonstration of a linear relationship between PVP and subarachnoid and intracranial pressure respectively.

The significance of ophthalmodynamometric examination with the aid of a new digital ophthalmodynamometer has now been sufficiently well demonstrated (4, 6, 9, 15, 17, 21).

Pulsating venous pressure is significant also in the case of other pathological conditions. It is important to differentiate the ischaemic form from the non-ischaemic form in a timely manner, for the purpose of choosing an appropriate therapy (2). Upon differential diagnosis of ischaemic and non-ischaemic occlusion of the VCR, D-ODM may provide us with valuable information. Upon isachemic occlusion of the VCR, PVP is significantly higher (91.5 ± 30.1 units as against non-ischaemic occlusion of the VCR: 52.4 ± 32.5 units. The physiological value is 4.8 ± 8.1 torr (20).

In the case of orbitopathies, in particular endocrine orbi-

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topathy, it is particularly the extraocular muscles and conjunctive tissues of the orbit that are damaged (5, 7, 11, 18). Direct measurement of intraorbital pressure is not possible under regular clinical conditions, because we can evaluate IorbitP only with the aid of an invasive orbital manometer. With the aid of D-ODM we can evaluate IorbitP only in the case that IorbitP exceeds ICP (active stage of endocrine orbitopathy, orbital tumours etc.). The physiological values of PVP in the orbit under physiological circumstances is 5.1 ± 8.4 torr. However, in the active state of endocrine orbitopathy the average values are 30.8 ± 22.7 torr (10). It is beneficial to recognise pathologically increased IorbitP during specific ophthalmological surgical procedures, predominantly on the anterior segment.

Physiological values of PVP are up to 15 torr. Above 20 torr there is a risk of increase of intracranial pressure. Physiological intraocular pressure is less than PVP by approx. 5 torr. Within this context an interesting finding was the relationship between IOP (in orthophoric position of the eyeball) and PVP with regard to deterioration of central visual acuity and scotomas in the visual field. When the difference between IOP and PVP was 0-5 torr, there was be no decrease of central visual acuity and scotomas within the visual field. By contrast, upon an increase of this difference to 5 torr, a deterioration of central visual acuity and scotomas in the visual field occurred, despite the fact that compression of the optic nerve was not so pronounced as to be able to influence the optic nerve. This applies both upon states with high and low IOP. Some authors state deterioration of the perfusion gradient as a cause of deterioration of central vision (6, 8, own observations).

We began to verify the practical use of D-ODM within the framework of inter-disciplinary co-operation of ophthalmology and neurosurgery. After processing, the results of this research will be the content of our next study.

D-ODM has its advantages and disadvantages. Its advantages include pain-free and non-invasive examination, and relative precision of the obtained values. Limitation of D-ODM are the need for a dilated pupil and co-operation of the patient during the examination, as well as pressure on the eyeball in the region of the limbus, expecially upon damage to collagen and the risk of detachment and luxation and the lens (3).

Transcranial Doppler ultrasonography is also a precise method for calculating approximate ICP. However, with regard to the fact that TDU is based on a display of the spectral speed curve of the blood flow in the intracranial blood vessels, in patients with head injuries or brain haemorrhage these parameters may change substantially, thereby altering the result obtained with the aid of TDU.

Similarly, with regard to the variability of the blood vessels of the brain, a high level of knowledge of the attending physician is essential.

CONCLUSION

- D-ODM is a useful screening method in the evaluation of ICP within the framework of diagnosis of hydrocephalus, brain tumours, brain haemorrhage and after brain trauma.
- D-ODM is relevant for immediate evaluation of ICP, but is not suitable for continuous monitoring. With regard to the fact that it may be repeated, it is suitable for follow -up examinations on patients with suspected increased ICP.
  - Indications for D-ODM:
  - Glaucomas, ocular hypertension
  - Orbitopathies, endocrine orbitopathy
  - Occlusion of VCR, ACR
  - Indirect detection of ICP
  - Carotid artery-cavernous fistula
  - Amaurosis fugax, neuropathy of optic nerve.

Abbreviations

- ACPb – arteriae ciliares posteriores breves
- ACR – arteria centralis retinae
- AO – arteria ophthalmica.
- D-ODM – digital ophthalmodynamometry
- CDU – colour Doppler ultrasonography
- ICP – intracranial pressure
- IorbitP – intraorbital pressure
- PI – pulsatility index
- PCSF – pressure of cerebrospinal fluid
- TDU – transcranial Doppler ultrasonography
- VCR – vena centralis retinae
- IOP – intraocular pressure
- PVP – pulsating venous pressure (venous outflow pressure – retinal venous pressure).

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