ABSTRACT
So far, the impact of fluid shift on intracranial pressure never has been a topic for research or even discussion in space flight. Why: Indeed a rapid, precise follow up of changes in intracranial pressure is not only very difficult to perform non-invasively – but to do so under space flight conditions – the astronaut being his own experiment – is even more difficult. But even in modern clinical medicine – under gravity conditions – it took almost a century, before from application of very complicated methods this very important value could be measured precisely. So the aim of our study was to describe the technical solution, final development and application of a new system for automatic ophthalmodynamometry – to be used as well for even long term space flights as later on for clinical medicine.

The principle and instrumentation follows closely our automatic self tonometer for intraocular pressure, successfully used in 3 former space missions and now for many years one of the greatest achievements for early detection and follow up of the glaucomas, the most frequent definite reason for permanent blindness in the world.

The increase of arterial and venous intracranial pressure under microgravity conditions leads also to a rise of the intraocular pressure: The increased perfusion rate in the ciliary body enlarges the production of the aqueous humour. The congestion in the venous system and the pressure rise in the episcleral vessels forming an increased outflow resistance for the aqueous humour. If now the already increased intraocular pressure is furthermore rised by additional indentation of the corneal surface, the central retinal artery will collaps at reaching their intravasal pressure. This collaps indicates almost precisely pressure in the A. carotis interna, reflecting the intracranial pressure. Using this non-invasive technique allows for estimating intracranial pressure without needing an additional examiner for optical control of the arterial collaps (as formally needed in early ophthalmodynamometers). The major difference to ocular tonometry is the variable applanation surface in ophthalmodynamometry allowing for inducing increase of intraocular pressure. There is a steep correlation between applanation diameter and induced intraocular pressure, already 1954 (Friedenwald) this correlation between displaced volume and increase of pressure was calculated. The necessary variation of applanation surface needs a completely different pressure sensor, independent from any actual applanation diameter. Using a piezo-electric element for direct pressure registration in a wide range (0 – 155 mm Hg) was the solution. Contrary to all previous ophthalmodynamometers needing at least 1, 2 or even 3 examiners our fully automated instrument allows for a one hand application needing less than 1 sec. for the total measurement procedure. The sensor head is moved towards the corneal apex by a linear drive, increasing intraocular pressure by rapidly growing force. The very moment pressure oscillation stops to represent the collaps pressure of the central retinal artery. The general design of this instrument is very similar to that of the OCUTON self tonometer.

Possibly our expected results in rise of intracranial pressure may explain some neuronal and hormonal changes reported in former missions, e.g. space sickness is not only released by otolitic action. Of course, such a handsome practical instrument later on might also be used for clinical application in neurology, neurosurgery, internal medicine, ophthalmology.

Fig: 1: Title
Microgravity leads to a so called “fluid shift” towards the upper parts of the body, increasing the intracranial as well as the intraocular pressure (fig. 2).

Fig. 2: D1-Emblem
October 1985 on occasion of the last launch of the space shuttle “Challenger” the German-D1-Mission took off into the orbit (fig. 3).

Fig. 3: Last launch of space shuttle “Challenger”, Oct. 1985
Already the first measurements during this mission using my former “Handapplanation-Tonometer”
proved a pressure rise of 20 – 25 % with respect to the base line values taken before launch (fig. 4).

Fig. 4: German astronaut Messerschmid and American Col. Blueford while performing tonometry in space flight

But we assumed that at this moment intraocular pressure already had partially adapted to microgravity. For this reason a new fully automatic instrument would allow a much earlier tonometry directly after entering microgravity.

During the German-Russian manned Mission in March 1992, selftonometry was performed for the first time under longlasting micro-G-conditions (fig. 5).

Fig. 5: German Cosmonaut Flade, performing tonometry in Soyuz-TM

The first measurements of intraocular pressure could be performed already 16 min. after entering into microgravity. The pressure peak in this early phase revealed a 102 increase compared to the base line data taken before launch. Further experiments have also been performed during the Spacelab D2-Mission, May 1993, leading to the very same results (fig. 6).

Fig. 6: Increase of intraocular pressure after entering microgravity

As this handsome instrument allowed frequent tonometry not only by the astronauts but also by the patients we derived a smaller, more handsome, even more precise instrument for clinical use (fig. 7).

Fig. 7: Selftonometer applied by a patient suffering from primary open angle glaucoma

So a really dense diurnal curve as required by Prof. Roberto Sampaolesi almost 40 years ago now easily could be assessed (fig. 8).

Fig. 8: Diurnal amplitude in chronic open angle glaucoma

Also in other medical disciplines self monitoring of disease parameter, blood pressure in patients with arterial hypertension, self measurement of blood glucose concentration in diabetes meanwhile is commonly accepted as a great progress in clinical medicine.

While single measurements now office often miss a typical peaks as this occured during night or early in the morning, only selftonometry allows to detect these dangerous pressure peaks being even more harmfull as vascular pressure at the same time often is temporarily lower. As Prof. Goldmann already 1958 has emphasized there is a time lag between onset of pressure peaks and development of neuronal or even functional defects of 10 years, only application of Sampaolisis diurnal curve might allow from very early detection of the glaucomas and also for precise control during follow up. Of course, the technical advantage of the new technology also is available for the ophthalmologist himself (fig. 9).

Fig. 9: Automatic selftonometer for the ophthalmologist

By implementation of an eye piece for direct coaxial observation of the corneal vortex during measurement the ophthalmologist is able to apply this new system also to patients who are unable for selftonometry – e. g. young babies with congenital glaucoma, almost blind eyes, unable for precise fixation, patients under general anaesthesia, etc. (fig. 10).

Fig. 10: Application of the new tonometer for the ophthalmologist in the operation theater

Of course, like having experienced successfully with our former hand applanation tonometer also for this new instrument an automatic UV-desinfection is provided (fig. 11).

Fig. 11: Automatic UV-desinfection

Within only 30 s. every kind of germ or virus is destroyed, no contamination to the other eye – or another patient - is possible.

This new way of selftonometry will lead into a new future of our understanding of glaucoma physiology, clinical pathology and follow up – allowing for the most appropriate kind of therapy in every stage of the disease! By improving the compliance of the patient is understanding of this disease this cooperation will be enhanced.
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