Telemetric Intracranial Pressure Monitoring with the Raumedic Neurovent P-tel

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■ BACKGROUND: **Devices enabling long-term intracranial pressure monitoring have been demanded for some time. The first solutions using telemetry were proposed in 1967. Since then, many other wireless systems have followed but some technical restrictions have led to unacceptable measurement uncertainties. In 2009, a completely revised telemetric pressure device called Neurovent P-tel was introduced to the market. This report reviews technical aspects, handling, possibilities of data analysis, and the efficiency of the probe in clinical routine.**

■ METHODS: **The telemetric device consists of 3 main parts: the passive implant, the active antenna, and the storage monitor. The implant with its parenchymal pressure transducer is inserted via a frontal burr hole. Pressure values can be registered with a frequency of 1 Hz or 5 Hz. Telemetrically gathered data can be viewed on the storage monitor or saved on a computer for detailed analyses. A total of 247 patients with suspected (*n* = 123) or known (*n* = 124) intracranial pressure disorders underwent insertion of the telemetric pressure probe.**

■ RESULTS: **A detailed analysis of the long-term intracranial pressure profile including mean values, maximum and negative peaks, pathologic slow waves, and pulse pressure amplitudes is feasible using the detection rate of 5 Hz. This enables the verification of suspected diagnoses as normal-pressure hydrocephalus, benign intracranial hypertension, shunt malfunction, or shunt overdrainage. Long-term application also facilitates postoperative surveillance and supports valve adjustments of shunt-treated patients.**

■ CONCLUSIONS: **The presented telemetric measurement system is a valuable and effective diagnostic tool in selected cases.**

INTRODUCTION

External ventricular drains and intraparenchymal monitors (IPMs) are prevalently used to monitor intracranial pressure (ICP).[1-5] These methods are believed to be fast, safe, effective and precise. However, the application is always limited to a few days to avoid infectious complications.[6-13] Consecutively, over the years, new techniques enabling long-term ICP monitoring have been demanded.[6-9,13-17] The surveillance of patients after severe traumatic brain injury or subarachnoid hemorrhage, ICP control after neuroendoscopy or cerebral shunt insertion, verification of chronic shunt under- or overdrainage, and the optimization of shunt valve settings have been the most intended indications for long-term measurements.[1,7,8,15,17-22]

The first technical proposals for a solution can be traced back to 1965. MacKay[23] recommended the integration of "radio telemetry technique" in fully implantable devices. In 1967, the first 2 prototypes (developed independently by Atkinson et al.[14] and Olsen et al.[24]) were mentioned in the literature. Wireless ICP data transmission was based on the principle of 2 inductively coupled resonant circuits: an external sensing device generates an electromagnetic field, and consecutively the inner coil capacitor circuit (in the implant) starts to oscillate. The capacitor consists of 1 flexible electrode, which is in contact with the brain pressure (eg, in epidural localization). A change in ICP modifies the distance of the capacitor electrodes,

Key words
- Hydrocephalus
- Intracranial pressure
- P-tel
- Telemetric ICP measurement
- Telemetry

Abbreviations and Acronyms
BIH: Benign intracranial hypertension
CSF: Cerebrospinal fluid
CT: Computed tomography
DP valve: Differential pressure valve
ETV: Endoscopic third ventriculostomy
G valve: Gravitational valve
ICP: Intracranial pressure
IPM: Intraparenchymal monitor
LP: Lumbar puncture
MRI: Magnetic resonance imaging
NPH: Normal-pressure hydrocephalus
VP: Ventriculoperitoneal

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resulting in frequency variations of the resonant circuit. These variations affect the frequency of the sensing device, which converts the electric alterations into a signal indicating ICP.

Based on this concept, many other technically advanced telemetric systems followed.[6-9,13,15-17,25-30] The use of various materials and the localization of pressure detection (intraventricular, intraparenchymal, subdural, epidural) were the major differences between the new probes.[6,13,16,17,25-27,29,30] Although more than 90% of all telemetric devices consisted of a passive implant that is activated by an external electromagnetic field, some prototypes worked with an integrated battery.[16,27,30] Other innovating developments calculated the ICP by measuring cerebrospinal fluid (CSF) flow in a cerebral shunt tube.[26,31] In this context, Hara et al.[26] introduced a unique invention in 1983. They developed a shunt-integrated device involving electrolysis. This chemical process resulted in the formation of gas bubbles in drained CSF that could be detected by external ultrasonic Doppler probes. By using a mathematical algorithm implying bubble amount, velocity, and tube diameter, the CSF flow could be calculated and used for estimation of ICP.

Although numerous developments were described in the literature, no device has been commercially used in clinical routine until now.[7,16,20,29] The main reasons therefore have been the inability to register negative ICP values in some probes, the complicated practical application, unstable material properties, and significant zero-point drifts, which mostly occurred within a few days after implantation.[6,8,9,13,16,17,28,29]

In 2009, the Raumedic company (Helmbrechts, Germany) introduced a new telemetric device called Neurovent P-tel. Experimental preliminary animal tests confirmed sufficient measuring accuracy with a negligible zero-point drift as well as long-term stability of used materials during the first year after implantation.[21,32-34]

This is the first report presenting clinical experiences with the P-tel probe over a period of almost 6 years. Technical aspects, indications for implantation, clinical efficiency, and complications as well as possibilities of data analysis are reviewed.

METHODS

The Telemetric Measurement System

The hardware of the measurement system can be divided into 3 main parts: the passive implant, the active antenna, and the display and storage unit (Figure 1). The passive implant for intraparenchymal ICP registration (the Neurovent P-tel) consists of a piezoresistive pressure transducer (Figure 2, see magnification), which is located at the tip of a polyurethane catheter (length, 30 mm; diameter, 1.67 mm). The pressure transducer contains several electric resistors doped on a flexible membrane. This membrane is in direct contact with the pulsating brain tissue. An increase in ICP leads to stretching of the membrane. This consecutively influences the length of the doped resistors and the electric resistance of the system. Such changes are registered by a microchip (see later discussion), which converts these electric modifications into ICP values. The microchip is installed in the roundly configured ceramic housing (diameter, 31.5 mm; height, 4.3 mm). Activation of the microchip can be realized by placing the antenna (Reader TDT1 readP) close to the housing (Figure 2). Simultaneous energy supply and ICP data transmission is based on radiofrequency identification technique: the TDT1 readP generates an oscillating electromagnetic field that activates the P-tel microchip. Depending on the current ICP and the electric resistance (see earlier discussion), the microchip reversely influences the electromagnetic field by producing repetitive short-circuits. This process is known as load modulation. To display and store transmitted ICP data, the TDT1 readP is connected to a special monitor (Datalogger MPR-1).

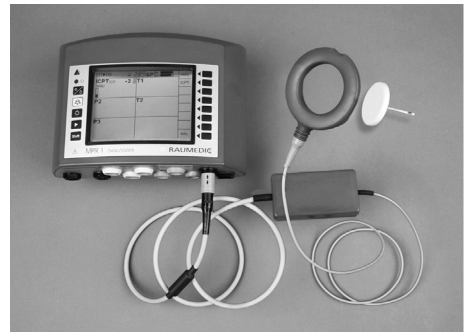

Figure 1. Hardware for telemetric measurement of intracranial pressure. The display and storage unit (Datalogger MPR-1) is connected to the antenna (Reader TDT1 readP). A cable-free connection for transmission of intracranial pressure data can be established by placing the reader unit close to the implant (Neurovent P-tel).

Insertion and Removal of the P-tel Probe

Simple surgical insertion of the P-tel probe can be performed under general or local anesthesia. A short and straight skin

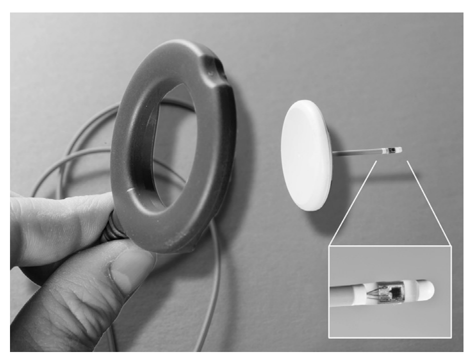

Figure 2. (*Right*) Neurovent P-tel. The pressure transducer (see magnification) for intraparenchymal measurement of intracranial pressure is located at the distal end of the polyurethane catheter. The pressure transducer contains several electric resistors, which are doped on a flexible membrane. This membrane is stretched differently depending on the current ICP. (*Left*) Reader TDT1 readP. Intracranial pressure measurement can be initiated by placing the TDT1 readP close to the P-tel probe. Simultaneous energy supply (from TDT1 readP to P-tel) and data transmission (from P-tel to TDT1 readP) is based on radiofrequency identification technique.