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Clinical experience with telemetric intracranial pressure monitoring in a Danish neurosurgical center

Alexander Lilja*, Morten Andresen, Amer Hadi, Dorthe Christoffersen, Marianne Juhler

Department of Neurosurgery, Rigshospitalet University Hospital of Copenhagen, Copenhagen, Denmark

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ABSTRACT

Background: Monitoring of intracranial pressure (ICP) is important in the optimal treatment of various neurological and neurosurgical diseases. Telemetric ICP monitoring allows long-term measurements in the patient's everyday life and the possibility to perform additional measurements without the procedure related risks of repeated transducer insertions.
Materials and methods: We identified all patients in our clinic with an implanted Raumedic® telemetric ICP probe (NEUROVENT®-P-tel). For each patient we identified diagnosis, indication for implantation, surgical complications, duration of ICP reading, number of ICP recording sessions (in relation to symptoms of increased ICP) and their clinical consequence.
Results: We included 21 patients in the evaluation (11 female and 10 male). Median age was 28 (2–83) years and median duration of disease was 11 (0–30) years. Eleven patients had various kinds of hydrocephalus, seven patients had idiopathic intracranial hypertension (IIH) and three patients had normal pressure hydrocephalus (NPH). Fifteen patients had a shunt prior to implantation. Median duration of implantation was 248 (49–666) days and median duration from implantation to last recording session was 154 (8–433) days. In total, 86 recording sessions were performed; 29 resulted in surgical shunt revision, 30 in change of acetazolamide dose or programmable valve setting, 20 required no action and 5 resulted in a new recording session. No surgical complications occurred, except for late wound infection at the surgical site in two patients.
Conclusion: Telemetric ICP monitoring is useful in patients with complicated CSF dynamic disturbances who would otherwise require repeated invasive pressure monitoring. It seems to be a feasible method to guide adjustment of programmable valve settings and to identify patients with chronic or repeated shunt problems.

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Monitoring of intracranial pressure (ICP) in a repeated fashion is essential in the optimal treatment of various neurological and neurosurgical diseases [1,2]. Traditionally, ICP has been estimated by lumbar puncture or by surgical insertion of an intracranial wired pressure transducer followed by monitoring in a neurosurgical ward or at home using a mobile monitor [3,4]. The idea of being able to monitor ICP through a telemetric device is more than 40 years old [5–7], but commercially available and clinically useful systems have been scarce. Telemetric ICP monitoring allows continuous measurements in the patient's everyday life at home as well as the possibility to perform additional measurements without the procedure related risks of repeated transducer insertions (bleeding, infection, neurological symptoms). A new telemetric device (Raumedic® NEUROVENT®-P-tel) is now available, but so far, clinical experience with this telemetric ICP monitoring system has been limited to case reports [8,9], and two patient series, primarily in the setting of endoscopic third ventriculostomy (ETV) [10,11].

The objective of this study is to evaluate the clinical utility of long-term telemetric ICP monitoring, and to identify advantages and challenges in this setting for future improvement of the technology. We report data from a consecutive series of patients with complex CSF dynamic diseases; primarily hydrocephalus and idiopathic intracranial hypertension.

* Corresponding author at: Department of Neurosurgery, Rigshospitalet, Blegdamsvej 9, DK-2100 Copenhagen, Denmark. Tel.: +45 3545 9850.
E-mail addresses: al@cphcsf.dk, alx.lilja@gmail.com (A. Lilja).

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1. Materials and methods

1.1. Patient selection

We included all patients that had a telemetric ICP probe implanted on clinical indications. We retrospectively identified all patients in our clinic with an implanted Raumedic® telemetric ICP probe between September 2011 and June 2013. The procedure has a unique 5-digit registration code in our surgical planning system, and thus all cases could be retrieved. For each patient we identified demographic data, diagnosis, indication for implantation, surgical complications related to implantation, number of ICP recording sessions (in relation to symptoms of increased ICP), consequence of each reading session, and reason for explantation, if performed. Follow-up for this report ended September 25th 2013.

1.2. ICP telemetry system

The ICP monitoring system consists of an implantable ICP sensor (RAUMEDIC® NEUROVENT®-P-tel), a reading device (RAUMEDIC® TDT readP), and a portable recording unit (RAUMEDIC® MPR1 DATALOGGER). The recording device can be programmed to display different aspects of the monitoring and alarm limits of ICP can be set. After a recording session the data is transferred to a PC for ICP data storage and analyzing using the supplied software (RAUMEDIC® Datalogger ver. 1.7). Implantation of the telemetric ICP sensor can be performed in general or local anesthesia and no calibration is needed. The preferred placement is through a right frontal burr hole, but parietal and left side placement is also possible. The sensor has a 5F catheter tube with a length of 30 mm, which is inserted into the brain parenchyma, and is compatible with MRI scanners up to 3 Tesla. Drift is reported to be ±2 mmHg per month [10], but long-term evaluation of. Reading and monitoring of ICP is performed by externally fixating the TDT readP device, which can be activated and removed at any time.

1.3. Interpretation of collected ICP data

Interpretation of ICP curves is performed during a weekly conference by the hydrocephalus team in our department. This team consists of 3 neurosurgical consultants and 2 neurosurgical residents. The ICP curves were examined for abnormal ICP during daytime and nighttime, presence of B-waves, episodes of raised ICP, and finally evaluation of pulse wave morphology by direct visual inspection of the curve (Fig. 1). In case of more than one recording, the curve was compared to previously obtained curves. The ICP curve evaluation was performed in order to guide clinical treatment of the patient – the conclusion and consequence of this evaluation was later retrospectively collected for this study.

1.4. Statistics

Data management and statistical analysis was carried out using IBM SPSS Statistics package version 20 (IBM Corporation, Armonk, NY, USA). For numerical data, median value and range are presented.

1.5. Ethical considerations

This telemetric ICP probe is approved for an implantation time up to 3 months. Some of the patients in this report had implantation times longer than this period. The primary concern in this regard is validity of measurements due to potential zero drift, but previous reports indicate this to be minimal [9,10,12,13]. Instead of exposing these patients to the risk of another surgical procedure to remove the probe, we informed the patients about the option to leave the probes implanted to perform further diagnostic recordings as long as clinically needed. Decisions on patient treatment were never made solely based on absolute ICP-values, but rather based on the complete curve pattern in relation to patient symptoms, and findings on neuroimaging.

Table 1
Median duration of implantation period, reading period, and number of ICP recording sessions according to diagnosis. Twenty-two telemetric sensors were implanted in 21 patients (one patient with IIH had two sensors implanted due to wound infection in relation to the first implant).

	N	Implantation period (days)	Reading period (days)	ICP recording sessions (per patient)
All implants	22	248 (49–666)	154 (8–433)	4 (1–11)
Hydrocephalus	11	174 (49–523)	154 (8–433)	4 (2–6)
IIH	8	220 (51–589)	111 (28–432)	3 (1–11)
NPH	3	562 (421–666)	266 (57–300)	2 (1–4)

2. Results

2.1. Patient characteristics

We identified 29 patients with an implanted telemetric probe in the study period. Twenty-one patients had the probe implanted in relation to clinical treatment and 8 patients were participating in a clinical trial to identify normal values of ICP, and these were excluded from the present report. Eleven of the patients were female and ten were male. Median age was 28 years (range 2–83 years) and median time from diagnosis of disease to implantation of telemetric probe was 11 years (range 0–30 years). The majority of patients were diagnosed with hydrocephalus (11 patients) or idiopathic intracranial hypertension (IIH, 7 patients), and three patients had normal pressure hydrocephalus (NPH). Of the 11 patients with hydrocephalus, 6 patients had congenital hydrocephalus. Fifteen patients had a ventriculoperitoneal (VP) or ventriculoatrial (VA) shunt at the time where the ICP sensor was implanted. Indication for implantation was optimization of shunt treatment (through valve change or optimization of programmable valve settings), documentation of response to acetazolamide treatment (IIH patients) or diagnostic verification of pathologic ICP.

2.2. Probe implantation

We implanted 22 telemetric probes in 21 patients; one patient had 2 implantations due to infection 5 months after implantation of the first probe. Implantation was performed in general (15) or local (7) anesthesia through a right frontal (8), left frontal (12) or right parietal (2) burr hole. When general anesthesia was used, it was occasionally in relation to another procedure, *i.e.* shunt revision (5 of the 15). We experienced no surgical complications in direct relation to implantation of the probes, but two patients had a late wound infection at the surgical site more than 3 months after implantation. Measurements could be made immediately following surgery through the wound dressing.

Median implantation time in study period was 248 (49–666) days (Table 1). Divided in 6-month intervals, 10 patients had the probe implanted for less than 6 months, 4 patients for 6–12 months, 5 patients for 12–18 months, and 3 patients for 18–24 months (Fig. 2). When looking at the measuring period (time from implantation to last reading session), the median was 154 (8–433) days, with 10 patients having measuring periods exceeding 6 months (Fig. 3). In 4 patients we had to explant the probe due to local infection (2 cases) and ethylene oxide allergy (2 cases). Ethylene oxide allergy was clinically suspected in patients with numerous shunt

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