

External re-programmation by a new radionuclidic technique of electronic cerebrospinal fluid valve in case of hydrocephalus

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Abstract

Hydrocephalus is defined as an abnormal enlargement of the ventricles of the brain due to an excessive accumulation of cerebrospinal fluid (CSF) because of a disturbance of its flow, absorption and/or secretion. The usual method of CSF diversion is a ventriculo-peritoneal shunt. Complications of implanted shunt systems include mechanical failure, shunt pathway obstruction, infection, foreign body (allergic) reaction to implants and CSF leakage along the implanted shunt pathway. These problems are solved with the use of programmable ventricular-peritoneal CSF valves. In this case, we describe a radionuclidic method for the control of successful reprogramming of the CSF valve. Furthermore, we analyze some technical data of such a valve-type are essential for the application of the above technique by nuclear medicine physicians. Scintigraphic evaluation of the electronic V-P drainage valve regulation is a noninvasive, not expensive, rapid and safe method with no complications for the patient and provides a reliable proof of the patency of the V-P shunt.

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Introduction

Hydrocephalus is defined as an abnormal enlargement of the ventricles of the brain due to an excessive accumulation of cerebrospinal fluid (CSF) because of a disturbance of its flow, absorption and/or secretion [1]. A usual method of treatment is CSF diversion by a ventricular-peritoneal shunt (V-P). In such cases a proximal catheter (ventricular catheter) is placed into the lateral ventricle and is connected to a valve, which is attached to a distal catheter threaded subcutaneously down to the abdomen and inserted into the peritoneal cavity (peritoneal catheter) [1, 2].

Complications of similar implanted shunt systems include mechanical failure, shunt pathway obstruction, infection, foreign body (allergic) reaction to implants and CSF leakage along the implanted shunt pathway [1-4]. An additional complication is an excessive CSF drainage that may cause subdural haematomas, slit-like ventricles and in infants, sunken fontanelles. Furthermore, the ventricular catheter can become obstructed by excessive reduction of ventricle size. Nowadays, some of these problems are solved with the use of programmable ventricular-peritoneal CSF valves. A programmable valve is an implantable device that provides constant intraventricular pressure and drainage of CSF, allowing neurosurgeons to adapt the valve to changing patient conditions, rather than forcing patients to adapt to fixed pressure valves. This is possible with the external use (percutaneously) of the programmer without operation.

In the present case we describe a radionuclidic method for monitoring the reprogramming of the CSF draining valve. Furthermore, we analyze some technical details of this type of valve informing nuclear medicine physicians before applying this technique.

Case report

A 7 years old boy was admitted to our hospital because of vomiting, headache and lethargy. He had a history of a subtotal resection of an ependymoma located at the fourth ventricle four years ago. Due to obstructive hydrocephalus at that time, a programmable V-P CSF valve (type Codman Hakim) had been placed (Fig. 1 and 2). A cerebral computed tomography (CCT) scan was performed, showing a dilatation of the ventricular system and periventricular hypodensities due to CCF penetration to the brain parenchyma (Fig. 3). A plain X-rays film of the skull showed that the programmed value of functioning pressure of the valve



Figure 1. The programmable valve.

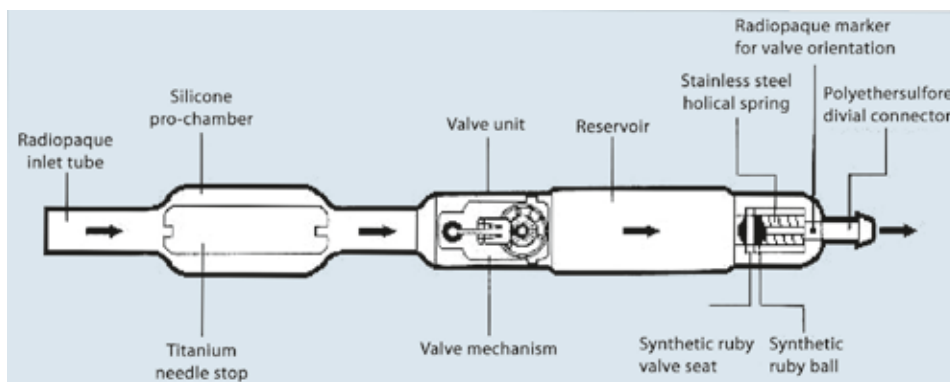


Figure 2. The mechanism of a programmable valve system.

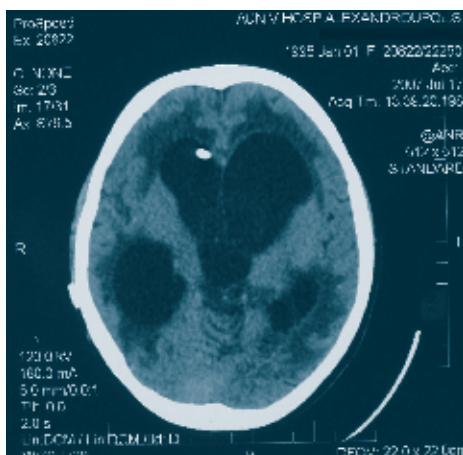


Figure 3. Dilatation of the ventricular system on computed tomography with periventricular white matter hypodensity due to CSF diffusion.



Figure 4. Skull radiography. Valve functioning value has not been changed.



Figure 5 and 6. The injection of the radiopharmaceutical into the reservoir.

had not been changed (Fig. 4). To examine the dynamic function of the valve, a scintigraphic examination was scheduled with gamma Camera Millennium MRP GE Milwaukee USA. Under aseptic conditions, the shunt reservoir was punctured and we performed aspiration of a small sample of CSF for culture and instillation of 37-40 MBq of ^{99m}Tc-pertechnetate in a volume of 0.1 ml. To avoid reservoir cap damage, we used a Huber-point needle (24 or 26 gauge) to penetrate its dome. We inserted the needle at an oblique angle to achieve the greatest yield of CSF and to prevent the needle point from piercing the ventricular catheter (Fig. 5 and 6). Initially, no radiopharmaceutical fluid was observed into the peritoneal cavity and this was considered as an indication of valve pressure dysfunction (Fig. 7). Consequently, we tried external reprogramming of the valve with the valve programmer (Fig. 8). The valve pressure was adjusted at a lower level and thereafter, radiopharmaceutical fluid passed free, through the V-P drainage system and radioactivity was concentrated into the peritoneal cavity (Fig. 9). The follow-up CCT revealed the disappearance of the periventricular hypodensity (Fig. 10). During the next days, the patient's clinical condition was well improved and finally he left the hospital 4 weeks later, without any need for surgical intervention.

Discussion

The use of the peritoneal cavity for CSF absorption in V-P shunting was introduced in 1905 by Kausch. Since then, this method is amongst the most frequently performed operations for the management of hydrocephalus [1]. Many different complications related to this procedure have been reported [1-4]. These can be summarized into three groups: a) mechanical failure related to improper function of the device, b) infection related to implanted foreign material, and c) functional failure resulting from an inadequate flow rate of the functioning CSF shunt. In an attempt to reduce the third group of complications, programmable CSF shunt valves were manufactured [3, 4]. These are implantable devices that

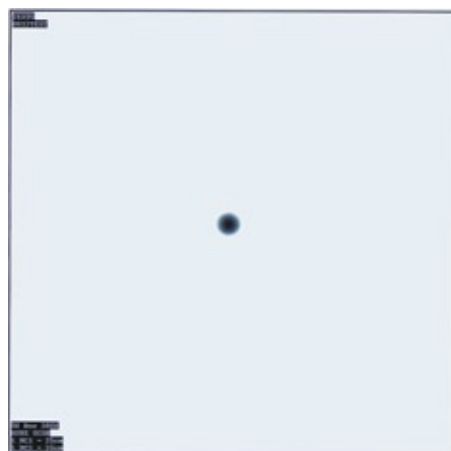


Figure 7. No flow of radiopharmaceutical from the reservoir is seen: valve dysfunction.

provide constant intraventricular pressure and drainage of CSF. The valve mechanism includes a rotor retention spring, which stabilizes the valve performance level setting, minimizing the risk of inadvertent pressure changes. Also the valve includes occludes for selective flushing and an injectable reservoir dome for CSF sampling. With easily discernible radiopaque markers and adjustment of the valve mechanism, post-implant settings may be verified with X-rays films. The valve mechanism incorporates a flat stainless steel spring in which the calibration is accomplished by a combination between a pillar and a micro-adjustable telescoping fulcrum. The valve chassis is made of titanium. The ball and cone are from synthetic ruby. Intraventricular pressure is maintained at a constant level by the ball and cone valve seat design. The pressure setting of the spring in the inlet valve unit is noninvasively adjusted by the use of an external programmer, which activates the stepper motor within the valve housing. In our case, the programmer transmits a codified magnetic signal to the motor allowing eighteen pressure settings, ranging from 30mm to 200mm H₂O (294 to 1960 Pa) in 10mm (98 Pa) increments. These are operating pressures of the valve unit and are adjusted to a flow rate of 15-25ml H₂O per hour. The valve is classified by its working pressure with a specified flow rate and not by the opening and closing pressures. The pressure that a valve sustains with a given flow is the parameter that reflects the working pressure of the valve once it is implanted. Several models of the valve have been marked with an X-rays detectable direction of flow indicator. The use of magnetic resonance imaging (MRI) systems (up to 2 Teslas or 20 kGauss) will not damage the valve mechanism, but may change the operating pressure of the valve. In this case, the valve pressure setting must be confirmed. Accumulation of any biological matter i.e. blood, proteins, tissue fragments etc. in the programming mechanism or in the catheters can cause inability of the device to shunting with the presetting pressure. Clinical signs such as headache, irritability, vomiting, drowsiness, or mental deterioration may be signs of a non-functioning shunt.

Nuclear medicine procedures are often used in Neurosurgery [5,6]. We here report that they can help in the successful

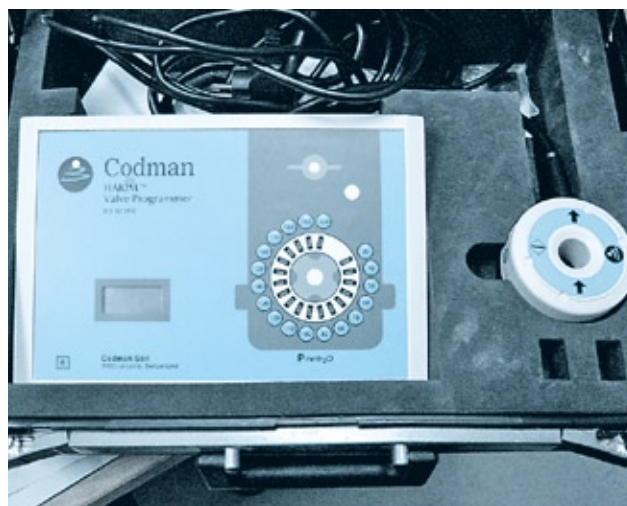


Figure 8. The external Valve Programmer.

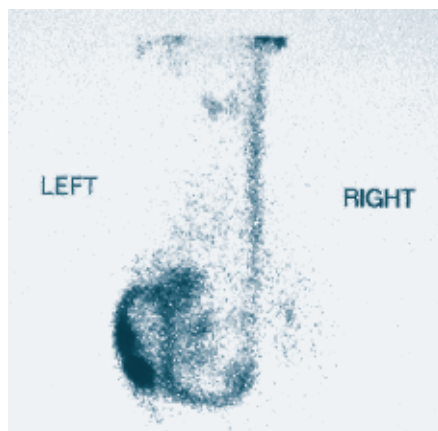


Figure 9. Free radiopharmaceutical fluid is passing through the V-P drainage system and radioactivity concentrated into the peritoneal cavity.

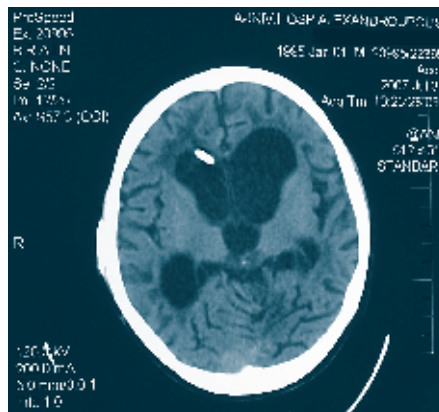


Figure 10. CT scan acquired 13 days after the first one (Fig. 3). Reduction of ventricular dilatation and cessation of periventricular white matter hypodensity.

reprogramming of the CSF valve without surgical intervention. For shunting studies, sodium ^{99m}Tc-pertechnetate (Na^{99m}TcO₄) is preferable because it is used as taken directly from the generator without any further preparation or labeling and has a low radiation burden. The effective dose equivalent for a normally functioning shunt using Na^{99m}TcO₄ is 0.07mSv and 0.1mSv when distal obstruction exists. The radiopharmaceutical is continuously mixed with CSF during administration. The patient remains in the supine position throughout the study and is allowed to stand and walk around for a while, only if

the tracer is not seen at the distal end of the tube. Serial planar images of skull and abdomen are acquired until the distal end or the peritoneal cavity is shown, at least up to 30min or more after the tracer installation. The distal shunt tubing is visualized as a linear band of radioactivity. Signs of shunt dysfunction include: a) Lack of free intraperitoneal flow or a located collection of the radioactivity at the peritoneal tip (distal obstruction). b) Absence of reflux into the ventricular system and rapid filling of the distal shunt or failure of the tracer to clear from the ventricles after several hours (proximal obstruction). c) Extravasation or pooling of the tracer at the reservoir (mechanical stress or discontinuity of connections). d) Non visualization of the parotid glands after 30min (distal obstruction, as normal parotid gland activity appears in 5 to 30min) [7, 8]. At the time of the injection, the physician must be sure that the needle is in the reservoir or in the shunt tube, otherwise $\text{Na}_2^{99\text{m}}\text{TcO}_4$ diffuses in soft tissues and excreted via the kidneys. Apart from the obvious presence or absence of radioactivity in the peritoneal cavity, attempts have been made to quantify shunt function as a percentage clearance of the radioactivity from the ventricles at various time intervals. It has been reported that the $^{99\text{m}}\text{Tc}$ -DTPA half-disappearance time in normally functioning shunts is 0.5-6.0 min [9, 10].

In conclusion, for the complications of implanted CSF programmed valves we developed for the first time a nuclear medicine technique using $\text{Na}_2^{99\text{m}}\text{TcO}_4$. By this technique, a noninvasive performance level adjustment by scintigraphic evaluation of the electronic V-P drainage valve was achieved. This is regulation is a noninvasive, not expensive, rapid technique also provides a reliable proof of the patency of the V-P shunt.

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