

RESEARCH ARTICLE

THE ENHANCED IMPLANTABLE INTRATHECAL PUMP ON CSF-COMPENSATION

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ABSTRACT

This paper accounted for an advanced intrathecal infusion pump by using never-trying-before cerebrospinal fluids compensation for pain patients by transplantation. The system provided the authentic administrations of morphine with one-way valve to cope with the problem that cerebrospinal fluids flowed backward. In addition, it was possible to connect the catheters with case that the devices to hold catheter was embedded according to doctor's advices, or to create sealed-reservoir spontaneously at the same time as combining case. Moreover it accessed about a long lasting battery life with 2 years to flow amount of morphine with 2 gram per day. Since this medical instrument has been particularly devised for the safety, biocompatibility, stability, accuracy, connectivity and durability, it was possible to be substantiated that the intrathecal pump with CSF compensation made it easy to provide lucratively and draw attention to patients with cancer pain throughout in-vivo performance and safety evaluations.

Key words: Morphine; Administration; Pain; Implantation; CSF

INTRODUCTION

It is discerned that spinal cord is a predominant region clustered with receptors of the narcotics analgesic in 1970's. It began to blossom the rudimentary implantable infusion pump as a safe and easy method to administrate a drug in 1990's. The Intrathecal pump to inject morphine directly spinal cord neural pathway which delivers pain was useful to patient with cancer pain because it has more than 300 times effect compared to oral administration and 100 times effect compared to intravenous administration quantitatively. Clinical trial have shown that an drug delivery system implanted under the skin of the abdomen and connected to a small catheter tunneled to the site of spinal entry, effectively delivers small doses of morphine directly to the spinal fluid (Tomas at al, 2003).

Because side effect profiles was dramatically improved with intrathecal delivery, drug titration requires hours instead of days, and pain can be aggressively treated with less risk of life-threatening toxicities, Rapid pain relief also results in fewer hospitalizations for pain control and thus saves healthcare dollars (Lisa at al, 2005). Several experiments and evaluations by method which is used gas compensation have preceded a few years ago. According to previous researches, the counterbalance of reservoir by CSF circulated was offset by the negative pressure of the gas. Moreover, administration of morphine with never-trying-before CSF compensation was much more stable than the method by gas (C₅H₁₀) compensation. This paper introduced a preeminent implantable intrathecal pump responded doctor's requirements in terms of technical facets.

MATERIALS AND METHODS

Apparatus and Materials

In this system, reservoir structure to enrich convenience, devices to hold catheter (Hankook Mechatronics), and one-way valve (Hankook Mechatronics) are distinct compared to primitive example with CSF-Compensation (Figure 1).

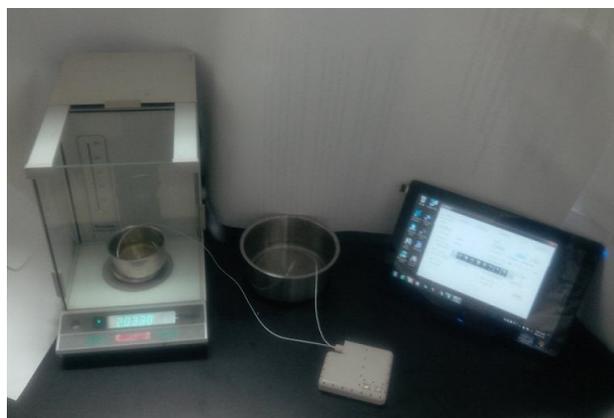


Figure 1. The configuration of implantable intrathecal pump

The reservoir and PCB constitute a large part of the entire case. A gasket (Hanil Hightech) with viton separates not only these two parts but also inside of case to outside. And a diaphragm is also designed by o-ring around of it that the reservoir is preserved intact because the case must undergo a mandatory inserting diaphragm before combining upper and lower case. This new way is a highly desirable structure that needed only low-cost, and is specially appreciated, thereby avoiding needless hardware for reservoir. Morphine through a

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silicon tube (Hansung Medical appliances) flows in a direction of actuator (Metrotech) by motor (Maxon) on PCB (Pando) with 2 batteries (Saft) with AA size which is connected in parallel. And this medication passes through a filter (Hankook Mechatronics) that it was recommended to apply membrane (Merck Millipore) with 0.22um thickness to prevent bacteria infection into brain that can lead to deadly results. In reference, it is connected the tube which transfers the medication to the device which hold catheter from case. This device is embedded in case (Hankook Mechatronics), and silicon-tube (Silitech) existed in the inner space of it that connection between catheter and case is completely long-lasting. As the morphine is administrated to spinal-cord, cerebrospinal fluids consecutively flow in another catheter. One-way valve (Hankook Mechatronics) contrived to wholly limit a slight backward flow is connected to the device which hold this catheter in series.

Procedures

The medical instrument comprised of pumping-device and extracorporeal wireless monitor is accessible to supply stable flow rates in a wide range from a small amount of several micro-milliliters per minute to several milliliters per minute. CSF compensation is the bulk of system that makes medication administration to infuse at a uniform speed in a day. CSF spontaneously induced into pump at the same time administrating morphine creates balanced pressure in the reservoir. This propensity accesses stroke volume at a uniform speed. At first, a medication-reservoir is filled with amount Morphine with 30mL through the port, or septum (Hanil-Hightech) with silicon-rubber by using a disposable syringe. As morphine is directly administrated to a patient’s spinal cord neural pathway which delivers pain according to the amount of medication and infusion-rate which is programmed by extracorporeal monitor, CSF which is equal to injected amount of morphine is spontaneously preserved in CSF-reservoir (Figure 2).

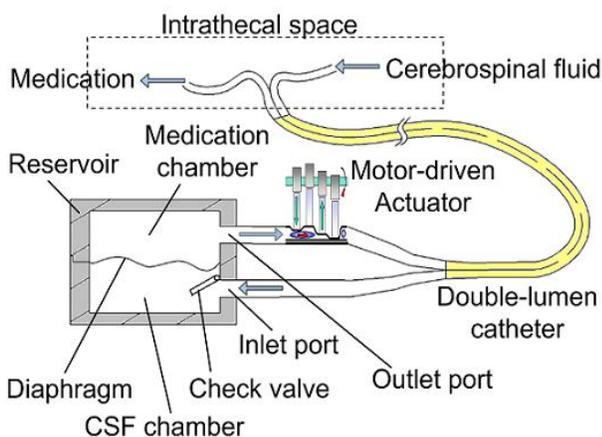


Figure 2. Cerebrospinal fluid compensation medication repository overview

Since the reservoir with 30mL is divided by elastic and thin diaphragm (Hanil-Hightech) between upper case and lower case, it is possible to maintain a constant flow rate without fluctuation under the stable pressure. After 2 weeks, amount of CSF with 30mL can be totally released to outside of body in

conjunction with refill of amount of morphine with 30mL (Figure 3).

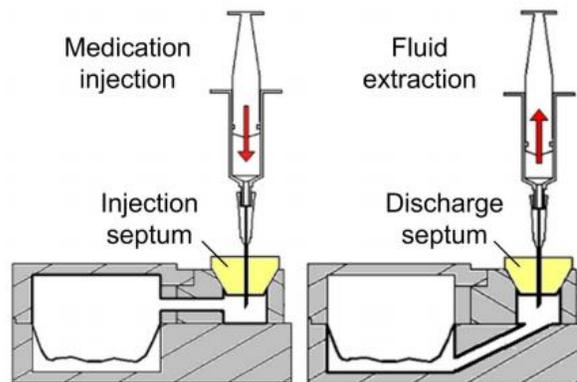


Figure 3. Medication refill of morphine & discharge of CSF

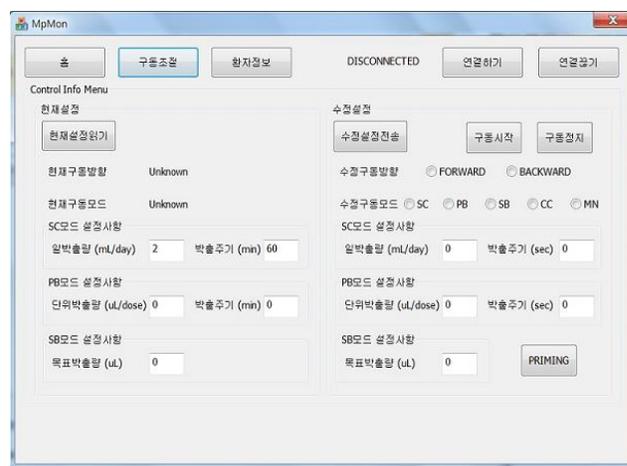


Figure 4. External monitoring program interface

The developed micro pump can control a morphine quantity per time through various modes. The modes to administrate modest volume in a day are continuous, simple continuous, single bolus, periodic bolus, and complex. The external monitoring program interface is based on the Visual C++ 6.0, and accesses to set information of administration for patient.

RESULTS

Continuous infusion mode and simple continuous mode among administration pattern were experienced in vitro. The experiments were carried out within the scope of similar to real situation using water instead of morphine (Table 1).

Table 1. Results experienced at continuous infusion mode and simple continuous mode (The pressure by flowing morphine in tube was assumed 1 atmosphere for efficient calculation.)

Mode	Flow rate
Continuous infusion	28.1 microliter/sec
Simple Continuous	8.08 microliter/rev

With respect to pi-graph of Figure 5, the experiments enlisted about 11uA to minimize power consumption in the sleep state of the simple continuous mode. And it exhibited that motor consumed most of power.

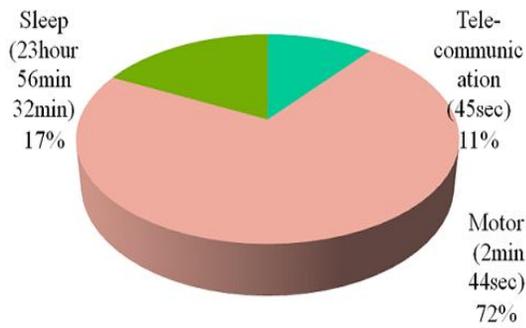


Figure 5. Daily Power consumption

After the flow-sequence of morphine with 2 grams per day under the SC mode repeats during 2 weeks, discharging of CSF and refill of morphine are undertaken by operator. It is anticipated that a battery life is about 2 years by power consumption in a day (Table 2).

Table 2. The power consumption evaluation measured by Agilent (The experiment didn't executed under the pump-case. The medication-container located in the remote CSF-container. Of cause water through a tube is used instead of medication and CSF.)

Mode	Power Consumption [mA]		
	Telecommunication	Motor	Sleep
Continuous infusion		100.12	
Simple Continuous	21.45	83.5	0.011

DISCUSSION

This paper deal with implantable intrathecal pump system by using never-tried-before CSF-Compensation considered as a versatile implement to perpetual and stable administration. As the system harnessed medication flow, it could be easy to maintain a constant flow rate without fluctuation. There are risks inherent in the system which includes a sudden backward flowing and a difficulty of connection between case and catheter during the operation. Therefore, the system functions as a compact instrument that the operator claims to use by inserting reservoir created spontaneously after combining

case, devices to hold catheter embedded within case and elaborate one-way valve contrived to restrict flowing backward. Thus these seem prospect to make contributions to provide operator and manufacturer with efficiency, convenience and safety. It is possible for the enhanced implantable intrathecal pump system with these three hardwares on CSF compensation to infuse amount of morphine with 8.08 microliter in 1 revolution of motor, and use during 2 years at single continuous mode of 2mg/day. Even though materials that animal experiment was in progress to evaluate biological safety are used, it was a standard and indispensable procedure for medical device to be gone through all related safety evaluations. It is suggested that this implantable intrathecal pump can be more suitable system considered safety, biocompatibility, accuracy, durability and so on through in-vivo evaluation and in clinical transplanting. Or, it is expected to explore a possible avenue to infuse more stable, increase battery-life and be constituted by alarming-system.

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