

DEVELOPMENT OF TEST BENCH FOR BIOFIDELIC INTRACRANIAL PRESSURE

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ABSTRACT

Intracranial Pressure (ICP) is the force exerted within the cranium, caused by the accumulation of blood, brain tissue, and cerebrospinal fluid (CSF). Excessive ICP (>20mmHg) poses health risks, including strokes, tumors, brain bleeds, and cerebral deformities if untreated. Ventriculoperitoneal (VP) shunts relieve ICP by draining excessive CSF. However, current shunts experience complications such as blockages and malfunctions, leading to costly, high-risk surgical revisions for up to one in five patients. Existing testing methods involve injecting fluid at 20mmHg and measuring drainage (30ml), but more biofidelic testing is needed. This work documents a test bench designed to evaluate VP shunts under real ICP conditions. The proposed test bench hardware includes a fluid pump, ventricular chamber, reservoir chamber, capacitive pressure sensor, two flow sensors, two check valves, and flexible silicone tubing. An Arduino microcontroller collects ICP data in real-time. The system pumps fluid from the reservoir into the ventricle chamber, where the capacitive pressure sensor measures ICP. Flow sensors monitor drainage, while check valves regulate fluid pathways. The test bench simulates real-time ICP from 5 to 150 mmHg and ventricular flow from 0 to 300 ml/min, allowing dynamic VP shunt evaluation. This enables preliminary functional assessments before animal or human trials, supporting shunt development. This versatile test bench enables controlled VP shunt evaluations, reducing surgical risks and costs. By optimizing shunt designs, it enhances reliability and improves patient outcomes in hydrocephalus and ICP-related conditions.

Keywords: Intracranial Pressure, Compliance Measurement, Ventriculoperitoneal Shunts, Biofidelic Testing, Arduino Control

INTRODUCTION

Neurological conditions such as hydrocephalus and traumatic brain injuries often require integrated intracranial pressure (ICP) monitoring to detect complications [1]. Elevated ICP, defined as pressure exceeding 20 mmHg, can lead to severe outcomes, including brain herniation, impaired neurological function, and reduced perfusion [2]. The timing and accuracy of ICP monitoring is crucial in preventing catastrophic outcomes. The human body is very unpredictable in every aspect and as such ICP is no different. Having effective ICP management is essential to improving patient care, especially in patients with hydrocephalus, where there is a buildup of CSF, which puts excessive amount of pressure inside of the cranium [3].

VP shunts are commonly used to relieve elevated ICP by diverting the excess CSF into other parts of the body [4]. These devices are frequently used for conditions like hydrocephalus, where there is an imbalance in the production and absorption of CSF. The process of VP shunts is to regulate CSF and prevent the buildup of pressure. However, these shunts can be associated with complications, such as blockages, tubing failures, and infections, often requiring surgical procedures [5]. There are a high number of complications in VP shunts, based on studies there is an average of 21.3 complications per 100 patients that need VP shunts which sets a clear example of improvements needed in design and testing to ensure better patient outcomes and to minimize further surgeries [6]. The average person that has hydrocephalus does not want to consistently go