Chapter 11
Outcomes Research in Hydrocephalus Treatment

Damien Wilburn
University of Louisville, USA

ABSTRACT

Hydrocephalus is a disorder where cerebrospinal fluid (CSF) is unable to drain efficiently from the brain. This paper presents a set of exploratory analyses comparing attributes of inpatients under one-year old diagnosed with hydrocephalus provided by the Agency for Healthcare Research and Quality (AHRQ) as part of the National Inpatient Sample (NIS). The general methods include calculation of summary statistics, kernel density estimation, logistic regression, linear regression, and the production of figures and charts using the statistical data modeling software, SAS. It was determined that younger infants show higher mortality rates; additionally, males are more likely to present hydrocephalus and cost slightly more on average than females despite the distribution curves for length of stay appearing virtually identical between genders. Diagnoses and procedures expected for non-hydrocephalic infants showed a negative correlation in the logistic model. The study overall validates much of the literature and expands it with a cost analysis approach.

BACKGROUND

The rising cost of healthcare in America is a frequent issue raised by various media outlets as well as politicians. In 2007, the total spending on healthcare reached $2.3 billion, and that number is estimated to reach $3 billion by 2011. In 2006, the total cost accounted for 16% of the United States’ gross domestic product (GDP) (Poisal, Truffer, & Smith, 2007). These figures represent the national totals, but costs of individual patients must also be considered. Particularly for infants, the costs can be especially high due to the requirement of more sophisticated techniques and equipment.

Hydrocephalus, literally meaning “water head”, is a disorder that can occur at any age, but experts predict that it affects approximately 1 in 500 infants. It is characterized by an excess of cerebrospinal fluid
(CSF) filling the ventricles of the brain and not draining efficiently. Most early models presume that resistance to CSF is pressure-independent, and thus, will be constant regardless of secretion rates (Meier, Zeilinger, & Kintzel, 1999). Most newer models are built around Hakim et al.’s hypothesis that the brain acts as an open submicroscopic sponge of viscoelastic matter (Hakim, Venegas, & Burton, 1976). In particular, Nagashima et al. constructed a model using the finite element method to predict the dynamic flow of CSF in cases of hydrocephalus (Nagashima, Tamaki, Matsumoto, & Seguchi, 1986); combined with pressure dependent models of draining and arterial resistance/compliance (Meier et al., 1999), a positive feedback loop could influence the progression of the disease. The exact causes of the disorder are not well understood and are believed to vary from case to case. Several hypothesized causes include inherited genetic abnormalities, developmental disorders, meningitis, tumors, traumatic head injury, or subarachnoid hemorrhage. Multiple forms of hydrocephalus exist, including congenital, acquired, communicating, or obstructive. Two other forms that primarily affect adults are hydrocephalus ex-vacuo and normal pressure hydrocephalus ((NINDS), 2008).

The symptoms also vary between patients, but in infants, it is normally accompanied by an enlarged head via their soft skulls, expanding to compensate for the increased CSF pressure. Other symptoms can include vomiting, sleepiness, irritability, downward deviation of the eyes, and seizures. Hydrocephalus is regularly diagnosed by some form of advanced cranial imaging, including ultrasonography, computed tomography (CT), magnetic resonance imaging (MRI), or pressure-monitoring techniques. The normal treatment for hydrocephalus is surgically inserting a shunt system to redirect the flow of CSF to other parts of the body, where it can eventually be recycled or excreted ((NINDS), 2008). The two common shunt systems for infants include ventriculoatrial (VA) and ventriculoperitoneal (VP), but follow-up studies demonstrate that, on average, VA systems require more adjustments, present with more complications, and complications are more serious (Keucher & Mealey, 1979).

Data mining is the analytical practice designed to explore large and complex data sets in search of patterns, systematic relationships between variables, and eventually validating relationships with new subsets of data. Thus, the three major steps of data mining involve data exploration, model construction, and validation. For a study such as this, the objectives will rely principally on exploration and model construction. Exploration involves primarily summary statistics: mean, median, mode, and frequency calculations on different subsets of the data, presented in simple graphical or tabular formats. Kernel density estimation is an extension of these techniques by interpolating frequencies for continuous variables to produce an approximate probability density curve. Based on both initial and final results obtained during exploration, the data must also be “cleaned” or formatted in a matter conducive to further statistical analysis and modeling. A simple example is the division of age into groups to allow a reasonable number of values per group for significant calculations. A particular consideration that needs to be made in rare-occurrence events for diseases such as hydrocephalus is proper controls. If one were to use a full dataset and the event only occurs 1% of the time, simply assuming all cases to be non-occurrence yields 99% accuracy by default. Thus, an effective technique in cleaning the data to circumvent this is to only include a random subset of non-occurrence cases equal in size to the subset that is occurrence cases (StatSoft, 2007).

Linear regression is a popular and powerful technique used in multivariate modeling. Utilizing multiple independent variables and calculating coefficients to weight their individual and independent impact, the likelihood of a single continuous dependent variable can be predicted.

\[ y = b_0 + b_1 x_1 + b_2 x_2 + \ldots + b_n x_n \]

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