Emergency Department Use of Computed Tomography for Children with Ventricular Shunts

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Objectives To quantify rates and variation in emergency department (ED) cranial computed tomography (CT) utilization in children with ventricular shunts, estimate radiation exposure, and evaluate the association between CT utilization and shunt revision.

Study design Retrospective longitudinal cohort study of ED visits from 2003-2013 in children 0-18 years old with initial shunt placement in 2003. Data were examined from 31 hospitals in the Pediatric Health Information System. Main outcomes were cranial CT performed during an ED visit, estimated cumulative effective radiation dose, and shunt revision within 7 days. Multivariable regression modeled the relationship between patient- and hospital-level covariates and CT utilization.

Results The 1319 children with initial shunt placed in 2003 experienced 6636 ED visits during the subsequent decade. A cranial CT was obtained in 49.4% of all ED visits; 19.9% of ED visits with CT were associated with a shunt revision. Approximately 6% of patients received ≥10 CTs, accounting for 37.2% of all ED visits with a CT. The mean number of CTs per patient varied nearly 20-fold across hospitals; the individual hospital accounted for the most variation in CT utilization. The median (IQR) cumulative effective radiation dose was 7.2 millisieverts (3.6-14.0) overall, and 33.4 millisieverts (27.2-43.8) among patients receiving ≥10 CTs.

Conclusions A CT scan was obtained in half of ED visits for children with a ventricular shunt, with wide variability in utilization by hospitals. Strategies are needed to identify children at risk of shunt malfunction to reduce variability in CT utilization and radiation exposure in the ED. *(J Pediatr 2015;167:1382-8)*.

Approximately 150 000 children in the US rely on a cerebrospinal fluid ventricular shunt to treat hydrocephalus. In children, placement of ventriculoperitoneal (VP) shunts, the most common form of cerebrospinal fluid shunt, has doubled over the last 3 decades.[1] Although VP shunts have dramatically improved survival for children with hydrocephalus, they are associated with high rates of complications, such as mechanical failure and infection, which result in cranial imaging and surgical revision.[2]

Children are at highest risk for shunt failure within the first year of placement; shunt revision rates are approximately 40% in the first year, and reach as high as 60% within 10 years, with substantial variation in failure rates across hospitals.[3,4]

Children with concern for VP shunt-related complications are frequently evaluated in the emergency department (ED), where cranial computed tomography (CT) is often used to diagnose shunt malfunction and differentiate malfunction from other conditions.[2,5-8] CT use exposes children to ionizing radiation, and greater cumulative radiation exposure might be associated with a greater incidence of malignancy.[7,9,10] Children with VP shunts represent a particularly vulnerable group, as they often undergo multiple CT scans, and may be exposed to large cumulative radiation doses over the course of their lives.[10] Rapid cranial magnetic resonance imaging (MRI) has recently been explored as an alternative to CT to diagnose shunt malfunction.[11,12] To date,

CCC	Complex chronic condition
CT	Computed tomography
ED	Emergency department
ICD-9-CM	*International Classification of Diseases, 9th Revision Clinical Modification*
MRI	Magnetic resonance imaging
mSv	Millisievert
PHIS	Pediatric Health Information System
VP	Ventriculoperitoneal

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the extent of CT and MRI use in the ED setting for children with VP shunts is unknown.

Using a longitudinal cohort of children with VP shunts, the objectives of this study were to: (1) quantify the rates and variation of cranial diagnostic imaging during ED visits; (2) estimate the cumulative effective radiation dose for children with VP shunts from CT imaging performed during ED encounters; and (3) evaluate the association between ED CT use and shunt revision.

Methods

Data for this retrospective longitudinal cohort study were obtained from the Pediatric Health Information System (PHIS), an administrative database containing clinical information from 44 children's hospitals in the US. Individual institutions provide de-identified data. Encrypted medical record numbers enable tracking individual patients across hospital visits. The Children's Hospital Association (Overland Park, Kansas) and participating hospitals jointly ensure data quality.[13] Data for this study were obtained from 31 hospitals with complete data for the duration of the study period. This study was granted exemption from human subjects approval by the Boston Children's Hospital Institutional Review Board.

Children 0-18 years of age who experienced initial ventricular shunt placement between January 1, 2003 and December 31, 2003 were eligible for inclusion. Patients were identified using the *International Classification of Diseases, 9th Revision Clinical Modification* (ICD-9-CM) procedural code for ventricular shunt placement (02.3x) during a hospitalization. Patients with a principal ICD-9-CM diagnosis code of a mechanical complication of a neurosurgical device (996.2), a procedural code for ventricular shunt replacement (02.42 or 54.95), or ventricular shunt removal (02.43) on or before the date of the initial shunt placement, were excluded.[4,14] We also excluded patients with a procedural code of 02.39, as this represents an external ventricular drainage device and not an intraventricular shunt. Data from 2002 was examined to ensure that included patients did not have a shunt-related visit code for the year preceding study entry.

Children were followed from 2003 through 2013 to assess 3 main outcomes: (1) rates of cranial diagnostic imaging in the ED; (2) cumulative, effective radiation dose from cranial CT scans; and (3) prevalence of a shunt complication that required surgery within 7 days of an ED visit. Diagnostic imaging was defined as a cranial CT and/or brain MRI performed during the first day of the billing record as identified by administrative billing data. Imaging can be ascertained only by day of service and not by location; consistent with prior studies using PHIS, we anticipate that the vast majority of imaging on day 1 occurred in the ED.[15] Given that individual patient exposure data were not available, effective radiation dosage was calculated to estimate radiation exposure.[16] We used age-based conversion coefficients derived previously from age- and region-specific dose length product to estimate the effective radiation dose per CT scan.[16] The effective dosage estimates the risk of exposure attributable to a CT scan. Although this does not provide the actual risk for an individual patient, this measure permits comparisons across facilities to determine the effectiveness of dose optimization strategies.

Similar to prior studies, we utilized reasonable estimates of the amount of radiation exposure stratified by age.[16-20] Shunt revisions performed within 7 days of an ED encounter were identified by ICD-9-CM procedure codes for ventricular shunt replacement [02.42 or 54.95], ventricular shunt removal [02.43], or new ventricular shunt placement [02.34] if the procedure was performed within 7 days of the ED visit. If a patient had more than 1 revision within 7 days, the individual was counted only once in the analysis.

Demographic characteristics were ascribed at the time of initial shunt placement and included age, sex, race/ethnicity, and insurance status. Clinical characteristics included the principal diagnosis associated with initial shunt placement (obstructive hydrocephalus [331.4], congenital hydrocephalus [742.3], spina bifida [741.xx], communicating hydrocephalus [331.3], trauma [432.1, 995.55, 995.54, 852.2], and other) and complex chronic conditions (CCCs). CCCs represent defined diagnosis groupings expected to last longer than 12 months, and involve either a single organ system severely enough to require specialty pediatric care and hospitalization, or multiple organ systems.[21] The number of CCCs was assessed for each patient (1, 2, 3, or more) at the initial visit; all patients included in this study met criteria for at least one CCC based upon the presence of a ventricular shunt (neuromuscular CCC). US Census Tract Region was used to categorize hospital location.[22]

Statistical Analyses

Patients were categorized based upon the number of CT scans received during the follow-up period (0, 1, 2, 3-5, 6-9, or 10 or more). Bivariate analyses were performed to explore the relationships between potential covariates and CT utilization categories using the χ^2 test. Hospitals were dichotomized into low and high shunt volume categories based upon the number of patients experiencing an initial VP shunt in 2003. The Wilcoxon rank-sum test was used to determine the association of the hospital-level volume (low vs high) of VP shunts placed in 2003 with hospital-level CT utilization. A multivariable negative binomial regression model was used to model the total number of CT scans using covariates significant in bivariate analyses ($P < .1$). Results are presented as aOR with 95% CI. The contribution of each individual predictor of obtaining a CT scan was determined using the adequacy statistic.[23] Overall and annual radiation dose exposure and rates of shunt revision were compared across CT utilization categories using the Kruskal-Wallis test. All analyses were performed using SAS v.9.3 (SAS Institute, Cary, North Carolina). A two-sided $P < .05$ was considered statistically significant.