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The Pediatric Intracerebral Hemorrhage Score: A Simple Grading Scale for Intracerebral Hemorrhage in Children

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Abstract

Background and Purpose—The ICH Score is the most commonly used clinical grading scale for outcome prediction after adult intracerebral hemorrhage (ICH). We created a similar scale in children to inform clinical care and assist in clinical research.

Methods—Children, full-term newborns to 18 years, with spontaneous ICH were prospectively enrolled from 2007-2012 at three centers. The pediatric ICH score was created by identifying factors associated with poor outcome. The score's ability to detect moderate disability or worse and severe disability or death was examined with sensitivity, specificity, and area under the receiver operating characteristic (ROC) curves.

Results—The pediatric ICH score components include ICH volume >2-3.99% of total brain volume (TBV)=1 point, ICH volume ≥4% TBV=2 points; acute hydrocephalus=1 point; herniation=1 point; and infratentorial location=1 point. The score ranges from 0-5. At 3-month follow-up of 60 children, 10 were severely disabled or dead, 30 had moderate disability, and 20 had good recovery. A pediatric ICH score of ≥1 predicted moderate disability or worse with a sensitivity of 75% [95% confidence interval (CI): 59-87%] and a specificity of 70% (95% CI: 46-88%). A pediatric ICH score of ≥2 predicted severe disability or death with a sensitivity and specificity of 90% (95% CI: 55-99%) and 68% (95% CI: 53-80%). The area under the ROC curve for classifying outcome as severe disability or death was 0.88 (95% CI: 0.78-0.97).

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Disclosures

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Conclusions—The pediatric ICH score is a simple clinical grading scale that may ultimately be used for risk stratification, clinical care, and research.

Keywords

intracerebral hemorrhage; outcome; pediatric stroke; hemorrhage

Introduction

Hemorrhagic stroke represents an important cause of critical illness and morbidity in children. In a large retrospective study of children with stroke from a large northern California health system, hemorrhagic stroke had an incidence of 1.4 per 100,000 person-years.[1] In this cohort of children with hemorrhage, 73% were admitted to the ICU, 42% were intubated, and 19% underwent decompressive neurosurgery.[2] Neurologic deficits at discharge were documented in 48%. Intracerebral hemorrhage (ICH) is the most common type of hemorrhagic stroke and accounts for almost 50% of pediatric stroke[3], whereas in adults ICH only comprises about 12% of strokes.[4] ICH is comprised of intraparenchymal hemorrhage (IPH) and intraventricular hemorrhage (IVH). IPH and IVH are incompletely understood in children given the distinct etiologies compared to those in adults. Large evidence gaps exist regarding the optimal acute management of ICH in children. The strongest associations with outcome after pediatric ICH are the intraparenchymal component of ICH >2% of total brain volume (TBV) resulting in moderate disabilities and ≥4% resulting in severe disability or death.[5, 6] Another reported predictor of poor outcome has been altered mental status within 6 hours of hospital arrival.[5]

The ICH Score is the most commonly used clinical grading scale after adult ICH and predicts both 30-day mortality and 12-month outcome.[7, 8] It can be rapidly and accurately assessed at the time of presentation with ICH. The score has helped advance both patient care and clinical research following adult ICH. Our goal was to create a similar scale in children to inform clinical care and assist in clinical research.

Methods

Study Design and Subjects

This is a prospective cohort study of perinatal (full-term newborns ≥37 weeks gestation to ≤28 days) and childhood subjects (>28 days of life to 18 years) presenting between 2007 and 2012 with spontaneous ICH at three tertiary care institutions. Consent was obtained from subjects' parents and assent from children ≥7 years. The institutional review boards of all three institutions approved the study. Ascertainment was thought to be near complete since the institutions have clinical protocols for ICH management that include stroke service consultation.

Definitions

Spontaneous ICH was defined as intraparenchymal hemorrhage (IPH) and/or intraventricular hemorrhage (IVH) not caused by trauma, brain tumor, or hemorrhagic transformation of arterial ischemic stroke or cerebral sinus venous thrombosis. Isolated subarachnoid hemorrhages were excluded. For this sub-study, those with isolated IVH were excluded, as were children with pre-existing neurological deficits or death due to non-ICH causes. All ICHs were confirmed on head computed tomography (CT) or magnetic resonance imaging (MRI).

Intraparenchymal Volume Assessments

IPH volume and total brain volume (TBV) were calculated via the ABC/2 (also called ABC/XYZ for children) method, a bedside measure for childhood ICH volume as a percent of TBV that has previously been demonstrated to have excellent interrater reliability.[9] This method is modified from the ABC/2 method used in adults and has been shown to be accurate and reliable among raters in 2 pediatric ICH studies.[9, 10] As in previous studies, IPH was expressed as a percentage of TBV.[5, 6, 10] ABC/2 volumes and TBVs were measured by a trained research assistant (MG) with 30% of the sample confirmed by a pediatric neurologist (LJ). The intraclass correlation coefficient for the two raters' ABC/2 volumes was 0.90 (95% CI 0.83-0.97), indicating excellent interrater reliability.[11] The ABC/2 raters were blinded to outcome.

Outcome Assessment

Children were assessed at 3-month follow-up by a pediatric stroke neurologist with the King's Outcome Scale for Childhood Head Injury (KOSCHI).[12] The KOSCHI incorporates functional impairments as well as periodic symptoms like headaches and seizures. Scores are 1 for death, 2 for a vegetative state, 3a and 3b for severe disability (3a worse), 4a and 4b for moderate disability (4a worse), and 5a and 5b for good recovery (5b full recovery, no residual symptoms). In our study, the KOSCHI was determined from history obtained via parental interview and a standardized neurological examination at follow-up. Very poor outcome was defined as KOSCHI ≤3b. Good outcome was defined as a KOSCHI of 5a or 5b. KOSCHI score was assigned by a study pediatric stroke neurologist who evaluated the child in the clinic for follow-up and was blinded to the ICH score.

Pediatric ICH Score

The components of the pediatric ICH score were based on those in the adult score with some alterations. The adult score is comprised of the following: Glasgow Coma Scale score (3-4 = 2 points, 5-12 = 1 point, 13-15 = 0 points), ICH parenchymal volume ≥30 cm^3 (1 point) or <30 cm^3 (0 points), presence of intraventricular hemorrhage (1 point), infratentorial origin of hemorrhage (1 point), and age ≥80 years (1 point) or <80 years (0 points). Based on the adult score, we examined putative risk factors for poor outcome including presence or absence of uncal or transtentorial brain herniation (proxy for Glasgow Coma Scale score which is rarely recorded in pediatric ICH), size of hemorrhage, presence or absence of IVH, infratentorial location, and age <1 year or ≥1 year. We also evaluated risk factors thought to be uniquely important in pediatric ICH, such as presence or absence of hydrocephalus, hemorrhage etiology, elevated ICP requiring intervention, and need for surgical evacuation (Table 1). These risk factors were assessed using the initial head CT or MRI when CT was not performed. Any risk factors that predicted moderate disability or worse or severe disability or death in univariable analyses were considered for the final score. Multivariable analyses were not performed because of the relatively small sample size.

Statistical Analysis

Our pre-specified hypothesis was that all of the components of the adult ICH score would be important for children. However, based on our prior work in this population, we examined other potential predictors of poor outcome including hydrocephalus, herniation, and vascular etiology of ICH. Each potential component of the pediatric ICH score was assessed via univariable analysis. Fisher exact test for categorical variables was used rather than logistic regression because the sample size is relatively small and the variable distributions are not normal.

Outcome prediction of the pediatric ICH score was compared to the KOSCHI score using receiver operating characteristic (ROC) curves. The ICH score's ability to detect moderate disability or worse, severe disability or death, and death alone was examined with sensitivity, specificity, and area under the ROC curve. We created different versions of the pediatric ICH score in which we sequentially eliminated different components of the score and compared the sensitivity, specificity, and area under the curve to those for our complete score to ensure that our score was the most parsimonious. A two-sided p-value of ≤0.05 was considered statistically significant. Statistical analysis was performed using STATA version 11.0 (STATA Corporation, College Station, TX).

Results

Seventy-nine children enrolled during this study period. Fifteen subjects were excluded for isolated IVH, 3 were excluded because they were neurologically abnormal at baseline, and 1 because death was due to a cardiac cause rather than ICH. Sixty children met all inclusion/exclusion criteria. Median age was 7.2 years [interquartile range (IQR) 0.2-13.1 years]; 11 (18%) were perinatal. Thirty-two were male (53%). Forty-one subjects were Caucasian (68%, 3 Hispanic) and 19 (32%) were Black or African American. Isolated IPH occurred in 34 (57%) subjects, and 26 (43%) had both IPH and IVH. Six subjects (10%) had infratentorial origin of hemorrhage. Primary ICH etiology was a vascular malformation in 34 (57%), anticoagulation or coagulopathy in 12 (20%), thrombocytopenia in 1 (2%), and unknown in 13 (21%). Median IPH volume was 13.9 cm^3 (range 0.06-134.3 cm^3) by the ABC/2 method.[13] Correcting for brain volume, median IPH was 1.4% of TBV (range 0.01-13.2%) by the ABC/XYZ method which incorporates TBV.[9] Outcome was assessed at a median of 3 months post-ICH (IQR 2.1-3.7 months) and was available in all subjects.

Three months post-ICH, the median KOSCHI was 4b consistent with moderate disability (range 1-5b, IQR 4a-5a). KOSCHI was 1 (death) in 3 subjects (5%), 3b (severe disability) in 7 (12%), 4a or 4b (moderate disability) in 30 (50%), and 5a or 5b (good recovery) in 20 (33%). Univariable analyses of subject and hemorrhage characteristics for outcome prediction are presented in Table 1. For the final score, IPH volume, hydrocephalus, herniation, and infratentorial location were included. IPH volume was adjusted for TBV to account for the varying brain sizes of children of different ages, and was trichotomized (≤2% TBV, >2-3.99% TBV, ≥4% TBV). Infratentorial location was not significantly associated with outcome in univariable analysis, but was included since 67% of those with infratentorial origin of hemorrhage had moderate disability. The pediatric ICH score ranges from 0-5 points (Table 2). Median ICH score was 1 (range 0-4, IQR 0-2). ICH score was 0 in 24 subjects (40%), 1 in 11 subjects (18%), 2 in 13 subjects (22%), 3 in 8 subjects (13%), and 4 in 4 subjects (7%).

In ROC analysis, a pediatric ICH score of 1 or higher maximized our ability to predict moderate disability or worse (KOSCHI of 4b or lower) with a sensitivity of 75% [95% binomial exact confidence interval (CI): 59-87%] and a specificity of 70% (95% CI: 46-88%), respectively (Table 3). The area under the ROC curve for classifying a child's outcome as moderate disability or worse was 0.74 (95% CI: 0.61-0.87), Figures 1 and 2. In the 40% of our cohort (24/60) with a pediatric ICH score of 0, 58% had a good outcome (KOSCHI of 5a or 5b), 100% survived, and none had a KOSCHI ≤3b (severe disability or death). When examining the pediatric ICH score's ability to predict a severe outcome (3b or worse), the area under the ROC curve was 0.88 (95% CI: 0.78-0.97). A pediatric ICH score of 2 or higher maximized our ability to predict a KOSCHI of 3b or worse with a sensitivity and specificity of 90% (95% CI: 55-99%) and 68% (95% CI: 53-80%), respectively. A pediatric ICH score of 3 or greater maximized the ability to predict death with a sensitivity of 100% (95% CI: 29-100%) and a specificity of 84% (95% CI: 72-93%), respectively. The

area under the ROC curve for predicting death was 0.89 (95% CI: 0.81-0.96). In 12 subjects with less favorable ICH scores (≥3), only 2 (17%) had a good outcome, 25% died, and the remainder had moderate-severe disabilities. To ensure that our score was parsimonious, we created four new scores, each by eliminating one variable from the full score. In all cases, the new score with an eliminated variable had lower sensitivities, specificities, and area under the ROC curves than our original pediatric ICH score except for the model in which infratentorial location was eliminated (data not shown). However, the model without infratentorial hemorrhage did not have significantly different sensitivities, specificities, or areas under the ROC curve from our full model. We therefore maintained infratentorial location in the pediatric ICH score because there is biological plausibility that infratentorial location of ICH does worsen outcome based on clinical experience in children and the adult ICH score.[7, 8]

Discussion

The adult ICH score is used as a clinical tool to predict 30-day mortality after adult ICH and more recently 12-month functional outcome.[7, 8] In childhood ICH, death is less common, as rare as 5% in some cohorts[2, 5], so it is more useful for a grading scale to predict level of disability. In this study, we demonstrated that a pediatric ICH score of ≥2 is sensitive for predicting severe disability or death and that a score of ≥1 is sensitive for predicting moderate disability or worse. Our score required several alterations to the adult score based on unique pediatric features like the varying brain sizes of children of different ages and the lack of availability of certain data like a clinical indicator of mental status at presentation (GCS score). Most children with acute ICH are transferred to tertiary pediatric medical centers and GCS at presentation is often not well documented in young children. In pediatric and adult ICH studies, ICH volume has consistently been associated with outcome. In adults, ICH volume has been divided into 3 groups representing small, medium, and large hematoma size. Small hematomas are defined as <30 cm^3 and large hematomas as >60 cm^3.[14] In children, similar cut points have been applied, correcting for hemorrhage as a percentage of total brain volume, so that small, medium, and large hematomas are defined as those <2% of TBV[5], 2-3.99% of TBV, and ≥ 4% of TBV[6], respectively. The presence or absence of IVH is a weak predictor of outcome in the adult ICH score (p=0.052), and has not been independently associated with poor outcome in previous studies of childhood ICH.[7, 15] In our model, presence or absence of IVH was not a predictor of outcome, most likely because dichotomizing IVH as present or absent does not account for the volume of IVH which may be important. In our pediatric score, we replaced IVH with hydrocephalus, which predicted poor outcome. We also surmised that hydrocephalus was a marker of significant IVH. While infratentorial origin of ICH was not predictive of outcome in our cohort, only 6 children had infratentorial origin, limiting our ability to detect its effect on outcome. Two-thirds of children with infratentorial origin had moderate disability, and infratentorial location predicts poor outcome in adult ICH, so we included this variable in the pediatric ICH score. Finally, while age greater than 1 year was predictive of moderate disability or worse, it was not predictive of severe disability or death. Outcome assessments are more difficult in younger children. Deficits acquired during the perinatal period and in early childhood may become more obvious as the child grows older when cognitive, language, and motor difficulties become more apparent.[16, 17] Therefore, we chose not to include age as a component of the pediatric ICH score as information on long-term outcome (at least 2-year outcome) is needed to assess the impact of age on outcome after ICH in young infants.

A significant strength of this study was the prospective nature of the data collection and outcome assessment by a pediatric stroke neurologist. Limitations include the sample size, though this study represents the largest prospective pediatric ICH cohort to-date, and the fact

that years of follow-up may be required to detect mild to moderate cognitive deficits in very young children. We did not have a large enough sample to perform multivariable analyses on the components of our score, but by sequentially eliminating variables from the score, we demonstrated that our combination of variables is parsimonious. Finally, de-escalation of care may have contributed to poor outcomes in some children as has been demonstrated for the adult ICH score.[18] In our cohort, of 3 children who died, 1 was brain dead and 2 had care withdrawn after massive ICH and uncal herniation accompanied by dilated and fixed pupils. These 2 children did not meet criteria for brain death at the time that care was withdrawn, but progression to brain death or very poor neurological outcomes were expected.

The pediatric ICH score has predictive validity at 3 months after ICH and may be useful for clinicians and in the research setting. A major strength of the score is that the components included are all easily assessed in the acute setting at the patient's bedside.

Summary

The pediatric ICH score is a simple clinical grading scale that may ultimately be used for risk stratification, clinical care, and research for children with non-traumatic intraparenchymal hemorrhage. Specifically the score may be helpful for assessing the severity of the initial presentation in studies focused on measuring the efficacy of treatments for ICH in children. The score mirrors the scale that is useful in adults, though some components differ, specifically, the lack of an age variable, the use of hydrocephalus rather than presence or absence of IVH, the use of herniation rather than GCS, and a trichotomized stratification of ICH volume as a percent of total brain volume. Validation in a second large cohort is necessary.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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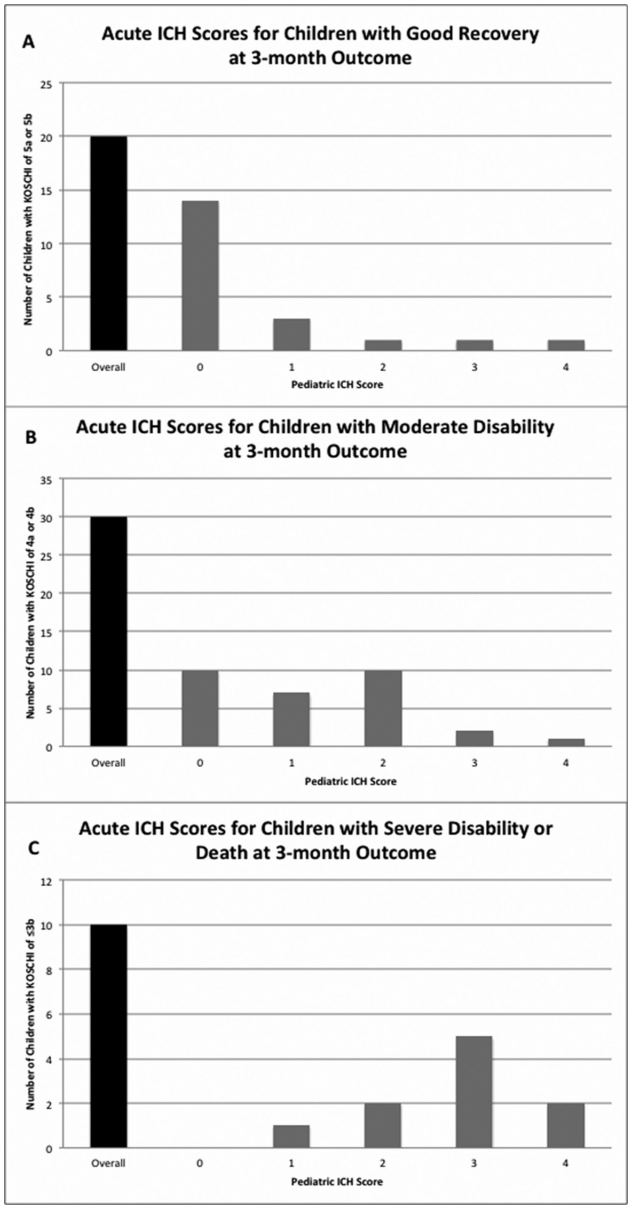
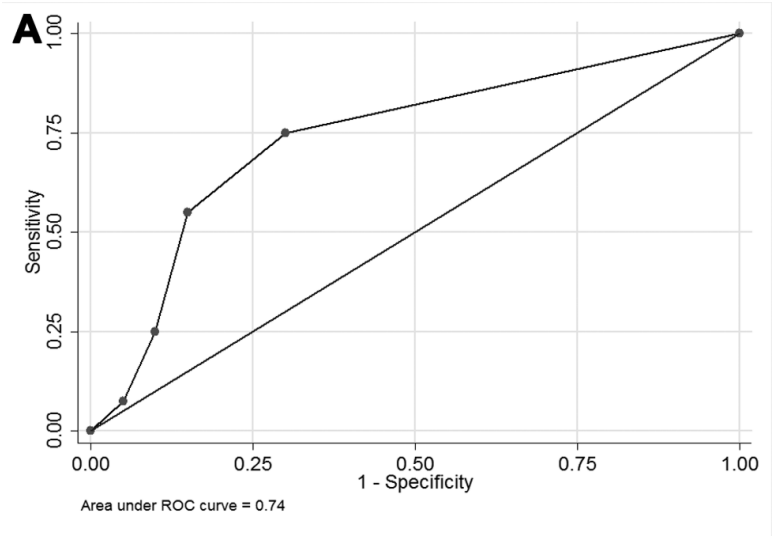
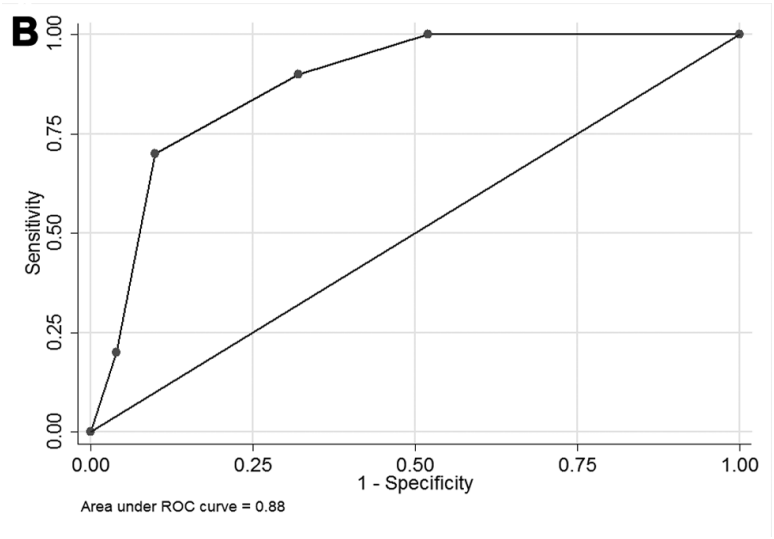


Figure 1. Comparison of Acute Pediatric ICH Scores and 3-Month Outcome (N=60)

Distribution of King's Outcome Scale for Childhood Head Injury (KOSCHI) scores at 3 months after intracerebral hemorrhage (ICH) compared with pediatric ICH scores. Panel A, shows the distribution of pediatric ICH scores in children with KOSCHI ≤3b (severe disability or death). Panel B, KOSCHI 4a and 4b (moderate disability). Panel C, KOSCHI 5a and 5b (good recovery).





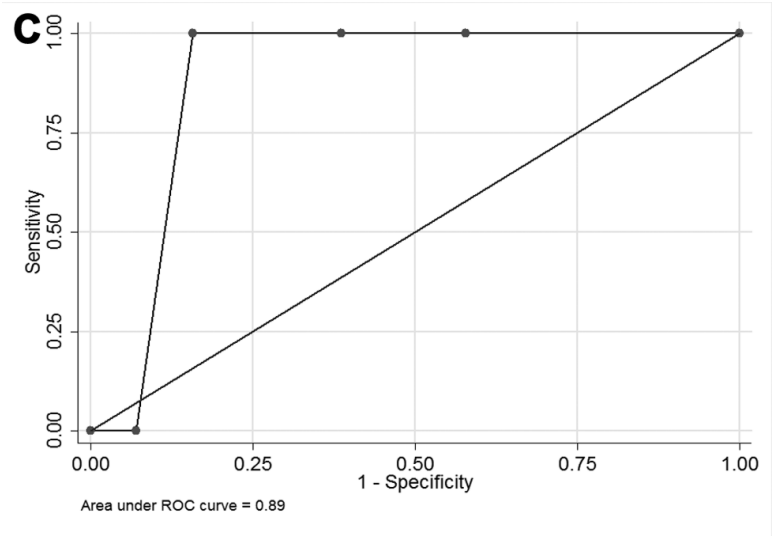


Figure 2. Receiver Operating Characteristic Curves for Pediatric ICH Scores

Panel A, moderate disability or worse. Panel B, severe disability or death. Panel C, death.

Table 1

Univariable Analysis of Characteristics of the Cohort and 3-Month Outcome (N=60)

Characteristics	N (%)	Moderate disabilty or worse, N (%)	P-value	Severe disability or death, N (%)	P-value
Sex					
Male	32 (53)	22 (69)	0.79	6 (19)	0.74
Female	28 (47)	18 (64)		4 (14)	
Age					
Under 1 year	18 (30)	8 (44)	0.034	3 (17)	1.00
Over 1 year	42 (70)	32 (76)		7 (17)	
Location					
Infratentorial	6 (10)	4 (67)	1.00	0 (0)	0.58
Supratentorial	54 (90)	36 (67)		10 (19)	
Etiology					
Vascular lesion	34 (57)	26 (76)	0.10	7 (21)	0.49
Other etiology	26 (43)	14 (54)		3 (12)	
Elevated ICP requiring intervention					
Yes	21 (35)	19 (90)	0.004	5 (24)	0.30
No	39 (65)	21 (54)		5 (13)	
Surgical Hematoma Evacuation					
Yes	21 (35)	20 (95)	<0.001	6 (29)	0.14
No	39 (65)	20 (51)		4 (10)	
ICH Volume, % of TBV					
≥4	11 (18)	8 (73)	0.07	6 (55)	<0.001
>2-3.99	12 (20)	11 (92)		3 (25)	
≤2	37 (62)	21 (57)		1 (3)	
IVH					
Present	26 (43)	19 (73)	0.42	6 (23)	0.31
Absent	34 (57)	21 (62)		4 (12)	
Hydrocephalus					
Present	19 (32)	17 (89)	0.017	6 (32)	0.059
Absent	41 (68)	23 (56)		4 (10)	
Herniation					
Present	17 (28)	16 (94)	0.005	7 (41)	0.003
Absent	43 (72)	24 (56)		3 (7)	

% of TBV, percent of total brain volume.

Table 2

Pediatric ICH Score Components and Scoring Parameters

Component	ICH Scoring
IPH Volume, % of TBV	
≤2	0
>2 -3.99	1
≥4	2
Hydrocephalus	
No	0
Yes	1
Herniation	
No	0
Yes	1
Infratentorial	
No	0
Yes	1
Total ICH Score	0 - 5

% of TBV, percent of total brain volume.

Table 3

Sensitivities and Specificities for Pediatric ICH Scores

Outcome	Sensitivity (95% CI)	Specificity (95% CI)
Moderate Disability or Worse (ICH score ≥1)	75% (59-87%)	70% (46-88%)
Severe Disability or Death (ICH score ≥2)	90% (55-99%)	68% (53-80%)
Death (ICH score ≥3)	100% (29-100%)	84% (72-93%)

CI, confidence interval; ICH score, intracerebral hemorrhage score.