****Hydrocephalus in patients with encephalocele: introduction of a scoring system for estimating the likelihood of hydrocephalus based on an 11-year experience from a tertiary center

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OBJECTIVE The goal of this study was to investigate and identify the predictors associated with the incidence of hydrocephalus requiring shunt insertion in patients with encephalocele (EC), and to develop a scoring system to estimate the probability of hydrocephalus occurrence over time in these patients.

METHODS A retrospective analysis was undertaken on data from patients treated for EC at a tertiary medical center between 2010 and 2021. Data including patient age at presentation, sex, sac location, sac size, contents, presence of ventriculomegaly/hydrocephalus, CSF leakage, and other associated intracranial/extracranial anomalies were among the variables evaluated for their predictive value. In addition, logistic regression analyses were performed to identify the independent predictors. A predictive scoring system was developed based on regression coefficients.

RESULTS A total of 102 cases of EC were identified. The patient group consisted of 52 boys and 50 girls. Seventy-one patients (69.6%) had posterior ECs. Forty-three (42.2%) of the ECs contained neural tissue. Thirty-three patients presented with ventriculomegaly (32.4%), 30 of whom (90.9%) underwent ventriculoperitoneal shunt placement for hydrocephalus. Multivariate analysis revealed that the presence of other associated anomalies (OR 2.8, 95% CI 1.1–7.4, p = 0.027), larger EC sac size (OR 1.3, 95% CI 1.01–1.6, p = 0.042), and infections (OR 6.8, 95% CI 1.3–34.8, p = 0.034) were associated with ventriculomegaly. The logistic regression model consisted of 5 variables including the patients’ history of meningitis, their sex, sac location, sac size, and presence of other other associated anomalies; analysis resulted in the maximum accuracy of 86% for the prediction of hydrocephalus occurrence.

CONCLUSIONS According to the findings, the presence of other associated anomalies, a larger sac, and infections are significant independent predictors of hydrocephalus. By considering these 3 predictors as well as sac location and the patient’s sex, it will be possible to predict hydrocephalus occurrence in patients with EC with significant accuracy.


KEYWORDS encephalocele; hydrocephalus; prediction; congenital

ENCEPHALOCELEs (ECs) are a congenital herniation of the brain tissue through a defect in the cranium.1 They are categorized based on the cranial location that they affect,2,3 and although the specific cause of this malformation remains unknown, a mesodermal aberration is thought to be the cause of the defect in the calvaria and dura mater that allows the cerebral contents to herniate.4 The association of ECs with other congenital malformations is widely described,1,5 with more than 60% of infants with EC observed to have other anomalies like microcephaly, hydrocephalus, arachnoid cyst, Chiari malformations, Dandy-Walker syndrome, cleft palate, hypertelorism, spina bifida, and syndactyly/polydactyly, etc.2,3,5

Hydrocephalus is a disorder in which CSF collects abnormally within the ventricles, causing ventricular dilatation and increased intracranial pressure. Approximately 60%–90% of posterior ECs and 10%–15% of anterior ECs are associated with hydrocephalus.5–7 However, the main mechanism that leads to hydrocephalus in patients with ECs is poorly understood,8 even though it is a strong deter-
minant of poor survival, and has been correlated with a neurodevelopmental delay in infants and children with EC.

Ultrasound has been used to diagnose ventriculomegaly, microcephaly, and EC, both prenatally and postnatally. Although recent data suggest that the majority of cases of hydrocephalus often develop progressively after the EC repair surgery, due to torsion of the aqueduct of Sylvius, venous sinuses, or aqueductal stenosis, the evidence underpinning whether hydrocephalus is an essential feature of the congenital malformation or whether it develops as a result of surgical intervention or meningitis remains inconclusive. Other authors have also suggested that the larger the EC sac size, the greater will be the likelihood of hydrocephalus development. Predicting the likelihood of hydrocephalus development and the associated risk factors in patients with EC can help physicians tailor their treatment strategies to ensure lower mortality and morbidity rates in affected patients. In this study, we reviewed our series of patients with EC and analyzed the risk factors/predictors that correlate with the occurrence of hydrocephalus. We have also tried to develop a scoring system that can predict the likelihood of a need for shunt placement in these patients.

Methods

This study was approved by the institutional ethics committee before its inception. All pediatric patients with EC who underwent surgery in the pediatric neurosurgery department of Children’s Medical Center between the years 2010 and 2021 were included in this study. The demographic information of 102 pediatric patients who were diagnosed and treated for EC was collected retrospectively. Data on the age at surgery, sex, location of EC sac, sac size, imaging data, presence of preoperative ventriculomegaly, presence of neural tissue within the EC sac, the time between EC repair and shunt placement, the postoperative occurrence of ventriculomegaly or symptomatic hydrocephalus, presence of other intracranial and/or extracranial anomalies, seizure disorders, meningitis, other infections including sepsis or wound infections, and final status as alive or dead were gathered. We have classified the cases with ventriculomegaly under 2 main categories: primary ventriculomegaly was defined as being present prenatally based on available prenatal imaging studies (ultrasound, fetal MRI) or postnatally before any surgical intervention for EC repair, and any new-onset ventriculomegaly after EC repair was classified as secondary ventriculomegaly. Primary ventriculomegaly was further subclassified into 2 groups (progressive and nonprogressive ventriculomegaly) based on its progressive or stable course following EC repair. Also, the EC sac size was categorized into 3 groups: < 5 cm, 5–10 cm, and > 10 cm. However, for logistic regression analysis, we classified all lesions into < 3 cm and ≥ 3 cm based on the 3-cm calculated median of EC sac sizes. The contents of the EC sac were confirmed by histopathological reports after surgical repair or by a detailed imaging report. The EC sac location was categorized into 2 groups: anterior and posterior. Hydrocephalus was defined as an active and progressive ventricular dilatation accompanied by signs or symptoms of intracranial hypertension, caused by insufficient flow of CSF from its source of production to its point of absorption and requiring surgical intervention. The diagnosis of hydrocephalus was primarily based on imaging data including ultrasound, brain CT scan, or MRI, and also on clinical signs and symptoms including an unusual or rapid increase in the head circumference, presence of a tense or bulging fontanel, or sun-setting eyes. After surgery all patients had been followed up on an outpatient schedule and, during clinical visits, patients had been examined for signs of hydrocephalus. All data had been documented in the patient’s medical files and kept in the medical archives. Besides the collection of data from medical records, parents were also interviewed for additional data about signs of hydrocephalus or shunt failure through telephone calls and direct interviews.

Statistical Analyses

Statistical analyses were performed using SPSS statistical software (version 25.0 for Windows; IBM Corp.). Categorical variables were described as frequency, constituent ratio, and cross-tabulation. Continuous variables were presented as median (IQR), and dichotomous variables were expressed as percentages. Cross-tabulation analysis and univariate analysis of various predictors of hydrocephalus were performed. Variables with statistically significant association with hydrocephalus were included in multivariate logistic regression. The exact logistic regression was used to estimate and test the associations of independent variables and hydrocephalus. All statistical tests were 2-sided, and data were deemed statistically significant at p < 0.05.

We have tried to develop a scoring system for the prediction of hydrocephalus in patients with EC based on regression coefficients and using the statistical method proposed by Han and colleagues. Given that the prediction is about the estimation of probabilities rather than risk factor extraction, we used all clinically relevant predictors in the primaryprediction model regardless of univariable association or multicollinearity. We then excluded the nonsignificant predictors from our multivariate regression equation in a stepwise fashion while taking the change in the accuracy score of the model into consideration. For continuous variables such as age and sac size, we calculated entropy measures using the scikit-learn library of the Python programming package to find the best discriminative cut point for the dichotomization of these variables.

Results

Demographic and Clinical Characteristics

In total, 102 patients were included in the study, including 52 male and 50 female patients. The median age at surgery was 4 months (IQR 0.3–90 months). Seventy-one patients (69.6%) had posterior ECs, of which the vast majority of cases were occipital, 6 (8.5%) were parietal, 4 (5.6%) were parieto-occipital, and 1 (1.4%) was temporal, whereas 31 patients (30.4%) had anterior ECs. The anterior ECs consisted of 5 sincipital (16.1%), 6 transsphenoidal (19.4%), 10 nasofrontal (32.3%), and 6 nasoethmoidal.
(19.4%), and 4 basal (19.4%) ECs. The EC sac size ranged from 0.5 to 15 cm, with a median sac size of 3 cm (IQR 2–5 cm). Forty-three (42.2%) ECs contained neural tissue, whereas 31 (30.4%) did not. Thirty-nine patients (38.2%) had associated anomalies, of which 17 (43.6%) were only intracranial, 16 (41%) were only extracranial, and the remaining 6 patients had both intracranial and extracranial associated anomalies. Twenty-six patients presented with seizures. Six patients (5.9%) developed meningitis, and 15 patients (14.7%) developed other infections. Preoperative CSF leakage was present in 16 cases, and 3 other patients developed a CSF leakage postoperatively (Table 1).

Outcomes

A total of 33 patients (32.4%) had ventriculomegaly, of which 28 (84.8%) cases were diagnosed as primary ventriculomegaly and 5 (15.2%) developed secondarily. Ventriculoperitoneal (VP) shunt placement was performed in 25 (89.3%) of the 28 patients with primary ventriculomegaly due to the progressive course toward symptomatic hydrocephalus following EC repair. All VP shunt insertions in this group were performed within days after EC repair while most patients were still admitted at our institution. Also, VP shunt surgery was performed for all 5 patients with secondary ventriculomegaly who developed the first signs and symptoms of primary ventriculomegaly and remained stable after EC repair. Eleven shunt revisions were performed throughout the 8-year follow-up period.

The median follow-up by the last clinical visit was 9 months, whereas the median follow-up by direct interview or telephone calls was 96 months. The overall survival rate was 94.7% (89/94). Five patients (5.3%) were dead at the time of the last follow-up, whereas 8 patients were lost to follow-up (Table 2).

Cross-Tabulation Analysis of Various Predictors of Ventriculomegaly

We considered the entire group of ventriculomegaly cases (n = 33) in the cohort for cross-tabulation and univariate and multivariate analyses of the correlation between predictors and ventriculomegaly. Separate subgroup analyses were not conducted due to the statistical limitations posed by relatively small sample sizes within each subgroup.

There was a strong correlation between the patient’s sex and sac location (p = 0.0001), with females having a higher prevalence of posterior EC. Although the larger sac size (p = 0.0001) and content of the sac (p = 0.037) correlated with ventriculomegaly, there was no association between sac size and sac content (p = 0.478). There was a strong correlation between the EC sac located posteriorly and the larger sac size (p = 0.0001). In addition, sac location correlated with ventriculomegaly (p = 0.002), in that 29 (40.8%) of the 71 patients with posterior EC were found to have ventriculomegaly, compared to 4 of the 31 patients with anterior EC (12.9%). Meningitis (p = 0.011), the pres-
ence of other intracranial anomalies (p = 0.003), and other infections (p = 0.02) also correlated with ventriculomegaly. However, the presence of extracranial anomalies (p = 0.681, not shown), seizures (p = 0.113), and CSF leakage (p = 0.453) did not show a significant correlation with ventriculomegaly (Table 3).

Logistic Regression Analyses of Various Predictors of Ventriculomegaly

The ORs and 95% CIs from the univariate and multivariate models are presented in Table 3. Univariate analysis showed that female sex, posterior EC location, larger sac size, presence of other associated anomalies, meningitis, and other infections are associated with ventriculomegaly (p < 0.05). A multivariate model analyzed after adjusting for age revealed that the presence of other associated anomalies (OR 2.8, 95% CI 1.1–7.4, p = 0.027), larger EC sac size (OR 1.3, 95% CI 1.01–1.6, p = 0.042) and presence of infections other than meningitis (i.e., sepsis and superficial wound infection) (OR 6.8, 95% CI 1.3–34.8, p = 0.034) were significantly associated with ventriculomegaly. Although not statistically significant, children with meningitis and posterior EC location were 18 and 1.6 times more likely to have ventriculomegaly, respectively. In addition, female patients were 2.3 times more likely to present with ventriculomegaly compared to male patients. Cox regression for survival analysis revealed ventriculomegaly as the only variable that had a marginal association with survival (p = 0.057).

Predictive Scoring System

We only considered patients with hydrocephalus (n = 30) as the group with our outcome of interest for developing the predictive scoring system. Following the calculation of entropy measures for continuous variables, the threshold of 5 cm for sac size and 4 months for the patient’s age at surgery were defined as the most discriminative thresholds. However, age at the time of surgery was not among the significant predictors in our final model. Our final model consisted of 5 predictor variables including the history of meningitis, the patient’s sex, sac location, sac size (dichotomized), and presence of intracranial anomalies (Table 4). This model resulted in a considerably high accuracy rate of 86%, and the Hosmer and Lemeshow test did not reach statistical significance (p = 0.264), confirming the model’s goodness of fit. We consequently applied this scoring system to our entire data set, resulting in a well-discriminative distribution of probabilities with

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value (%)</th>
<th>Cross-Tabulation (p value)</th>
<th>Univariate OR (95% CI), p Value</th>
<th>Multivariate OR (95% CI), p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total no. of pts</td>
<td>33/69</td>
<td>0.002</td>
<td>4.4 (1.7–10.9), &lt;0.001</td>
<td>2.3 (0.7–7.5), 0.089</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>9 (27.3%)</td>
<td>43 (62.3%)</td>
<td>0.308</td>
<td>1.8 (0.3–9.8), 0.151</td>
</tr>
<tr>
<td>Female</td>
<td>24 (72.7%)</td>
<td>26 (37.7%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Term delivery</td>
<td>30 (90.9%)</td>
<td>65 (94.2%)</td>
<td>0.002</td>
<td>4.6 (1.4–14.7), &lt;0.01</td>
</tr>
<tr>
<td>Posterior location</td>
<td>29 (87.9%)</td>
<td>42 (60.9%)</td>
<td>0.0001</td>
<td>1.3 (1.13–1.57), &lt;0.001</td>
</tr>
<tr>
<td>Sac size ≥3 cm</td>
<td>25 (75.8%)</td>
<td>31 (44.9%)</td>
<td>0.037</td>
<td>2.2 (0.7–6.3), 0.719</td>
</tr>
<tr>
<td>Neural tissue present</td>
<td>17 (51.5%)</td>
<td>26 (37.7%)</td>
<td>0.113</td>
<td>1.8 (0.7–4.5), 0.47</td>
</tr>
<tr>
<td>Seizures</td>
<td>11 (33.3%)</td>
<td>15 (21.7%)</td>
<td>0.022</td>
<td>2.4 (1.2–4.9), 0.05</td>
</tr>
<tr>
<td>Other associated anomalies</td>
<td>18 (54.5%)</td>
<td>21 (30.4%)</td>
<td>0.011</td>
<td>12.1 (1.3–108.6), 0.03</td>
</tr>
<tr>
<td>Meningitis</td>
<td>5 (15.2%)</td>
<td>1 (1.4%)</td>
<td>0.001</td>
<td>12.1 (1.3–108.6), 0.03</td>
</tr>
<tr>
<td>Other infections</td>
<td>15 (45.5%)</td>
<td>10 (14.5%)</td>
<td>0.02</td>
<td>4.9 (1.8–12.8), &lt;0.001</td>
</tr>
<tr>
<td>CSF leak</td>
<td>6 (18.2%)</td>
<td>10 (14.5%)</td>
<td>0.453</td>
<td>1.3 (0.4–3.9), 0.89</td>
</tr>
</tbody>
</table>

Pts = patients. The p values are significant at < 0.05.
TABLE 4. Proposed scoring system for predicting hydrocephalus requiring a shunt in patients with EC

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>History of meningitis</td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>0</td>
</tr>
<tr>
<td>Present</td>
<td>3</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>0</td>
</tr>
<tr>
<td>Female</td>
<td>1</td>
</tr>
<tr>
<td>Sac location</td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>0</td>
</tr>
<tr>
<td>Posterior</td>
<td>1</td>
</tr>
<tr>
<td>Sac size</td>
<td></td>
</tr>
<tr>
<td>&lt;5 cm</td>
<td>0</td>
</tr>
<tr>
<td>≥5 cm</td>
<td>1</td>
</tr>
<tr>
<td>Accompanying intracranial anomalies</td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>0</td>
</tr>
<tr>
<td>Present</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>7</td>
</tr>
</tbody>
</table>

3 distinct peaks for the shunt procedure in EC with hydrocephalus (Table 5).

Discussion

In this study, we have analyzed the predictors that correlate with the incidence of ventriculomegaly/hydrocephalus in a series of 102 patients with ECs, trying to introduce a predictive measure that can be applied in clinical settings. The impact of hydrocephalus on overall survival and the pathophysiology underlying the development of hydrocephalus in affected patients were also investigated.

Pathophysiology of Hydrocephalus in Patients With EC

The incidence of hydrocephalus in patients with EC has ranged between 16% to 60%.

TABLE 5. The probability of a need for shunt placement in patients with EC, based on the score calculated from our proposed scoring system

<table>
<thead>
<tr>
<th>Scores</th>
<th>Probability of Hydrocephalus</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–2</td>
<td>14%</td>
</tr>
<tr>
<td>3–4</td>
<td>71%</td>
</tr>
<tr>
<td>5–7</td>
<td>Almost always</td>
</tr>
</tbody>
</table>

In our series, we discovered that 89.3% of patients with primary ventriculomegaly progressed significantly in the days following EC repair, necessitating VP shunt insertion. We also performed VP shunt insertion for 5 patients who developed progressive ventriculomegaly and symptomatic hydrocephalus days to months after EC repair. Notably, these 5 patients did not have ventriculomegaly or any signs/symptoms of hydrocephalus before EC repair, thus suggesting that the disorder occurred as a result of surgery or postoperative complications like infection. It seems that the EC sac works as an extra space for CSF and when this compensating space is obliterated, the CSF pathway is compromised and cannot adapt to this new situation, resulting in intracranial hypertension and ventricular dilatation or progressive enlargement of a previously dilated ventricle.

Sac Location and Venticulomegaly/Hydrocephalus

The effect of the location of the EC sac on the development of hydrocephalus is a matter of debate, with various studies yielding mixed results. According to some researchers, surgical removal of the EC sac may alter CSF flow or obstruct the sagittal sinus once the EC sac has been closed.

Warf found that most hydrocephalus cases were associated with aqueductal stenosis. Evidence from Lorber’s study indicated that hydrocephalus is an essential component of the clinical syndrome and was most likely present from birth in all infants who later exhibited clinical indications of the disorder. Our series, we discovered that 89.3% of patients with primary ventriculomegaly and subsequent hydrocephalus. However, we admit that our hydrocephalus diagnosis was primarily based on clinical evidence.

The surgical technique used for EC repair in occipital lesions may have any bearing on the development of hydrocephalus, suggesting the influence of other intracranial anomalies. In addition, occipital ECs can result in fourth ventricle outlet obstruction when associated with DWM. On the contrary, Lorber observed that most of the infants with EC developed secondary hydrocephalus after EC resection. Similarly, 3 studies observed a higher incidence of hydrocephalus after surgical repair of the EC. According to some researchers, surgical removal of the EC sac may alter CSF flow or obstruct the sagittal sinus once the EC sac has been closed.

Interestingly, our data showed an increased prevalence of anterior lesions among male children (46.2%), whereas 86% of female children had occipital lesions. In addition, 72.7% of female patients had ventriculomegaly and 34% had symptomatic hydrocephalus (compared to 15.4% of...
male patients). We performed logistic regression analyses to examine the relationship between the female sex and ventriculomegaly. Our findings revealed that, although not statistically significant in a multivariate model, female sex was associated with a 2.3 times greater probability of developing ventriculomegaly. Among the anterior lesions, we found that primary ventriculomegaly was predominant.

**EC Size and Incidence of Venticulomegaly/Hydrocephalus**

Our results show a significant correlation between larger sac size and ventriculomegaly. This finding was consistent with other cohorts. Da Silva and colleagues found that patients who had an EC sac size > 2 cm were 1.7 times more likely to have hydrocephalus (p = 0.68). Similarly, we discovered that patients with an EC sac size ≥ 3 cm were 1.3 times more likely to present with symptomatic hydrocephalus; however, when compared to Da Silva and colleagues’ conclusion, our result was statistically significant (p = 0.042). Inan and colleagues reported a case of a male infant born with a huge EC sac, with subsequent evaluation showing severe ventriculomegaly, cerebellar atrophy, and transposition of the great arteries. In addition, chi-square analysis in this study revealed a strong correlation between the EC sac located posteriorly and a size ≥ 3 cm, leading us to speculate that the combination of a larger sac and location in the posterior area may contribute to hydrocephalus formation. However, El Refae and colleagues proposed that the size of the EC sac did not affect the postoperative progression of hydrocephalus.

**Intracranial Anomalies and Venticulomegaly/Hydrocephalus Development**

Da Silva and colleagues discovered an association between cranial anomalies and hydrocephalus; patients with EC and at least one other related cranial anomaly were 2.4 times more likely to have hydrocephalus (p = 0.63). In this cohort, the most significant predictor of ventriculomegaly in children with EC was the presence of other associated anomalies (p = 0.027). Venticulomegaly was most commonly associated with corpus callosum agenesis, DWM, and microcephaly. Also, Chiari malformation and arachnoid cysts were among other defects found to be correlated with hydrocephalus. Congruent to our findings, Protzenko and colleagues showed that hydrocephalus was commonly associated with DWM and Chiari malformation. These authors postulated that this correlation may be due to a compensatory mechanism for increased intracranial pressure during fetal life, but because hydrocephalus symptoms appeared only after EC repair, they concluded that EC and hydrocephalus in DWM could occur as separate phenomena.

In this study, a cross-tabulation analysis revealed a significant correlation between the presence of neural tissue within the EC sac and ventriculomegaly development; however, a logistic regression analysis revealed no such correlation. On the contrary, Da Silva and colleagues showed that patients with neural tissue within the EC sac were 5.8 times more likely to develop hydrocephalus (p = 0.09). Their finding was consistent with another report. The histopathological data confirming the presence or absence of the neural tissue within the EC sac were available for only 74 cases in our series; therefore we may infer that the lack of complete data may have affected our conclusion.

**Infections and Venticulomegaly/Hydrocephalus Development**

The risk of infection has been associated with larger EC sacs and the presence of CSF leakage. In addition, the findings in this cohort demonstrated a significant association between infections and ventriculomegaly development. Infections observed in this study were sepsis, meningitis, and wound infections. We observed that although meningitis was associated with ventriculomegaly, it did not correlate with CSF leakage. In a case study, Andarabi and colleagues found that hydrocephalus and infections were the most frequent complications encountered during the postoperative period after EC repair. According to another study, a delay in the closure of EC associated with ventriculomegaly may lead to a higher incidence of infections. In addition, Mahajan and colleagues observed that children who developed hydrocephalus, meningitis, and other infections including respiratory infection had significantly prolonged stays in the hospital, predisposing them to further detrimental outcomes. Similarly, Kabré and colleagues witnessed infection and hydrocephalus, among other predictors correlated with poor prognosis.

**Impact of Hydrocephalus on Overall Survival and Morbidity/Mortality**

Our data showed that only ventriculomegaly had a significant influence on overall survival. Overall mortality in patients with EC has varied among different studies with the lowest and highest mortality rates of 5% and 40% reported by Lo et al. and Warf et al., respectively. Furthermore, several authors found that hydrocephalus, intracranial anomalies, and the presence of neural tissue within the sac significantly influenced the developmental status of affected children. Among other predictors correlated with poor prognosis.

**Prediction of a Need for Shunt Placement Based on the Proposed Scoring System**

To our knowledge, this is the first report of an attempt to predict the probability of a need for shunt placement in patients with EC. Prediction of shunt-dependent hydrocephalus in these patients provides the chance to portray a more realistic perspective for their guardians as well as help the treating physicians tailor their follow-up sessions. It also equips healthcare-related organizations with a tool for prediction of the costs for the management of a patient with EC, given the fact that shunt placement and its subsequent complications or needs for revisions pose a sizeable financial burden on the healthcare system. Given the large sample size of this series, the external validity and generalizability of this scoring system are expected to be promising. Although it is best to have an ex-
ternal data set obtained from another medical center with which to validate this scoring system, most of the available data in the literature are small case series without available individual patient data, which precludes them from being used as a validation data set. Despite this shortcoming, we believe that this scoring system can be implemented and tested in other referral medical centers that are responsible for the management of developmental and congenital anomalies, and can also act as a stepping-stone for the development of more complex and more accurate prediction models in this field.

Management of Hydrocephalus

VP shunt placement is the mainstay treatment of hydrocephalus in children with EC lesions. However, other CSF diversion procedures such as endoscopic third ventriculostomy have also been shown to be effective in affected children. In this study, no endoscopic third ventriculostomy was performed. In terms of the timing of shunt insertion, some authors recommended simultaneous VP shunt placement during EC repair surgery for patients with primary hydrocephalus, whereas one study suggested preoperative VP shunt insertion before EC repair. Protzenko and colleagues also suggested a postrepair VP shunt placement procedure performed in a separate session to avoid the risk of infection. In our experience, it is better to consider patients with severe primary ventriculomegaly for VP shunt insertion before or during EC repair surgery. However, patients with progressive primary ventriculomegaly and symptomatic hydrocephalus can be managed with a VP shunt placement procedure performed in another session after EC repair surgery.

Limitations

The main limitation of this study was its retrospective nature, which was associated with missing data. For instance, although 102 patients were included in this study, data on the histopathological diagnosis of the presence or absence of neural tissue within the sac was available only in 74 cases. We were also unable to externally validate our proposed scoring system on a validation data set obtained from another institution, due to the lack of a sufficiently large data set of patients with EC in whom individual patient data including outcomes were available. Moreover, the lack of a treatment group and a control group is another important limitation of the study. Despite these limitations, we believe that the findings of this retrospective study will be relevant to the literature and that they provide pertinent information for the neurosurgical management of patients with EC. Furthermore, although we attempted to identify the pathophysiology and the incidence of hydrocephalus among patients with ECs, the data we found in the literature to support our understanding of this event remain inconclusive. Future research is therefore mandated to provide evidence-based concepts to elucidate this constraint.

Conclusions

Hydrocephalus is commonly associated with EC, and significantly influences the overall survival of patients. In a multivariate model, the presence of other associated anomalies, larger EC sac size, and infections were significantly associated with ventriculomegaly. The presence of neural tissue in the sac and the occurrence of seizures did not have a statistically significant association with the incidence of ventriculomegaly. Although not statistically significant, meningitis, posterior lesions, and female sex were 1.6, 2.3 times more likely to be associated with ventriculomegaly, respectively. Our proposed scoring system consisted of 5 variables including a history of meningitis, patient sex, sac location, sac size, and presence of other accompanying intracranial anomalies that can predict hydrocephalus and the need for VP shunt insertion with significant accuracy.

References

16. Lorber J. Systematic ventriculographic studies in infants born with meningomyelocele and encephalocele. The incidence
305

Kankam et al.

Disclosures
The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions
Conception and design: A Nejat, F Nejat. Acquisition of data: Kankam, A Nejat. Analysis and interpretation of data: Tavallaii, Kankam, A Nejat, Habibi, F Nejat. Drafting the article: Kankam. Critically revising the article: Tavallaii, Kankam, A Nejat, Habibi, F Nejat. Reviewed submitted version of manuscript: Tavallaii, Kankam, Tayebi Meybodi, F Nejat. Approved the final version of the manuscript on behalf of all authors: Tavallaii. Statistical analysis: Tavallaii, Kankam, F Nejat. Administrative/technical/material support: Tavallaii. Study supervision: F Nejat.

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