Fetal ventriculomegaly: Predicting the need for post-natal cerebrospinal fluid diversion using image analysis and machine learning techniques

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Background: Fetal ventriculomegaly (VM) refers to enlargement of the cerebral ventricles diagnosed in utero. A subset of fetal VM patients will develop increased intracranial pressure, or hydrocephalus; however, it is unclear which children with fetal VM will become symptomatic and require surgical treatment after birth.

Objective: In this study, we set out to develop a pre-natal fetal MRI-based model using image analysis and machine learning techniques to predict the need for cerebrospinal fluid (CSF) diversion in fetal VM patients after birth.

Design/Methods: We performed a retrospective cohort study of fetal VM patients treated at one of two academic children’s hospitals. Demographics and gestational age were extracted from the medical record. Subjects with myelomeningocele were excluded. The decision to divert CSF in the post-natal period was based on criteria for shunt failure used in the Shunt Design Trial. Multiple imaging features were extracted from fetal MRI including atrial diameter, fronto-occipital horn ratio, ventricle area, volume, and morphological features. A machine learning algorithm was used to analyze multiple features to sequentially find the combination most predictive of the need for post-natal CSF diversion. Leave-one-out cross validation was used to determine the accuracy of the model.

Results: Overall, 29 of the 74 fetal VM patients (39%) underwent CSF diversion. Among treated patients, the median time to intervention was 6 days (mean 28 days). Among patients that did not require post-natal CSF diversion, the median follow-up period was 59 days (mean 32 days). Ninety-seven imaging features were extracted for each patient from fetal images. The minor axis of the length of the smaller occipital horn of the lateral ventricle was the most predictive feature. Using leave-one-out cross validation, the fetal MRI-based model successfully classified fetal VM patients with an optimal accuracy of 81% (sensitivity 79% and specificity 82%). A receiver operating characteristic curve is shown in figure 1 (area under the curve 0.86).
Conclusions: The use of image analysis and machine learning techniques can be successfully applied to fetal MRIs to predict the need for post-natal shunting with high accuracy among patients from two separate institutions. The fetal-MRI based model provides prognostic information to patients and families in the prenatal period, aids in post-natal clinical care, and may help select patients for enrollment in potential future trials of in-utero surgical intervention.

Figure 1. Receiver operating characteristic (ROC) analysis. The ROC curve shows sensitivity on the y-axis versus 1-specificity on the x-axis. The diagonal is equivalent to chance.