

Clinical Characteristics and Risk Factors of Severe Motor Impairment in Children with Cerebral Palsy in Northwest China (Xinjiang): A Single-Center Retrospective Study

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Research Article

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Abstract

Aim

To characterize the clinical features of children with cerebral palsy (CP) and identify factors associated with severe motor impairment (GMFCS IV–V) in Xinjiang, Northwest China.

Methods

This single-center retrospective study included 818 children with CP (491 males, 327 females) admitted to a tertiary referral center between January 2020 and December 2025. Severe motor impairment was defined as GMFCS IV–V. Demographic, perinatal, clinical, and imaging variables were collected. Univariate and multivariable logistic regression were performed. Model discrimination and calibration were assessed using AUC and the Hosmer–Lemeshow test.

Results

Of 818 children, 544 (66.5%) had GMFCS IV–V. Independent factors were male sex (OR = 1.530, 95% CI 1.117–2.096, $P = 0.008$), asphyxia (OR = 2.276, 95% CI 1.598–3.240, $P < 0.001$), and MRI abnormality (OR = 2.752, 95% CI 1.988–3.810, $P < 0.001$). NICU admission, low birth weight, intellectual disability, epilepsy, and spastic type were not independently associated. The model showed limited discrimination (AUC = 0.677, 95% CI 0.637–0.717) with good calibration (Hosmer–Lemeshow $\chi^2 = 9.885$, $df = 8$, $P = 0.273$). Nagelkerke R^2 was 0.130. Maximum VIF was 1.356.

Interpretation:

Male sex, asphyxia, and MRI abnormality were independently associated with severe motor impairment in this tertiary referral cohort. The limited model discrimination suggests that additional factors contribute to motor severity. These findings may inform early risk stratification and targeted intervention strategies in this understudied region.

What this paper adds:

☒. Male sex, asphyxia, and MRI abnormality were independently associated with GMFCS IV–V; ☒. NICU admission lost significance after adjustment for asphyxia and MRI abnormality; ☒. The model showed limited discrimination (AUC = 0.677).

Introduction

Cerebral palsy (CP) is the most common childhood-onset motor disability, with a global prevalence of approximately 1.6 per 1000 live births in high-income countries and up to 3.4 per 1000 in low- and middle-income countries in some regions¹. The prevalence of CP declines markedly with advancing gestational age from 29 weeks onwards, with the risk increasing substantially in extremely preterm infants². Beyond motor dysfunction, CP is frequently accompanied by a range of comorbidities, including epilepsy, intellectual disability, communication disorders, and sensory impairments³, which collectively impose a significant burden on children, families, and healthcare systems.

The Gross Motor Function Classification System (GMFCS) is a standardized tool for classifying the severity of motor impairment in children with CP, with levels IV–V representing severe impairment characterized by limited or absent independent mobility⁴. Children with GMFCS IV–V require assistance for most daily activities⁵ and are at heightened risk for multiple associated impairments⁶. Identifying risk factors for severe motor impairment is therefore critical for early risk stratification, targeted intervention, and resource allocation, particularly in resource-limited settings.

The etiology of CP is multifactorial, involving prenatal, perinatal, and postnatal factors. In children with cerebral palsy, lower gestational age and lower birth weight are associated with more severe levels of motor compromise⁷. In children with CP secondary to birth asphyxia, asphyxia has been linked to a more severe spectrum of motor outcomes⁸. MRI abnormalities, including white matter injury and deep gray matter injury, have also been associated with the severity of motor impairment⁹. However, the relative contribution of these factors to severe motor impairment may vary across populations and healthcare settings.

In China, epidemiological data on CP have been generated mainly through multi-province surveys¹⁰, with limited data from northwestern and remote regions. Xinjiang, located in Northwest China, is a vast region with a unique demographic composition, including a high proportion of ethnic minority populations, predominantly Uyghur¹¹. Previous studies conducted in this region have described the demographic and clinical characteristics of children with CP as part of broader investigations¹², and the associations between risk factors and GMFCS levels have been explored in other regions of China⁷, but these factors have not been systematically investigated in children with CP from Xinjiang. Understanding the determinants of severe motor impairment in this specific context is essential for developing culturally and regionally appropriate prevention and intervention strategies.

The objective of this study was to characterize the clinical features of children with CP in Xinjiang and to identify risk factors associated with severe motor impairment (GMFCS IV–V). We hypothesized that perinatal factors, including asphyxia and low birth weight, as well as MRI abnormalities, would be independently associated with severe motor impairment.

Method

Study design and participants

This was a single-center retrospective study conducted at the Cerebral Palsy Center of the Second Affiliated Hospital of Xinjiang Medical University, a tertiary referral center for children with CP in Northwest China. Children diagnosed with CP between January 1, 2020, and December 31, 2025, were identified from the hospital registry. The diagnosis of CP was confirmed by a multidisciplinary team of pediatric neurologists and rehabilitation specialists according to the Chinese expert consensus on the diagnostic definition of cerebral palsy¹³.

The inclusion criteria were: (1) diagnosis of CP confirmed before the age of 18 years; (2) availability of complete data on the Gross Motor Function Classification System (GMFCS) and key perinatal variables. The exclusion criteria were: (1) age > 18 years at the time of data extraction (N = 22); (2) CP caused by acquired postnatal injury, such as violence or trauma (N = 15); (3) missing key variables (N = 10); and (4) duplicate records (N = 8). A total of 873 children with CP were initially screened. Of these, 37 were excluded: 22 were older than 18 years at data extraction, and 15 had CP caused by acquired postnatal injury. The remaining 836 children met the inclusion criteria. A further 18 children were excluded: 10 had missing key variables, and 8 were duplicate records. Finally, 818 children were included in the analysis (Fig. 1).

Ethical considerations

Institutional research ethics board approval was obtained from the Second Affiliated Hospital of Xinjiang Medical University[KY2026090715]. The requirement for written informed consent was waived due to the retrospective nature of the study and the fact that many patients had been discharged or lost to follow-up, making it impractical to obtain consent from all participants. All data were anonymized before analysis.

Variables

Demographic and perinatal variables included sex (male vs. female), ethnicity (Uyghur vs. non-Uyghur), region of residence (southern Xinjiang vs. other), residence (rural vs. urban), age at onset (≤ 12 months vs. > 12 months), preterm birth (< 37 weeks vs. ≥ 37 weeks), low birth weight (< 2500 g vs. ≥ 2500 g), asphyxia (yes vs. no), intracranial hemorrhage (yes vs. no), pathological jaundice (yes vs. no), and NICU admission (yes vs. no). Clinical variables included CP type (spastic vs. non-spastic), motor distribution (quadriplegia vs. diplegia), and GMFCS level (I–III vs. IV–V). Imaging variables included MRI performance (yes vs. no) and MRI abnormality. MRI abnormality was defined as MRI performed with an MRICS classification other than “normal findings”¹⁴. Comorbidities included intellectual disability (yes vs. no), speech impairment (yes vs. no), motor impairment (yes vs. no), epilepsy (yes vs. no), and drooling (yes vs. no). The primary outcome was severe motor impairment, defined as GMFCS levels IV–V. GMFCS

levels I–III were classified as mild to moderate motor impairment. The definitions and coding of all variables are provided in Supplementary Table S4.

Statistical analysis

Binary variables were expressed as frequencies and proportions. Continuous variables were expressed as medians with interquartile ranges (IQR). Proportions were compared using the Pearson χ^2 test for binary or ordinal variables. Fisher's exact test was used when expected cell counts were less than 5.

Univariate logistic regression was performed to assess the association between each variable and severe motor impairment (GMFCS IV–V). Variables with $P < 0.20$ in univariate analysis, along with clinically relevant variables, were considered candidates for the multivariable model. Based on prior literature and clinical relevance, a fixed set of eight variables was entered into the multivariable model. Multicollinearity was assessed using variance inflation factors (VIF), with $VIF > 5$ considered indicative of significant multicollinearity.

Multivariable logistic regression was performed using the enter method. Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were reported. Model calibration was assessed using a modified Hosmer-Lemeshow goodness-of-fit test designed for large samples, which standardizes the noncentrality parameter to produce a sample-size-independent measure of fit¹⁵. Model discrimination was assessed using the area under the receiver operating characteristic curve (AUC)¹⁶, which quantifies the model's ability to distinguish between individuals with and without the outcome of interest¹⁷. Nagelkerke R^2 was reported as a measure of explained variance for the logistic regression model¹⁸. Statistical significance was set at a two-sided $P < 0.05$. All analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA).

Results

Participant characteristics

A total of 818 children with CP were included in the final analysis. The median age at onset was 8.5 month (IQR 5–18). Males accounted for 60.0% (491/818) of the cohort, and the majority were of Uyghur ethnicity (90.0%, 736/818) and resided in southern Xinjiang (82.9%, 678/818). Most children lived in rural areas (79.0%, 646/818). Preterm birth was documented in 44.9% (367/818) of participants, low birth weight in 23.8% (195/818), asphyxia in 48.4% (396/818), NICU admission in 36.3% (297/818), pathological jaundice in 13.0% (106/818), and intracranial hemorrhage in 5.0% (41/818) (Figure S2). The distribution of characteristics between Uyghur and non-Uyghur children, between GMFCS I–III and IV–V groups, and between spastic and non-spastic CP are shown in Supplementary Tables S1, S2, and S3, respectively.

The most common CP subtype was spastic (56.4%, 461/818), followed by mixed (30.6%, 251/818). Quadriplegia was the most common motor distribution (48.8%, 399/818). Severe motor impairment (GMFCS IV–V) was present in 66.5% (544/818) of the cohort. The distribution of CP subtypes and GMFCS levels is illustrated in Figure S1a and Figure S1b, respectively. MRI was performed in 87.7% (717/818) of children, and MRI abnormalities were identified in 547 of 818 (66.9%) participants. The most common comorbidities were motor impairment (99.5%, 814/818), speech impairment (83.4%, 682/818), and intellectual disability (83.0%, 679/818). Epilepsy was present in 15.4% (126/818), drooling in 9.0% (74/818), visual impairment in 2.2% (18/818), and hearing impairment in 1.2% (10/818) (Figure S3). Full baseline characteristics are presented in Table 1.

Univariate analysis

Univariate logistic regression identified several factors significantly associated with severe motor impairment (Supplementary Table S5, Figure S4). Male sex was associated with increased odds of GMFCS IV–V (OR = 1.39, 95% CI 1.03–1.86, $P = 0.029$). Asphyxia was strongly associated with severe motor impairment (OR = 2.28, 95% CI 1.69–3.07, $P < 0.001$), as was NICU admission (OR = 1.53, 95% CI 1.12–2.09, $P = 0.007$) and MRI abnormality (OR = 2.84, 95% CI 2.09–3.86, $P < 0.001$). The distribution of key factors across GMFCS groups is illustrated in Figure S4. Low birth weight showed a trend toward association (OR = 1.34, 95% CI 0.94–1.90, $P = 0.105$). Other variables, including age at onset, ethnicity, region, residence, preterm birth, intracranial hemorrhage, pathological jaundice, CP type, motor distribution, intellectual disability, speech impairment, epilepsy, and drooling, were not significantly associated with severe motor impairment in univariate analysis.

Multivariable analysis

In the multivariable logistic regression model (Table 2, Fig. 2), three variables emerged as independent risk factors for severe motor impairment (GMFCS IV–V): male sex (OR = 1.530, 95% CI 1.117–2.096, $P = 0.008$), asphyxia (OR = 2.276, 95% CI 1.598–3.240, $P < 0.001$), and MRI abnormality (OR = 2.752, 95% CI 1.988–3.810, $P < 0.001$). The adjusted ORs and 95% CIs are illustrated in Fig. 2.

NICU admission, low birth weight, intellectual disability, epilepsy, and spastic type were not independently associated with severe motor impairment in the multivariable model. Notably, NICU admission showed a marked attenuation of effect, from OR = 1.53 in univariate analysis to OR = 0.928 in the multivariable model, suggesting that its univariate association was largely explained by other variables, particularly asphyxia.

The model demonstrated limited discrimination with an AUC of 0.677 (95% CI 0.637–0.717, $P < 0.001$) (Fig. 3). The Hosmer-Lemeshow test indicated good calibration ($\chi^2 = 9.885$, $df = 8$, $P = 0.273$). Nagelkerke R^2 was 0.130. No multicollinearity was observed, with a maximum VIF of 1.356. The forest plot of the multivariable model is presented in Fig. 2, and the ROC curve is shown in Fig. 3.

Discussion

In this single-center retrospective study of 818 children with CP in Northwest China, we found that male sex, asphyxia, and MRI abnormality were independent risk factors for severe motor impairment (GMFCS IV–V). The model showed limited discrimination and good calibration, although the Nagelkerke R^2 of 0.130 indicates that the identified factors explain only a modest proportion of the variation in motor severity. These findings contribute to the understanding of risk factors for severe motor impairment in a region where such data have been limited.

The association between male sex and severe motor impairment is consistent with previous reports¹⁹. In a study of 127 children with CP in eastern India, male sex was more prevalent (74.0%), and severe motor impairment was present in 63.8% of the cohort. The higher proportion of males among children with severe CP may reflect sex-related differences in vulnerability to perinatal brain injury or in the clinical expression of motor impairment²⁰. However, the mechanism underlying this association warrants further investigation.

Asphyxia emerged as the strongest independent risk factor for severe motor impairment in our cohort, consistent with reports that asphyxia is associated with worse neurodevelopmental outcomes⁸. This finding aligns with previous research demonstrating that term-born children with CP after neonatal encephalopathy and suspected birth asphyxia have a higher frequency of non-ambulatory GMFCS status (OR = 3.4, 95% CI 1.72–6.8) compared to those without suspected asphyxia. Asphyxia contributes to hypoxic-ischemic brain injury, which can result in extensive damage to motor pathways and is a well-recognized cause of severe CP²¹. Our findings underscore the importance of perinatal monitoring and timely intervention for asphyxia to potentially mitigate the severity of motor impairment.

MRI abnormality was another independent risk factor in our cohort (OR = 2.752), consistent with previous reports showing a strong association between MRI abnormalities and severe motor impairment²². This is consistent with the understanding that the type and extent of brain injury, as assessed by MRI, are more predictive of later motor impairment than gestational age at birth. In our cohort, MRI abnormalities were identified in 66.9% of children, reflecting the high burden of brain injury in this population. The association between MRI abnormality and severe motor impairment supports the role of neuroimaging in early risk stratification and prognostication²³.

Notably, NICU admission was significantly associated with severe motor impairment in univariate analysis (OR = 1.53, $P = 0.007$) but lost its significance in the multivariable model (OR = 0.928, $P = 0.698$). This attenuation suggests that the univariate association was confounded by asphyxia and MRI abnormality. NICU admission was significantly associated with severe motor impairment in our cohort, consistent with previous reports showing a significant association between NICU admission and moderate-to-severe CP²⁴. This finding highlights the importance of multivariable modeling to disentangle the effects of correlated perinatal variables.

Low birth weight showed a trend toward association with severe motor impairment in univariate analysis (OR = 1.34, P = 0.105) but was not significant in the multivariable model. Previous studies have identified low birth weight as an important predictor of CP and severe motor disorders²⁵. The lack of independent association in our model may be due to the relatively high prevalence of low birth weight in our cohort (23.8%) and its correlation with other perinatal factors²⁶. Similarly, intellectual disability, epilepsy, and spastic type were not independently associated with severe motor impairment, which may reflect the complex interplay among these factors and the severity of brain injury.

The model's AUC of 0.677 indicates limited but limited discriminatory ability. This suggests that additional factors not captured in this study, such as genetic predisposition, socioeconomic status, access to rehabilitation, and timing of intervention, may contribute to the severity of motor impairment²⁷. The Nagelkerke R² of 0.130 further underscores that the identified risk factors explain only a modest proportion of the variance in motor severity. Future studies incorporating a broader range of variables, including genetic and environmental factors, are needed to improve prediction.

Previous studies have shown that the number of risk factors is associated with GMFCS classification and comorbidities⁷. A study from Eastern India reported a similar spectrum of comorbidities in children with CP²⁸. Previous predictive models for CP have also reported limited discriminatory ability, highlighting the need for additional variables²⁹. Comorbidities, including epilepsy, intellectual impairment, and speech impairment, have been shown to be associated with GMFCS levels in children with CP⁶.

Limitations

This study has several limitations. First, it is a single-center retrospective study, which may limit the generalizability of the findings to other populations. Second, the use of a single-center cohort may introduce selection bias, as children referred to a tertiary center may have more severe presentations. Third, the AUC of 0.677 indicates that the model has limited discriminatory ability, and the identified risk factors explain only a modest proportion of the variance in motor severity. Fourth, missing data on some variables, such as the specific MRICS classification, may have affected the analysis³⁰. Fifth, the study was conducted in a specific geographic and ethnic context, and the findings may not be directly applicable to other regions. Finally, the retrospective design precludes the assessment of causality. Prospective studies with larger, multicenter cohorts are needed to validate these findings³¹.

Conclusions

In this retrospective study of children with CP in Northwest China, male sex, asphyxia, and MRI abnormality were identified as independent risk factors for severe motor impairment (GMFCS IV–V). The model demonstrated limited discrimination and good calibration, although its predictive ability was limited. These findings may inform early risk stratification and targeted intervention strategies in this

understudied region. Future research should focus on incorporating additional variables to improve prediction and on validating these findings in multicenter prospective cohorts.

Declarations

Conflict of interest

The authors have no conflicts of interest to declare.

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Author Contribution

YR was responsible for setting the direction of the study, analyzing the data, and writing the manuscript. YR was responsible for reviewing the literature and organizing the references. XPL was responsible for developing writing ideas, guiding the writing process, interpretation of data, designing the figures and finalizing the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

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Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Tables

Tables 1 and 2 are available in the Supplementary Files section.

Figures

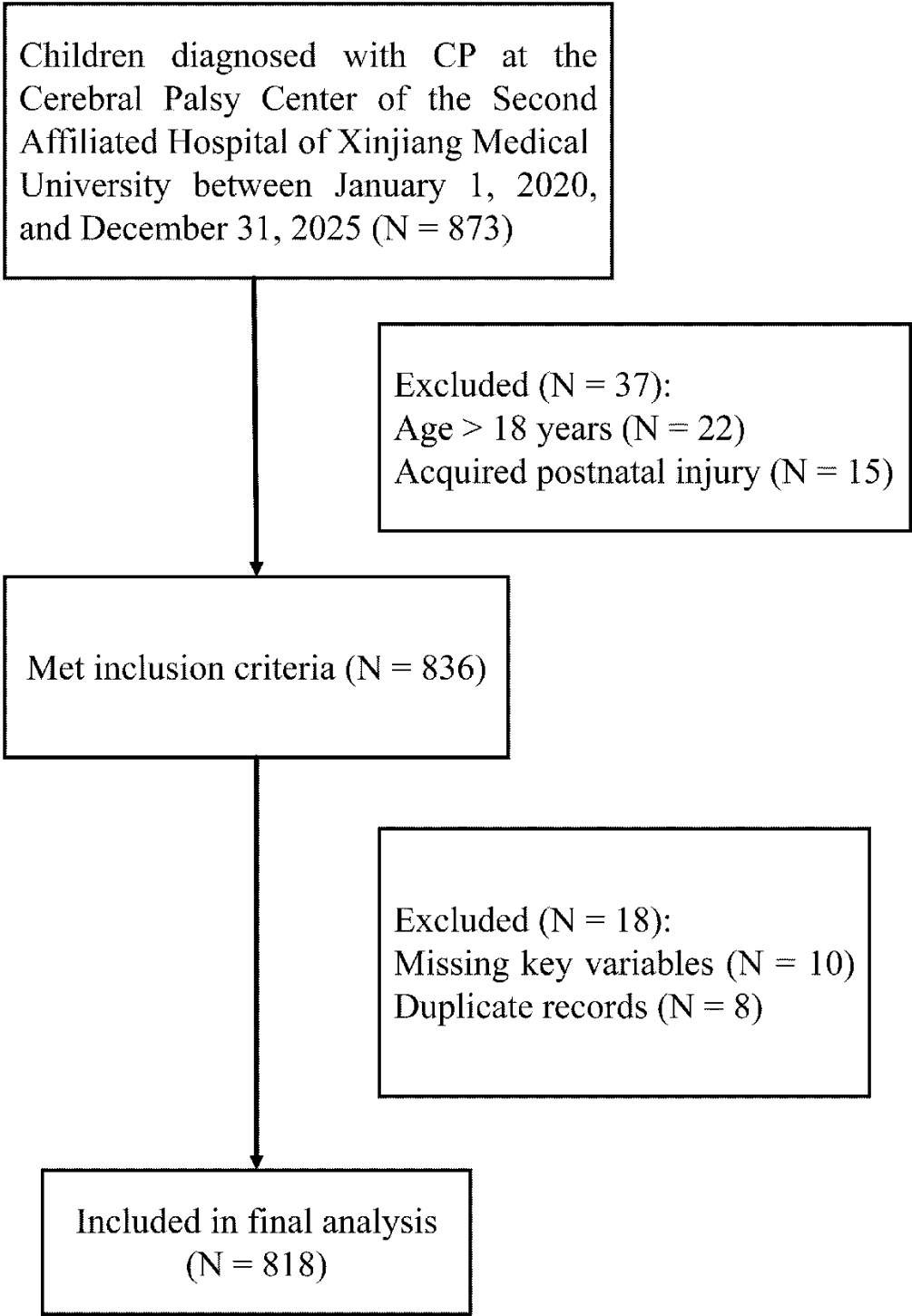


Figure 1

Flowchart of participant selection.

A total of 873 children with cerebral palsy (CP) were screened. Of these, 37 were excluded: 22 were older than 18 years at data extraction, and 15 had CP caused by acquired postnatal injury. The remaining 836 children met the inclusion criteria. A further 18 children were excluded: 10 had missing key variables, and 8 were duplicate records. Finally, 818 children were included in the analysis. CP, cerebral palsy.

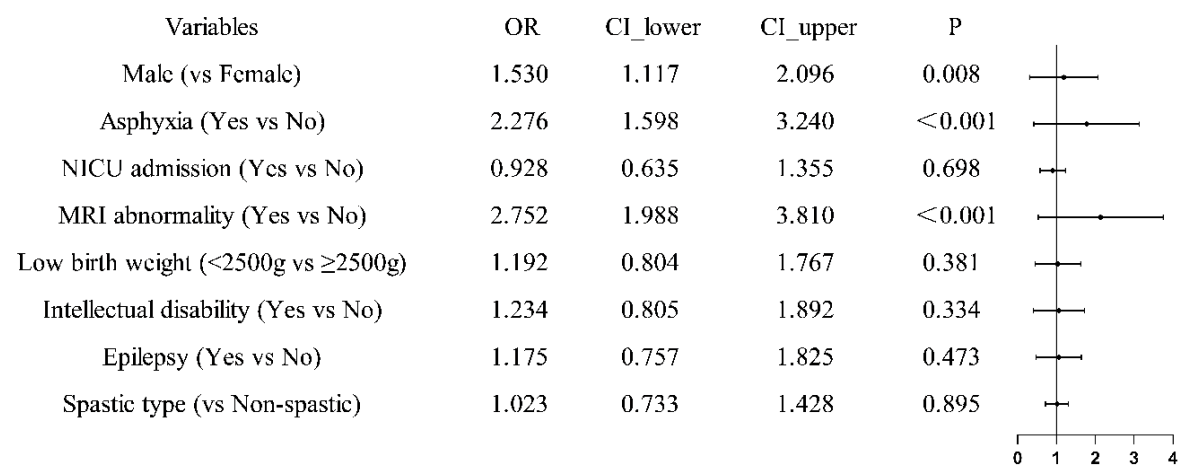


Figure 2

Forest plot of multivariable logistic regression for severe motor impairment (GMFCS IV–V).

Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) are shown. The model included [male sex, asphyxia, MRI abnormality, NICU admission, low birth weight, intellectual disability, epilepsy, and spastic type]. OR, odds ratio; CI, confidence interval; GMFCS, Gross Motor Function Classification System; MRI, magnetic resonance imaging; NICU, neonatal intensive care unit.

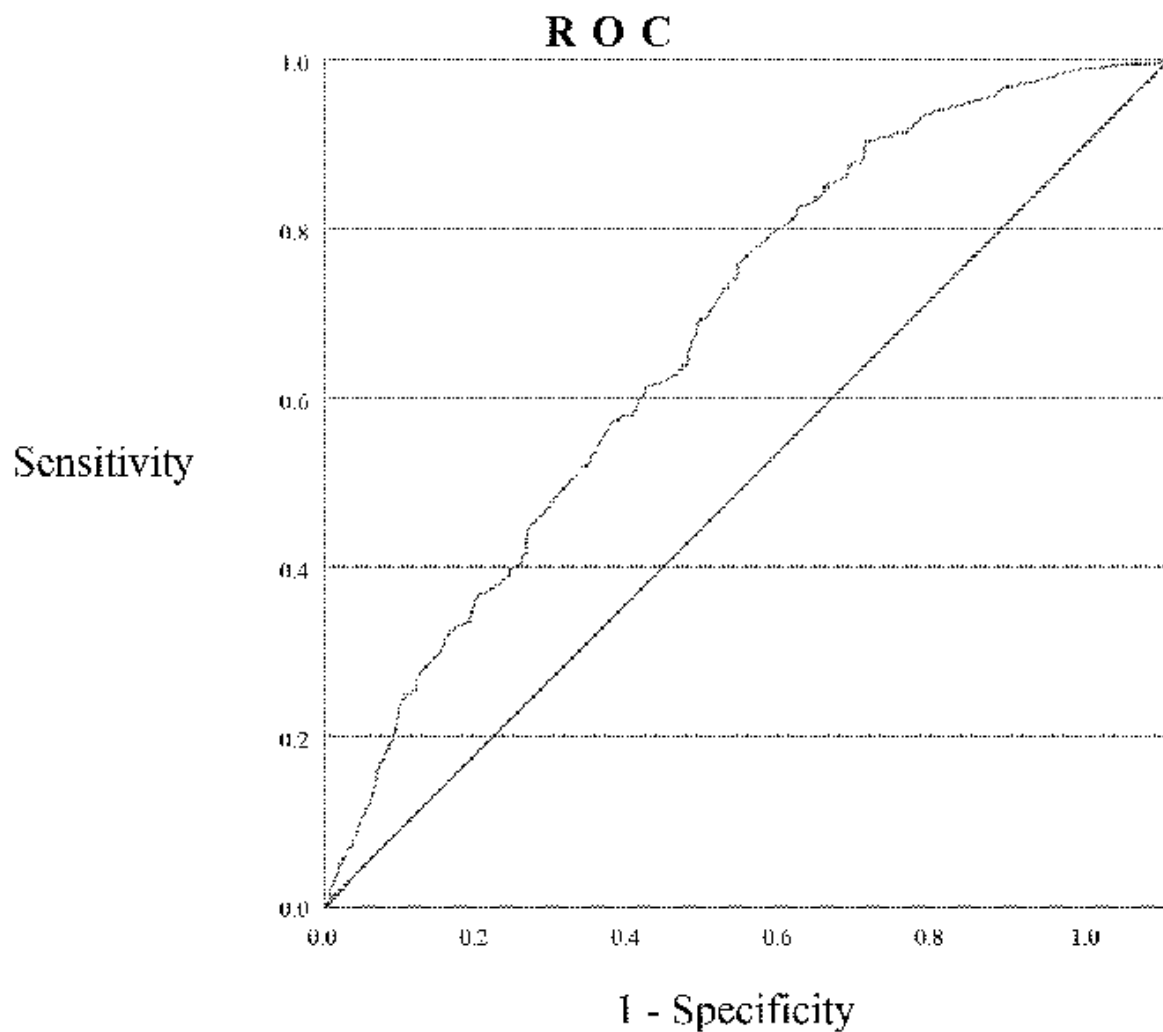


Figure 3

Receiver operating characteristic (ROC) curve of the multivariable logistic regression model for predicting severe motor impairment (GMFCS IV–V).

AUC = 0.677 (95% CI 0.637–0.717, $P < 0.001$). AUC, area under the curve; CI, confidence interval; GMFCS, Gross Motor Function Classification System.

Supplementary Files

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