Early Identification and Early Neurorehabilitation in CP

Summary and subsequently developed Guidelines from the 2014 IMPACT for CP Summit on Early Identification and Early Neurorehabilitation in CP

Summit Summary

Dates: 1st - 2nd July 2014
Venue: Vienna, Austria

IMPACT for CP generously funded by the Balnaves Foundation brought together some of the world’s leading researchers to present their latest findings and define a research agenda to move the field forward. These researchers were invited to attend and work together to agree on a research plan to accelerate outcomes research and translation of findings into clinical practice. The summit was held in Vienna, Austria on the 1st and 2nd of July, just prior to the European Academy of Childhood Disability annual conference.

Despite advances in neuroimaging techniques, early identification of CP is challenging, with the average age of diagnosis occurring between 18 months and 2 years of age. Late detection often delays the onset of early neurorehabilitation and creates difficulties in recruiting to these and other studies. Neuroplasticity evidence increasingly points to the importance of intervening early after brain injury to optimise motor and cognitive outcomes.

Purpose

The purpose of the summit was to:

1. Review the state of the evidence regarding identification of CP in infancy and make recommendations for early detection with a plan to translate into clinical practice
2. Review the state of the evidence regarding the efficacy of current early neurorehabilitation interventions for infants with CP or at very high risk of CP
3. Define a research agenda for the next wave of intervention studies with a recommended core set of measures and common data elements
4. Prepare findings of the summit as guidelines for publication

Outcomes

Summit outcomes included:

1. An agreement for the development publication, and dissemination of clinical practice guidelines on the early detection and neurorehabilitation of CP

The guideline will include the following recommendations:

- Early detection of infants at high risk of CP under 5 months using General Movements Assessment (human scored) + MRI for high risk infants
- Using best available neurological assessments and motor measures to screen for CP (3-24mon) & as a diagnostic alternative when GMs & MRI are not available

2. The identification of research gaps including:
   - A need for the development of non-motor cognitive function test for young infants.
Longitudinal studies of infants at high risk of CP
Multicentre trial of active motor intervention for infants at high risk of CP

Attendees

AUSTRALIA

Prof Nadia Badawi, The Children’s Hospital at Westmead; Cerebral Palsy Alliance, Australia
Prof Roslyn Boyd, Queensland Cerebral Palsy and Rehabilitation Research Centre, University of Queensland, Australia
Dr Susan Greaves, Royal Children’s Hospital, Melbourne, Australia
Petra Karlsson, Cerebral Palsy Alliance, University of Notre Dame Australia
Dr Alison Loughran-Fowlds, The Children’s Hospital at Westmead, Sydney, Australia
Dr Sarah McIntyre, Cerebral Palsy Alliance, University of Notre Dame Australia
Cathy Morgan, Cerebral Palsy Alliance, University of Notre Dame Australia
Prof Iona Novak, Cerebral Palsy Alliance, University of Notre Dame Australia
Prof Roberta Shepherd, University of Sydney, Australia
Dr Alicia Spittle, Royal Women's Hospital, University of Melbourne, Australia
Dr Jane Valentine, University of Western Australia, Australia
Dr Karen Walker, Cerebral Palsy Research alliance, University of Sydney, Australia
Mr Rob White, Cerebral Palsy Alliance, Australia
Mr William Bartlett, Cerebral Palsy Alliance, Australia

AFRICA

Dr Angelina Kakooza, Makerere University, Kampala, Uganda

EUROPE

Dr Lars Adde, Norwegian University of Science and Technology, Norway
Prof Giovanni Cioni, University of Pisa, Italy
Prof Linda S. de Vries, UMCU, Wilhelmina Children’s Hospital, The Netherlands
Prof Ann-Christin Eliasson, Karolinska Institute, Stockholm, Sweden
Prof Christa Einspieler, University of Graz, Austria
Prof Hans Forssberg, Karolinska institute, Sweden
Prof Mijna Hadders-Algra, University medical Centre Groningen, The Netherlands
A/Prof Andrea Guzzetta, University of Pisa, Italy
A/Prof Lena Krumlinde-Sundholm, Karolinska institute, Sweden
Dr Kerstin Pannek, Imperial College London, UK
Dr Lindsay Pennington, Newcastle University, UK
Dr Domenico Romeo, Catholic university, Rome, Italy
Dr Beatrice Latal, University Children’s Hospital, Zurich, Switzerland

NORTH AMERICA

Dr James A. Blackman, Cerebral Palsy International Research Foundation, USA
Dr Janice E. Brunstrom-Hernandez, Washington University School of Medicine, St. Louis Children’s Hospital, USA
Prof Dianne Damiano, National Institutes of Health, Bethesda
Prof Johanna Darrah, University of Alberta, Canada
Prof Darcy Fehlings, University of Toronto, Canada
Prof Donna M. Ferriero, UCSF Benioff Children’s Hospital, USA
Prof Linda Fetters, University of Southern California, USA
Prof Andrew Gordon, Columbia University, USA
Prof Regina Harbourne, University of Nebraska Medical Centre, Nebraska, USA
Dr Nathalie Maitre, The Children’s Hospital at Vanderbilt, Nashville, USA
Dr Gary Noritz, Ohio State University, USA
IMPORTANCE Cerebral palsy describes the most common physical disability in childhood and occurs in 1 in 500 live births. Historically, the diagnosis has been made between age 12 and 24 months but now can be made before 6 months’ corrected age.

OBJECTIVES To systematically review best available evidence for early, accurate diagnosis of cerebral palsy and to summarize best available evidence about cerebral palsy–specific early intervention that should follow early diagnosis to optimize neuroplasticity and function.

EVIDENCE REVIEW This study systematically searched the literature about early diagnosis of cerebral palsy in MEDLINE (1956-2016), EMBASE (1980-2016), CINAHL (1983-2016), and the Cochrane Library (1988-2016) and by hand searching. Search terms included cerebral palsy, diagnosis, detection, prediction, identification, predictive validity, accuracy, sensitivity, and specificity. The study included systematic reviews with or without meta-analyses, criteria of diagnostic accuracy, and evidence-based clinical guidelines. Findings are reported according to the PRISMA statement, and recommendations are reported according to the Appraisal of Guidelines, Research and Evaluation (AGREE) II instrument.

FINDINGS Six systematic reviews and 2 evidence-based clinical guidelines met inclusion criteria. All included articles had high methodological Quality Assessment of Diagnostic Accuracy Studies (QUADAS) ratings. In infants, clinical signs and symptoms of cerebral palsy emerge and evolve before age 2 years; therefore, a combination of standardized tools should be used to predict risk in conjunction with clinical history. Before 5 months’ corrected age, the most predictive tools for detecting risk are term-age magnetic resonance imaging (86%-89% sensitivity), the Prechtl Qualitative Assessment of General Movements (98% sensitivity), and the Hammersmith Infant Neurological Examination (90% sensitivity). After 5 months’ corrected age, the most predictive tools for detecting risk are magnetic resonance imaging (86%-89% sensitivity) (where safe and feasible), the Hammersmith Infant Neurological Examination (90% sensitivity), and the Developmental Assessment of Young Children (83% C index). Topography and severity of cerebral palsy are more difficult to ascertain in infancy, and magnetic resonance imaging and the Hammersmith Infant Neurological Examination may be helpful in assisting clinical decisions. In high-income countries, 2 in 3 individuals with cerebral palsy will walk, 3 in 4 will talk, and 1 in 2 will have normal intelligence.

CONCLUSIONS AND RELEVANCE Early diagnosis begins with a medical history and involves using neuroimaging, standardized neurologic and standardized motor assessments that indicate congruent abnormal findings indicative of cerebral palsy. Clinicians should understand the importance of prompt referral to diagnostic-specific early intervention to optimize infant motor and cognitive plasticity, prevent secondary complications, and enhance caregiver well-being.

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According to a 2007 report, “Cerebral palsy is a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain.”16 Cerebral palsy is a clinical diagnosis based on a combination of clinical and neurological signs. Diagnosis typically occurs between age 12 and 24 months.2-4 The following 4 motor types exist but may emerge and change during the first 2 years of life: (1) spasticity (85%-91%), (2) dyskinesia (4%-7%), including dystonia and athetosis; (3) ataxia (4%-6%); and (4) hypotonia (2%), which is not classified in all countries.5 Dyskinesia, ataxia, and hypotonia usually affect all 4 limbs, whereas spasticity is categorized topographically as (1) unilateral (hemiplegia) (38%) and (2) bilateral, including diplegia (lower limbs affected more than upper limbs) (37%) and quadriplegia (all 4 limbs and trunk affected) (24%).2 Co-morbidities and functional limitations are common and disabling, including chronic pain (75%), epilepsy (35%), intellectual disability (49%), musculoskeletal problems (eg, hip displacement) (28%), behavioral disorders (26%), sleep disorders (23%), functional blindness (11%), and hearing impairment (4%).5

Cerebral palsy is the most common physical disability in childhood, with a prevalence of 2.1 cases per 1000 in high-income countries.6 The prevalence is declining in Australia and Europe.7,8 Exact rates in countries of low to middle income are less certain9 but appear to be higher, with worse physical disability, because of greater infectious disease burden and prenatal and perinatal care differences.10 The complete causal path to cerebral palsy is unclear in approximately 80% of cases, but risk factors are often identifiable from history taking about conception, pregnancy, birth, and the postneonatal period.11 The full causal path is a complex interplay between several risk factors across multiple epochs,11 including new evidence suggesting that 14% of cases have a genetic component.12-14 Early diagnosis does not preclude further specific etiological investigation, and identifying a specific etiology does not then preclude individuals from also having cerebral palsy. Genetic advances are likely to soon amend the diagnostic process.

Our primary objective was to systematically review best available evidence for early, accurate diagnosis of cerebral palsy. Our secondary objective was to summarize best available evidence about cerebral palsy-specific early intervention that should follow early diagnosis to optimize neuroplasticity and function.

Methods

We conducted a systematic review to develop an international clinical practice guideline in accord with the World Health Organization’s Handbook for Guideline Development15 and the Institute of Medicine’s standards.16 We followed the Equator Network reporting recommendations outlined in the Appraisal of Guidelines, Research and Evaluation (AGREE) II instrument17 and the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement.18 We systematically searched MEDLINE (1956-2016), EMBASE (1980-2016), CINAHL (1983-2016), and the Cochrane Library (1988-2016) and hand searched using the following terms: cerebral palsy, diagnosis, detection, prediction, identification, predictive validity, accuracy, sensitivity, and specificity. We included systematic reviews with or without meta-analyses, criteria of diagnostic accuracy, and evidence-based clinical guidelines. Quality was appraised using the Quality Assessment of Diagnostic Accuracy Studies (QUADAS) methodological rating checklist for systematic reviews of diagnostic accuracy.19

The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) framework was used to assess quality and formulate recommendations along a 4-part continuum, including strong for, conditional for, conditional against, and strong against.20 As per the GRADE method, we weighed (1) the balance between desirable and undesirable consequences of different management strategies or not acting; (2) family preferences, including benefits vs risks and inconvenience; and (3) cost. Recommendations were discussed face-to-face among all authors, and the manuscript was reviewed, edited, and agreed on by all coauthors. Authors were clinicians involved in the diagnosis of cerebral palsy, including neurologists, pediatricians, neonatologists, rehabilitation specialists, general practitioners, neuroradiologists, psychiatrists, physical therapists, psychologists, occupational therapists, speech pathologists, nurses, and early educators. Individuals with cerebral palsy and parents also contributed as equal authors, ensuring that recommendations addressed their views and preferences.

Results

Six systematic reviews21-26 and 2 evidence-based clinical guidelines27,28 met inclusion criteria. The methodological quality of the evidence was very high (eTable in the Supplement), enabling strong GRADE recommendations.20 Many standardized tools exist that predict risk of cerebral palsy early. Best available evidence was summarized (eTable in the Supplement), and a PRISMA diagram summarized study flow (eFigure in the Supplement).

Advances in Diagnosis: Early Clinical Diagnosis Is Now Possible

Before age 12 to 24 months was historically regarded as the latent or silent period where cerebral palsy could not be identified accurately. Experts now consider the silent period as outdated because
cerebral palsy or “high risk of cerebral palsy” can be accurately predicted before age 6 months’ corrected age.

The 3 tools with best predictive validity for detecting cerebral palsy before 5 months’ corrected age are (1) neonatal magnetic resonance imaging (MRI) (86%-89% sensitivity),21,27 (2) the Prechtl Qualitative Assessment of General Movements (GMs) (98% sensitivity),2,28 and (3) the Hammersmith Infant Neurological Examination (HINE) (90% sensitivity).25 (eTable in the Supplement). After 5 months’ corrected age, the most predictive tools for detecting risk are MRI (86%-89% sensitivity) (where safe and feasible), the HINE (90% sensitivity), and the Developmental Assessment of Young Children (83% C index). High-quality evidence also indicates that a trajectory of abnormal GMs or HINE scores, in combination with abnormal MRI, producing congruent findings, is even more accurate than individual clinical assessments in isolation.21,25

To make an early clinical diagnosis before 6 months’ corrected age, a combination of assessments with strong predictive validity coupled with clinical reasoning is recommended. We have made 12 recommendations from best available evidence (Table 1). A highly experienced clinical team should ideally conduct and interpret the standardized assessments and then communicate the news compassionately.

Interim High Risk of Cerebral Palsy Clinical Diagnosis
When the clinical diagnosis is suspected but cannot be made with certainty, we recommend using the interim clinical diagnosis of high risk of cerebral palsy until a diagnosis is confirmed. We recommend specifying cerebral palsy because infants with cerebral palsy require and benefit from different early interventions than infants “at risk of developmental delay,” “at risk of autism,” “at risk of harm,” or with “social risk.” When the infant is perceived to be at risk of cerebral palsy, he or she should be referred for cerebral palsy-specific early intervention (see the Advances in Treatment section), with regular medical, neurological, and developmental monitoring from the infant’s pediatrician or neurologist to assist with forming a diagnostic picture. To assign the interim clinical diagnosis of high risk of cerebral palsy, the infant must have motor dysfunction (essential criterion) and at least one of the other 2 additional criteria.

Essential Criterion (Required)

Motor Dysfunction
In motor dysfunction, the infant’s quality of movement is reduced (eg, absent fidgety GMs)28 or neurologically abnormal (eg, early observable hand asymmetry or suboptimal HINE scores).30 In addition, the infant’s motor activities may be substantially below those expected for chronological age (eg, abnormal score on a standardized motor assessment or parent and caregiver or clinical observations of head lag, not sitting, inability to grasp, or not reaching for a toy when appropriate).

As a caveat, in milder presentations, especially unilateral cerebral palsy, it is possible for an infant to score within the normal range on a standardized motor assessment, while still displaying abnormal movements. For example, an infant with hemiplegia might obtain a normal fine-motor score but complete the assessment one-handed. Similarly, an infant with diplegia may achieve normal upper limb scores and abnormal lower limb scores, producing a combined total motor score within the normal range. Therefore, it is essential that assessments be carried out by a professional skilled at determining atypical movement from variation in typical movement.

Additional Criteria (at Least One Required)

Abnormal Neuroimaging
Abnormal MRI21,27 with or without serial cranial ultrasound in premature-term infants21,28 may identify neuroanatomical abnormalities predictive of cerebral palsy. The most predictive patterns are (1) white matter injury (cystic periventricular leukomalacia or periventricular hemorrhagic infarctions) (56%), (2) cortical and deep gray matter lesions (basal ganglia or thalamus lesions, watershed injury [parasagittal injury], multicystic encephalomalacia, or stroke) (18%), and (3) brain maldevelopments (lissencephaly, pachygyria, cortical dysplasia, polymicrogyria, or schizencephaly) (9%).

Clinical History Indicating Risk for Cerebral Palsy

Preconception risks include history of stillbirths, miscarriages, low socioeconomic status, assisted reproduction, and abnormal genetic copy number variations.

Pregnancy risks include genetics, birth defects, multiples, maternal thyroid disease or preeclampsia, infection, intrauterine growth restriction, prematurity, and substance abuse.

Perinatal birth risks include acute intrapartum hypoxia-ischemia, seizures, hypoglycemia, jaundice, and infection.

Postneonatal risks include stroke, infection, surgical complications, and accidental and nonaccidental brain injury31 occurring before age 24 months, as per the Surveillance of Cerebral Palsy Europe and Australian Cerebral Palsy Register inclusion criteria.

Two Early Detection Pathways Based on Different Risks

Half of all infants with cerebral palsy have high-risk indicators identifiable in the newborn period, enabling early screening31 (eg, prematurity, atypical intrauterine growth, encephalopathy, genetic abnormalities, and seizures). We have described this population as having “newborn-detectable risks for cerebral palsy,” and this pathway occurs before 5 months’ corrected age. For the other half of all infants with cerebral palsy, the pregnancy and labor may have appeared to be uneventful,31 and parents, caregivers, or community-based professionals first notice delayed motor milestones (eg, not sitting at 9 months or hand asymmetry). This finding may be especially true for infants with unilateral cerebral palsy, who often master early rudimentary motor skills, such as smiling, swallowing, and head control, and it is not until they attempt more complex motor skills, such as grasp, that asymmetries become observable. We have described this population as having “infant detectable risks for cerebral palsy,” and this pathway occurs after 5 months’ corrected age.

We developed a conceptual framework for early diagnosis based on these 2 pathways to ensure that the most sensitive and specific tools are used to reduce false-positive and false-negative results. The clinical diagnostic pathway algorithm for these 2 groups varies because the tools have different psychometric properties depending on the infant’s age (Figure).

Determining Severity
Parents or caregivers will want to learn about the severity of their infant’s physical disability to understand his or her capabilities to plan their future. In infants younger than 2 years, motor severity is difficult to accurately predict for the following reasons: (1) almost half
### Table 1. Early Detection and Diagnosis Recommendations From Best Available Evidence

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Strength of Recommendations and Quality of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 The clinical diagnosis of CP can and should be made as early as possible so that: • The infant can receive diagnostic-specific early intervention and surveillance to optimize neuroplasticity and prevent complications • The parents can receive psychological and financial support (when available)</td>
<td>Strong recommendation based on moderate-quality evidence for infant and parent outcomes</td>
</tr>
<tr>
<td>1.1 When the clinical diagnosis is suspected but cannot be made with certainty, the interim clinical diagnosis of high risk of CP should be given so that: • The infant can receive diagnostic-specific early intervention and surveillance to optimize neuroplasticity and prevent complications • The parents can receive psychological and financial support (when available) • Ongoing diagnostic monitoring can be provided until a diagnosis is reached</td>
<td>Strong recommendation based on moderate-quality evidence for infant and parent outcomes</td>
</tr>
<tr>
<td>2.0 Early standardized assessments and investigations for early detection of CP should always be conducted in populations with newborn-detectable risks (ie, infants born preterm, infants with neonatal encephalopathy, infants with birth defects, and infants admitted to the NICU)</td>
<td>Strong recommendation based on high-quality evidence of test psychometrics</td>
</tr>
<tr>
<td><strong>Early Detection of CP Before 5 mo CA</strong></td>
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<tr>
<td>3.0 Option A: The most accurate method for early detection of CP in infants with newborn-detectable risks and younger than 5 mo (CA) is to use a combination of a standardized motor assessment and neuroimaging and history taking about risk factors</td>
<td>Strong recommendation based on high-quality evidence of test psychometrics in newborn-detectable risk populations</td>
</tr>
<tr>
<td>3.1 Test: GMs to identify motor dysfunction (95%-98% predictive of CP), combined with neuroimaging</td>
<td>Strong recommendation based on high-quality evidence of test psychometrics in newborn-detectable risk populations</td>
</tr>
<tr>
<td><strong>Neuroimaging</strong></td>
<td></td>
</tr>
<tr>
<td>3.2 Test: MRI (before sedation is required for neuroimaging) to detect abnormal neuroanatomy in the motor areas of the brain (80%-90% predictive of CP). Note that normal neuroimaging does not automatically preclude the diagnosis of risk of CP</td>
<td>Strong recommendation based on high-quality evidence of test psychometrics in newborn-detectable risk populations</td>
</tr>
<tr>
<td>4.0 Option B: In contexts where the GMs assessment is not available or MRI is not safe or affordable (eg, in countries of low to middle income), early detection of CP in infants with newborn-detectable risks and younger than 5 mo (CA) is still possible and should be carried out to enable access to early intervention</td>
<td>Strong recommendation based on moderate-quality evidence of test psychometrics in newborn-detectable risk populations</td>
</tr>
<tr>
<td><strong>Standardized neurological assessment</strong></td>
<td></td>
</tr>
<tr>
<td>4.1 Test: HINE (scores &lt;57 at 3 mo are 96% predictive of CP)</td>
<td>Strong recommendation based on moderate-quality evidence of test psychometrics in newborn-detectable risk populations</td>
</tr>
<tr>
<td>4.2 Test: TIMP</td>
<td>Conditional recommendation based on low-quality evidence of test psychometrics in at-risk populations</td>
</tr>
<tr>
<td><strong>Early Detection of CP After 5 mo CA</strong></td>
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<tr>
<td>Accurate early detection of CP in those with infant-discriminable risks and age 5-24 mo can and should still occur as soon as possible, but different diagnostic tools are required</td>
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<tr>
<td>5.0 Any infant with: (a) Inability to sit independently by age 9 mo, or (b) Hand function asymmetry, or (c) Inability to take weight through the plantar surface (heel and forefoot) of the feet should receive standardized investigations for CP</td>
<td>Strong recommendation based on high-quality evidence of motor norms</td>
</tr>
<tr>
<td>6.0 Option A: The most accurate method for early detection of CP in those with infant detectable risks older than 5 mo (corrected for prematurity) but younger than 2 y is to use a combination of a standardized neurological assessment, neuroimaging, and a standardized motor assessment with a history taking about risk factors</td>
<td>Conditional recommendation based on moderate-quality evidence of test psychometrics in newborn-detectable risk populations</td>
</tr>
<tr>
<td><strong>Standardized neurological assessment</strong></td>
<td></td>
</tr>
<tr>
<td>6.1 Test: HINE (90% predictive of CP). Those with HINE scores &lt;73 (at 6, 9, or 12 mo) should be considered at high risk of CP. HINE scores &lt;40 (at 6, 9, or 12 mo) almost always indicate CP, combined with neuroimaging and standardized motor assessments</td>
<td>Conditional recommendation based on moderate-quality evidence of test psychometrics in newborn-detectable risk populations</td>
</tr>
<tr>
<td><strong>Neuroimaging</strong></td>
<td></td>
</tr>
<tr>
<td>6.2 Test: MRI to detect abnormal neuroanatomy in the motor areas of the brain (sedation may be required from &gt;6 wk up to age 2 y). Well-defined lesions can be seen early, but subtle white matter lesions may be difficult to detect owing to rapid growth, myelination, and activity-dependent plasticity. Repeated MRI scans are recommended at age 2 y for infants with initially normal findings on MRI (at 12-18 mo) but persistent motor or neurological abnormality, combined with standardized motor assessments</td>
<td>Conditional recommendation based on moderate-quality evidence of test psychometrics in newborn-detectable risk populations</td>
</tr>
<tr>
<td>6.3 Test: DAYC for parents to self-report and quantify motor delay (89% predictive of CP) Additional assessments can improve triangulation of findings</td>
<td>Conditional recommendation based on moderate-quality evidence of test psychometrics in newborn-detectable risk populations</td>
</tr>
<tr>
<td>6.4 Tests: AIMS (86% predictive of an abnormal motor outcome) and NSMDA (82% predictive of an abnormal motor outcome)</td>
<td>Conditional recommendation based on moderate-quality evidence of test psychometrics in newborn-detectable risk populations</td>
</tr>
<tr>
<td>7.0 Option B: In contexts where MRI is not safe or affordable, early detection of CP is still possible in those with infant detectable risks between 5 and 24 mo CA and should be carried out to enable access to early intervention</td>
<td>Strong recommendation based on moderate-quality evidence of test psychometrics in newborn-detectable risk populations</td>
</tr>
<tr>
<td><strong>Standardized neurological assessment</strong></td>
<td></td>
</tr>
<tr>
<td>7.1 Test: HINE (90% predictive of CP at age 2-24 mo) HINE scores at 6, 9, or 12 mo: &lt;73 Indicates high risk of CP &lt;40 Indicates abnormal outcome, usually CP</td>
<td>Strong recommendation based on moderate-quality evidence of test psychometrics in newborn-detectable risk populations</td>
</tr>
<tr>
<td><strong>Standardized motor assessment</strong></td>
<td></td>
</tr>
<tr>
<td>7.2 Test: DAYC to quantify motor delay (89% predictive of CP)</td>
<td>Conditional recommendation based on low-to moderate-quality evidence of test psychometrics in newborn-detectable risk populations</td>
</tr>
<tr>
<td>7.3 Test: MAI to quantify motor delay (73% predictive of CP)</td>
<td></td>
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</tbody>
</table>

(continued)
Parents or caregivers may mistakenly assume that the diagnosis means their child will need a wheelchair and have an intellectual disability. However, in high-income countries, population data indicate that 2 in 3 individuals with cerebral palsy will walk, 3 in 4 will talk, and 1 in 2 will have normal intelligence.5

**Determining Motor Type and Topography**

The motor types and topography of cerebral palsy may emerge and change during the first 2 years of life. Cerebral palsy can be difficult to accurately classify early, but clinical signs exist33-37 (Table 2). For example, the onset of spasticity may occur after age 1 year; therefore, the absence of early detectable spasticity does not mean that the infant does not have spastic cerebral palsy. In addition, infants may have more than one motor disorder because spasticity and dystonia often coexist. As the infant’s voluntary activity levels increase, some symptoms may resolve (eg, nonuse of a limb), while other symptoms may worsen (eg, increased involuntary dystonic contractions). The motor types and topography of cerebral palsy may emerge and change during the first 2 years of life. Cerebral palsy can be difficult to accurately classify early, but clinical signs exist33-37 (Table 2). For example, the onset of spasticity may occur after age 1 year; therefore, the absence of early detectable spasticity does not mean that the infant does not have spastic cerebral palsy. In addition, infants may have more than one motor disorder because spasticity and dystonia often coexist. As the infant’s voluntary activity levels increase, some symptoms may resolve (eg, nonuse of a limb), while other symptoms may worsen (eg, increased involuntary dystonic contractions).
posturing in response to voluntary movement). Wherever possible, differentiate between unilateral vs bilateral cerebral palsy early because treatments differ.\textsuperscript{5,38}

**False Positives and False Negatives**

Without a laboratory biomarker, an early diagnosis is not always clinically clear-cut because of the possibility of false positives and false

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**Figure. Algorithm for Early Diagnosis of Cerebral Palsy or High Risk of Cerebral Palsy**

<table>
<thead>
<tr>
<th>Newborn detectable risks</th>
<th>Infant detectable risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preterm</td>
<td>History or neurological risk factors (eg, birth defect, IUGR)</td>
</tr>
<tr>
<td>Encephalopathy</td>
<td>Parent identified concern</td>
</tr>
<tr>
<td></td>
<td>Unable to sit at 9 mo or hand asymmetry</td>
</tr>
</tbody>
</table>

Risks or concerns warrant an investigation for CP

- Conduct a medical history and clinical examination with or without investigations for etiology and differential diagnoses (as indicated)

- <5 mo CA
  - 1.1 GMs
  - 4.1 HINE
  - 6.2 MRI

- >5 mo CA
  - 1.1 GMs
  - 4.2 TIMP
  - 6.3 DAYC

Combined assessment data indicates

- 1.1 High risk of CP
  - 8.0 Determine preliminary severity of CP
    - 8.1 HINE ≥40
    - 8.1 MRI WMI
    - 8.1 HINE <40
    - 8.1 MRI GMI
  - Likely ambulant
  - Likely nonambulant
  - 9.0 Determine preliminary topography
  - 11.0 Assess for associated impairments
  - 12.0 Communicate findings to parents compassionately
  - 10.0 Arrange early intervention and parent support

- 1.1 Definitely CP
  - 8.1 HINE ≥40
  - 8.1 MRI WMI
  - 8.1 HINE <40
  - 8.1 MRI GMI
  - Likely ambulant
  - Likely nonambulant
  - 9.0 Determine preliminary topography
  - 11.0 Assess for associated impairments
  - 12.0 Communicate findings to parents compassionately
  - 10.0 Arrange early intervention and parent support

- 1.1 Unclear
  - As indicated, continue testing for differential diagnoses and relevant associated impairments

- 1.1 Definitely NOT CP
  - As indicated, continue testing for differential diagnoses and relevant associated impairments

A indicates the best available evidence pathway. B indicates the next best available evidence pathway when some pathway A tools are not available. The numerals correspond to the numbering in Table 1. AIMS indicates Alberta Infant Motor Scale; CA, corrected age; CP, cerebral palsy; DAYC, Developmental Assessment of Young Children; GMs, Prechtl Qualitative Assessment of General Movements; HINE, Hammersmith Infant Neurological Examination; IUGR, interuterine growth restriction; MAI, Motor Assessment of Infants; MRI, magnetic resonance imaging; NSMDA, Neuro Sensory Motor Development Assessment; TIMP, Test of Infant Motor Performance; and WMI, white matter injury.
Early, Accurate Diagnosis and Early Intervention in Cerebral Palsy

Table 2. Clinical Signs Indicating Motor Type and Topography in Infants

<table>
<thead>
<tr>
<th>Unilateral Spastic Hemiplegia</th>
<th>Bilateral Spastic Diplegia</th>
<th>Bilateral Spastic Quadriplegia</th>
<th>Dyskinesia</th>
<th>Ataxia</th>
</tr>
</thead>
<tbody>
<tr>
<td>GMSs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Poor repertoire or cramped</td>
<td>• Cramped synchronized</td>
<td>• Early onset and long</td>
<td>• Poor</td>
<td>• Unknown</td>
</tr>
<tr>
<td>synchronized GMs, followed by</td>
<td>GMs, followed by absent</td>
<td>duration of cramped</td>
<td>repertoire</td>
<td></td>
</tr>
<tr>
<td>absent fidgety movements</td>
<td>fidgety movements</td>
<td>synchronized GMs, followed by</td>
<td>GMs,</td>
<td></td>
</tr>
<tr>
<td>plus an asymmetry in</td>
<td></td>
<td>absent fidgety movements</td>
<td>followed by</td>
<td></td>
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<tr>
<td>segmental movements (eg,</td>
<td></td>
<td></td>
<td>arm</td>
<td></td>
</tr>
<tr>
<td>wrist or hand).</td>
<td></td>
<td></td>
<td>movements</td>
<td></td>
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<tr>
<td>Note that some cases of</td>
<td></td>
<td></td>
<td>and finger</td>
<td></td>
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<tr>
<td>hemiplegic CP may be missed</td>
<td></td>
<td></td>
<td>spreading</td>
<td></td>
</tr>
<tr>
<td>by GMSs.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MRI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Focal vascular insults (24%)</td>
<td>• Bilateral white matter</td>
<td>• Gray matter injury (34%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Malformations (13%)</td>
<td>injury (31%-60%)</td>
<td>• Malformations (16%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Unilateral hemorrhage (grade IV) with porencephaly</td>
<td>• Cystic PVL (grade II-III) with sparse or absent myelination of the PLIC</td>
<td>• Cystic PVL (grade III) with absent myelination of the PLIC</td>
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<tr>
<td>• Lesions in the parietal white matter involving the trigone</td>
<td>Moderate to severe white matter injury (also known as PVE)</td>
<td>Severe white matter injury with or without deep nuclear gray matter</td>
<td></td>
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<tr>
<td>• Middle cerebral artery stroke with asymmetry of myelination of the PLIC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HINE Scores &lt;27</td>
<td>&lt;50</td>
<td>&lt;50</td>
<td>&lt;50</td>
<td>Unknown</td>
</tr>
<tr>
<td>Motor Tests</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Asymmetrical hand preference</td>
<td>• Good hand function</td>
<td>• Head lag</td>
<td>• Twisting arm or neck</td>
<td>*Non specific</td>
</tr>
<tr>
<td>• Stuck in floor sitting (ie, unable to transition out of sitting)</td>
<td>compared with lower limb function</td>
<td>• Persistent rounded back in supported sitting</td>
<td>• Postures on voluntary movement (may be painful)</td>
<td></td>
</tr>
<tr>
<td>• Cruises or steps consistently in one direction or with the same leg always leading</td>
<td>• Dislike or avoidance of floor sitting</td>
<td>• Bilateral fist ed hands</td>
<td>• Finds midline play difficult, prefers toys positioned at shoulder width</td>
<td></td>
</tr>
<tr>
<td>• Reduced variation in motor behavior</td>
<td>• Weight bears on toes</td>
<td>• Slow to reach and grasp with either hand</td>
<td>• Requires a lot of extra time to initiate movement</td>
<td></td>
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<td></td>
<td>• Reduced variation in motor behavior</td>
<td>• Reduced variation in motor behavior</td>
<td>• Voluntary movement and emotion worsens</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>postures</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Reduced variation in motor behavior</td>
<td></td>
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</tbody>
</table>

Abbreviations: CP, cerebral palsy; GMFCS, Gross Motor Function Classification System; GMS, Precht’s Qualitative Assessment of General Movements; HINE, Hammersmith Infant Neurological Examination; MRI, magnetic resonance imaging; PLIC, posterior limb internal capsule; PVE, periventricular echogenicity; PVL, periventricular leukomalacia.

negatives. Experienced clinicians acknowledge that, because all infants have an expanding and changing voluntary motor repertoire, determining whether their current motor dysfunction is permanent and causing long-term activity limitations, as per the international definition, is difficult. False negatives can occur for the following reasons: (1) there is a latency between the initial brain lesion and the later onset of clinical neurological signs (eg, exaggerated spasticity or dystonia from voluntary movement), (2) approximately 10% have normal neuroimaging, and half have a seemingly uneventful pregnancy and birth, and (4) one-third have the mildest form (GMFCS I), and may initially achieve all of their motor milestones on time, offering false reassurance about their motor development. False positives can also occur because prematurity, stroke, and encephalopathy do not always result in long-term motor disabilities. Australian cerebral palsy population register data indicate that less than 5% of registrations are false-positive diagnoses. In almost all of these instances, the infant was re-diagnosed as having another neurological disability (eg, intellectual disability or autism), not a normal developmental outcome.

Eighty-six percent of parents of a child with cerebral palsy suspect it before the clinical diagnosis is made. Population data indicate that seeking to avoid false-positive results by delaying diagnosis is harmful to parent and caregiver well-being. Parents and caregivers dissatisfied with a prolonged diagnostic process are more likely to experience depression and lasting anger. Parents and caregivers acknowledge that, while receiving the diagnosis is always difficult, they prefer to know earlier rather than later so that they can assist in their infant’s development. Early detection is important for the whole family unit because it helps foster acceptance and leads to increased confidence in the infant’s medical team. Early detection allows improved access to early intervention and efficient use of resources.

Advances in Treatment: Cerebral Palsy-Specific Early Intervention Improves Outcomes

Neuroscience evidence indicates that brain development and refinement of the motor system continue postnatally, driven by motor cortex activity. Early active movement and intervention are essential because infants who do not actively use their motor cortex risk losing cortical connections and dedicated function. Furthermore, there is increasing evidence that the infant’s motor behavior, via discovery and interaction with the environment, controls and generates the growth and development of muscle, ligament, and bone, as well as driving ongoing development of the neuromotor system.

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The aim of early intervention for children with cerebral palsy should be to (1) optimize motor, cognition, and communication outcomes using interventions that promote learning and neuroplasticity (all have motor impairments, 1 in 2 have intellectual disability, and 1 in 4 are nonverbal); (2) prevent secondary impairments and minimize the influence of complications that worsen function or interfere with learning (3 in 4 have chronic pain, 1 in 3 have hip displacement, 1 in 4 have epilepsy, 1 in 4 have bladder control problems, 1 in 5 have a sleep disorder, 1 in 5 have sialorrhea, 1 in 10 are blind, 1 in 15 require tube feeding, and 1 in 25 are deaf); and (3) promote parent or caregiver coping and mental health to reduce stress, anxiety, and depression, which are compounded when a behavior disorder is present (1 in 4 have behavior disorders). Recommendations from best available evidence are listed below.

Early Interventions to Optimize Motor, Cognition, and Communication Skills

For motor and cognition, physical and occupational therapy interventions should use child-initiated movement, task-specific practice, and environmental adaptations that stimulate independent task performance. These include Learning Games Curriculum (diplegia), CIMT or bimanual (hemiplegia), and GAME (all subtypes).

For communication, speech language pathology interventions should foster parent-infant transactions and provide compensation when speech is not possible or is inadequate. Examples include the Hanen It Takes Two to Talk and More Than Words programs, as well as alternative and augmentative communication.

Interventions to Prevent Secondary Impairments and Minimize Complications

Regarding pain, procedural pain should be avoided where possible because untreated pain elevates the risk for long-term neuropathic pain. Recommendations include pharmacological therapy and environmental interventions for ongoing pain and preemptive analgesia for procedural pain.

Orthopedics

For hips, anteroposterior pelvic radiographs every 6 to 12 months are recommended commencing at age 12 months. This recommendation is in accord with hip surveillance guidelines.

Neurologic

For epilepsy, standard antiepileptic pharmacological management is recommended.

Urinary Tract

For the bladder, medical investigations should be conducted because abnormal anatomical findings are common. Standard toilet training should be provided over a longer duration because control may take longer.

Sleep

For sleep, specialist assessments and early treatment are recommended before secondary academic and behavioral problems emerge. Examples include sleep hygiene, parental education, spasticity management, melatonin (2.5-10 mg), and gabapentin (5 mg/kg).

Oral Care

For sialorrhea, botulinum toxin A, benztpine mesylate, or glycopyrrolate should be considered.

Ophthalmologic Issues

Vision can be assessed in the first 48 hours of life using the early assessment of visual function in full-term newborns by Ricci et al. Any infant with abnormal vision at term-equivalent age should receive vision intervention and be reassessed at 3 months. Vision intervention is recommended.

Feedings

For nonoral feeding, swallowing safety should be comprehensively assessed if concerns or clinical history of pneumonia exists because it is the leading cause of death in individuals with cerebral palsy and is mitigated by tube feeding. Weight should be measured regularly because severe physical disability elevates the risk for malnutrition.
Interventions to Promote Parent or Caregiver Coping and Mental Health

Parental education in behavior management is recommended. An example is the Positive Parenting Program (Triple P). Parent-child attachment interventions are also helpful. Kangaroo Mother Care and music therapy are examples. Finally, parent or caregiver mental health interventions are suggested. One such intervention is Acceptance and Commitment Therapy (ACT).

Discussion

Clinical Bottom Line

- Infants with cerebral palsy require an early diagnosis because motor and cognitive gains are greater from diagnosis-specific early intervention.
- An interim diagnosis of high risk of cerebral palsy should be used if a diagnosis of cerebral palsy cannot yet be used with certainty.
- Clinical signs emerge and evolve before age 2 years. Therefore, a combination of standardized tools should be used to predict risk.
- Before 5 months’ corrected age, MRI, GMs, or the HINE are most predictive of risk for cerebral palsy.
- After 5 months’ corrected age, MRI and the HINE are most predictive of risk for cerebral palsy.
- In countries of low to middle income where MRI is not available, the HINE is recommended.
- Topography and severity of cerebral palsy are important to establish for clinical purposes. Magnetic resonance imaging and the HINE provide guidance.
- False positives occur less than 5% of the time with standardized tools.
- False negatives resulting in late diagnoses and late intervention are detrimental to parents, caregivers, and infants.

Limitations

This review article has some limitations. First, our literature search revealed that almost all studies focus on identifying cerebral palsy in infants with newborn discernible risks (eg, prematurity and encephalopathy) because these infants are more often in newborn follow-up. Little has been published about early diagnosis in the 50% of all cerebral palsy cases that are discernible later in infancy after a seemingly uneventful pregnancy and birth because these samples are difficult to assemble. Advances in genetics and understanding of congenital anomalies may provide more clues about how to identify these children earlier. Second, no study to date has investigated the combined predictive power of 3 or more of the individual tools identified in this review article and represents a gap in the literature. Third, we have not reviewed or discussed the literature about evidence-based testing for other childhood disabilities on the differential diagnosis list. Fourth, we have not provided a systematic description of the early intervention evidence. More information on assessment tools and early intervention is contained in a related but separate clinical guideline that is being developed from systematic review data.

Conclusions

Cerebral palsy or high risk of cerebral palsy can be diagnosed accurately and early using clinical reasoning and a combination of standardized tools. High-quality evidence indicates that, for infants with newborn-detectable risks before 5 months’ corrected age, the GMs assessment plus neonatal MRI is more than 95% accurate and is thus recommended. For infants with infant detectable risks after 5 months’ corrected age, the HINE plus neonatal MRI is more than 90% accurate and is therefore recommended. The accuracy of these diagnostic methods in infants with later infancy discernible risks for cerebral palsy is not yet known, but they are conditionally recommended. Accurate early diagnosis is possible even when assessments of GMs are not available or MRI is not safe or affordable (eg, in countries of low to middle income) by using the HINE, which detects cerebral palsy with more than 90% accuracy and provides objective information about severity. Early detection of high risk of cerebral palsy, followed by cerebral palsy-specific early intervention, is recommended and should be the standard of care to optimize infant neuroplasticity, prevent complications, and enhance parent and caregiver well-being.
responsibility for the integrity of the data and the accuracy of the data analysis.


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Early, Accurate Diagnosis and Early Intervention in Cerebral Palsy


