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Original article

From congenial paralysis to post-early brain injury developmental condition: Where does cerebral palsy actually stand?

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ABSTRACT

Cerebral palsy (CP), an umbrella term for a developmental motor disorder caused by early brain injury (EBI)/interference, remains debated. In this essay, we present a narrative, beginning with the original anatomical-clinical description of the so-called *paralysie congéniale* (congenial paralysis) by the French psychiatrist Jean-Baptiste Cazauvieilh. We then discuss how the concept has evolved over the last 2 centuries. We aim to illustrate these ideas with the biopsychosocial model of health, especially in light of the current neuroscientific and sociological knowledge of human development. We endeavour to integrate 3 connected but distinct entities: (1) the EBI as a seminal turning point of the individual's story; (2) the clinical findings we call CP, when motor impairment and activity limitation related to post-EBI (or other early non-progressive brain interference) appears, and; (3) a post-EBI developmental condition that encompasses the overall consequences of an EBI. This framework should guide individual, familial and collective care discussions and research strategies beyond the scope of CP.

1. Introduction

Q2 Cerebral palsy (CP) is a developmental condition that persists throughout the lifetime [1,2]. However, this umbrella term has been criticized by people with CP, families, support groups, and scientific and medical communities [3–9]. According to these groups, the current name and its definition — used to describe individuals with motor impairments and activity limitations either with or without associated impairments — is viewed as insufficiently representative of the diverse changes that occur during development after an early brain injury (EBI)/interference. It also poorly evokes the challenges of the combination of impairments and disturbances that may have consequences throughout life. As such, it does not sufficiently illustrate the fact that post-EBI development is a dynamic, multidimensional

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condition that must be considered in the context of the individual. Eventually, all of these limitations might affect the understanding of CP diversity and restrict opportunities for innovative care interventions and research.

In 1827, Jean-Baptiste Cazauvieilh's medical thesis described the anatomical-clinical picture of *paralysie congéniale* (congenial paralysis; Fig. 1) [10]. Further studies of similar conditions followed, with diverse appellations including *Cerebrallähmung der Kinder*, spasmodic infantile hemiplegia, Little's disease and *infirmité* (or *déficience*) *motrice cérébrale*. These descriptions were then combined under the one term, cerebral palsy, with the goal of allowing a common language to be shared among the medical and the scientific communities and facilitating the organisation of large international registries and clinical trials. Years later, this nosography has helped families identify the condition and be supported by advocacy groups [11].

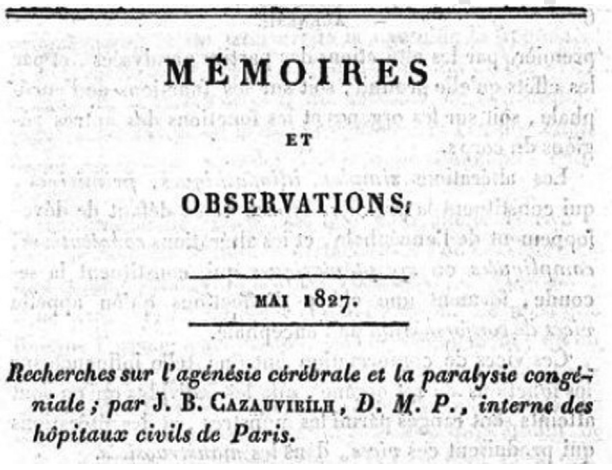
For the purposes of this article, we returned to Cazauvieilh's original anatomical-clinical description to highlight both the similarities and differences with the modern definition of CP. Then, based on recent professional, patient and familial approaches, we discuss how different notions have changed over time to reach the concept of early developmental brain injury/interference [8]. Finally, we use our own experience of perinatal stroke [12] to illustrate how these concepts fit with the current biopsychosocial model of health, especially in light of the current neuroscientific and sociological knowledge of human development.

2. Current definitions of CP

In 2004, a symposium of the Executive Committee for the Definition of CP composed of international experts met in Bethesda (USA) and agreed on a multiple-point definition. Their guidance statement was first published in 2005 [13] and on the basis of feedback and further correspondence from people involved in CP, was updated in 2007 [1]. Seven key points described CP as: "(1) a group of (2) permanent disorders of (3) the development of movement and posture, (4) causing activity limitation, (5) that are attributed to non-progressive disturbances (6) that occurred in the developing fetal or infant brain. (7) The motor disorders of CP are often accompanied by disturbances of sensation, perception, cognition, communication and behaviour; by epilepsy, and by secondary musculoskeletal problems."

The Surveillance of CP in Europe (SCPE) network and the Australian CP registries also present the following multiple-point definition of CP: "(1) a group of disorders i.e. it is an umbrella term; (2) it is permanent but not unchanging; (3) it involves a disorder of movement and/or posture and of motor function; (4) it is due to a non-progressive interference/lesion/abnormality; (5) this interference/lesion/abnormality arises in the developing/immature brain" [14].

Thus, 5 key points are common to both definitions. The SCPE does not take "activity restriction" into account (point 4 from the Executive Committee's definition) nor the "associated symptoms" (point 7); however, these 2 domains were further delineated in the SCPE papers [15].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Recherches sur l'agénésie cérébrale et la paralysie congéniale ; par J. B. CAZAUVIEILH, *D. M. P., interne des hôpitaux civils de Paris.*

Fig. 1. Original medical thesis defended by Jean Baptiste Cazauvieilh, *Recherches sur l'agénésie cérébrale et la paralysie congéniale*, published in May 1827.

3. Palsy (the core of CP): an obvious symptom

This neurological impairment interested the medical community very early on because it was easy to associate with neuropathological studies. *Paralysie* (paralysis/palsy) was defined by the *Dictionnaire encyclopédique des sciences médicales* in 1874 as "the abolition or reduction of muscle contractility by their natural stimulant [...] paralysis is simply a symptom [...] not an actual disease, it is a phenomenon that demonstrates an alteration (anatomical or dynamic) of the nervous or muscle system itself that depends on a true morbid state, a real disease" [16].

3.1. Cazauvieilh's description of paralysie congéniale in 1827

Cazauvieilh was born in 1802 near Bordeaux (France). He undertook his medical residency in Paris, in the women's mental health department of the hôpital de la Salpêtrière. This was the dawn of the modern psychiatry era (although it was not yet clearly distinguished from neurology), when the medical community was becoming aware that mental conditions could be improved with appropriate care.

Cazauvieilh was particularly interested in women with signs of paralysis. Through his observations of their clinical presentation as well as the autopsies he carried out, he developed the notion of *paralysie congéniale* (from the ancient Greek , meaning origin/formation/genesis). This was the subject of his medical thesis, entitled *Recherches sur l'agénésie cérébrale et la paralysie congéniale,* published in *Archives générales de médecine* (see Fig. 1) [10].

In his thesis, Cazauvieilh reported his observations of 12 women, between 19 and 68 years old, who had a unilateral form of paralysis. All individual cases were precisely described and none was reported with progressive findings during their adulthood. However, Cazauvieilh emphasized that these women were paralysed since they were young, and he specified that "The specie (sic) of paralysis described in this memoir occurs in the foetus or during early childhood". He described how the deficiency affected the thoracic limb (that could sometimes "fulfill no function") more than the pelvic limb and was predominant in the extensor muscles of the thoracic limb and the flexor muscles of the pelvic limb. He also described the typical postural pattern of the thoracic limb in adduction/flexion/pronation. He observed the abnormal postures and movements, describing "the forced separating of the toes and particularly the hand in a fan shape [...] that was even more pronounced when the person wishes to carry out large movements", as well as involuntary movements: "The flexor muscles tightened like ropes, [...] the limb was agitated by irregular movements". In the pelvic limb, Cazauvieilh noted the presence of equino-varus deformities caused by contracture of the triceps surae and that the affected limbs were generally shorter and thinner than the unaffected limbs. Gait and balance abnormalities were also detailed as follows: "Some walked on the anterior half of the foot, others on the external edge [...], and others on the tip toes only", "Locomotion is very exhausting, and if hasty, the patient falls". In addition, he reported that 7 women had

"underdeveloped intellectual faculties", one had epilepsy, and many had sensory impairments and experienced pain in their paralysed limbs.

Cazauvieilh performed brain autopsies of 6 women with *paralysie congéniale*. He reported "alteration of the tissues, accompanied by a lack of development of the affected part and the surrounding parts" that could have happened "at any stage of the foetal or newborn life". Although he did not attempt to explain his findings, Cazauvieilh highlighted that the condition affecting these women was distinguishable from insults occurring "once the organ has acquired all its development". Finally, Cazauvieilh concluded that among the different opinions suspected to explain what he observed, "none is sufficiently satisfactory to be received".

On the basis of his findings, Cazauvieilh outlined a concept that is similar to the current definition of CP:

- key point 3): the individual has a movement disorder that includes specific gait abnormalities, balance, abnormal limb postures and abnormal movements;
- key point 5): only cases with non-progressive injury are included;
- key point 6): the injury occurs in the developing brain;
- key point 7): the motor disorder is accompanied by disturbances of sensation and cognition as well as epilepsy, pain and secondary musculoskeletal problems.

Cazauvieilh and his contemporaries were already aware that palsy was "simply a symptom" and might be caused by lesions of multiple aetiology with common clinical consequences (umbrella term; point 1) [16,17]. The concepts of activity (point 4) and participation were not considered at that time and thus did not figure in Cazauvieilh's definition.

4. From Cazauvieilh 1827 to Shusterman 2015

4.1. 19th century

In 1877, the French neurologist Pierre Marie developed the term "hémiplégie spasmodique infantile", explaining that "Although it describes [...] a reasonably homogenous group", is not "a disease, or even a special affection, but a symptomatic expression that seems to depend on three factors:

- the young age of the subject, who is thus affected during the period of development;
- the role of the lesions on the cerebral cortex [...]; and;
- a sufficient lapse of time for the complete development of the symptoms" [17].

Marie acknowledged the importance of work by the French surgeon Claude François Lallemand, published in 1834. Although he did not specifically study congenial palsy, Lallemand associated Cazauvieilh's clinical observations with his own pathological findings from brain autopsies [18].

In Great Britain, William John Little, a surgeon who himself had a talipes equino-varus foot, developed renowned expertise in treating orthopaedic deformities. In 1843, *The Lancet* published his famous lectures [19] in which he described specific spastic deformities in children, known as Little's disease in the 1960s and which later became known as a bilateral form of CP. Little recognized that the paralysis (and subsequent rigid spasticity of the limb muscles leading to joint deformities) was caused by brain lesions. He defined diverse situations that could induce these lesions: "Premature birth, difficult labours, mechanical injuries during parturition to head and neck, [...] convulsions following the act of birth, were apt to be succeeded by a determinate affection of the limbs [...], which I designated spastic rigidity [...] sometimes produced at later periods of existence" [20].

In 1888, the Canadian physician Sir William Osler delivered a series of lectures entitled The Cerebral Palsies of Children, thus spreading the term that was already being used by Adolph Wallenberg in Germany (1886) and William Gowers in Great Britain (1888) [21]. Osler drew attention to the fact that the different clinical presentations of the condition were not easily defined according to the aetiology and thus developed a classification system based on the distribution of motor impairment in the limbs: infantile hemiplegia, bilateral spastic hemiplegia and spastic paraplegia.

Soon after, in Austria, Sigmund Freud expressed great interest in neurology and neuropathology. Prior to his work in psychiatry [22,23] and between 1891 and 1897, he published several papers about *Cerebrallähmung der Kinder* (CP of children), which he defined as "the general concept of all cerebral diseases in infancy caused by a direct effect of accidental aetiology, occurring either in the foetal period or after birth, and affecting one or more neuron systems". He proposed one of the earliest topographical classifications of CP, which became the most accepted, based on the distribution of the paralysis and muscle hyperactivity: "Spastic hemiplegia, generalized rigidity, paraplegic rigidity, paraplegic paralysis, double hemiplegia, generalized chorea of infancy and bilateral athetosis". Freud also reported that other disorders could be associated with the condition, in particular intellectual and psychological impairments, and epilepsy.

4.2. 20th century

In the 1950s, the French physician Guy Tardieu proposed the term "infirmité motrice cérébrale" to define non-evolving, predominantly motor disorders "resulting from pre-, peri- or early post-natal lesions", sometimes accompanied by "sensory impairment and partial impairment of the higher functions with no intellectual deficiency" [24]. Although this term is rarely used today in France, it is still common in other French-speaking regions. For example, the term "déficience motrice cérébrale" (cerebral motor deficiency) is used in Quebec, Canada. CP was further refined by the Little Club in the United Kingdom in 1959 as "a persisting qualitative motor disorder appearing before the age of three years, due to a non-progressive interference with development of the brain" [25]. In 1964, Martin Bax (United Kingdom) defined CP as "a disorder of movement and posture due to a defect or lesion of the immature brain" [26]. Following international meetings on the epidemiology of CP held in the late 1980s, Lesley Mutch and colleagues agreed that CP was "biologically [...] an artificial concept" and they defined it as "an umbrella term covering a group of non-progressive, but often changing, motor impairment syndromes secondary to lesions or anomalies of the brain arising in the early stages of its development" [27].

At that time, all definitions thus focused on the EBI[1] and included both the motor and associated consequences (Fig. 2). Yet, 2 developments greatly influenced the concept of CP at the end of the 20th and beginning of the 21st centuries: advances in neurophysiology and neuroimaging (and the subsequent understanding of neuroplasticity) and the reconceptualization of health and health conditions.

[1] The term "brain" refers here to the encephalon (i.e., the brain per se + the brainstem + the cerebellum).

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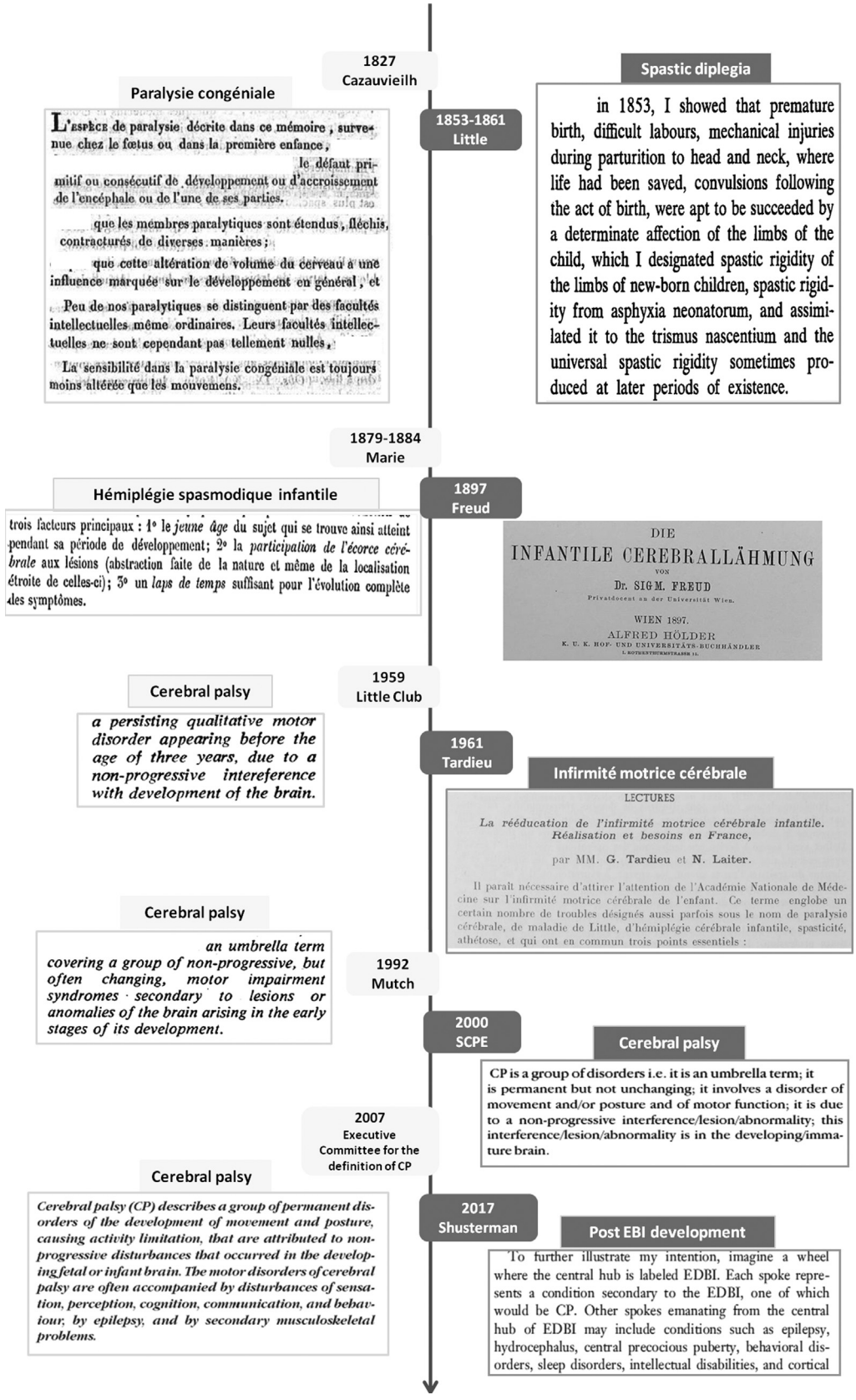

Fig. 2. Perspective of cerebral palsy from 1827 to 2015.

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4.3. 21st century

Several committees (the SCPE, Australian registrants and the international Executive Committee for the Definition of CP) agreed that a diagnosis of CP must be based on the presence of non-progressive disturbances, interference, lesions, or abnormality of the developing/immature brain. As a consequence, the American Academy of Neurology recommended that MRI be performed when the aetiology could not be established [28]. However, this recommendation was called into question when large comprehensive registers revealed that 10% to 30% of people with CP showed no or non-specific lesions on MRI [29,30]. This situation led to a re-evaluation of how to define CP without identified EBI. Numerous hypotheses were put forward to explain this conceptual discrepancy [31–33], and some authors chose to exclude such cases from CP, using terms such as "occult-CP", "CP-like", "CP-mimics" or "masqueraders of CP" [31,32].

The WHO International Classification of Functioning, Disability and Health (ICF) framework was developed in 2001, and it changed the perception of health. The framework brought awareness that the characterization of the health condition of an individual based only on the medical diagnosis did not define the person's needs [34]. It became accepted that the main issues faced by patients, in particular those with impairments and chronic conditions, were the result of interactions between their functional status and the context of their everyday life. Because it is now recognized that these interactions better describe the overall health of the patients, rehabilitation goals have also begun to be based on the ICF. The ICF–Children and Youth version (ICF-CY), developed in 2007, was immediately considered well adapted for CP. All of these developments have led to a better understanding of the needs of people with CP and their caregivers, notably their family [3,35].

5. The need for a more global vision

According to this new paradigm, the Canadian physician Peter Rosenbaum has regularly brought to attention (in 2009, 2014 and 2018) [3,36–38] that "our expanded view [has to] move well beyond classic biomedical preoccupations". For Rosenbaum, "exploring and understanding the lives of children and youths with CP" was complementary to the knowledge of the underlying pathophysiological mechanisms. The importance of comprehending CP in context will "help them reframe their goals toward successful child development and meaningful functional achievements in a life-course perspective". This approach is motivating for children and parents and it challenges how many institutions now address them, even if, in our experience, the method used to achieve these new goals and opportunities must be regularly reformulated and clarified.

However, according to the authors of the 2007 definition, the recent consensus does not go far enough [P. Rosenbaum, personal communication]. For example, while highlighting the universal hallmark of CP described in the first sentence, the second sentence (i.e., "The motor disorders of CP are often accompanied by…") was a useful and important addition [1]. Even if it was noted as far back as Cazauvieilh and reiterated thereafter, this statement essentially provided for the first time a formal recognition of the frequent coexistence of many activity limitations that may be experienced by people with CP. CP was then not just a motor syndrome as it had classically been framed. However, 12 years later, we believe that those non-motor impairments are not associated (or comorbid or secondary). When they are present, they are fully part of the development of the person with CP: global intellectual, social, emotional, personal etc.

This is one of the reasons why in 2015, Michele Shusterman, a US parent of a child with CP, claimed in an opinion piece published in *Developmental Medicine and Child Neurology* that the term CP could be "confusing" because it referred "only to a subcategory of an early developmental brain injury/interference" [9]. She advocated the idea of a post-EBI developmental condition that integrated both the historical definition of CP — an accidental injury occurring in the developing brain — and current definitions including the multiple key points and the ICF approaches.

As a group of parents and professionals from different backgrounds, countries and cultures, we agree with these recent perspectives that offer a global developmental and contextualized vision of CP. However, based on current evidence in the literature, as well as our own experience of perinatal stroke, we believe that 3 main issues still require clarification:

The connected but distinct entities of EBI, CP and the post-EBI developmental condition.

The position of motor impairments within the overall condition.

Although development is disturbed by the EBI, its novel pathway still follows the general rules of human development.

5.1. EBI, CP and post-EBI developmental condition: connected but distinct entities

Until the first half of the 20th century, CP was considered the consequence of an anatomical insult that occurred in early development: Cazauvieilh's "alteration of the tissues" (currently called EBI). However now, CP is considered a clinical formulation based on personal history and clinical assessment, and the identification of cerebral lesions on imaging is no longer a requirement to consider CP. In addition, the notion of well-recognizable damage has shifted to the more global conception of interference proposed by the Little club ("damage caused intrinsically or extrinsically in the developing brain occurring before, at, or after birth" [25]) and already used by the SCPE and Shusterman. Today, children with CP and with non-specific or normal MRI findings have particular histories and clinical (ataxic, dystonic/hypotonic, spastic paraplegic) profiles [39]. Many are found with monogenic mutations causing hereditary spastic paraplegia, epileptic encephalopathy, autosomal-dominant spinocerebellar ataxia or early dystonic syndromes [31,40].

Thus, debate within the SCPE and other networks had focused on whether "cases that have an identified syndrome or identifiable chromosomal anomaly" (and now causative genetic mutations) should be excluded from the definition of CP [14]. For some groups, such cases must remain a subcategory of CP ("CP with pathogenic variants") with the argument that "removing genomic causes may disenfranchise these patients and families from the support they need", whereas others prefer to consider (and so exclude) them as "masqueraders of CP" [12,31,41]. This question is particularly pertinent because the proportion of cases with genetic associated abnormalities is likely to increase with the use of new genetic screening tools, as in parallel, the number of obstetrically determined CP cases decreases [42].

One dimension of this debate concerns who the debaters are. Neurobiologists and geneticists may be more interested in the underlying biomedical process, whereas families and clinicians may be more preoccupied with how best to address the functional challenges. Both groups have legitimate positions, so this discussion is challenging and may remain pointless unless these varied perspectives are acknowledged. However, a person with CP has a unique developmental trajectory that differs depending on whether the CP is caused by a single event or a persisting genetic

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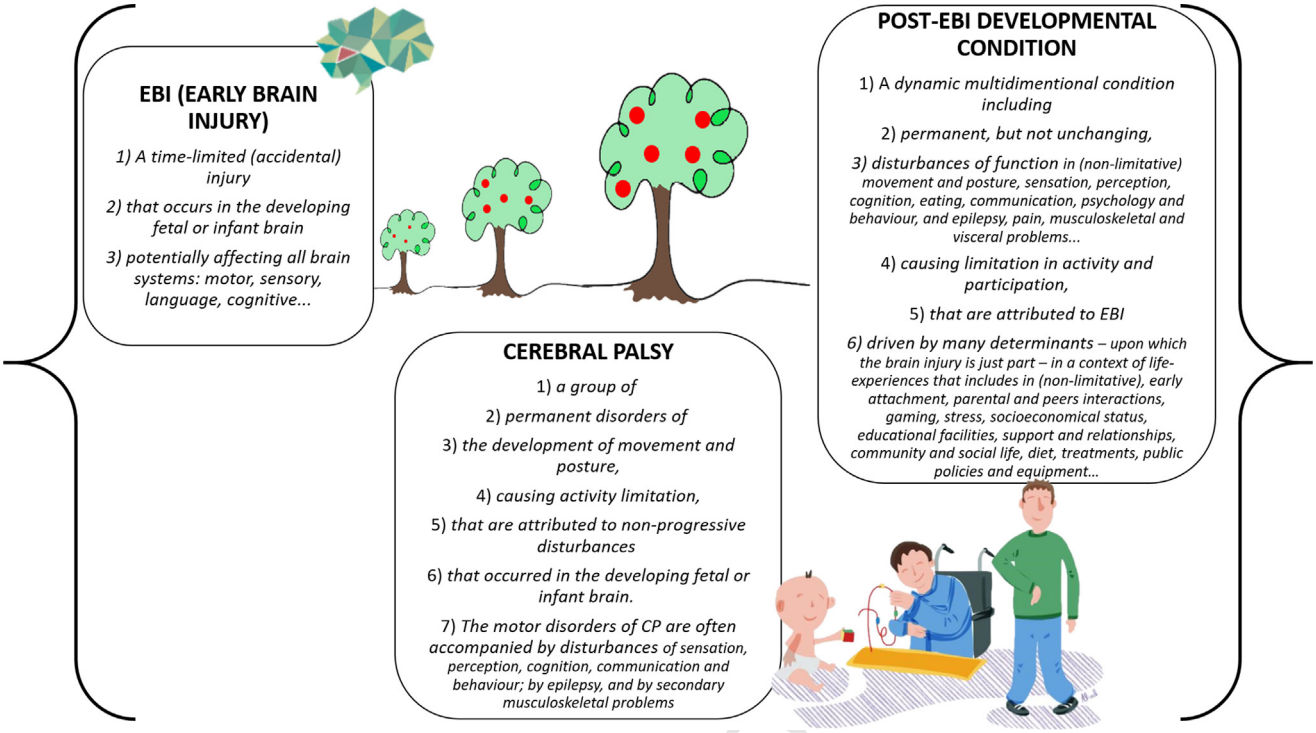

Fig. 3. Early brain injury (EBI), cerebral palsy and post-EBI developmental condition: connected but distinct entities.

disease (Fig. 3). In this latter case, the consequences on the brain and other organs are more widespread, persistent and changing. Therefore, if a genetic anomaly increases the individual's susceptibility to EBI in a stochastic manner, it could be related to the development of a post-EBI developmental condition (e.g., *COL4A* mutations predispose to perinatal periventricular brain haemorrhage [43]) but not if it determines the effects directly (e.g., monogenic hereditary causes of paraplegia, epilepsy, ataxia or dystonia).

Therefore, in our view, CP, EBI and genetic entities are connected but should be remain distinct: the accidental versus determined dichotomy indeed affects the follow-up and also etiological strategies and familial genetic counselling. For example, a child with a *COL4A* mutation will require treatment of the eventual resulting CP. However, the genetic diagnosis may also modify the organization of the familial and individual follow-up because of the risk of disease progression (i.e., the biomedical process) and further complications in the eyes, muscles, kidneys and cerebral white matter.

This leads to the second point of our discussion: the position of the motor component within the overall post-EBI developmental condition.

5.2. All parts of human development are coextensive

The motor dimension (i.e., obvious; see above) has long been the image of disability in cerebellar syndromes, Parkinson disease, Sydenham chorea, kernicterus, developmental coordination disorders, Tourette syndrome etc., as well as in CP, although they all include many other functional limitations. As a consequence, the description of CP includes the possibility of multiple deficiencies and symptoms, such as pain and epilepsy. However, although such features are caused by the same EBI or genetic cause/interference, these impairments are considered in the current definitions of CP as *secondary* or *associated* or *comorbid*. Using this terminology tends to reduce their importance in terms of management priorities. Eventually, the focus on the motor aspects restricts the view of the wider and multidimensional activity limitations that people with CP and their families have to cope with, with the risk that these aspects are not fully assessed [9]. In reality, pain, epilepsy, eating difficulties, communication and behavioural disorders all have serious and cumulative impacts on the development and everyday life of those with CP. A survey by the family support group La Fondation Paralysie Cérébrale and the French Solidarity Fund for Autonomy confirmed that pain relief is the highest priority for people with CP, their families and healthcare professionals [44]. In addition, and to underline the role of the importance of the everyday life context highlighted above, even if a person with CP acquires new motor functions over time and with rehabilitation, this will not automatically improve their autonomy if other limitations (e.g., due to visuo-spatial abilities) are such that they cannot find their way around a school, a subway station or a shop.

An illustration of this is neonatal arterial ischemic stroke (NAIS): the localization of the cerebrovascular accident as well as its temporality during the short timeframe of the peripartum period are precisely defined via brain imaging. Therefore, NAIS is a useful clinical model for understanding post-EBI development and brain (re)organisation [45]. The AVCnn Study allowed us to monitor a cohort of 100 term-born children with NAIS [46]: a minority (32%) have CP, but evaluation at 7 years of age has shown significant rates of 49%, 42%, 28%, 11%, and 8% for language impairment, behavioural disturbance, low academic skills, active epilepsy and global intellectual deficiency, respectively. Finally, most children exhibit specific needs when they start their elementary schooling.

Furthermore, all of the impairments described above are highly correlated, notably manual ability/global intelligence and language impairment/low academic skills. This tight clustering suggests that all developmental aspects are coextensive and will determine the overall post-EBI developmental condition. This point is also supported by neuroscientific approaches: as demonstrated by the AVCnn study, even if the EBI is focal and acute by definition, its consequences interfere with the developing

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connectome within the entire brain [47,48]. This situation introduces our third point: even with EBI, human development follows a general framework in which motor control is one aspect that is highly connected with the other aspects of development and function [11].

5.3. Post-EBI development: a new dimension of the developmental pathway that follows the general rules of human development

According to the ICF framework, the overall post-EBI consequences (health condition) cannot be determined linearly by the EBI (aetiology). An individual's function, activity and participation in everyday life will evolve within a context that includes socio-economic status, educational facilities, community and social life as well as public policies and equipment, support and relationships etc. This ecosystemic model may be described as experience-expectant and experience-dependant plasticity, from which all interactions result in a phenomenon of so-called metaplasticity [49]. Within this framework, the developing child is especially sensitive to a wide range of life experiences, such as early attachment, parental and peer interactions, play, stress, diet and treatments.

Again, the NAIS illustrates the use of such a model. Although it is well accepted that CP can be predicted by the localization of the infarct [50], no correlation was found between language impairment and the number or side of affected arterial territories [46,51]. In contrast, high maternal educational level and socio-economic status of the family were found as protective factors of the development of language and global intelligence [52]. These powerful systemic determinants as well as the correlation between manual ability and global intelligence and between early language impairment and low academic skills found in the AVCnn cohort are also found in typically developing children [52,53]. Thus, the post-EBI development fits with current developmental theories [49,52]. This observation is of importance because of increasing evidence that early interventions promoting caregiving interactions and relationships (through the Video Interaction Project, for example) catalyses a quicker development of the vulnerable child with sustained effects in the long term, notably on language skills [53,54].

This optimistic and existentialist approach considers deficit measurement and associated risks for a negative outcome and also promotes resilient factors that will construct health and development. Consequently, the long-term developmental consequences of an EBI should not be speculated on without considering the context, and the attention must shift to a global framework that supports development, with the family at the frontline [3,55]. Family-centred services recognize that "each family is unique" and that "[families] are the experts on the child's abilities and needs" with consequently better development and social adjustment, parental well-being, perception of competency and control, and satisfaction [3,56].

According to the contextualization of health and development, knowledge translation to policy-makers is now crucial, with the goal to provide accessible facilities to encourage exercise, culture and socialization [38,57]. Evidence now shows that early language interactions improve cognitive and school outcomes, so public policies must also promote a population-level environment (with the same rationale that is proposed at a family level) for speech-, play- and reading-based exchanges from a young age [53,54]. Such a global strategy toward a healthy and equitable daily-life environment (so-called Healthy Cities) is a unique opportunity to improve health and development for everyone at low cost [53,54,57,58]. This third environmental level of intervention is essentially complementary to the first 2 (individual care and family support) with cascading impacts across the life span.

6. Conclusion

In this diachronic narrative of CP, from the earliest clinical-pathological descriptions to recent neuroscientific and social theories that include the relationships among health, development and environment, we have tried to clarify the definitions and the underlying concepts. Our aim was to facilitate an understanding of the related issues for people with CP, their families, and the many relevant communities: caregivers, researchers, stakeholders, policy-makers etc.

At this stage of the on-going story, we agree with the statement that "CP is not a diagnosis, it's an assessment!" [6]. According to this view, CP is an everyday life condition that encompasses the motor component resulting from the combination of:

- an EBI as a seminal turning point of the individual's story;
- the development of the otherwise healthy young brain, in;
- a specific personal and environmental context. These 3 points as a whole define the overall post-EBI developmental condition (see Fig. 3).

Furthermore, in accordance with the ICF, this view will situate the perception of each person with CP while highlighting the individual's potentials and limitations, other than just the motor aspects. This integrative approach considerably expands how to formulate points of entry about activity and participation in light of the interests of each person, for example, through the 6 F-words package: Function, Family, Fitness, Fun, Friends and Future [59]. Q3 These ideas promote a positive vision of the person with CP and help gather cooperation between the family, professionals, education services and environment opportunities in helping everyone to reach their goals throughout their life journey.

Finally, the reappraisal of the distinguishable entities of EBI, post-EBI developmental conditions, and CP provides a common language across the communities and offers wide-ranging prospects for intervention and research while focusing on the appropriate concepts.

Disclosure of interest

The authors declare that they have no competing interest.

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References

[1] Rosenbaum P, Paneth N, Leviton A, Goldstein M, Bax M. A report: the definition and classification of cerebral palsy. Dev Med Child Neurol 2007;49:8–14.
[2] Barnett R. Cerebral palsy. Lancet 2018;392:545.
[3] Rosenbaum P. Cerebral palsy in the 21st century: is there anything left to say? Neuropediatrics 2009;40:56–60.
[4] Shevell M. Cerebral palsy to cerebral palsy spectrum disorder: time for a name change? Neurology 2019. http://dx.doi.org/10.1212/WNL. 0000000000006747 Q4 [Epub ahead of print].
[5] Baxter P. For and against the term cerebral palsy. Dev Med Child Neurol 2015;57:592.
[6] Rosenbaum P. Cerebral palsy: is the concept still viable? Dev Med Child Neurol 2017;59:564.
[7] Ellenson R. Are we there yet? Celebrating progress in cerebral palsy research. Dev Med Child Neurol 2017;59:987.
[8] Fahey M. Early developmental brain injury/interference: moving on from cerebral palsy. Dev Med Child Neurol 2015;57:681.
[9] Shusterman M. Introducing the term "early developmental brain injury/interference" and a new framework for discussing cerebral palsy. Dev Med Child Neurol 2015;57:110–1.

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[10] Cazauvieilh J-B. Recherches sur l'agénésie cérébrale et la paralysie congéniale. Paris Bechet Jeune 1827;1:5–33 [347–66].
[11] MacLennan AH, Lewis S, Moreno-De-Luca A, Fahey M, Leventer RJ, McIntyre S, et al. Genetic or other causation should not change the clinical diagnosis of cerebral palsy. J Child Neurol 2019. http://dx.doi.org/10.1177/0883073819840449 [Epub ahead of print].
[12] Fluss J, Dinomais M, Chabrier S. Perinatal stroke: distinct causes, diverse outcomes. Eur J Pediatr Neurol 2019. http://dx.doi.org/10.1016/j.ejpn.2019.02.013 [Epub ahead of print].
[13] Bax M, Goldstein M, Rosenbaum P, Leviton A, Paneth N, Dan B, et al. Proposed definition and classification of cerebral palsy. Dev Med Child Neurol 2005;47:571–6.
[14] Smithers-Sheedy H, Badawi N, Blair E, Cans C, Himmelmann K, Krägeloh-Mann I, et al. What constitutes cerebral palsy in the twenty-first century? Dev Med Child Neurol 2014;56:323–8.
[15] Cans C, Dolk H, Platt M, Colver A, Prasauskiene A, Krägeloh-Mann I. Recommendations from the SCPE collaborative group for defining and classifying cerebral palsy. Dev Med Child Neurol 2007;49:35–8.
[16] Grasset. Paralysie. In: Dictionnaire encyclopédique des sciences médicales Deuxième série, L-P Tome vingtième, PAL-PAR/publ sous la dir A. Dechambre [puis de] L. Lereboullet ; L. Hahn secrétaire de la dir [puis] directeur-adjoint. Paris: Masson; 1874. p. 542–764 [P. Asselin (Paris)].
[17] Marie P. Hémiplégie spasmodique infantile. In: Dictionnaire encyclopédique des sciences médicales Quatrième série, F-K Tome premier, FAA-FET/publ sous la dir. de A. Dechambre [puis de] L. Lereboullet ; L. Hahn secrétaire de la dir [puis] directeur-adjoint [Internet]. Paris: Asselin et Houzeau; 1877. p. 200–36. http://gallica.bnf.fr/ark:/12148/bpt6k31288m [Last accessed: June 07, 2019].
[18] Lallemand C-F. Recherches anatomico pathologiques sur l'encéphale et ses dépendances. Paris Bechet Jeune 1834;3:221–364.
[19] Little WJ. Hospital for the cure of deformities – Course of lectures. Lancet 1843;41:285–8.
[20] Little WJ. On the influence of abnormal parturition, difficult labours, premature birth, and asphyxia neonatorum, on the mental and physical condition of the child, especially in relation to deformities. In: Transactions of the Obstetrical Society of London. London: Longman, Green, Longman, and Roberts; 1862. p. 293–334.
[21] Gilles FH. Classification of cerebral palsy: neuropathologist's perspective. Dev Med Child Neurol 2007;49:19–21.
[22] Longo LD, Ashwal S. William Osler, Sigmund Freud and the evolution of ideas concerning cerebral palsy. J Hist Neurosci 1993;2:255–82.
[23] Korzeniewski SJ, Slaughter J, Lenski M, Haak P, Paneth N. The complex aetiology of cerebral palsy. Nat Rev Neurol 2018;14:528–43.
[24] Tardieu G. Association nationale des infirmes moteurs cérébraux. Les feuillets de l'infirmité motrice cérébrale. Paris: Chez l'Auteur; 1961.
[25] Keith RCM, Mackenzie ICK, Polani PE. The Little Club: Memorandum on terminology and classification of "Cerebral Palsy" 1959 in Cerebral Palsy Bulletin No 5. Dev Med Child Neurol 2008;1:27–35.
[26] Bax MC. Terminology and classification of cerebral palsy. Dev Med Child Neurol 1964;6:295–7.
[27] Mutch L, Alberman E, Hagberg B, Kodama K, Perat MV. Cerebral Palsy epidemiology: Where are we now and where are we going? Dev Med Child Neurol 2008;34:547–51.
[28] Ashwal S, Russman BS, Blasco PA, Miller G, Sandler A, Shevell M, et al. Practice Parameter: Diagnostic assessment of the child with cerebral palsy Report of the Quality Standards Subcommittee of the American Academy of Neurology and the Practice Committee of the Child Neurology Society. Neurology 2004;62:851–63.
[29] Bax M, Tydeman C, Flodmark O. Clinical and MRI Correlates of cerebral palsy: The European Cerebral Palsy Study. JAMA 2006;296:1602–8.
[30] Benini R, Dagenais L, Shevell MI. Registre de la paralysie cérébrale au Québec (Quebec Cerebral Palsy Registry) Consortium. Normal imaging in patients with cerebral palsy: what does it tell us? J Pediatr 2013;162 [369-374.e1].
[31] Takezawa Y, Kikuchi A, Haginoya K, Niihori T, Numata-Uematsu Y, Inui T, et al. Genomic analysis identifies masqueraders of full-term cerebral palsy. Ann Clin Transl Neurol 2018;5:538–51.
[32] Duan S, Mu X, Huang Q, Ma Y, Shan B. Occult spastic diplegic cerebral palsy recognition using efficient machine learning for big data and structural connectivity abnormalities analysis. J Med Imag Health Inform 2018;8:317–24.
[33] Mu X, Wang Z, Nie B, Duan S, Ma Q, Dai G, et al. Altered regional and circuit resting-state activity in patients with occult spastic diplegic cerebral palsy. Pediatr Neonatol 2018;59:345–51.
[34] World Health Organization. International classification of functioning, disability and health: ICF. Geneva: World Health Organization; 2001. p. 299.
[35] Weltgesundheitsorganisation. International classification of functioning, disability and health: Children & youth version; ICF-CY. Geneva: World Health Organization; 2007. p. 322.
[36] Rosenbaum P, Stewart D. The World Health Organization International Classification of Functioning, Disability, and Health: a model to guide clinical thinking, practice and research in the field of cerebral palsy. Semin Pediatr Neurol 2004;11:5–10.
[37] Dan B, Rosenbaum P. Podcasted discussion [Internet]. Dev Med Child Neurol 2015, https://youtu.be/ZDAbJWxLoZo [Last accessed June 07, 2019].
[38] Rosenbaum P. Childhood disability and how we see the world. Dev Med Child Neurol 2018;60:1190.
[39] Fahey MC, Maclennan AH, Kretzschmar D, Gecz J, Kruer MC. The genetic basis of cerebral palsy. Dev Med Child Neurol 2017;59:462–9.
[40] MacLennan A, Gecz J, Pérez-Jurado L. A genomic cause of cerebral palsy should not change the clinical classification. Ann Clin Transl Neurol 2018;5:1011.
[41] Sellier E, Platt MJ, Andersen GL, Krägeloh-Mann I, De La Cruz J, Cans C, et al. Decreasing prevalence in cerebral palsy: a multi-site European population-based study, 1980 to 2003. Dev Med Child Neurol 2016;58:85–92.
[42] Meuwissen ME, Halley DJ, Smit LS, Lequin MH, Cobben JM, de Coo R, et al. The expanding phenotype of COL4A1 and COL4A2 mutations: clinical data on 13 newly identified families and a review of the literature. Genet Med 2015;17:843–53.
[43] La Fondation Motrice. Infirmité Motrice Cérébrale/Paralysie Cérébrale. Prospective. La Douleur p33 [Internet]; 2009, https://www.fondationparalysiecerebrale.org/sites/default/files/inline-files/Prospective-IMC-PC_06-10-2009_1.pdf [Last accessed June 6, 2019].
[44] Kirton A. Modeling developmental plasticity after perinatal stroke: defining central therapeutic targets in cerebral palsy. Pediatr Neurol 2013;48:81–94.
[45] Chabrier S, Peyric E, Drutel L, Deron J, Kossorotoff M, Dinomais M, et al. Multimodal outcome at 7 years of age after neonatal arterial ischemic stroke. J Pediatr 2016;172 [156-61.e3].
[46] Pretzel P, Dinomais M, Hertz-Pannier L, Dhollander T, Chabrier S, Groeschel S.In: Reduced structural connectivity after NAIS: a whole brain analysis. 2019Paris (France). Q5
[47] Al Harrach M, Rousseau F, Groeschel S, Wang X, Hertz-Pannier L, Chabrier S, et al. Alterations in cortical morphology after neonatal stroke: compensation in the contralesional hemisphere? Dev Neurobiol 2019. http://dx.doi.org/10.1002/dneu.22679 [Epub ahead of print].
[48] Kolb B, Harker A, Gibb R. Principles of plasticity in the developing brain. Dev Med Child Neurol 2017;59:1218–23.
[49] Dinomais M, Hertz-Pannier L, Groeschel S, Chabrier S, Delion M, Husson B, et al. Long term motor function after neonatal stroke: lesion localization above all. Hum Brain Mapp 2015;36:4793–807.
[50] Wagenaar N, Martinez-Biarge M, van der Aa NE, van Haastert IC, Groenendaal F, Benders MJNL, et al. Neurodevelopment after perinatal arterial ischemic stroke. Pediatrics 2018;142. http://dx.doi.org/10.1542/peds.2017-4164.9 [pii: Q6 e20174164].
[51] Thébault G, Martin S, Brouillet D, Brunel L, Dinomais M, Presles É, et al. Manual dexterity, but not cerebral palsy, predicts cognitive functioning after neonatal stroke. Dev Med Child Neurol 2018;60:1045–51.
[52] Mendelsohn AL, Klass P. Early language exposure and middle school language and IQ: implications for primary prevention. Pediatrics 2018;142. http://dx.doi.org/10.1542/peds.2018-2234 [pii: e20182234].
[53] Gleason MM. Early childhood health interventions in the primary care setting promote developmental outcomes. J Pediatr 2018;199:13–5.
[54] Ferrand A, Gorgos A, Ali N, Payot A. Resilience rather than medical factors: How parents predict quality of life of their sick newborn. J Pediatr 2018;200:[64–[7000000.
[55] Shevell M, Oskoui M, Wood E, Kirton A, Van Rensburg E, Buckley D, et al. Family-centred health care for children with cerebral palsy. Dev Med Child Neurol 2019;61:62–8.
[56] Martin C. The evolution of universally accessible building design. Lancet Neurol 2018;18:34.
[57] Cole H, Shokry G, Connolly JJT, Pérez-Del-Pulgar C, Alonso J, Anguelovski I. Can Healthy Cities be made really healthy? Lancet Public Health 2017;2:e394–5.
[58] Rosenbaum P, Gorter JW. The "F-words" in childhood disability: i swear this is how we should think! Child Care Health Dev 2012;38:457–63.

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