Chiari I Malformation: Opinions on Diagnostic Trends and Controversies from a Panel of 63 International Experts

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BACKGROUND: **Chiari I malformation (CMI) and the topics concerning it have been the subject of numerous discussions and polarizing controversies over the course of the last 20 years.**

METHODS: **The opinions of 63 recognized international CMI experts from 4 continents, with a collective surgical experience of >15,000 CMI cases, were gathered through a detailed questionnaire.**

RESULTS: **Three facts emerged from the analysis of the results:**

1) Most of the replies showed a high level of consensus on most CMI-related topics.

2) Several topics, which had been considered controversial as recently as 10 years ago, are now more widely accepted.

3) The so-called 5-mm rule was rejected by 88.5% of the CMI experts who responded to the questionnaire.

CONCLUSIONS: **Sixty three recognized international CMI experts from 4 continents, with a collective surgical experience of >15,000 CMI cases were polled about a number of CMI topics. The results showed a high level of consensus, as well as a paradigm shift.**

INTRODUCTION

Chiari I malformation (CMI) and the topics concerning it have been the subject of numerous discussions and polarizing controversies over the course of the last 20 years.[1-4] During the last decade, a vibrant debate has resulted in a progressive shift of opinions among many of the leaders in the field.[5-7]

To obtain a clearer idea of current opinions among clinicians focused on CMI management, we contacted 100 clinicians with a recognized interest in CMI from 4 continents to answer an ad hoc questionnaire, as a preface to the XXIX Conference of the American Chiari and Syringomyelia Alliance Project, which took place in Long Island, New York on July 19–23, 2017. These clinicians were identified from a PubMed search of authors of Chiari-related articles over the last 20 years. We received replies from 63 CMI experts, with a collective surgical experience of >15,000 CMI cases.

METHODS

The questionnaire contained 90 items and was administered through the Survey Monkey platform. The first part of the questionnaire (questions 1–51) focused on various CMI topics: pathophysiology, epidemiology, signs and symptoms, and comorbidities. The questions presented a statement or an axiom, with which the responder had to agree or disagree. The second part of the questionnaire (questions 52–90, with multiple choice format) focused on surgical management, surgical techniques, and professional profiles.

The results of the questionnaire underwent basic descriptive statistical analysis on Microsoft Excel for Mac (version 16.19). The 63 responders to the questionnaire hailed from 4 continents and had a collective reported surgical experience of >15,000 CMI cases. Some of the responders opted to enter their replies anonymously. The list of the poll participants is shown in **Table 1**.

This article focuses on the analysis of the results of the first part of the questionnaire (pathophysiology, epidemiology, signs and symptoms, and comorbidities). A separate article dealing with the second part of the questionnaire (surgical management, surgical techniques, and professional profiles) will be released in the future.

Key words
- Chiari I malformation
- Questionnaire
- Syringomyelia

Abbreviations and Acronyms
CMI: Chiari I malformation
MRI: Magnetic resonance imaging
SM: Syringomyelia

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Table 1. List of the Polled International Chiari Experts

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Paolo Bolognese, Chiari Neurosurgical Center, Oceanside, New York, USA
Douglas Brockmeyer, University of Utah, Salt Lake City, Utah, USA
Andrew Brodbelt, The Walton Centre, Liverpool, United Kingdom
Brian Dlouhy, University of Iowa, Iowa city, Iowa, USA
Richard Ellenbogen, University of Washington, Seattle, Washington, USA
Neil Feldstein, Columbia University, New York, New York, USA
Graham Flint, Queen Elizabeth Hospital, Birmingham, United Kingdom
Clair Francomano, Harvey Institute, Baltimore, Maryland, USA
David Frim, University of Chicago, Chicago, Illinois, USA
Lorenzo Genitori, Istituto Meyer, Florence, Italy
Timothy George, Dell Children's Hospital, San Antonio, Texas, USA
Atul Goel, King Edward Memorial Hospital, Mumbai, India
Gerald Grant, Stanford University, Stanford, California, USA
Jeffery Greenfield, Cornell University, New York, New York, USA
Dan Heffez, Chiari Institute of Wisconsin, Milwaukee, Wisconsin, USA
Ian Heger, Medical College of Georgia, Augusta, Georgia, USA
John Heiss, National Institutes of Health, Bethesda, Maryland, USA
Bermans Iskandar, University of Wisconsin, Madison, Wisconsin, USA
John Jane Jr., Medical College of Virginia, Richmond, Virginia, USA
Robert Keating, Washington Children's Hospital, Washington, DC, USA
Jörg Klekamp, MVZ am Christlichen Krankenhaus, Quakenbrück, Germany
Petra Klinge, Brown University, Providence, Rhode Island, USA
Ilzumi Koyanagi, Hokkaido Neurosurgical Memorial Hospital, Hokkaido, Japan
Jorge Lazareff, University of California at Los Angeles, Los Angeles, California, USA
David Limbrick, Washington University, Saint Louis, Missouri, USA
Kenneth Liu, Penn State University, Hershey, Pennsylvania, USA
Yung Liu, Department of Syringomyelia, Tsinghua University, Beijing, China
Yongli Lou, Zhengzhou University, Zhengzhou Shi, Henan Province, China
Tina Loven, Drexler University, Philadelphia, Pennsylvania, USA
Mark Luciano, Johns Hopkins, Baltimore, Maryland, USA
Cormac Maher, University of Michigan, Ann Arbor, Michigan, USA
Francesco Mangano, Cincinnati Children's Hospital, Cincinnati, Ohio, USA
Arnold Menezes, University of Iowa, Iowa City, Iowa, USA
Sylvia Morar Putze, Hôpital Bicêtre, Paris, France
Misao Nishikawa, University of Osaka, Osaka, Japan
Jerry Oakes, University of Alabama, Birmingham, Alabama, USA
John Oro', Chiari Clinic, Aurora, Colorado, USA
Fabrice Parker, Hôpital Bicêtre, Paris, France
Antonia Poca, Hospital Universitario Vall d'Hebron, Barcelona, Spain
Harold Rekate, Chiari Institute, Manhasset, New York, USA
Brandon Roque, University of Alabama, Birmingham, Alabama, USA
Juan Sahuquillo, Hospital Universitario Vall d'Hebron, Barcelona, Spain
Mirko Scagnet, Istituto Meyer, Florence, Italy
Wouter Schievink, Cedars-Sinai, Los Angeles, California, USA
Michael Scott, Brigham & Women, Boston, Massachusetts, USA
Michael Seiff, Sunrise Hospital and Medical Center, Las Vegas, Nevada, USA
Konstantin Slavin, University of Illinois, Chicago, Illinois, USA
Mark Souweidane, Cornell University, New York, New York, USA
Paul Steinbok, BC Children's Hospital, Vancouver, British Columbia, Canada
Marcus Stoodley, Macquarie University, Sydney, Australia
Vadivelu Sudhakar, Cincinnati Children's Hospital, Cincinnati, Ohio, USA
Charles Tator, University of Toronto, Toronto, Canada
Laura Valentini, Istituto Besta, Milano, Italy
Erol Veznedaroglu, Drexler University, Philadelphia, Pennsylvania, USA
Nicholas Wetjen, Mayo Clinic, Rochester, Minnesota, USA
Jeffrey Wisoff, New York University, New York, New York, USA
Shokei Yamada, Loma Linda University, Loma Linda, California, USA

Continues

RESULTS

The list of the axioms is presented in Table 2. Each axiom was identified by its progressive number in the questionnaire. The axioms are arranged in numeric order, grouped by topic, along with the polling results, as a percentage of the responders. In the third column of Table 2, we reported the percentage of the responders who agreed to each axiom. The axioms ranked on the grounds of the poll statistics are presented in Table 3.

Fifteen of the 51 axioms were agreed on by >90% of the poll responders, 29 were agreed on by >75% of the poll responders, and 38 were agreed on by >60% of the poll responders.

Most of the responders disagreed on 13 of the 51 axioms (6, 10, 12, 29, 30, 36–40, 47–49). Such axioms collected agreement scores ranging between 29% and 46%. The individual responders decided on the grounds of their own clinical experience or personal opinion, regardless of the fact that many such topics had been formerly reported and/or were being presented at the then upcoming XXIX Conference of the American Chiari and Syringomyelia Alliance Project (July 19–23, 2017).

DISCUSSION

The results of a questionnaire about CMI were reported in 2004 by Schijman and Steinbok. The report focused on CMI surgical practices, and there were 76 responders.[8]

No questionnaire is perfect, and the current one was no exception. The same questions could have been asked in many other ways. Many other questions could have been asked. Many other topics could have been explored. The structure of the answers could have been different.

Table 2. List of the Axioms Polled in the Questionnaire Grouped by Topic

Axiom Number	Axiom	% Agreement
Pathophysiology		
1	**Every Chiari I malformation (CMI) has a tonsillar herniation, but tonsillar herniation can also be caused by mechanisms and disease processes other than CMI**	95.1
2	***In its typical and pure form, Chiari I malformation (CMI) is a mesenchymal disorder resulting in a herniation of the cerebellar tonsils***	78.6
3	A volumetrically small posterior fossa is the driving force causing the tonsillar herniation in typical CMI	75.4
4*	The range of normal for the posterior fossa volume in adult individuals is between 175 and 200 cm^3	18.3
5	*An old radiologic axiom states that a tonsillar herniation less than 5 mm excludes the diagnosis of CMI. A number of CMI experts have disagreed with this principle during the last 2 decades. Do you reject this old axiom?*	88.5
6*	Typical CMI could be regarded as a focal form of craniosynostosis of the posterior fossa	37.7
7	**Cerebellar tonsillar herniation can affect CSF fluid dynamics**	100.0
8	**The tonsillar herniation can exert a mass effect on the surrounding anatomical structures**	98.3
9	CMI is characterized by a volumetrically small posterior fossa, obliteration of the cisterna magna, and tonsillar herniation of variable degree	70.4
10*	Chiari zero is defined by a volumetrically small posterior fossa, obliteration of the cisterna magna, cerebellar tonsils positioned at the foramen magnum, and the presence of a slitlike syringomyelia (SM) cavity within the cervical spinal cord	38.9
11	An imperforated medullary velum can sometimes be the cause of persistent syringomyelia, in the aftermath of uncomplicated posterior fossa decompression	71.6
12*	The anomalies of a CMI skull include small posterior fossa, short supraocciput, small mandible, overbite, arched palate, and an anomalous temporo-mandibular junction	28.8
Epidemiology		
13	Typical CMI is a congenital disorder	67.8
14	*Typical CMI is hereditary in less than 25% of cases*	82.7
15	**Tonsillar herniations secondary to hydrocephalus, mass-occupying lesions of the posterior fossa, or driven by lumboperitoneal shunting are examples of acquired tonsillar herniation and should not be confused with CMI, for both diagnostic and therapeutic purposes**	93.2
16	*Crouzon syndrome is an example of syndromic CMI*	77.1
17	*CMI has a genetic basis as suggested by family pedigrees and genetic studies, but its genetic basis has not yet been identified with certainty*	79.3
18	*CMI is more prevalent in females*	77.1
19	**The exact prevalence of CMI is unknown, but the current data suggest that CMI should no longer be considered a rare disorder (i.e., affecting fewer than 1 in 1500 people as per the Rare Diseases Act of 2002)**	93.2
Signs and symptoms		
20	**CMI can remain asymptomatic. The incidence and prevalence of asymptomatic CMI subjects are unknown**	96.6
21	CMI usually becomes symptomatic after an asymptomatic period of variable length	66.1
22	**CMI can become symptomatic during childhood, during adolescence, or during young adult life**	94.8
23	**CMI can become symptomatic spontaneously**	96.6
24	**CMI can become symptomatic after head and/or neck trauma**	91.5
25	*CMI can become symptomatic after a whiplash injury*	78.9
26	*CMI can become symptomatic after delivery*	82.1
27	*CMI can become symptomatic after a lumbar puncture or a "wet" epidural*	81.3

Axioms agreed on by >90% of responders indicated in bold. Axioms agreed on by 75%—89% of responders indicated in italics.

CMI, Chiari I malformation; CSF, cerebrospinal fluid; SM, syringomyelia; FSH, follicle-stimulating hormone; LH, luteinizing hormone; EDS, Ehlers-Danlos syndrome; ADD, attention-deficit disorder; ADHD, attention-deficit/hyperactivity disorder; OCD, obsessive-compulsive disorder.

*Axioms with remarkable disagreement, ranging between 29% and 49%, despite supportive literature to the contrary.

Continues

Table 2. Continued

Axiom Number	Axiom	% Agreement
28	*There are a few cases in which CMI can anatomically and/or clinically improve during adolescent growth spurt*	82.7
29*	A red discoloration ("stork bite") can be found in the skin of the supraoccipital region in a small number of patients with CMI	48.2
30*	CMI is more prevalent in Caucasians and Asians. It is less prevalent in the Black population	54.7
31	**Suboccipital tussive headache is not the only symptom caused by CMI**	98.2
32	**Signs and symptoms of lower cranial nerve and lower brainstem compromise can be found in CMI**	100.0
33	**Blurred vision and nystagmus can be found in CMI**	93.2
34	*Hearing loss (in the high-frequency bandwidth), tinnitus, and disequilibrium can be found in CMI*	87.7
35	Short-term memory compromise, decreased ability to focus and multitask (collectively described as "brain fog") can be found in CMI	67.8
36*	Supraventricular tachycardia (SVT) and ectopic beats are not infrequent in patients with CMI	44.4
37*	Decreased gastrointestinal motility and irritable bowel syndrome are not infrequent in patients with CMI	45.4
38*	Multiple allergies (to food, drugs, environmental factors) are quite frequent in patients with CMI	25.0
39*	Gluten intolerance is not infrequent in patients with CMI	25.9
40*	Hormonal abnormalities (hypothyroidism, low and irregular FSH/LH levels, sometimes low adrenal function) can be found in a sizeable proportion of patients with CMI	28.5
41	**In some cases, patients with large SM cavities can be asymptomatic and have a normal neurologic examination**	91.3
42	**In some pediatric cases, large SM cavities can cause scoliotic deformities, which can subside after successful deflation of the SM**	96.5
Comorbidities		
43	*Ehlers-Danlos syndrome and other connective tissue disorders are comorbidities of CMI*	77.5
44	*Pseudotumor cerebri is a comorbidity of CMI in a small subset of patients with CMI*	77.5
45	**Complex CMI is a disorder in which CMI presents alongside a pathology of the craniocervical junction (such as basilar impression, basilar invagination, craniocervical instability, etc.)**	96.5
46	Dysautonomia and postural orthostatic tachycardia syndrome are often found to be present in patients with CMI with EDS comorbidity	72.7
47	ADD and ADHD are frequent comorbidities in CMI	32.1
48	Mast cell activation disorder is not unusual among patients with CMI/EDS	41.1
49	Psychiatric diagnoses ranging from reactive depression to OCD can be found in >50% of patients with CMI	35.7
50	Pseudotumor cerebri identified in a subset of patients with CMI is often secondary to a dural sinus problem (obstruction or atrophy)	62.9
51	The occult variant of tethered cord can sometimes occur as a comorbidity of CMI	66.0

Axioms agreed on by >90% of responders indicated in bold. Axioms agreed on by 75%—89% of responders indicated in italics.

CMI, Chiari I malformation; CSF, cerebrospinal fluid; SM, syringomyelia; FSH, follicle-stimulating hormone; LH, luteinizing hormone; EDS, Ehlers-Danlos syndrome; ADD, attention-deficit disorder; ADHD, attention-deficit/hyperactivity disorder; OCD, obsessive-compulsive disorder.

*Axioms with remarkable disagreement, ranging between 29% and 49%, despite supportive literature to the contrary.

Past Controversies and Current Opinions

CMI has been the subject of several debates over the years, with topics spanning from its definition, diagnostic criteria, and surgical techniques.

The name Chiari I malformation itself has a troublesome origin. The first case described by Hans Chiari in the scientific literature was a tonsillar herniation secondary to massive hydrocephalus, in the general context of a tuberculotic infection.[9] Several years later, the pupils of Julius Arnold suggested changing the name of the malformation to Arnold-Chiari, a term that stuck for most of the twentieth century, until a puristic perspective prevailed and Arnold's name was removed from the diagnosis.[10] Some British neurosurgeons favor the anatomic descriptive term of hindbrain herniation. Lately, in the face of the realization that many patients with CMI are and remain asymptomatic, Dr. Di Rocco suggested the term Chiari anomaly.[7]

The advent of magnetic resonance imaging (MRI) allowed for an easy and early diagnosis of CMI, with rapidly expanding databases in dedicated centers. In 1986, Barkovich et al.[11] described the range of normal position of the cerebellar tonsils and suggested the 5-mm

Table 3. Axioms Ranked Statistically

Axioms with 90%—100% Agreement	1, 7, 8, 15, 19, 20, 22, 23, 24, 31, 32, 33, 41, 42, 45
Axioms with 80%—89% agreement	5, 14, 26, 27, 28, 34
Axioms with 75%—79% agreement	2, 3, 16, 17, 18, 25, 43, 44
Axioms with 70%—74% agreement	9, 11, 46
Axioms with 60%—69% agreement	13, 21, 35, 50, 51
Axioms with 29%—46% agreement	4, 6, 10, 12, 29, 30, 36, 37, 38, 39, 40, 47, 48, 49

rule, which defines as pathologic any tonsil protruding ≥5 mm below the McRae line. Toward the end of the 1990s, Milhorat et al.[5] observed that the 5-mm rule was inconsistent from a clinical perspective, because several patients with <5 mm of tonsillar herniation in that clinical series did have signs and symptoms of CMI and improved after surgical decompression. One percent of the population is believed to have tonsillar descent of ≥5 mm and most are asymptomatic. Describing and treating patients with symptoms synonymous with a Chiari malformation but with <5 mm of tonsillar descent split the neurosurgical community in two. On one hand, Drs. Oakes and Iskandar adopted the concept of a symptomatic CMI with <5 mm of herniation and created the categories of Chiari 0 (symptomatic patient with tonsils at the McRae line, plus a slitlike cervical syrinx)[12] and Chiari 1.5 (symptomatic patient with tonsils and brainstem herniated below the McRae line),[13] with many colleagues following suit. However, only 39% of our responders agreed with this Chiari 0 definition. This tendency may be because of medicolegal concerns about the potential deregulation of the CMI diagnosis, with the feared possibility of unnecessary surgeries. In addition, many general neurosurgical practitioners simply remained unaware of such debate and remained loyal to the old 5-mm rule by default. In this questionnaire, 88.5% of the respondents agreed in rejecting the 5-mm rule (axiom 5). This widespread rejection of the 5-mm rule, and the many asymptomatic patients with ≥5 mm of tonsillar descent support a mechanism in which tonsillar herniations driven in typical CMI by an anatomically small posterior fossa (74% of respondents) can trigger symptoms via a physiological fluid dynamic obstruction (100% of respondents) and a mass effect on the surrounding anatomical structures (98.3% of respondents).

A further complication is represented by the fact that many neurosurgeons and neuroradiologists consider tonsillar herniation to be tantamount to CMI, with obvious subsequent confusion in terms of etymology, definition, and therapy. Although in some instances (e.g., large tumor masses[14-16] and severe hydrocephalus[17]), the pathophysiologic mechanisms of the non-CMI-related tonsillar herniations are obvious, some other scenarios are less self-evident (e.g., intracranial hypotension[18,19] and unrecognized tethered cord).[20] In simple terms, the cerebellar tonsils can be pushed out, squeezed out, pulled down, or they can sag out of the skull.[21] Recent morphometric studies have suggested that the term CMI should be reserved for those cases in which the tonsillar herniation is secondary to the squeezing effect of a volumetrically small and underdeveloped posterior fossa, but despite several reports,[22-25] this concept is not universally known or accepted in the neurosurgical community at large (axioms 1, 2, 3, 9, 15, and 16).

In this questionnaire, 95.1% of the respondents agreed with axiom 1, stating that "Every CMI has a tonsillar herniation, but tonsillar herniation can also be caused by mechanisms and disease processes other than CMI," suggesting broad support for this more inclusive definition.

The coexistence of CMI along with anatomic deformities of the craniocervical junction has been mentioned by Menezes et al. in the past. The description of connective tissue disorders as a comorbidity (96% agree) in many patients with CMI was reported in 2006 by Milhorat et al.,[26] again creating a rift between believers and skeptics of this concept. Years later, Brockmeyer et al.[27] revamped the issue, and labeled it with the term "Complex Chiari", using a similar diagnostic approach revolving around morphometric parameters (axioms 43 and 45).

Besides connective tissue disorders (mainly Ehlers-Danlos syndrome),[28] other disease processes have been proposed as frequent CMI comorbidities but have not always been accepted as a true comorbidity, including tethered cord (66% agree),[29,30] attention-deficit disorder (only 32% agree),[31-34] mast cell activation disorder (41% agree), postural orthostatic tachycardia syndrome,[35] dysautonomia (72% agree),[36] and pseudotumor cerebri (62% agree)[37] (axioms 44 and 47—51)

Tussive (or Valsalva induced) headache and syringomyelia (SM) have been known as by-products of CMI for several years.[3,38] The description of a larger Chiari syndrome, with a wider array of signs and symptoms, was introduced in the late 1990s after the analysis of the largest CMI database available at that time, and again split the expert community in two, with skeptics and believers.[5]

The results of the questionnaire have shown a shift toward the concept of a larger Chiari syndrome, especially compared with a decade ago, although many symptoms still received low polling scores. Grouping symptoms together for diagnostic purposes does not obviously guarantee them similar postsurgical outcomes (axioms, 31—40).

Originally, CMI was considered a rare disorder, but this concept was proved inaccurate after the systematic use of MRI allowed a higher rate of diagnosis (93% agree). The studies of several familial pedigrees showed evidence of an autosomal dominant transmission with incomplete penetration in some instances.[5] Asymptomatic patients in the face of incidental MRI diagnoses have been described,[39] as well as symptomatic conversion after traumatic events,[40] such as whiplash injuries,[41] barotraumas, and wet epidurals (82% agree) during delivery.[42,43] Spontaneous anatomical and clinical improvement in a few pediatric patients has been identified during the phase of adolescent growth.[44] The relatively small incidence of clinical deterioration leading to surgical correction after the fourth decade of life has been noticed. However, we do not have an exact idea of the pie-chart distribution among the asymptomatic, oligosymptomatic, and

symptomatic populations. In addition, besides the simplistic impression that worse anatomies tend to lead to worse clinical presentations, we do not have a full understanding of why certain patients remain asymptomatic, whereas others require surgical intervention (axioms 12–14, 17–19, and 20–29).

Seventy-five percent of the responders agreed that a volumetrically small posterior fossa is the driving force causing the tonsillar herniation in typical CMI (axiom 3), but only 18.3% of the responders guessed correctly about the normal values for the posterior fossa volume, as inquired in a companion question (axiom 4: The range of normal for the posterior fossa volume in adult individuals is between 175 and 200 cc).[22,45-47] Furthermore, 21.6% of the responders guessed wrong, whereas 60% admitted that they did not know the answer. This finding is surprising within a group of experts, but it may relate to a perceived lack of ease or practical usefulness of such measurement.

The traditional definition of CMI was anatomically relying only on the 5-mm rule,[11] with the clinical presentation being limited to tussive headache and/or SM. Several seminal and groundbreaking studies,[5,48,49] along with the accumulation of a larger clinical experience in an increasing number of dedicated Chiari centers, have progressively broadened and expanded the anatomic, pathophysiologic, epidemiologic, and clinical understanding of this disorder, thus rendering the traditional definition more and more obsolete over the years. This situation has pressed most of the international CMI experts to produce an updated and comprehensive redefinition of CMI. The evolution of defining and understanding the Chiari malformation is ongoing and has been helped by dedicated international conferences (Sydney, 2013; Long Island, 2017; Birmingham, 2018; Niagara Falls, 2019; National Institutes of Health, 2019; and Milan, 2019), with the participation of many of the experts who have been polled for the questionnaire reported in this article.

After years of animated debates and incensed controversies, the results of this questionnaire provide a glimpse into the position of many international experts in CMI. We hope to use the results of this questionnaire as a stepping stone for the ongoing process leading to a modern redefinition of this disorder.

If we collect the axioms with an agreement above the threshold of 75%, several tentative consensus statements can be made about the pathophysiology, epidemiology, signs and symptoms, and comorbidities of CMI.

Tentative Consensus Statements

In its typical and pure form, CMI is a mesenchymal disorder, resulting in a volumetrically small posterior fossa.[22,45] This factor, in turn, is the driving force behind the herniation of the cerebellar tonsils.[5,46]

The cerebellar tonsillar herniation can affect cerebrospinal fluid dynamics and exert mass effect on the surrounding anatomic structures.[50-54]

The old 5-mm rule, according to which any cerebellar herniation <5 mm automatically disqualifies the diagnosis of CMI,[11,55,56] is no longer considered valid.[5]

Tonsillar herniation should not be regarded as synonymous with CMI, because tonsillar herniations can also be caused by other mechanisms and disease processes, such as spinal leaks,[18,19] hydrocephalus,[17] and tumors.[14,16]

Although the exact prevalence of CMI is unknown, the current data suggest that CMI should no longer be considered a rare disorder.[5] CMI is more prevalent in females.[57,58] The genetic basis of CMI has been suggested by family pedigrees[58,59] but has not yet been identified.[60] Typical CMI is inheritable in <25% of cases.[5] CMI can be part of larger diseases, such as Crouzon syndrome[61]; in these cases, it is identified as syndromic CMI.[62]

CMI can remain asymptomatic in an unknown number of individuals.[39] Most of the time, CMI becomes symptomatic during childhood, adolescence, or young adulthood.[5] The symptomatic conversion can occur spontaneously,[5] or after a traumatic event, such as head/neck trauma,[40] whiplash injury,[41] troublesome vaginal delivery, lumbar puncture, or a wet epidural.[42,43] CMI can anatomically and/or clinically improve in a few cases, such as during adolescent growth spurts.[44] CMI symptoms are not limited to suboccipital tussive headache[3,38] but can also include blurred vision,[63] nystagmus,[63] high-frequency hearing loss,[64-66] tinnitus,[67] disequilibrium, signs/symptoms of lower cranial nerves,[5] and lower brainstem compromise,[68] as well as several others.

SM is a known effect of CMI. In some cases, patients with large SM cavities can be asymptomatic and have a normal neurologic examination result (91.3%). In some pediatric cases, large SM cavities can cause scoliotic deformities,[27] which can subside after successful deflation of the SM, after appropriate surgical treatment.[27]

CMI comorbidities include connective tissue disorders (such as Ehlers-Danlos syndrome and Marfan)[28] and pseudotumor cerebri.[37] Complex CMI is a disorder in which CMI presents alongside a disease of the craniocervical junction (e.g., basilar impression, basilar invagination, and craniocervical instability).[6,49]

CONCLUSIONS

CMI has been the subject of debates, disagreements, and controversies over the years.

A redefinition and a reclassification of CMI are now overdue, but any future effort to do so requires a stepping stone: the impassionate knowledge of the spectrum of collective opinions among the leading experts in the field.

The analysis of the replies to the first part of the questionnaire (pathophysiology, epidemiology, signs and symptoms, and comorbidities) showed an unexpectedly high level of agreement and convergence among the responders about most of the polled topics.

Three surprising facts emerged from the analysis of the results of the first part of the questionnaire (pathophysiology, epidemiology, signs and symptoms, and comorbidities).

1) Most of the replies showed a high level of convergence and consensus on several topics.

2) Several topics that had been considered fringy and controversial (as recently as 10 years ago) are now regarded as mainstream, as reflected by the results of this poll.

3) Of the polled international world experts in CMI, 88.5% rejected the concept of the 5-mm rule, which has traditionally disqualified herniations of <5 mm from the diagnosis of CMI.

The second part of the questionnaire, dealing with surgical criteria and technical preferences, will be analyzed and presented in a separate upcoming report.

The reclassification/redefinition will not happen overnight; it will take time, effort, iterations, and polish. The results of this questionnaire not only give us an up-to-date roadmap of the opinions of most of the world experts in CMI but they also provide us with several building blocks with which to start the new redefinition and reclassification effort of this disorder.

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