Outcome methods used in clinical studies of Chiari malformation Type I: a systematic review

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OBJECT Chiari malformation Type I (CM-I) is a common and often debilitating neurological disease. Efforts to improve treatment of CM-I are impeded by inconsistent and limited methods of evaluating clinical outcomes. To understand current approaches and lay a foundation for future research, the authors conducted a systematic review of the methods used in original published research articles to evaluate clinical outcomes in patients treated for CM-I.

METHODS The authors searched PubMed, Embase, the Cumulative Index to Nursing and Allied Health Literature, ClinicalTrials.gov, and Cochrane databases to identify publications between January 2003 and August 2013 that met the following criteria: 1) reported clinical outcomes in patients treated for CM-I; 2) were original research articles; 3) included at least 10 patients or, if a comparative study, at least 5 patients per group; and 4) were restricted to patients with CM-I.

RESULTS Among the 74 papers meeting inclusion criteria, there was wide variation in the outcome methods used. However, all approaches were broadly grouped into 3 categories: 1) “gestalt” impression of overall symptomatic improvement (n = 45 papers); 2) postoperative change in specific signs or symptoms (n = 20); or 3) results of various standardized assessment scales (n = 22). Among standardized scales, 11 general function measures were used, compared with 6 disease-specific tools. Only 3 papers used scales validated in patients with CM-I. To facilitate a uniform comparison of these heterogeneous approaches, the authors appraised articles in multiple domains defined a priori as integral to reporting clinical outcomes in CM-I. Notably, only 7 articles incorporated patient-response instruments when reporting outcome, and only 22 articles explicitly assessed quality of life.

CONCLUSIONS The methods used to evaluate clinical outcomes in CM-I are inconsistent and frequently not comparable, complicating efforts to analyze results across studies. Development, validation, and incorporation of a small number of disease-specific patient-based instruments will improve the quality of research and care of CM-I patients.

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KEY WORDS assessment tools; Chiari malformation Type I; outcome methods; systematic review; treatment outcome

CHIARI malformation Type 1 (CM-I) is a common and often debilitating neurological condition. According to some estimates, CM-I is identified in almost 1% of all brain and cervical spine MRI studies,⁵⁵ although recent evidence suggests that in children the MRI prevalence may be closer to 4%.⁸⁰ While some individuals with radiological evidence of CM-I are asymptomatic, the clinical manifestations of the disease are broad, complicat-

ing efforts to guide patient management and study treatment response.

Corresponding to the recent expansion in the utilization of MRI is the growth in research related to CM-I. The number of PubMed results for the term “Chiari Malformation” increased from 83 in the year 2000 to 162 in the year 2012. This expanding research drive is focused in large part on comparative effectiveness research,^{18,28} and

ABBREVIATIONS CCOS = Chicago Chiari Outcome Scale; CM-I = Chiari malformation Type I; JOA = Japanese Orthopaedic Association; VAS = visual analog scale.

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more recently extends to efforts to improve the reporting of clinical outcomes.^{2,27} Nevertheless, despite this recent emphasis on the inclusion of outcome tools in published research, there remains only anecdotal evidence describing the approaches used in contemporary research to evaluate treatment results. Therefore, a critical evaluation of current outcome reporting systems is needed to effectively interpret the published literature and to promote the development of clinically meaningful and rigorously validated outcome measures. The objective of this systematic review is to comprehensively assess the outcome methods used in the contemporary CM-I literature to lay a foundation for future clinical research in this growing field.

Methods

Inclusion and Exclusion Criteria

For this review, we only included studies that 1) reported clinical outcomes in patients with CM-I after a therapeutic intervention; 2) were original research articles; 3) included at least 10 patients or, if a comparative study, at least 5 patients per group; and 4) were restricted to patients with CM-I. We excluded from the final analysis review articles, meta-analyses, editorials, abstracts not accompanied by a full-text article, and studies only examining treatment results related to a single sign or symptom, rather than general clinical outcomes.

Search Procedures and Data Abstraction

We systematically searched the biomedical literature in PubMed, Embase, the Cochrane Database of Systematic Reviews, the Cumulative Index to Nursing and Allied Health Literature, and ClinicalTrials.gov, in addition to performing a manual search of reference lists to identify relevant publications between January 2003 and August 2013. We searched the controlled vocabulary of each database and used plain language in creating a search strategy for the terms “Arnold Chiari Malformation” (including 27 additional variations for Chiari Type I malformation), “Treatment Outcome,” “Data Collection,” “Questionnaires,” and “Outcome and Process Assessment (Health Care).” The final search results were limited to human studies and English-language articles.

All titles and abstracts identified from the search procedure were independently evaluated by 2 reviewers (J.K.G. and E.M.). Instances of disagreement were resolved by discussion, and articles were subsequently chosen for detailed review. Decisions regarding the application of inclusion criteria were agreed upon by both reviewers and D.D.L. Data from full-length articles meeting inclusion criteria, including patient demographics and narrative summaries of outcome methods, were abstracted using a standardized form designed a priori. Outcome systems were then independently evaluated and classified by both reviewers according to predetermined criteria. Disagreements were resolved by discussion, or when needed, a third arbiter (D.D.L.). Descriptive summary statistics were calculated using SPSS (version 21, IBM).

Article Appraisal

The primary aim for this review was to identify the

outcome methods used in the CM-I literature. However, to facilitate a uniform comparison among heterogeneous approaches, we also appraised articles for their adherence to a set of criteria that we defined a priori as key to reporting clinical outcomes in this population. We thus noted 1) inclusion of patient-response instruments (i.e., an outcome measure based on direct patient responses rather than clinician impression of available data); 2) inclusion of any quality of life or overall function assessment; 3) evaluation of new disease-related symptoms that developed after treatment; 4) appropriate multidimensional assessment of outcome for distinct signs or symptoms present preoperatively in individual patients; 5) documentation of rates of revision surgery for persistent disease; and 6) inclusion of detailed reports of headache symptom resolution, given that headaches are the most stereotypical but often poorly defined symptom associated with CM-I.

Results

Our initial literature search returned a total of 669 results, including 518 unique citations (Fig. 1). After abstract appraisal, 97 articles were selected for full-text review, and 4 additional results were added from review of article references. Our final analysis included 74 articles. Basic study characteristics, including sample size and patient ages, along with additional abstracted information regarding the outcome measures used, are shown in the *Appendix*.

Outcome Measures

There was a wide array of methods used to evaluate clinical outcome. However, we identified 3 broad approaches into which all systems could be categorized: 1) providing overall “gestalt” impression of improvement (e.g., patient “improved,” “remained unchanged,” or “worsened”); 2) providing a description of improvement for each individual or group of signs and symptoms (sign/symptom-specific reporting); and 3) utilizing one of several standardized outcome scoring systems, defined as any formalized, quantifiable metric for assessing outcome. We further divided standardized scores into those that primarily evaluated disease-specific improvement in signs, symptoms, and overall function—including measures adopted from the general spine literature⁹⁶ and visual analog scales (VASs) for symptoms such as pain^{1,64}—and those assessing general quality of life or disability (general function score). Applying this categorization, we found at least 18 different approaches to classifying clinical outcome, although this number is higher if minor modifications made by some groups to gestalt and sign/symptom-specific systems are considered.

Overall, we found that gestalt was the most common system used (used in 45 studies), and 35 articles (47%) relied on gestalt impression alone to evaluate clinical outcome (Fig. 2). Sign/symptom-specific reporting was present in 20 studies (27%), and was the lone outcome measure in 9 (12%). Twenty-two articles (30%) used standardized scoring systems.

Six articles used a total of 11 quality of life or general disability tools to evaluate clinical outcome (Table 1). No measure was used more than once. Four of these 11 tools

FIG. 1. A flow chart demonstrating the databases searched in the systematic review and the results retrieved. CINAHL = Cumulative Index to Nursing and Allied Health Literature.

demonstrated varying degrees of criterion validity in patients with CM-I, i.e., the instrument’s assessments were correlated with well-accepted measures of outcome.^{13,32} One tool, the Headache Disability Index, failed to meet a threshold for accurate discrimination of meaningful improvement prespecified by the study’s authors.²⁷ Notably, the validity of all 4 tools was established in the same study, and only adult patients were included.²⁷ The reliability of these tools was not specifically assessed in patients with CM-I.

Disease-specific scoring systems were more common

than general function scores, with a total of 6 scales used in 17 studies (Table 2). The most common measures used were modifications of the Klekamp and Samii score (n = 6 articles) and the Japanese Orthopaedic Association (JOA) score (n = 4). Visual analog scale scores for pain symptoms (n = 3) were grouped into a single category. Validations were attempted for 2 of the 6 scales, with 1 (the Chicago Chiari Outcome Scale [CCOS]) demonstrating criterion validity in retrospective chart review,^{2,93} and another (the VAS for either head or neck pain) failing to meet a prespecified threshold for meaningful discrimination of

FIG. 2. A summary of the systems used to evaluate clinical outcomes in patients treated for CM-I. The Venn diagram demonstrates the approximate prevalence of each method as well as the overlap of various systems used in the same article. Figure is available in color online only.

TABLE 1. General quality of life or disability scales used to evaluate clinical outcomes in patients with CM-I

Outcome Tool*	Age Group	CM-I Validity	Reliability in CM-I
EuroQol-5D ²¹	Adults	Yes†	No
Headache Disability Index ⁷⁰	Adults	No	No
Karnofsky Performance Scale ⁹⁴	Adults & children	No	No
Neck Disability Index ⁸⁹	Adults	Yes†	No
Noudel et al.'s adapted functional grading system ⁶³	Adults & children	No‡	No‡
Rankin Scale ^{67§}	Adults & children	No	No
Short Form-12 Health Survey ⁷¹	Adults	Yes†	No
Short Form-36 Health Survey ⁷¹	Adults, unclear if children as well	No	No
Sickness Impact Profile ⁵⁹	Adults & children	No	No
VAS for Disease Impact on Daily Life ⁶²	Adults & children	No	No
Zung Self-Rating Depression Scale ¹⁰⁰	Adults	Yes†	No

* All outcome tools used only once.

† Demonstrated criterion validity, i.e., the instrument's assessments were correlated with well-accepted measures of outcome.

‡ Scale originally published in French and could not be directly evaluated.

§ The citation provided refers to the modified Rankin Scale, although the article included in the review does not distinguish whether the original or modified Rankin Scale was used.

outcome.²⁷ Among the 6 disease-specific tools, reliability statistics in patients with CM-I were only available for the CCOS.

Inclusion of Disease-Appropriate Information

Our ability to consistently assess the outcome methods used by each study was complicated by the heterogeneity of the approaches identified, including a majority of nonstandardized systems, and the absence of accepted guidelines for reporting treatment results in CM-I. To facilitate uniform evaluation of all studies, we appraised each article for the adequacy of its reporting in 6 domains particularly relevant to patients treated for CM-I. These results are summarized in Table 3.

Overall, only 7 articles (9%) used direct patient-response instruments when reporting clinical outcome. The vast majority of studies relied on clinician impressions of disease, commonly based on review of the existing medical record. Although the method of data collection was often unspecified, VASs were always considered patient-response instruments. Specifically among studies using standardized scoring systems, 4 (67%) of 6 articles using

general function scores incorporated patient-response instruments, whereas only 3 (18%) of 17 articles using disease-specific systems included such measures.

When evaluating the inclusion of quality of life assessments, we used a liberal definition that included any explicit consideration during outcome assessment of the influence of disease on quality of life or general function, whether based on clinician or patient impressions and whether a validated system was implemented. Even with this generous definition, less than 30% of articles included measures that considered the impact of disease on a patient's overall function or well-being.

A minority of articles (38%) explicitly considered new Chiari-related symptoms developing after surgery when evaluating outcome, more commonly focusing only on resolution of preoperative symptoms. Slightly more common, approximately half (51%) of the included studies explicitly provided a multidimensional appraisal of outcome for multiple distinct signs and symptoms present in individual patients preoperatively; the remaining articles typically provided only a 1-dimensional evaluation of whether patients globally "improved" or not. Most articles directly

TABLE 2. Disease-specific scales used to evaluate clinical outcomes in patients treated for CM-I

Outcome Tool	Age Group Studied	CM-I Validity	Reliability in CM-I	No. of Studies Used
Asgari score (modified) ^{24,39*}	Adults	No	No	2
CCOS ²	Adults & children	Yes (criterion validity)	Mean score deviation = 1.56 ± 0.74 points (interrater reliability)	2
JOA score ⁹⁶	Adults & children	No	No	4
Klekamp & Samii score ^{5,37†}	Adults & children	No	No	6
Limonadi score ⁴⁵	Adults & children	No	No	1
VAS-pain ^{64‡}	Adults	No	No	3

* Two articles created slightly different modifications of the same original scale, although the basic structure was comparable for both instruments.

† Two modifications were developed from a spine outcome system created by Klekamp and Samii,³⁸ although both tools were substantially similar.

‡ Visual analog scales for pain symptoms—including head, neck, and extremity pain—are grouped together.

TABLE 3. Assessment of 6 key domains relevant to reporting clinical outcome in CM-I and the number of papers fulfilling each domain

Study Domain	No. of Papers (%)
Source of outcome evaluation	
Clinician impression	67 (90.5)
Patient-response instrument	5 (6.8)
Clinician impression + patient-response instrument	2 (2.7)
Quality of life assessed	22 (29.7)
New symptoms reported	28 (37.8)
Multidimensional assessment performed	38 (51.4)
Revision surgery reported	45 (60.8)
Method of reporting headache symptoms	
Not reported or included in general pain scale	19 (25.7)
Described a single "headache" group	14 (18.9)
Combined headache w/ neck or back pain	6 (8.1)
Evaluated headaches by specific location/character	14 (18.9)
Unclear	21 (28.4)

reported rates of revision surgery for persistent disease, although a sizable minority (39%) did not.

In assessing how each article evaluated patients' common but often difficult-to-characterize headache symptoms, we identified 4 general approaches that were used. Fourteen studies (19%) reported headache outcome based on specific location or character. More commonly, headaches were not reported or were grouped in a general pain category (26%). In addition, 19% of articles reported all headaches as a single symptom type, and 28% of articles did not provide sufficient information to allow confident determination of how outcomes were analyzed.

Discussion

To our knowledge, this is the first systematic and comprehensive assessment of the outcome methods used in the CM-I literature. Overall, we found a great deal of inconsistency among the approaches used, with at least 18 different combinations of outcome systems identified. Most studies used gestalt impression to define outcome, with less than one-third using a standard scoring system and far fewer relying on a tool specifically validated in patients with CM-I. These results highlight the significant need for commonly accepted standards to guide clinical outcome reporting in CM-I research.

Identifying one, or even a few, consistent approaches to reporting outcome is essential to interpreting results from individual investigations as well as to comparing results across studies. Simple gestalt impression, the most common method identified, provides little detail about disease evolution and, due to its inherent ambiguity, is likely to be applied inconsistently across and even within studies.²² Likewise, when not part of a composite score, sign/symptom-specific reporting does not permit a clear comparison of results across patients. These shortcomings and the diversity of systems currently used severely limit the

ability to generalize results beyond a single sample. An initiative by the National Institute of Neurological Disorders and Stroke, the Common Data Elements Project,⁶¹ has addressed the inconsistent reporting of results for a number of neurological conditions,^{47,48,75} but only now are foundations and other groups with an interest in CM-I considering such efforts.

While reliable and consistent reporting is critical, another key consideration in outcomes assessment is instrument validity. Among the 17 standardized systems identified, 5 have been validated in CM-I patients.^{2,27,93} However, only 1, the CCOS, has been validated in adults and children.^{2,93} A 4-item scale assessing pain symptoms, nonpain symptoms, functionality, and complications, the CCOS is designed for retrospective chart review and thus is not suited for prospectively measuring patient-defined disease burden before and after treatment. In addition, some CCOS subscores, particularly functionality, have poor interrater reliability.⁹³ Notably, all instrument validations focused on criterion validity, or the extent to which the system at hand correlates with well-accepted measures.^{13,32} By contrast, the recently developed Chiari Symptom Profile has shown strong content validity (i.e., covering all the areas intended) but has not yet been applied to outcomes research.⁶⁰ Demonstrating validity in multiple domains is an important aspect of developing a meaningful outcome scale.

Because symptomatic outcomes for patients with CM-I are inherently subjective, one critical but often overlooked component of measuring outcomes is the utilization of patient-response instruments. In recent years, major initiatives including the Patient-Centered Outcome Research Institute^{25,76,90} and the Patient-Reported Outcomes Measurement Information System (<http://www.nihpromis.org/>) have promoted the incorporation of patient perspectives and values into treatment decisions. However, despite such efforts, only 7 articles (9%) in the contemporary CM-I literature incorporated any direct measure of patient opinion when reporting outcome. Consequently, there is little evidence regarding how patients' views of their own health change after CM-I surgery. Future research should strive to incorporate direct patient responses when assessing clinical outcome.

While patient-response measures lay a foundation for meaningful assessments, we identified several additional characteristics necessary in studies evaluating outcome in patients with CM-I. Many of the shortcomings we observed, such as not accounting for new symptoms postoperatively or not providing a multidimensional outcome assessment of distinct signs and symptoms present preoperatively, likely reflect the reliance on 1-dimensional gestalt assessments. Similarly, the limited assessment of headache symptoms reflects the need for validated tools that capture the complexity of the symptoms present in patients with CM-I.

To aid the development of novel outcome metrics, we created the checklist shown in Table 4. This Chiari-focused framework can be used along with general guides for evaluating health measurement instruments³⁶ to appraise the quality of future scales. Until new metrics are developed, researchers interested in studying general

TABLE 4. A checklist for evaluating clinical outcome methods in CM-I treatment studies

Key elements of a CM-I clinical outcome metric	Yes	No
Do measures of symptomatic outcome incorporate direct patient reporting?	()	()
Does the outcome metric include a specific assessment of patient quality of life?	()	()
Does the outcome metric assess for new symptoms that developed after initial surgery?	()	()
Does the outcome metric provide a sufficient multidimensional assessment of outcome for distinct signs & symptoms present preoperatively in individual patients?	()	()
Does the outcome metric assess in sufficient detail the location & character of headache symptoms?	()	()
Does the study report the rate of revision surgery for persistent disease?	()	()
Is the outcome metric valid in CM-I patients?*	()	()
Is the outcome metric reliable in CM-I patients?	()	()

* For a more detailed description of different types of validity, such as criterion, construct, and content validity, see resources provided by the COSMIN initiative.⁵⁷

quality of life could use tools such as the EuroQol-5D, which has shown criterion validity in adults.²⁷ However, given the substantial limitations of current systems, we are unable to endorse 1 or more disease-specific tools. Rather, we recommend researchers use our proposed checklist to weigh the strengths and weaknesses of existing methods in the context of their studies' goals.

Significantly, this study has several limitations. Most importantly, the classifications outlined, such as whether an article considered new symptoms developing after treatment or how an article evaluated multiple unique signs and symptoms in individual patients, inevitably involved subjective determination based on the limited information provided in each article. In addition, this review was restricted to the English-language literature, which may have excluded certain metrics.

Conclusions

In this review, we have identified significant weaknesses in the contemporary methods used to assess clinical outcomes in patients with CM-I and have provided a framework to improve future evaluations. The conclusive trends identified in this review, including the reliance on gestalt measures, highlight the critical need for multidisciplinary collaboration to develop patient-based, validated, and disease-specific tools for reporting clinical outcome in CM-I. Adopting such standardized scales will enable the most informative and generalizable conclusions to be drawn from each study and will serve as a critical step toward improving patient care.

References

- Alfieri A, Pinna G: Long-term results after posterior fossa decompression in syringomyelia with adult Chiari Type I malformation. Clinical article. *J Neurosurg Spine* 17:381–387, 2012
- Aliaga L, Hekman KE, Yassari R, Straus D, Luther G, Chen J, et al: A novel scoring system for assessing Chiari malformation type I treatment outcomes. *Neurosurgery* 70:656–665, 2012
- Anderson RC, Dowling KC, Feldstein NA, Emerson RG: Chiari I malformation: potential role for intraoperative electrophysiologic monitoring. *J Clin Neurophysiol* 20:65–72, 2003
- Arora P, Behari S, Banerji D, Chhabra DK, Jain VK: Factors influencing the outcome in symptomatic Chiari I malformation. *Neurol India* 52:470–474, 2004
- Arora P, Pradhan PK, Behari S, Banerji D, Das BK, Chhabra DK, et al: Chiari I malformation related syringomyelia: radionuclide cisternography as a predictor of outcome. *Acta Neurochir (Wien)* 146:119–130, 2004
- Arruda JA, Costa CM, Tella OI Jr: Results of the treatment of syringomyelia associated with Chiari malformation: analysis of 60 cases. *Arq Neuropsiquiatr* 62 (2A):237–244, 2004
- Attenello FJ, McGirt MJ, Garcés-Ambrossi GL, Chaichana KL, Carson B, Jallo GI: Suboccipital decompression for Chiari I malformation: outcome comparison of duraplasty with expanded polytetrafluoroethylene dural substitute versus pericranial autograft. *Childs Nerv Syst* 25:183–190, 2009
- Attenello FJ, McGirt MJ, Gathinji M, Datto G, Atiba A, Weingart J, et al: Outcome of Chiari-associated syringomyelia after hindbrain decompression in children: analysis of 49 consecutive cases. *Neurosurgery* 62:1307–1313, 2008
- Bao C, Yang F, Liu L, Wang B, Li D, Gu Y, et al: Surgical treatment of Chiari I malformation complicated with syringomyelia. *Exp Ther Med* 5:333–337, 2013
- Batzdorf U, McArthur DL, Bentson JR: Surgical treatment of Chiari malformation with and without syringomyelia: experience with 177 adult patients. Clinical article. *J Neurosurg* 118:232–242, 2013
- Behari S, Kalra SK, Kiran Kumar MV, Salunke P, Jaiswal AK, Jain VK: Chiari I malformation associated with atlanto-axial dislocation: focussing on the anterior cervico-medullary compression. *Acta Neurochir (Wien)* 149:41–50, 2007
- Caldarelli M, Novegno F, Vassimi L, Romani R, Tamburrini G, Di Rocco C: The role of limited posterior fossa craniectomy in the surgical treatment of Chiari malformation Type I: experience with a pediatric series. *J Neurosurg* 106 (3 Suppl):187–195, 2007
- Carmines EG, Zeller RA: **Reliability and Validity Assessment. Quantitative Applications in the Social Sciences.** Newbury Park, CA: Sage Publications, Vol 17, 1979
- Chauvet D, Carpentier A, George B: Dura splitting decompression in Chiari type I malformation: clinical experience and radiological findings. *Neurosurg Rev* 32:465–470, 2009
- Cui LG, Jiang L, Zhang HB, Liu B, Wang JR, Jia JW, et al: Monitoring of cerebrospinal fluid flow by intraoperative ultrasound in patients with Chiari I malformation. *Clin Neurol Neurosurg* 113:173–176, 2011
- Di X: Endoscopic suboccipital decompression on pediatric Chiari type I. *Minim Invasive Neurosurg* 52:119–125, 2009
- Dones J, De Jesús O, Colen CB, Toledo MM, Delgado M: Clinical outcomes in patients with Chiari I malformation: a review of 27 cases. *Surg Neurol* 60:142–148, 2003
- Durham SR, Fjeld-Olenec K: Comparison of posterior fossa

- decompression with and without duraplasty for the surgical treatment of Chiari malformation Type I in pediatric patients: a meta-analysis. **J Neurosurg Pediatr** 2:42–49, 2008
19. El-Ghandour NMF: Long-term outcome of surgical management of adult Chiari I malformation. **Neurosurg Rev** 35:537–547, 2012
 20. Erdogan E, Cansever T, Secer HI, Temiz C, Sirin S, Kabatas S, et al: The evaluation of surgical treatment options in the Chiari Malformation Type I. **Turk Neurosurg** 20:303–313, 2010
 21. EuroQol-Group: **About EQ-5D**. (<http://www.euroqol.org/about-eq-5d.html>) [Accessed October 1, 2014]
 22. Feinstein AR: **Clinical Epidemiology: The Architecture of Clinical Research**. Philadelphia: WB Saunders, 1985
 23. Foreman P, Safavi-Abbasi S, Talley MC, Boeckman L, Mapstone TB: Perioperative outcomes and complications associated with allogeneic duraplasty for the management of Chiari malformations Type I in 48 pediatric patients. Clinical article. **J Neurosurg Pediatr** 10:142–149, 2012
 24. Furtado SV, Thakar S, Hegde AS: Correlation of functional outcome and natural history with clinicoradiological factors in surgically managed pediatric Chiari I malformation. **Neurosurgery** 68:319–328, 2011
 25. Gabriel SE, Normand SL: Getting the methods right—the foundation of patient-centered outcomes research. **N Engl J Med** 367:787–790, 2012
 26. Galarza M, Sood S, Ham S: Relevance of surgical strategies for the management of pediatric Chiari type I malformation. **Childs Nerv Syst** 23:691–696, 2007
 27. Godil SS, Parker SL, Zuckerman SL, Mendenhall SK, McGirt MJ: Accurately measuring outcomes after surgery for adult Chiari I malformation: determining the most valid and responsive instruments. **Neurosurgery** 72:820–827, 2013
 28. Hankinson T, Tubbs RS, Wellons JC: Duraplasty or not? An evidence-based review of the pediatric Chiari I malformation. **Childs Nerv Syst** 27:35–40, 2011
 29. Heiss JD, Suffredini G, Smith R, DeVroom HL, Patronas NJ, Butman JA, et al: Pathophysiology of persistent syringomyelia after decompressive craniocervical surgery. Clinical article. **J Neurosurg Spine** 13:729–742, 2010
 30. Hekman KE, Aliaga L, Straus D, Luther A, Chen J, Sampat A, et al: Positive and negative predictors for good outcome after decompressive surgery for Chiari malformation type 1 as scored on the Chicago Chiari Outcome Scale. **Neurol Res** 34:694–700, 2012
 31. Hoffman CE, Souweidane MM: Cerebrospinal fluid-related complications with autologous duraplasty and arachnoid sparing in type I Chiari malformation. **Neurosurgery** 62 (3 Suppl 1):156–161, 2008
 32. Hulley SB, Cummings SR, Browner WS, Grady DG, Newman TB: **Designing Clinical Research**, ed 3. Philadelphia: Lippincott Williams & Wilkins, 2007
 33. Hyun SJ, Moon KY, Kwon JW, Lee CH, Kim J, Kim KJ, et al: Chiari I malformation associated with syringomyelia: can foramen magnum decompression lead to restore cervical alignment? **Eur Spine J** 22:2520–2525, 2013
 34. Kalb S, Perez-Orribo L, Mahan M, Theodore N, Nakaji P, Bristol RE: Evaluation of operative procedures for symptomatic outcome after decompression surgery for Chiari type I malformation. **J Clin Neurosci** 19:1268–1272, 2012
 35. Kim LJ, Rekate HL, Klopfenstein JD, Sonntag VKH: Treatment of basilar invagination associated with Chiari I malformations in the pediatric population: cervical reduction and posterior occipitocervical fusion. **J Neurosurg** 101 (2 Suppl):189–195, 2004
 36. Klekamp J: Neurological deterioration after foramen magnum decompression for Chiari malformation type I: old or new pathology? Clinical article. **J Neurosurg Pediatr** 10:538–547, 2012
 37. Klekamp J: Surgical treatment of Chiari I malformation—analysis of intraoperative findings, complications, and outcome for 371 foramen magnum decompressions. **Neurosurgery** 71:365–380, 2012
 38. Klekamp J, Samii M: Introduction of a score system for the clinical evaluation of patients with spinal processes. **Acta Neurochir (Wien)** 123:221–223, 1993
 39. Koç K, Anik Y, Anik I, Cabuk B, Ceylan S: Chiari 1 malformation with syringomyelia: correlation of phase-contrast cine MR imaging and outcome. **Turk Neurosurg** 17:183–192, 2007
 40. Kumar R, Kalra SK, Vaid VK, Mahapatra AK: Chiari I malformation: surgical experience over a decade of management. **Br J Neurosurg** 22:409–414, 2008
 41. Kunert P, Janowski M, Zakrzewska A, Marchel A: Comparison of results between two different techniques of craniocervical decompression in patients with Chiari I malformation. **Neurol Neurochir Pol** 43:337–345, 2009
 42. Lam FC, Penumaka A, Chen CC, Fischer EG, Kasper EM: Fibrin sealant augmentation with autologous pericranium for duraplasty after suboccipital decompression in Chiari I patients: a case series. **Surg Neurol Int** 4:6, 2013
 43. Lee HS, Lee SH, Kim ES, Kim JS, Lee JI, Shin HJ, et al: Surgical results of arachnoid-preserving posterior fossa decompression for Chiari I malformation with associated syringomyelia. **J Clin Neurosci** 19:557–560, 2012
 44. Levo H, Tapani E, Karppinen A, Kentala E: Chiari Malformation in otology practice. **Auris Nasus Larynx** 37:95–99, 2010
 45. Limonadi FM, Selden NR: Dura-splitting decompression of the craniocervical junction: reduced operative time, hospital stay, and cost with equivalent early outcome. **J Neurosurg** 101 (2 Suppl):184–188, 2004
 46. Litvack ZN, Lindsay RA, Selden NR: Dura splitting decompression for Chiari I malformation in pediatric patients: clinical outcomes, healthcare costs, and resource utilization. **Neurosurgery** 72:922–929, 2013
 47. Loring DW, Lowenstein DH, Barbaro NM, Fureman BE, Odenkirchen J, Jacobs MP, et al: Common data elements in epilepsy research: development and implementation of the NINDS epilepsy CDE project. **Epilepsia** 52:1186–1191, 2011
 48. Lynch DR, Pandolfo M, Schulz JB, Perlman S, Delatycki MB, Payne RM, et al: Common data elements for clinical research in Friedreich's ataxia. **Mov Disord** 28:190–195, 2013
 49. Massimi L, Caldarelli M, Paternoster G, Novegno F, Tamburrini G, Di Rocco C: Mini-invasive surgery for Chiari type I malformation. **Neuroradiol J** 21:65–70, 2008
 50. Massimi L, Pravata E, Tamburrini G, Gaudino S, Pettorini B, Novegno F, et al: Endoscopic third ventriculostomy for the management of Chiari I and related hydrocephalus: outcome and pathogenetic implications. **Neurosurgery** 68:950–956, 2011
 51. McGirt MJ, Atiba A, Attenello FJ, Wasserman BA, Datto G, Gathinji M, et al: Correlation of hindbrain CSF flow and outcome after surgical decompression for Chiari I malformation. **Childs Nerv Syst** 24:833–840, 2008
 52. McGirt MJ, Attenello FJ, Atiba A, Garces-Ambrossi G, Datto G, Weingart JD, et al: Symptom recurrence after suboccipital decompression for pediatric Chiari I malformation: analysis of 256 consecutive cases. **Childs Nerv Syst** 24:1333–1339, 2008
 53. McGirt MJ, Attenello FJ, Datto G, Gathinji M, Atiba A, Weingart JD, et al: Intraoperative ultrasonography as a guide to patient selection for duraplasty after suboccipital decompression in children with Chiari malformation Type I. **J Neurosurg Pediatr** 2:52–57, 2008
 54. McGirt MJ, Nimjee SM, Fuchs HE, George TM: Relationship of cine phase-contrast magnetic resonance imaging with outcome after decompression for Chiari I malformations. **Neurosurgery** 59:140–146, 2006

55. Meadows J, Kraut M, Guarnieri M, Haroun RI, Carson BS: Asymptomatic Chiari Type I malformations identified on magnetic resonance imaging. **J Neurosurg** **92**:920–926, 2000
56. Mokkink LB, Terwee CB, Patrick DL, Alonso J, Stratford PW, Knol DL, et al: The COSMIN checklist for assessing the methodological quality of studies on measurement properties of health status measurement instruments: an international Delphi study. **Qual Life Res** **19**:539–549, 2010
57. Mokkink LB, Terwee CB, Patrick DL, Alonso J, Stratford PW, Knol DL, et al: The COSMIN study reached international consensus on taxonomy, terminology, and definitions of measurement properties for health-related patient-reported outcomes. **J Clin Epidemiol** **63**:737–745, 2010
58. Mottolese C, Szathmari A, Simon E, Rousselle C, Ricci-Franchi AC, Hermier M: Treatment of Chiari type I malformation in children: the experience of Lyon. **Neurol Sci** **32** (Suppl 3):S325–S330, 2011
59. Mueller D, Oro' JJ: Prospective analysis of self-perceived quality of life before and after posterior fossa decompression in 112 patients with Chiari malformation with or without syringomyelia. **Neurosurg Focus** **18**(2):ECP2, 2005
60. Mueller DM, Oro' JJ: The Chiari Symptom Profile: development and validation of a Chiari-/syringomyelia-specific questionnaire. **J Neurosci Nurs** **45**:205–210, 2013
61. National Institute of Neurological Disorders and Stroke: Project overview. **NINDS Common Data Elements**. (<http://www.commondataelements.ninds.nih.gov/ProjReview.aspx#tab=Introduction>) [Accessed September 27, 2014]
62. Navarro R, Olavarria G, Seshadri R, Gonzales-Portillo G, McLone DG, Tomita T: Surgical results of posterior fossa decompression for patients with Chiari I malformation. **Childs Nerv Syst** **20**:349–356, 2004
63. Noudel R, Gomis P, Sotoares G, Bazin A, Pierot L, Pruvo JP, et al: Posterior fossa volume increase after surgery for Chiari malformation Type I: a quantitative assessment using magnetic resonance imaging and correlations with the treatment response. Clinical article. **J Neurosurg** **115**:647–658, 2011
64. Ono A, Numasawa T, Wada K, Yokoyama T, Takeuchi K, Suetsuna F, et al: Surgical outcomes of foramen magnum decompression for syringomyelia associated with Chiari I malformation: relation between the location of the syrinx and body pain. **J Orthop Sci** **15**:299–304, 2010
65. Ono A, Suetsuna F, Ueyama K, Yokoyama T, Aburakawa S, Numasawa T, et al: Surgical outcomes in adult patients with syringomyelia associated with Chiari malformation type I: the relationship between scoliosis and neurological findings. **J Neurosurg Spine** **6**:216–221, 2007
66. Panigrahi M, Reddy BP, Reddy AK, Reddy JJM: CSF flow study in Chiari I malformation. **Childs Nerv Syst** **20**:336–340, 2004
67. Perrini P, Benedetto N, Tenenbaum R, Di Lorenzo N: Extra-arachnoidal cranio-cervical decompression for syringomyelia associated with Chiari I malformation in adults: technique assessment. **Acta Neurochir (Wien)** **149**:1015–1023, 2007
68. Prat R, Galeano I: Pain improvement in patients with syringomyelia and Chiari I malformation treated with suboccipital decompression and tonsillar coagulation. **J Clin Neurosci** **16**:531–534, 2009
69. Pritz MB: Surgical treatment of Chiari I malformation: simplified technique and clinical results. **Skull Base** **13**:173–177, 2003
70. Pryse-Phillips W: Evaluating migraine disability: the headache impact test instrument in context. **Can J Neurol Sci** **29** (Suppl 2):S11–S15, 2002
71. QualityMetric: **SF Health Surveys**. (<http://www.qualitymetric.com/WhatWeDo/SFHealthSurveys/tabid/184/Default.aspx>) [Accessed September 27, 2014]
72. Ramnarayan R, Praharaj MS, Jayakumar PN: Chiari I malformations: an Indian hospital experience. **Singapore Med J** **49**:1029–1034, 2008
73. Romero FR, Pereira CA: Suboccipital craniectomy with or without duraplasty: what is the best choice in patients with Chiari type I malformation? **Arq Neuropsiquiatr** **68**:623–626, 2010
74. Sakushima K, Hida K, Yabe I, Tsuboi S, Uehara R, Sasaki H: Different surgical treatment techniques used by neurosurgeons and orthopedists for syringomyelia caused by Chiari I malformation in Japan. Clinical article. **J Neurosurg Spine** **18**:588–592, 2013
75. Saver JL, Warach S, Janis S, Odenkirchen J, Becker K, Benavente O, et al: Standardizing the structure of stroke clinical and epidemiologic research data: the National Institute of Neurological Disorders and Stroke (NINDS) Stroke Common Data Element (CDE) project. **Stroke** **43**:967–973, 2012
76. Selby JV, Beal AC, Frank L: The Patient-Centered Outcomes Research Institute (PCORI) national priorities for research and initial research agenda. **JAMA** **307**:1583–1584, 2012
77. Shamji MF, Ventureyra EC, Baronia B, Nzau M, Vassilyadi M: Classification of symptomatic Chiari I malformation to guide surgical strategy. **Can J Neurol Sci** **37**:482–487, 2010
78. Sivaramakrishnan A, Alperin N, Surapaneni S, Lichter T: Evaluating the effect of decompression surgery on cerebrospinal fluid flow and intracranial compliance in patients with Chiari malformation with magnetic resonance imaging flow studies. **Neurosurgery** **55**:1344–1351, 2004
79. Spina G, Bernucci C, Garbossa D, Valfrè W, Versari P: Clinical and radiological outcome of craniocervical osteodural decompression for Chiari I-associated syringomyelia. **Neurosurg Rev** **33**:297–304, 2010
80. Strahle J, Muraszko KM, Kapurch J, Bapuraj JR, Garton HJ, Maher CO: Chiari malformation Type I and syrinx in children undergoing magnetic resonance imaging. Clinical article. **J Neurosurg Pediatr** **8**:205–213, 2011
81. Takayasu M, Takagi T, Hara M, Anzai M: A simple technique for expansive suboccipital cranioplasty following foramen magnum decompression for the treatment of syringomyelia associated with Chiari I malformation. **Neurosurg Rev** **27**:173–177, 2004
82. Tisell M, Wallskog J, Linde M: Long-term outcome after surgery for Chiari I malformation. **Acta Neurol Scand** **120**:295–299, 2009
83. Tubbs RS, Beckman J, Naftel RP, Chern JJ, Wellons JC III, Rozzelle CJ, et al: Institutional experience with 500 cases of surgically treated pediatric Chiari malformation Type I. **J Neurosurg Pediatr** **7**:248–256, 2011 Clinical article.
84. Tubbs RS, Iskandar BJ, Bartolucci AA, Oakes WJ: A critical analysis of the Chiari 1.5 malformation. **J Neurosurg** **101** (2 Suppl):179–183, 2004
85. Tubbs RS, McGirt MJ, Oakes WJ: Surgical experience in 130 pediatric patients with Chiari I malformations. **J Neurosurg** **99**:291–296, 2003
86. Valentini L, Visintini S, Saletti V, Chiapparini L, Estienne M, Solero CL: Treatment for Chiari 1 malformation (CIM): analysis of a pediatric surgical series. **Neurol Sci** **32** (Suppl 3):S321–S324, 2011
87. van Swieten JC, Koudstaal PJ, Visser MC, Schouten HJ, van Gijn J: Interobserver agreement for the assessment of handicap in stroke patients. **Stroke** **19**:604–607, 1988
88. Ventureyra EC, Aziz HA, Vassilyadi M: The role of cine flow MRI in children with Chiari I malformation. **Childs Nerv Syst** **19**:109–113, 2003
89. Vernon H: The Neck Disability Index: state-of-the-art, 1991–2008. **J Manipulative Physiol Ther** **31**:491–502, 2008
90. Washington AE, Lipstein SH: The Patient-Centered Outcomes Research Institute—promoting better information, decisions, and health. **N Engl J Med** **365**:e31, 2011
91. Wetjen NM, Heiss JD, Oldfield EH: Time course of syringo-

- myelia resolution following decompression of Chiari malformation Type I. **J Neurosurg Pediatr** 1:118–123, 2008
92. Williams LE, Vannemreddy PS, Watson KS, Slavin KV: The need in dural graft suturing in Chiari I malformation decompression: a prospective, single-blind, randomized trial comparing sutured and sutureless duraplasty materials. **Surg Neurol Int** 4:26, 2013
93. Yarbrough CK, Greenberg JK, Smyth MD, Leonard JR, Park TS, Limbrick DD Jr: External validation of the Chicago Chiari Outcome Scale. Clinical article. **J Neurosurg Pediatr** 13:679–684, 2014
94. Yates JW, Chalmer B, McKegney FP: Evaluation of patients with advanced cancer using the Karnofsky performance status. **Cancer** 45:2220–2224, 1980
95. Yeh DD, Koch B, Crone KR: Intraoperative ultrasonography used to determine the extent of surgery necessary during posterior fossa decompression in children with Chiari malformation type I. **J Neurosurg** 105 (1 Suppl):26–32, 2006
96. Yilmaz A, Kanat A, Musluman AM, Colak I, Terzi Y, Kayaci S, et al: When is duraplasty required in the surgical treatment of Chiari malformation type I based on tonsillar descending grading scale? **World Neurosurg** 75:307–313, 2011
97. Zamel K, Galloway G, Kosnik EJ, Raslan M, Adeli A: Intraoperative neurophysiologic monitoring in 80 patients with Chiari I malformation: role of duraplasty. **J Clin Neurophysiol** 26:70–75, 2009
98. Zhang Y, Zhang N, Qiu H, Zhou J, Li P, Ren M, et al: An efficacy analysis of posterior fossa decompression techniques in the treatment of Chiari malformation with associated syringomyelia. **J Clin Neurosci** 18:1346–1349, 2011
99. Zhang ZQ, Chen YQ, Chen YA, Wu X, Wang YB, Li XG: Chiari I malformation associated with syringomyelia: a retrospective study of 316 surgically treated patients. **Spinal Cord** 46:358–363, 2008
100. Zung WW, Richards CB, Short MJ: Self-rating depression scale in an outpatient clinic. Further validation of the SDS. **Arch Gen Psychiatry** 13:508–515, 1965

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APPENDIX: Complete list of, and basic information about, each article meeting inclusion criteria

Authors & Year	Sample Size	Participant Age Group	Outcome System	Standardized Score	Source of Outcome Data
Alfieri & Pinna, 2012	109	Adult	DSS + SSR	VAS-pain	CI, PRI
Aliaga, et al., 2012	146	Child + adult	DSS	CCOS	CI
Anderson et al., 2003	11	Child + adult	Gestalt	NA	CI
Arora et al., 2004 ⁵	17	Child + adult	DSS	Klekamp & Samii score	CI
Arora et al., 2004 ⁴	48	Child + adult	DSS	Klekamp & Samii score	CI
Arruda et al., 2004	60	Child + adult	Gestalt + SSR	NA	CI
Attenello et al., 2008	49	Child	Gestalt + SSR	NA	CI
Attenello et al., 2009	67	Child	Gestalt	NA	CI
Bao et al., 2013	147	Child + adult	Gestalt	NA	CI
Batzdorf et al., 2013	177	Child + adult	SSR	NA	CI
Behari et al., 2007	39	Child + adult	DSS	Klekamp & Samii score	CI
Caldarelli et al., 2007	30	Child	Gestalt	NA	CI
Chauvet et al., 2009	11	Adult	SSR	NA	CI
Cui et al., 2011	20	Unclear	Gestalt	NA	CI
Di, 2009	26	Child	Gestalt + SSR	NA	CI
Dones et al., 2003	27	Child + adult	SSR	NA	CI
El-Ghandour, 2012	46	Adult	Gestalt	NA	CI
Erdogan et al., 2010	27	Unclear	Gestalt	NA	CI
Foreman et al., 2012	48	Child	Gestalt	NA	CI
Furtado et al., 2011	20	Child	DSS + SSR	Asgari score	CI
Galarza et al., 2007	60	Child	Gestalt	NA	CI
Godil et al., 2013	50	Adult	DSS, GFS	VAS-head/neck, Neck Disability Index, Head-ache Disability Index, EuroQoL-5D, SF-12, Zung Self-Rating Depression Scale	PRI
Heiss et al., 2010	16	Child + adult	SSR	NA	CI
Hekman et al., 2012	167	Child + adult	DSS	CCOS	CI
Hoffman & Souweidane, 2008	40	Child + adult	Gestalt	NA	CI
Hyun et al., 2013	30	Child + adult	DSS	JOA score	CI
Kalb et al., 2012	104	Child + adult	Gestalt + SSR	NA	CI
Kim et al., 2004	11	Child	Gestalt	NA	CI
Klekamp, 2012 ³⁶	107	Unclear	DSS	Klekamp & Samii score	CI
Klekamp, 2012 ³⁷	359	Unclear	Gestalt + DSS	Klekamp & Samii score	CI
Koç et al., 2007	18	Adult	DSS	Asgari score	CI
Kumar et al., 2008	87	Child + adult	DSS	Klekamp & Samii score	CI
Kunert et al., 2009	38	Child + adult	Gestalt, GFS	Rankin Scale, Karnofsky Performance Scale	CI
Lam et al., 2013	22	Adult	SSR	NA	PRI
Lee et al., 2012	25	Adult	Gestalt, SSR	NA	CI
Levo et al., 2010	46	Child + adult	Gestalt	NA	CI
Limonadi & Selden, 2004	24	Child + adult	DSS	Limonadi score	CI
Litvack et al., 2013	110	Child	SSR	NA	CI
Massimi et al., 2008	30	Child	Gestalt + SSR	NA	CI
Massimi et al., 2011	15	Child + adult	Gestalt	NA	CI
McGirt et al., 2006	130	Child + adult	Gestalt	NA	CI
McGirt et al., 2008 ⁵¹	44	Child	Gestalt	NA	CI
McGirt et al., 2008 ⁵²	256	Child	Gestalt	NA	CI
McGirt et al., 2008 ⁵³	256	Child	Gestalt	NA	CI
Mottolese et al., 2011	82	Child	Gestalt	NA	CI
Mueller & Oro, 2005	112	Child + adult	GFS	Sickness Impact Profile	PRI

(continued)

APPENDIX: Complete list of, and basic information about, each article meeting inclusion criteria (continued)

Authors & Year	Sample Size	Participant Age Group	Outcome System	Standardized Score	Source of Outcome Data
Navarro et al., 2004	96	Child	Gestalt	NA	CI
Noudel et al., 2011	11	Child + adult	GFS	Noudel's adapted functional grading system	CI
Ono et al., 2007	27	Adult	DSS	JOA score	CI
Ono et al., 2010	20	Adult	DSS	JOA score + VAS-pain	CI
Panigrahi et al., 2004	21	Child + adult	Gestalt	NA	CI
Perrini et al., 2007	24	Adult	SSR	NA	CI
Prat & Galeano, 2009	13	Child + adult	Gestalt	NA	CI
Pritz, 2003	14	Adult	Gestalt + SSR	NA	CI
Ramnarayan et al., 2008	51	Child + adult	Gestalt + SSR	NA	CI
Romero & Pereira, 2010	16	Adult	Gestalt	NA	CI
Sakushima et al., 2013	232	Child + adult	SSR	NA	CI
Shamji et al., 2010	24	Child	Gestalt	NA	CI
Sivaramakrishnan et al., 2004	12	Adult	Gestalt	NA	CI
Spena et al., 2010	36	Adult	Gestalt	NA	CI
Takayasu et al., 2004	16	Child + adult	Gestalt	NA	CI
Tisell et al., 2009	23	Child + adult	GFS + SSR	VAS-quality of life	PRI
Tubbs et al., 2004	22	Child + adult	Gestalt	NA	CI
Tubbs et al., 2003	130	Child + adult	Gestalt	NA	CI
Tubbs et al., 2011	500	Child	Gestalt	NA	CI
Valentini et al., 2011	99	Child	Gestalt	NA	CI
Ventureyra et al., 2003	24	Unclear	Gestalt	NA	CI
Wetjen et al., 2008	29	Child + adult	SSR	NA	CI
Williams et al., 2013	34	Unclear	GFS	SF-36	PRI
Yeh et al., 2006	130	Child	Gestalt	NA	CI
Yilmaz et al., 2011	82	Adult	DSS	JOA score	CI
Zamel et al., 2009	80	Child + adult	Gestalt	NA	CI
Zhang et al., 2011	132	Child + adult	Gestalt	NA	CI
Zhang et al., 2008	316	Child + adult	Gestalt	NA	CI

CI = clinician impression; DSS = disease-specific scale; GFS = general function scale; NA = not applicable; PRI = patient-response instrument; SF-12 = Short Form-12 Health Survey; SF-36 = Short Form-36 Health Survey; SSR = sign/symptom-specific reporting.