pii: jc-18-00615 https://dx.doi.org/10.5664/jcsm.7740

JCSM
Journal of Clinical Sleep Medicine

CASE REPORTS

Persistent Central Apnea and Long-Term Outcome After Posterior Fossa Decompressive Surgery for Arnold Chiari Type 1 Malformation in a Pediatric Patient

Abigail Strang, MD; Umakanth Katwa, MD

Sleep Center, Division of Respiratory Diseases, Department of Medicine, Boston Children's Hospital, Harvard Medical School, Boston, Massachusetts

Arnold Chiari malformation (ACM) is the most common cause of central sleep apnea (CSA) in otherwise healthy children. Although there are several case reports and series reported on this topic, there are limited descriptions of the long-term course of these children after the surgical interventions. Posterior fossa decompression surgery to relieve pressure of the herniating cerebellum on the brainstem is generally thought to significantly improve CSA in most cases, however, there are very limited data on the natural course of CSA in children following decompression surgery. There may be a subset of children in whom it may take much longer for CSA to resolve, and in some it may not resolve completely. Hence, these children need to be followed closely with sleep studies to document resolution of CSA. In this case report, we describe a 10-year-old male with severe CSA who was subsequently diagnosed with type 1 ACM and underwent posterior fossa decompressive surgery. However after surgery, although there was improvement in his CSA, he still had a significant degree of residual CSA which required bilevel positive pressure therapy and took more than 7.5 years to resolve. This case report illustrates the need for close follow-up in these children and for providers to understand the natural course so they can accurately counsel families about expectations after surgical treatments.

Keywords: central sleep apnea, Chiari, pediatrics

Citation: Strang A, Katwa U. Persistent central apnea and long-term outcome after posterior fossa decompressive surgery for Arnold Chiari type 1 malformation in a pediatric patient. *J Clin Sleep Med.* 2019;15(4):667–671.

INTRODUCTION

Arnold Chiari malformation (ACM) is the most commonly described cause of central sleep apnea (CSA) in children. Polysomnographic evidence of CSA may be the first indication of this congenital hindbrain abnormality.[1] In an otherwise healthy child, if significant CSA is noted on a polysomnogram, a provider should evaluate clinically for various causes of central apnea (including brainstem abnormalities) and may consider brain imaging.

The most common type of ACM is type 1 (ACM1), which is defined as herniation of the cerebellar tonsils > 6 mm below the foramen magnum. In cases of clinically significant CSA caused by ACM, neurosurgical intervention (posterior fossa decompression) is the recommended first-line treatment. However, there is limited data regarding the long-term prognosis of these children over time. Here we describe a 10-year-old male with severe CSA caused by ACM1 and describe his clinical course of persistent sleep apnea with gradual improvement over 7.5 years.

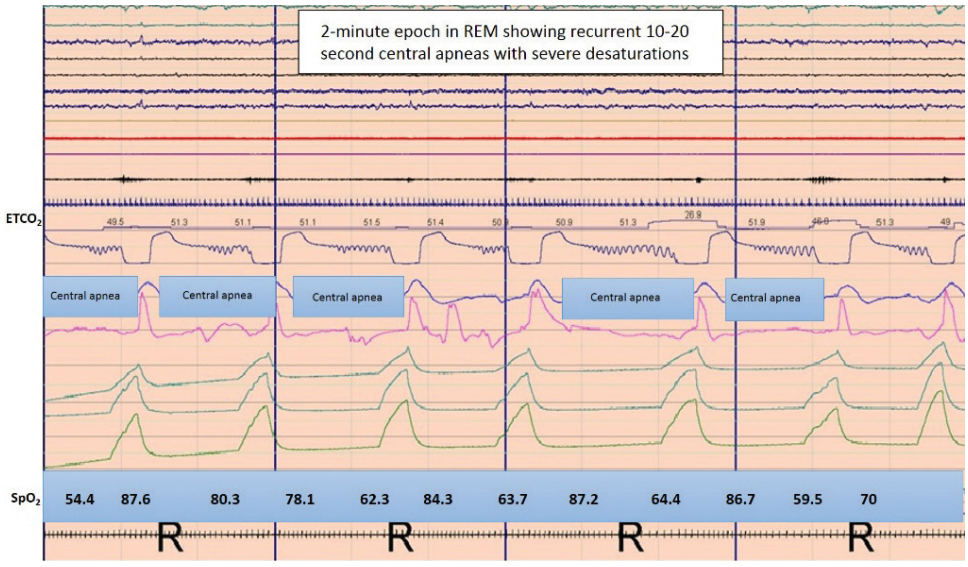
REPORT OF CASE

A 10-year-old male with a history of allergic rhinitis, snoring, and daytime sleepiness presented to otolaryngology clinic for evaluation of obstructive sleep apnea. Symptoms noted at the time of initial evaluation included frequent nighttime arousals with loud snoring. The patient's mother also reported that she noticed some pauses in his breathing during sleep followed by deep sigh breaths. The patient was also noted to have daytime sleepiness but overall normal daytime function and academic performance.

Past medical history was notable for seasonal allergies but otherwise unremarkable. The patient was on no chronic medications. On physical examination, the patient had a mild degree of adeno-tonsillar hypertrophy, enlarged nasal turbinates, and a normal body mass index. An overnight polysomnography was ordered to assess for obstructive sleep apnea.

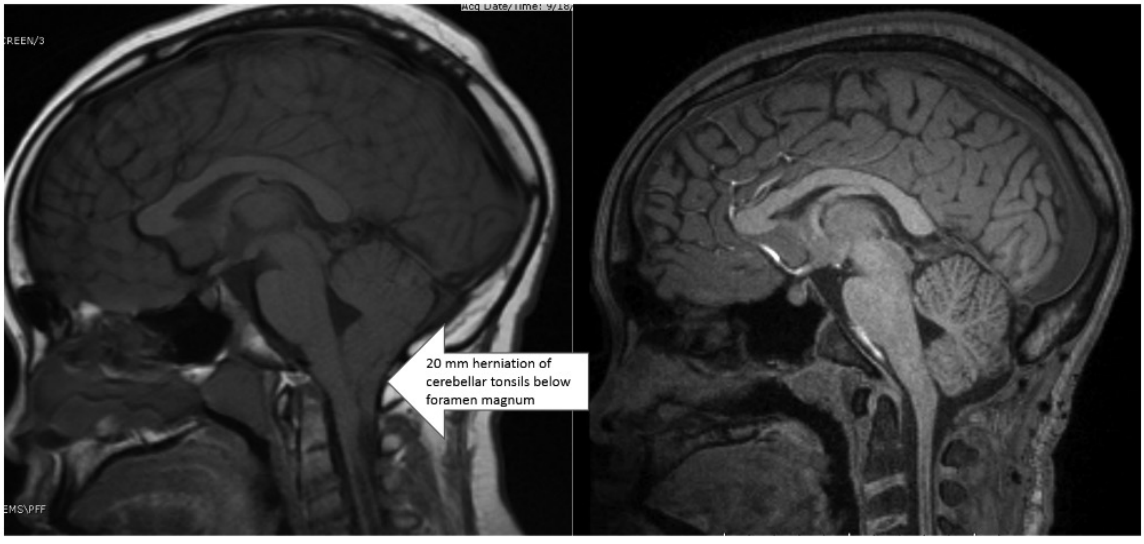
The initial polysomnography revealed a severe degree of CSA (central apnea index 53 events/h), seen both in REM and NREM sleep. The respiratory rate was low and ranged between 3–4 breaths/min. The central apneas lasted between 6–20 seconds in duration and were associated with severe oxygen desaturations (typically 70% to 80% with SpO_2 nadir of 54% in REM sleep) (**Figure 1**). Due to the severity of hypoxia, the patient was placed on supplemental oxygen half-way through the study which blunted the severity of the desaturations but did not affect the underlying breathing pattern. There was also a moderate elevation in end-tidal CO_2 ($ETCO_2$) values (with peak $ETCO_2$ 63 mmHg) with increase in $ETCO_2$ primarily during REM sleep. There was snoring noted but no obstructive sleep apnea on the study (obstructive apnea-hypopnea index 0 events/h).

Figure 1—Epoch of REM sleep.



This figure shows a 2-minute epoch of REM sleep showing recurrent 10 to 20-second central apneas with severe desaturation.

Figure 2—MRI.



Preoperative MRI (left) and postoperative MRI (after 2 years) (right).

Immediately following the outpatient polysomnogram, the patent was admitted to the pediatric inpatient ward for further work-up and treatment. An MRI of the brainstem area was performed. This imaging study revealed severe cerebellar tonsillar ectopia with the cerebellar tonsils extending 2 cm (20 mm) below the foramen magnum (normal < 6 mm) with resultant crowding and compression on the ventral surface of the medulla against the bony surface along with loss of adequate ventral and dorsal cerebrospinal fluid spaces (**Figure 2**). A syrinx was identified extending from C2 to T12 measuring a maximum of 8 mm at C6 and tapering in the mid-thoracic levels.

The patient was subsequently evaluated by otolaryngology who performed a nasolaryngoscopy which showed mild adenotonsillar hypertrophy and normal bilateral vocal cord movement. Swallow and gag function were normal. Upon more detailed history-taking, the patient described a low-grade occipital headache for several years. He also described an occasional pattern of numbness and tingling of his upper back/shoulders and bilateral extremities in a cape-like distribution. Physical examination revealed the presence of mild horizontal end-nystagmus.

The patient was started on bilevel positive airway pressure (BPAP) treatment with a backup rate (settings: IPAP 12, EPAP 6, rate 12) which was well-tolerated with improvements in gas exchange. During this admission, the patient underwent a C1 laminectomy, partial resection of the cerebellar tonsils, and full duroplasty (posterior fossa decompression). At the time of neurosurgical resection, the cerebellar tonsillar herniation was noted to be "very tight" by the surgeon, and there was a mild degree of necrosis of the tip of cerebellar tonsils which were resected. The recovery was uneventful. Postoperatively,

Table 1—Polysomnographic data.

Time Interval Post-Surgery	CAI (events/h)	%REM Sleep	REM CAI (events/h)	Avg. Respir. Rate (breaths/min)	SpO_2 nadir (%)	Time With SpO_2 < 92%	Time With $ETCO_2$ > 50
Pre-surgery	53.0	30.4	81	3–4	54	22.0	Not calculated, peak 63 mmHg
4 months	9.0	20.8	21	3–7	83	0.6	Not calculated, peak 59 mmHg
15 months	26.0	32.9	55	5–8	88	0.3	35
36 months	9.6	31.0	11	5–9	87	0.2	28
48 months	9.0	21.2	18	4–7	89	0.1	0
68 months	13.0	28.8	41	4–6	80	0.5	33
88 months	1.1	19.7	4	8–10	92	0.0	0

Obstructive apnea-hypopnea index is 0 events/h on all studies. Avg. = average, CAI = central apnea index, REM = rapid eye movement, Respir. = respiratory.

he continued to use BPAP during sleep with good clinical response. Due to severity of baseline CSA, the patient was discharged on BPAP during sleep.

On follow up, he reported significant improvement in his headaches and sleep quality. His neurologic symptoms, including nystagmus, numbness and tingling, also resolved. He felt more refreshed after sleep with improvements in daytime sleepiness. He underwent a first repeat sleep study off BPAP at 3 months post-surgery. In this study, the patient showed significant improvement in CSA compared to initial study but continued to show a pattern residual central apneas, worse in REM sleep. The central apnea index was 9 events/h (down from 53 events/h) with SpO_2 nadir of 83% (previous SpO_2 nadir 54%). These events were seen more frequently in REM (REM central apnea index 21 events/h). The patient continued on nocturnal BPAP, and continued to have follow-up polysomnograms on an annual basis to assess resolution and need for further treatment. Full details of these polysomnograms over time are presented in **Table 1**.

Around 15 months after surgery, the patient continued to have ongoing CSA (central apnea index of 26 events/h) associated with moderate oxygen desaturations (approximately 80%) as well as mild hypoventilation (35% of sleep time with $ETCO_2$ > 50 mmHg). These central apneas now appeared to be more prolonged in duration, up to 40 seconds. He continued to use BPAP over next 4 years with no changes in his settings required. Although the patient continued to show gradual improvement in CSA, mild hypoventilation, especially during REM sleep persisted.

At 68 months after decompression surgery, the residual central apnea index was improved to 13 events/h (REM-dominant, length: 10–28 seconds, associated with moderate SpO_2 desaturation to 80%). His last sleep study was completed 7.5 years following surgery and showed near complete resolution of CSA. Although there were occasionally few central pauses noted, there were no significant oxygen desaturations or hypoventilation noted. BPAP has now been discontinued. The patient has been followed at 4–6 month intervals in sleep clinic for the year after BPAP was discontinued. The patient has done well clinically, without any snoring or headaches and is doing well academically, now attending college. The patient continues to follow in sleep medicine clinic on an annual basis with plans to repeat sleep baseline sleep study in 2 years or sooner if concerning symptoms arise.

DISCUSSION

ACMs are a group of heterogeneous congenital disorders of the hindbrain and cervico-medullary junction. ACMs were first described based on autopsy reports in 1891.[2] The most common type of Arnold Chiari disorders is ACM1, which is characterized by downward herniation of the cerebellar tonsils through the foramen magnum displaced into the upper cervical canal. The clinical symptoms of this disorder are widely variable, ranging from patients who are asymptomatic to patients who present with a host of clinical symptoms, which may include posterior headaches, cranial nerve palsies, sensory deficits, nystagmus, scoliosis, torticollis and/or myelopathy due to syringomelia.[3]

Sleep-disordered breathing, including obstructive sleep apnea, bradypnea, CSA, and hypoventilation, are described in pediatric and adult patients with ACM1; sleep-disordered breathing is not uncommon and has been reported in up to 50% to 75% of patients.[4,5] CSA is usually detected on polysomnography and may be the presenting sign of this underlying condition in an otherwise asymptomatic patient.

Patients with ACM1 are at risk for various types of sleep-disordered breathing likely due to several mechanisms. Lower cranial nerve impairment may lead to obstructive apnea events by resultant pharyngeal collapse due to muscular hypotonia or atrophy.[6] Although the exact mechanism is not clear, CSA may occur as a result of dysfunction of ventral central respiratory centers in the medulla oblongata and reticular activating system.[1]

In our clinical experience, there may be night-to-night variability in the severity of the sleep apnea, which may be related to positional changes in the CSF flow dynamics or differences in the underlying arousal threshold. These children can also present with severe bradypnea (low respiratory rate) with a respiratory rate as low as 2–5 breaths/min. These central apneas can result in significant oxygen desaturations and/or EEG arousals causing sleep fragmentation leading to daytime sleepiness and learning difficulties.

The severity of central apneas in children with ACM is usually thought to be related to the degree of herniation; however, this association is not necessarily found in all patients. A prior study noted that children with even a mild degree of cerebellar herniation (6–7 mm) can also have severe CSA.[7] There are various additional anatomic factors which determine the severity of CSA. In a series of pediatric patients with ACM1, Katwa et al. describe multiple radiographic abnormalities including extent of herniation, angulation of dens, CSF fluid attenuation, and presence of syrinx as important radiographic factors which are associated with the severity of central sleep-disordered breathing, thus suggesting that the combination of multiple anatomic factors are likely involved in the pathogenesis of sleep-disordered breathing in these patients.[7]

Although there is some literature available describing MRI findings and polysomnographic data upon diagnosis of ACM1, there is very limited literature regarding long-term follow-up after decompression. The scant amount of available published follow-up data after decompression is limited to adult studies and only case reports in pediatric patients. In a 1994 case series by Nagib et al., five pediatric patients with sleep apnea and ACM were noted to have "improvement" in sleep apnea with time, but the details of the polysomnograms are not available, nor the timing of repeat studies. The ages of all children with sleep apnea in this cohort were less than 6 years at presentation.[8] In a 1995 case report by Keefover, a teenager was described who presented with daytime hypersomnia and severe CSA in the setting of ACM1. This patient was reported to have resolution of CSA at 1 month, but long-term data are not described.[9] Hershberger and Chidekel describe a 3-year-old female with severe sleep apnea at presentation with significant improvement at 12 months after surgery. Of note, the patient was noted to have some ongoing respiratory abnormalities on a study at 12 months post-surgery (5% of total sleep time with periodic breathing) and mild hypoventilation (27% of total sleep time > 50 mmHg), though she was doing well clinically requiring any further intervention.[10]

Similarly, in the adult literature, data regarding long-term outcomes in these patients are very limited. One case series by Gagnadoux at al. describes outcome of sleep apnea in a cohort of adult (mean age 38.1 years) patients with ACM1 with syringomyelia. Out of 12 patients with sleep apnea, 8 patients underwent posterior fossa decompression, and postoperative sleep study data are described in 6 of these patients. Although the authors report a significant decrease in the mean apnea-hypopnea index after surgery in these patients and significant reduction in central apnea burden, closer inspection of the details of the polysomnograms shows that 4/6 of the patients continued to have at least moderate severity of sleep apnea with apnea-hypopnea index > 15 events/h on postoperative studies. Two patients had severe sleep apnea with apnea-hypopnea index ≥ 75 events/h, and two patients continued to have predominantly central apnea.[11]

As limited long-term data exists regarding the prognosis of CSA in these patients over time, increased knowledge of the long-term prognosis is clearly needed so that providers can accurately counsel patients about expectations after surgery. Older pediatric patients with more severe sleep apnea at presentation may be less likely to have abrupt resolution of sleep apnea compared to younger patients. Therefore, noninvasive support may be necessary, before and at least for some period of time after surgery based on the severity of residual sleep apnea to prevent sleep fragmentation and gas exchange abnormalities and improve long-term neurocognitive function.

This case illustrates that CSA may take several years to completely resolve in children with ACM following decompression surgery even though there are significant improvements in other clinical symptoms. This patient was successfully treated with BPAP in the postoperative period and for several years following surgery. Regular follow-up and periodically performing polysomnograms are critical in understanding the natural course of the CSA in ACM after surgery, which may greatly vary in individual patients. Larger and multi-center reports and polysomnography data over time are needed in order to understand characteristics of children that are associated with persistent disease after surgery.

ABBREVIATIONS

ACM, Arnold Chiari malformation
ACM1, Arnold Chiari malformation type 1
BPAP, bilevel positive airway pressure
CSA, central sleep apnea
EPAP, expiratory positive air pressure
$ETCO_2$, end-tidal CO_2
IPAP, inspiratory positive air pressure
MRI, magnetic resonance imaging
REM, rapid eye movement

REFERENCES

1. Leu RM. Sleep-related breathing disorders and the Chiari I malformation. *Chest.* 2015;148(5)1346–1352.
2. Chiari H. Concerning alterations in the cerebellum resulting from cerebral hydrocephalus. 1891. *Pediatric neuroscience.* 1987;13(1):3–8.
3. Yassari R, Frim D. Evaluation and management of the Chiari malformation type 1 for the primary care pediatrician. *Pediatric clinics of North America.* 2004;51(2):477–490.
4. Ferre A, Poca MA, de la Calzada MD, et al. Sleep-related breathing disorders in Chiari malformation type 1: a prospective study of 90 patients. *Sleep.* 2017;40(6).
5. Ferre Maso A, Poca MA, de la Calzada MD, Solana E, Romero Tomas O, Sahuquillo J. Sleep disturbance: a forgotten syndrome in patients with Chiari I malformation. *Neurologia (Barcelona, Spain).* 2014;29(5):294–304.
6. Botelho RV, Bittencourt LR, Rotta JM, Tufik S. Adult Chiari malformation and sleep apnoea. *Neurosurgical review.* 2005;28(3):169–176.

7. Khatwa U, Ramgopal S, Mylavarapu A, et al. MRI findings and sleep apnea in children with Chiari I malformation. *Pediatric neurology.* 2013;48(4):299–307.
8. Nagib MG. An approach to symptomatic children (ages 4-14 years) with Chiari type I malformation. *Pediatric neurosurgery.* 1994;21(1):31–35.
9. Keefover R, Sam M, Bodensteiner J, Nicholson A. Hypersomnolence and pure central sleep apnea associated with the Chiari I malformation. *Journal of child neurology.* 1995;10(1):65–67.
10. Hershberger ML, Chidekel A. Arnold-Chiari malformation type I and sleep-disordered breathing: an uncommon manifestation of an important pediatric problem. *Journal of pediatric health care.* 2003;17(4):190–197.
11. Gagnadoux F, Meslier N, Svab I, Menei P, Racineux JL. Sleep-disordered breathing in patients with Chiari malformation: improvement after surgery. *Neurology.* 2006;66(1):136–138.

SUBMISSION & CORRESPONDENCE INFORMATION

Submitted for publication October 9, 2018
Submitted in final revised form December 26, 2018
Accepted for publication February 6, 2019
Address correspondence to: Dr. Umakanth Katwa, Boston Children's Hospital, 333 Longwood Avenue, LO 570, Boston, MA 02115; Email: Umakanth.katwa@childrens.harvard.edu

DISCLOSURE STATEMENT

All authors participated in this case report and approved this submission. The authors do not have any conflicts of interest to disclose.