

Otolaryngologic Manifestations of Achondroplasia

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Objective: To describe the common otolaryngologic manifestations in patients with achondroplasia.

Design: Retrospective review.

Setting: Tertiary care children's hospital.

Patients: Twenty-two patients with achondroplasia, who were treated from 1994 to 2005, with a focus on otolaryngologic diagnoses.

Main Outcome Measures: Descriptive statistics of common otolaryngologic diagnoses in patients with achondroplasia.

Results: Of the 22 patients, 15 (68%) received an otologic diagnosis, including 6 with recurrent otitis media and 5 with otitis media with effusion, and 11 patients (50%) underwent an otologic procedure, with 10 under-

going tympanostomy tube insertion. Nine patients (41%) had adenotonsillar hypertrophy, 6 of whom had polysomnogram-documented obstructive sleep apnea. Seven patients underwent adenotonsillectomy (TA). Two patients had significant residual postoperative obstructive sleep apnea, and 1 patient died from acute respiratory distress syndrome following TA. All patients had preoperative neurosurgical evaluation for foramen magnum stenosis, with 11 (50%) requiring decompression. No other airway or laryngeal diagnoses were seen.

Conclusion: Patients with achondroplasia often present with common diagnoses such as otitis media and adenotonsillar hypertrophy, and familiarity with the condition and its common otolaryngologic manifestations improves the likelihood of successful patient care.

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PREOPERATIVE NEUROSURGICAL evaluation for foramen magnum stenosis is essential. Patients undergoing adenotonsillectomy (TA) for obstructive sleep apnea (OSA) may be at a higher risk of postoperative respiratory complications and require close monitoring, often in the intensive care unit. These patients may also benefit from postoperative polysomnography (PSG) because they may have significant residual OSA following surgery.

As the most common of the more than 200 skeletal dysplasias, with an incidence between 1:15 000 and 1:40 000 live births,¹ achondroplasia is a diagnosis that pediatric otolaryngologists will likely encounter in clinical practice. Although patients may present with common otolaryngologic conditions such as otitis media (OM) and adenotonsillar hypertrophy, their treatment and outcomes can differ significantly.

The genetic defect for achondroplasia has been identified as an arginine for glycine substitution in amino acid 380 in the

gene encoding for fibroblast growth factor receptor 3 (FGFR3).² Faulty endochondral ossification results³ and produces the characteristic phenotype. Patients with achondroplasia are recognized by their short stature, with short proximal limb segments, referred to as rhizomelia. In the head and neck region, they often display macrocephaly and a prominent forehead. Midface hypoplasia and a depressed nasal bridge further characterize their appearance and can contribute to nasal and upper airway obstruction.¹

As a result of these anatomic characteristics, patients with achondroplasia are at risk for several complications resulting from their disease. The combination of narrow nasal cavities, midface hypoplasia, and hypotonia predisposes them to upper airway obstruction and OSA, which can be exacerbated by concomitant adenotonsillar hypertrophy. Foramen magnum stenosis requiring eventual surgery is common in patients with achondroplasia, with a cumulative rate of 16% by adulthood,⁴ and can contribute to cervicomedullary compression and central apneas

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Table 1. Summary of Otolaryngologic Diagnoses

Patient No./Sex	Ear	Nose	Throat	Comment
1/F	RAOM, CHL	AH, RARS	None	None
2/M	RAOM	RARS	None	None
3/M	None	AR, AH, ARS	ATH, OSA	Persistent OSA
4/M	RAOM	Nasal obstruction	None	Persistent central apneas
5/F	COME	None	ATH, OSA	No postoperative PSG
6/M	AOM	ARS, orbital cellulitis	ATH, OSA	None
7/M	RAOM	None	Snoring	None
8/F	None	None	None	Respiratory arrest
9/F	None	AR	None	None
10/F	OME, perforation	Rhinorrhea	ATH	None
11/F	None	None	None	None
12/M	COME, RAOM, CHL	None	ATH, OSA	Persistent OSA
13/M	None	Multiple URI	ATH	None
14/M	AOM	Nasal obstruction	ATH, OSA	No postoperative PSG
15/M	COME	None	ATH, OSA	Postoperative death
16/M	RAOM	None	None	None
17/M	None	None	None	None
18/M	None	None	None	None
19/F	COME, CHL	AH	ATH	None
20/M	COME	None	None	None
21/F	OME, CHL	None	None	None
22/M	Perforation	None	None	Residual perforation

Abbreviations: AH, adenoid hypertrophy; AOM, acute otitis media; AR, allergic rhinitis; ARS, acute rhinosinusitis; ATH, adenotonsillar hypertrophy; CHL, conductive hearing loss; COME, chronic otitis media with effusion; OME, otitis media with effusion; OSA, obstructive sleep apnea; PSG, polysomnogram; RAOM, recurrent acute otitis media; RARS, recurrent acute rhinosinusitis; URI, upper respiratory tract infection.

with or without hydrocephalus. In severe cases, sudden death^{5,6} has been reported. Lumbar spinal stenosis can also lead to neurologic deficits later in life, such as leg claudication and incontinence. There can often be a characteristic thoracic deformity, leading to restrictive lung disease, and further compounding any upper airway difficulties.

Prior studies have described either otologic disease⁷ or sleep-related breathing disorder⁸⁻¹⁰ in patients with achondroplasia. To our knowledge, no previous articles have attempted to comprehensively describe the otolaryngologic manifestations of achondroplasia in a specific patient population.

METHODS

Following approval by our institutional review board, the electronic and paper medical records of all patients with achondroplasia receiving care at a tertiary care pediatric hospital from 1994 to 2005 were reviewed. These patients were identified by a search for *International Classification of Diseases, Ninth Revision (ICD-9)* code 756.4 (chondrodystrophies). Only those patients formally labeled with the diagnosis of achondroplasia by a pediatric or pediatric subspecialty service were included for review in this project. Patients identified as having other skeletal dysplasias were excluded.

Medical records for each patient with achondroplasia were reviewed in their entirety, with particular attention paid to any otolaryngologic diagnoses or head and neck manifestations of the disease. A patient was recorded as having the diagnosis if it was listed in any medical note, progress note, clinic letter, operative report, or other formal documentation of a patient encounter with a physician or physician extender. The diagnosis was made on clinical and radiographic grounds. Otolaryngologic diagnoses were initially categorized as otologic, rhi-

nologic, pharyngeal/upper airway, and cervical. Because of significant overlap in the rhinologic and pharyngeal categories, they were eventually condensed into a single upper airway category. No cervical diagnoses were identified, and this category was eliminated from further review.

With each specific diagnosis, attempts were made to identify and record the age and timing of diagnosis, diagnostic studies performed, medical and surgical therapies instituted, outcomes, and complications. Descriptive statistics were used because of the small sample size.

RESULTS

Fifty-nine patients were identified by a search for the *ICD-9* code 756.4. On further review, 22 patients were diagnosed as having achondroplasia and were included for further detailed review. All of the excluded patients had diagnoses of skeletal dysplasias other than achondroplasia. Of the 22 patients, 14 were male and 8 were female.

When screening for otologic diagnoses, 15 (68%) of the 22 patients had some otologic pathologic condition documented (**Table 1**). Six patients had recurrent acute OM, while 5 patients were diagnosed as having chronic OM with effusion, indicating middle ear effusions persisting 3 months or longer. One patient had both diagnoses. Two patients were also diagnosed as having chronic tympanic membrane perforations. No patients were diagnosed as having cholesteatoma, chronic suppurative OM, mastoiditis, or other sequelae of OM.

Audiograms were available for review in 7 (47%) of 15 patients with otologic disease (**Table 2**). A cumulative total of 19 audiograms were performed in 7 patients, with 6 patients having multiple audiograms. Conductive hearing loss (CHL) predominated and was

Table 2. Audiometric Findings

Patient/Age	Right Tympanogram	Right Hearing	Left Tympanogram	Left Hearing	Comment
Patient 1					
2 y 3 mo	NA	NA	NA	CHL	None
11 y 10 mo	NA	NA	NA	CHL	None
Patient 5					
5 y 4 mo	B	Mild CHL	B	Mild CHL	BMT at age 5 y 5 mo
5 y 5 mo	Patent tube	Mild low-frequency CHL	Patent tube	Normal	None
5 y 11 mo	Patent tube	Normal	Patent tube	Normal	None
Patient 12					
3 y 0 mo	NA	CHL	NA	CHL	BMT at age 3 y 3 mo
3 y 4 mo	Patent tube	Normal	Patent tube	Normal	None
Patient 19					
7 y 9 mo	A	Normal	B	Mild to moderate CHL	BMT at age 7 y 11 mo
8 y 1 mo	Patent tube	Normal	Patent tube	Mild low-frequency CHL	None
Patient 20					
10 y 5 mo	Patent tube	Mild SNHL	Patent tube	Mild SNHL	None
10 y 8 mo	Patent tube	Mild SNHL	Patent tube	Mild SNHL	SNHL later worsened AU
13 y 0 mo	NA	High-frequency SNHL; low-frequency CHL	NA	High-frequency SNHL	Left tube removal and myringoplasty at age 13 y 1 mo
13 y 3 mo	Patent tube	High-frequency SNHL	C	High-frequency SNHL	None
13 y 6 mo	NA	High-frequency SNHL; low-frequency CHL	NA	High-frequency SNHL; mild to moderate CHL	Left tube inserted at age 13 y 6 mo
13 y 7 mo	Patent tube	Stable SNHL; mild CHL	Patent tube	Stable SNHL	None
Patient 21					
3 y 7 mo	B	Mild CHL	B	Mild CHL	None
Patient 22					
17 y 7 mo	NA	NA	NA	Mild CHL	
19 y 2 mo	NA	NA	NA	Mild to moderate CHL	Left tympanoplasty at age 21 y 6 mo
22 y 2 mo	NA	Normal (ABR)	NA	Mild hearing loss (ABR)	None

Abbreviations: ABR, auditory brainstem response; AU, both ears; BMT, bilateral myringotomy with tube; CHL, conductive hearing loss; NA, not available; SNHL, sensorineural hearing loss.

identified in at least 1 ear in 13 (68%) of the 19 audiograms performed, involving all 7 patients having audiograms at some point in their care. Only 1 patient (patient 20) had an underlying sensorineural hearing loss. This later worsened in the higher frequencies in both ears without an obvious precipitating cause. No records of hearing aid use were documented, and no radiologic imaging was performed.

Of the 22 patients, 11 underwent a cumulative total of 24 otologic procedures (**Table 3**). Ten different patients had tympanostomy tubes inserted, 9 of which were bilateral myringotomies with tube placement (BMT). Five of these patients required multiple tube insertions, with a range between 2 and 4 procedures. Two patients (patients 14 and 20) underwent myringoplasties, both in conjunction with tympanostomy tube removal. One patient (patient 22) had a type I tympanoplasty for a long-standing tympanic membrane perforation secondary to trauma. At the last documented postoperative follow-up 8 months after surgery, this patient still had a residual pinpoint perforation.

The CHL normalized in 4 (67%) of 6 ears after placement of tympanostomy tubes (Table 2). Two ears had documented low-frequency CHL even with patent tympanostomy tubes in place. In 1 ear (patient 5), the CHL normalized without further intervention, and in the other (patient 19), no further audiometric testing was performed.

When combining the rhinologic and pharyngeal categories into a single upper airway category, 9 (41%) of 22 patients were diagnosed as having adenotonsillar hypertrophy (Table 1). Three patients (14%) were specifically listed as having isolated adenoid hypertrophy. Two patients (10%) had recurrent acute rhinosinusitis, both of whom required only medical therapy. One patient required inpatient admission for intravenous antibiotics to treat an orbital cellulitis stemming from acute sinusitis.

Polysomnography was performed in 9 patients suspected of having sleep apnea (**Table 4**). They were performed at an age range of 2 months to 12 years 11 months, with a mean of 2 years 11 months. Findings from only 2 PSGs were interpreted as normal. Seven patients had a PSG demonstrating OSA (Table 4). The range of preoperative obstructive apnea-hypopnea indexes was from 2.0 to 35.2 events per hour, while the lowest preoperative oxygen saturations ranged from 46% to 82%. One of the 7 patients (patient 4) had primarily central sleep apnea and eventually underwent foramen magnum decompression. Of the remaining 6 patients with abnormal PSGs, 5 underwent TA, while 1 refused surgery.

A total of 7 patients (32%) underwent TA to correct upper airway obstruction (**Table 5**). None of the patients underwent TA for the indication of recurrent and/or chronic adenotonsillitis. Of these 7 patients, 5 had abnormal preoperative PSGs. At the discretion of the individual attending surgeon, 2 patients had no preopera-

Table 3. Otolgic Surgical Procedures

Patient/Age	Diagnosis	Otolgic Surgery	Complication
Patient 1 12 y 9 mo	RAOM	Left tube	None
Patient 2 0 y 6 mo	RAOM	BMT	Tube otorrhea
Patient 5 1 y 0 mo	COME	BMT	None
2 y 11 mo	COME	BMT	None
5 y 5 mo	COME	BMT	None
Patient 10 1 y 4 mo	CHL	BMT	None
2 y 10 mo	CHL	BMT	Right TM perforation
8 y 8 mo	OME	BMT	None
9 y 9 mo	OME	BMT	None
Patient 12 3 y 3 mo	COME	BMT	None
Patient 14 1 y 4 mo	AOM	BMT	Plugged right tube
2 y 6 mo	Plugged tube	Right tube	None
4 y 2 mo	Unknown	BMT	None
5 y 9 mo	Unknown	BMT, bilateral fat graft myringoplasties	None
Patient 15 2 y 5 mo	COME	BMT	Postoperative mortality
Patient 16 5 y 0 mo	RAOM	BMT	None
Patient 19 Unknown	COME	BMT	None
7 y 10 mo	COME	L tube	None
Patient 20 1 y 5 mo	COME	BMT	None
4 y 3 mo	COME	BMT	None
5 y 10 mo	COME	BMT	Left tube granuloma
13 y 2 mo	Left tube granuloma	Left tube removal and myringoplasty	Left COME
13 y 7 mo	Left COME	Left tube	None
Patient 22 21 y 6 mo	Left TM perforation	Left tympanoplasty	Residual pinpoint perforation

Abbreviations: AOM, acute otitis media; BMT, bilateral myringotomy with tubes; CHL, conductive hearing loss; COME, chronic otitis media with effusion; NA, not available; OME, otitis media with effusion; RAOM, recurrent acute otitis media; TM, tympanic membrane.

tive or postoperative PSGs. In addition, 2 patients (patients 1 and 14) underwent adenoidectomy without tonsillectomy. One patient (patient 1) required no further upper airway surgery, while another (patient 14) later required TA for persistent upper airway obstruction.

Of the 5 TA patients with preoperative PSGs, 2 were lost to follow-up during the postoperative period before obtaining a postoperative PSG. One postoperative mortality was observed. Two patients underwent postoperative PSG, and the results for both were abnormal. Further nonsurgical treatment was recommended based on these follow-up PSGs (**Figure**).

Table 4. Polysomnographic Findings

Patient/Age	OAHl	Lowest Oxygen Saturation, %	Comment
Patient 3 2 y 0 mo	24.8	56	TA at age 2 y 1 mo
2 y 7 mo	54.7	39	First postoperative PSG
2 y 9 mo	50.7	54	None
3 y 7 mo	85.8	35	OAHl off BiPAP = 120.5
4 y 5 mo	54.6	69	BiPAP continued
6 y 0 mo	27.4	56	None
Patient 4 0 y 2 mo	NA	81	1 Obstructive apnea, 109 obstructive hypopneas
0 y 4 mo	NA	NA	88 Total central apneas
Patient 5 2 y 9 mo	35.2	46	TA at age 2 y 11 mo
12 y 11 mo	22.3	68	No surgery
0 y 7 mo	NA	NA	Normal study findings
Patient 12 2 y 5 mo	5.65	84	None
2 y 10 mo	16.4	68	TA at age 3 y 3 mo
3 y 7 mo	12.4	73	Recommended VapoTherm (VapoTherm Inc, Stevensville, Md)
Patient 14 0 y 1 mo	NA	NA	9 Central apneas, 2 obstructive apneas, 17 hypopneas
2 y 5 mo	2.0	<82	TA at age 2 y 6 mo
Patient 15 3 y 8 mo	16.0	80	Postoperative mortality
Patient 21 1 y 3 mo	NA	NA	Normal study findings

Abbreviations: BiPAP, biphasic positive airway pressure; NA, not available; OAHl, obstructive apnea-hypopnea index; PSG, polysomnogram; TA, adenotonsillectomy.

One patient (patient 15) developed acute respiratory distress syndrome 1 day after undergoing TA. This patient had a preoperative obstructive apnea-hypopnea index of 16 events per hour and was monitored the first night after surgery in the intensive care unit. Shortly after transfer to the inpatient unit on postoperative day 1, the patient was found to be in significant respiratory distress and was transferred back to the intensive care unit. Chest radiographs demonstrated pulmonary infiltrates and reintubation was required. The patient's clinical condition deteriorated despite aggressive resuscitation in the intensive care unit, and the patient eventually died. A post-mortem study confirmed the diagnosis of acute respiratory distress syndrome.

No patients were diagnosed as having laryngeal or tracheal disorders such as laryngomalacia, vocal cord paralysis, glottic webs, subglottic stenosis, tracheomalacia, or tracheal stenosis.

One patient (patient 8) had a spontaneous cardiac arrest at the age of 6 months, unrelated to any surgical procedures. Speculation centered on hypotonia being a contributing cause because the event occurred while the patient was slumped in a car seat. He subsequently de-

Table 5. Upper Airway Surgical Procedures

Patient/Age	Upper Airway Diagnosis	Upper Airway Surgery	Complications	Outcome
Patient 1 12 y 9 mo	AH	Adenoidectomy	None	Clinically improved
Patient 3 2 y 1 mo	ATH	TA	None	Persistent OSA*
Patient 5 2 y 11 mo	ATH	TA	None	Clinically improved
Patient 10 13 y 1 mo	ATH	TA	None	Clinically improved
Patient 12 3 y 3 mo	ATH	TA	None	Persistent OSA*
Patient 14 1 y 4 mo	AH	Adenoidectomy	None	Recurrent obstruction
2 y 6 mo	ATH	TA	None	Clinically improved
Patient 15 2 y 5 mo	ATH	TA	ARDS and death	Postoperative mortality
Patient 19 Unknown	ATH	TA	None	Unknown

Abbreviations: AH, adenoid hypertrophy; ARDS, acute respiratory distress syndrome; ATH, adenotonsillar hypertrophy; OSA, obstructive sleep apnea; TA, adenotonsillectomy.

*Implies an abnormal preoperative polysomnogram.

veloped multiorgan system failure and died of his disease.

All patients underwent preoperative neurosurgical evaluation for foramen magnum stenosis and cervicomedullary compression. Eleven patients (50%) underwent neurosurgical decompression at some point during their care.

COMMENT

Achondroplasia is the most common genetic form of dwarfism, and is 1 of 3 forms of chondrodysplasia that result from mutations in the gene for the fibroblast growth factor receptor 3 (*FGFR3*). An arginine for glycine substitution in amino acid 380 results in continuous activation of a negative regulator of bone growth within the resting zone of the epiphyseal growth plate.¹¹ By effectively keeping the “off” switch that regulates the growth of long bones turned “on,” their longitudinal growth is stunted. As a result, short stature occurs, giving the characteristic phenotype seen in achondroplasia.

Although a relatively uncommon disorder, pediatric subspecialists practicing in a tertiary care children’s hospital are bound to be involved in their care. They may present with common diagnoses, but diagnostic and treatment strategies must be customized for the patient.

OTOLOGIC DISEASE

Little data have been published on the rates of OM and middle ear dysfunction in the achondroplastic population. Genetics textbooks report that patients with achondroplasia have high rates of OM and CHL and theorize that it is caused by a shortened eustachian tube.¹² Glass et al¹³ reported their comparison of the audiological findings in 28 patients with achondroplasia, with 10 patients having other skeletal dysplasias. The patients with

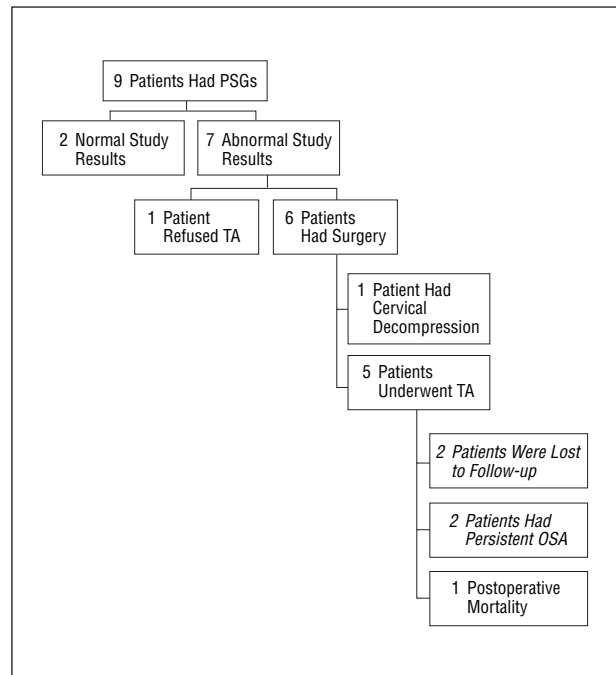


Figure. Outcomes in patients with abnormal polysomnograms (PSGs). TA indicates adenotonsillectomy; OSA, obstructive sleep apnea. Italics indicate clinical improvement.

achondroplasia were identified as having a greater rate of hearing loss than those with other skeletal dysplasias, of which CHL was more common than sensorineural hearing loss. As evidenced by abnormal tympanograms, 51% of the achondroplastic ears were discovered to have abnormal middle ear function.¹³ Only 30% of the other skeletal dysplasias had abnormal tympanograms. Hunter et al⁴ also reported a rate of CHL of 38% by adulthood in patients with achondroplasia, although audiograms were not available for review in all their patients.

Our experience agrees with the previous finding that CHL predominates in patients with achondroplasia. Conductive hearing loss was detected in all 7 of our patients having audiograms, including in 13 (68%) of the 19 audiograms. This CHL resolved after BMT in 4 of 6 ears. In 1 ear, CHL normalized after performing a second postoperative audiogram, while only 1 ear had CHL following BMT for which there was no documented normalization. Sensorineural hearing loss was identified in only 1 patient. The high rate of abnormal audiograms probably reflects in part referral patterns. Surveillance for OM with effusion and CHL in patients with achondroplasia is recommended by the American Academy of Pediatrics.¹⁴ Many patients with normal hearing screening results probably never make it to the attention of otolaryngologists, and therefore the rate of CHL in patients with achondroplasia may be overestimated in our review.

Other authors have chosen to examine the rate of tympanostomy tube insertion as a marker of otologic disease in patients with achondroplasia. Among a retrospective review of 61 patients with achondroplasia, 33 (54%) required tympanostomy tube insertion at some point during their care.⁷ The age at tube insertion ranged from 5 months to 15 years. The study population also developed some sequelae of OM, including a cholesteatoma in 1 patient and tympanic membrane perforations in 4 patients. Unfortunately, audiometric data were not available. In another small series of 9 patients who underwent temporal bone imaging for hearing loss, tympanostomy tubes were placed in 4, although a selection bias likely skewed this patient set toward the more severely otologically affected.¹⁵

Of our 22 patients, 11 (50%) underwent at least 1 otologic procedure, with BMT being the predominant procedure. Both our rate of tube insertion and the age range of patients undergoing BMT (50% [0 years 6 months–9 years 9 months] vs 54% [0 years 5 months–15 years]) are similar to previously published data.⁷ The study by Berkowitz et al⁷ may have included some of our patients' earlier procedures, however, since it was a multi-institutional study. Other authors have shown an even higher rate of OM and tympanostomy tube insertion.⁴ When compared with the rate of tympanostomy tube insertion in the general pediatric population, the patients with achondroplasia seem to be disproportionately affected by severe middle ear disease requiring surgical intervention. Although 15 (68%) of our 22 patients had documented middle ear disease, whether limited or chronic, 11 (73%) of these 15 patients required otologic surgery. A bias likely exists with our study population because 90% of children will develop at least transient OM with effusion before they reach school age.¹⁶ Undoubtedly, some of the 7 otologically "unaffected" patients with achondroplasia had at least sporadic episodes of acute OM or OM with effusion that were not captured within the medical records in our institution. Community general pediatricians likely managed many such minor and self-limited conditions without seeking referral to pediatric subspecialists. Our experience suggests that the most severely affected children with achondroplasia are referred to subspecialists and receive appropriate otologic intervention.

Prior studies have also described temporal bone imaging abnormalities in patients with achondroplasia. Cobb et al¹⁷

compared 9 patients with achondroplasia, who had high-resolution computed tomographic scanning for hearing loss, with 10 normal controls. Several characteristic findings were noted in the achondroplastic temporal bones. Their mastoid air cells were often poorly developed, the carotid canals were foreshortened, and there was narrowing of the skull base. In addition, the petrous ridges had a "towering" effect, which was most easily identified on the coronal images showing an upward lateral to medial tilt to the internal auditory canals. A rotation of the cochlea also caused the oval window to angle downward. A later analysis of the same patient population revealed that there was no correlation between computed tomographic findings in the temporal bone, such as the "towering" petrous ridges, internal auditory canal diameter or length, and the type or severity of hearing loss.¹⁵ Only 1 of our 22 study patients underwent dedicated computed tomography of the temporal bone. This was performed in patient 22 for suspected cholesteatoma, and the findings showed no evidence of congenital inner ear malformations, cholesteatoma-induced bony erosion, or other otologic anomalies such as those previously described in achondroplasia.

Jugular bulb dehiscence has also been described with a higher than expected frequency in patients with achondroplasia. In a population of 126 patients with achondroplasia, 4 were identified as having jugular bulb dehiscence.¹⁸ A true incidence is hard to extrapolate because not all the patients had adequate temporal bone imaging. Of particular note, however, 2 of the 4 patients had unexpectedly brisk bleeding following myringotomy. No myringotomy-related bleeding complications were documented in our study population. We do not routinely obtain computed tomographic scans of the temporal bone prior to BMT, given the overall low incidence of findings.

RESPIRATORY DIFFICULTIES

Respiratory difficulties are well described in the achondroplastic patient population and span the spectrum from upper to lower airway anomalies. Although not the direct responsibility of the otolaryngologist, pulmonary abnormalities such as restrictive lung disease have been previously documented in less than 5% of patients with achondroplasia younger than 3 years.¹⁹ In addition to their smaller stature, individuals with achondroplasia have been identified to have reduced vital capacity, which is thought to be due to decreased chest wall compliance.²⁰ The reduced vital capacity appears to be out of proportion even when taking the shortened limb size into account.²¹ Although otolaryngologists are rarely called on to manage intrinsic pulmonary disease, awareness of the comorbidities in patients with achondroplasia can help prevent perioperative complications.

Of more direct interest, however, are the upper airway anomalies previously described in patients with achondroplasia. Tasker et al²² described 3 distinct phenotypes of patients with achondroplasia based on their patterns of respiratory difficulties. The least severely affected group was characterized primarily by adenotonsillar hypertrophy and midface hypoplasia. This was also the subset of patients who had the greatest improvement after TA.

A second group had more severe respiratory difficulty but did not require supplemental oxygen.²² These patients more commonly had foramen magnum stenosis, hydrocephalus, and jugular foramen stenosis. They did not show great improvement following TA. The third and final group was the most severely affected. Most had severe gastroesophageal reflux disease and cor pulmonale and required supplemental oxygen. Adenotonsillectomy did not provide significant improvement in this population, since they often had central sleep apnea, as well as coexistent small airway disease.²² Although our patients did not stratify into distinct categories, we observed a spectrum of disease severity.

Sleep-related breathing disorders occur with an increased incidence in patients with achondroplasia, with incidences of upper airway obstruction and/or OSA quoted as high as 75%.⁸ Although central apneas occur, it appears that obstructive causes are more common and more problematic.⁸

Among a cohort of 88 patients with achondroplasia, 47% had abnormal sleep study findings, with the most common abnormality being hypoxemia.⁹ Much of the hypoxemia was not associated with discrete obstructive or central apneic episodes, suggesting intrinsic lung disease, such as poor pulmonary reserve. Among patients who underwent cervicomedullary decompression, the number of central apneas declined significantly. Eight of their study patients underwent TA for obstructive hypoventilation.⁹ Small numbers precluded statistical comparison, but the patients with the most severe obstruction had the greatest response to surgery. Nonetheless, 2 of these patients had persistent OSA following TA.

Residual OSA in patients with achondroplasia following surgical treatment has been described by other authors as well. The choice of surgery may play a significant role in predicting outcome. Of 10 patients undergoing adenoidectomy as the first-line surgical therapy for upper airway obstruction, 9 required further surgery to correct their obstruction.¹⁰ Sixty percent of a small subset of patients who underwent TA required further treatment for OSA, primarily involving continuous positive airway pressure.²³ Our experience confirmed the rather disappointing results of TA alone in the treatment of OSA in achondroplasia. Unfortunately, small patient numbers preclude statistical analysis, but of the only 2 patients (patients 3 and 12) with both pre-TA and post-TA sleep studies, both showed persistent OSA. One patient (patient 3) even showed an unexplained worsening of his OSA, as evidenced by the obstructive apnea-hypopnea index and lowest recorded oxygen saturation.

Despite the objective evidence, all of our patients were clinically improved at their first postoperative visits, including those with persistently abnormal PSGs. Other authors have suggested that clinical history can be suggestive of OSA in patients with achondroplasia, especially snoring, reported apneas, and glottal stops.¹⁰ Despite the apparent predictive value of snoring, 59% of patients in a study by Sisk et al¹⁰ still snored following TA, but only 8 of 22 patients were considered to have persistent symptoms requiring further investigation. Among our study population, clinical improvement was seen in all patients following TA, but in the 2 patients having postoperative PSGs, persistent OSA requiring further non-

surgical management was identified. This leads us to recommend preoperative and postoperative sleep studies in all patients with achondroplasia being considered for TA to identify and treat persistent OSA in otherwise clinically improved patients. Adenotonsillectomy is probably best reserved for patients with physical examination evidence of tonsillar and/or adenoid hypertrophy and documented OSA.

This high rate of OSA recidivism contrasts with the much higher success rate from TA commonly reported in normal subjects.²⁴ The discrepancy in outcomes points to the multifactorial cause of upper airway obstruction in patients with achondroplasia. Numerous studies have described abnormal somatosensory-evoked potentials (SSEPs) in patients with achondroplasia, indicating abnormalities of brainstem function. Treatment of the upper airway obstruction resulted in improvement of SSEP patterns in 71% of patients, although in this same study, a high rate of residual OSA following surgical therapy seemed to imply that the 2 findings were independent of each other.²³ Sleep architecture also improved following therapy, but obstructions persisted. This confirmed earlier reports that abnormal SSEPs did not correlate with either the type or severity of sleep-related breathing disorder.²⁵ No patients in our study had SSEPs documented for the dates reviewed. But certainly poor upper airway muscle tone, as well as narrowed bony dimensions of the upper airway, could contribute to a high rate of persistent OSA, even after successful performance of an otherwise highly efficacious procedure, such as TA.

In addition to TA, other surgical modalities are available to treat the most severely obstructed patients. Tracheotomy, the gold standard for severe upper airway obstruction and OSA, has been described in patients with achondroplasia.^{9,26} Midface distraction, based on the principle of distraction osteogenesis, has been shown to improve upper airway obstruction in 2 patients with achondroplasia who were tracheotomy dependent.²⁶ Distraction of the midface by 25 mm in each case allowed for resolution of OSA and decannulation. A follow-up of 18 to 24 months has shown no worsening of their airway obstruction.

COMPLICATIONS

Although improved awareness of the complications that can result from achondroplasia can assist the clinician in the care of these patients, significant morbidity and mortality can still occur. In our study population, 2 mortalities occurred. In 1 case (patient 8), a spontaneous cardiac arrest occurred without provocation. The treating physicians seemed to believe that poor head control while sitting in a car seat, possibly due to hypotonia, contributed to first respiratory, then cardiac arrest. In the second fatality (patient 15), the child had known OSA from a preoperative PSG and was appropriately monitored in an intensive care setting the first night after surgery. Only after transfer to the inpatient unit did an irreversible chain of events begin that ultimately led to severe acute respiratory distress syndrome and death.

Other mortalities have been documented in patients with achondroplasia. Sisk et al¹⁰ described 2 patients with achondroplasia, who were excluded from further study

because of their death, but did not provide further details as to the cause. In their most severely affected group, Tasker et al²² also reported that 3 of 5 patients died from severe cardiorespiratory failure. Sisk et al¹⁰ also described complications in 6 patients with achondroplasia after undergoing TA, including postoperative pneumonia, postobstructive pulmonary edema, and bleeding. In all of these cases, the fragile nature of the disease should provide caution to treating otolaryngologists of the high stakes in treating patients with achondroplasia.

As with any retrospective study, there are inherent flaws in our method. Our data are limited by the existing medical records, which are sometimes incomplete or illegible. Nonetheless, we tried to capture each patient visit that resulted in documentation of an otolaryngologic diagnosis, even if the event that occurred at another time was self-limited and did not ultimately lead to referral to a pediatric otolaryngologist. Because many of these patients seek basic primary medical care with community pediatricians, minor visits for acute OM, transient OM with effusion, viral upper respiratory tract infections, pharyngitis, and adenotonsillitis were likely not captured by our review of institutional records, and therefore their true incidence was underreported. It would be a stretch to believe that 15 (68%) of our 22 patients had otologic diagnoses, and such a high percentage (73% [11/15]) ultimately required otologic surgery, while the other 7 patients had absolutely no otologic disease. We believe that the rates of otologic and upper airway surgical procedures, especially BMT and TA, are more reflective of the overall incidence and severity of disease in these patients. Finally, our relatively small study population precludes more powerful statistical analysis. Only a large, multi-institutional study could capture adequate numbers of a relatively uncommon condition to allow stronger statistical analysis.

CONCLUSIONS

Patients with achondroplasia may present to the pediatric otolaryngologist with common complaints and routine diagnoses such as OM and adenotonsillar hypertrophy. Surgical management in these patients requires caution. High rates of residual or recurrent disease, even following successful surgery in clinically improved patients, humble the practitioner. In addition, high rates of foramen magnum stenosis mandate preoperative neurosurgical consultation. An understanding of achondroplasia and its manifestations allows the otolaryngologist to appropriately counsel and treat these patients with reasonable expectations of successful surgical outcomes.

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