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REVIEW ARTICLE Open Access

Causes and treatments of nasal obstruction in children and adolescents: a systematic literature review

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Abstract

Objective: To identify the causes and treatments of nasal obstruction in the paediatric population.

Methods: A systematic search of Medline and Embase was conducted to identify the relevant articles. A detailed inclusion and exclusion criterion was developed and implemented to screen the abstracts. Full texts of the selected studies were then assessed to establish their inclusion or exclusion in our review. All relevant data were extracted, and the results were summarised narratively.

Results: Fifty-nine studies met out inclusion-exclusion criteria and were included in this systematic review. All of these primary research studies were categorised into causes and treatments. Cleft lip and palate was the most reported cause of nasal obstruction among congenital causes. However, among the acquired causes, allergic rhinitis was the most reported. Twenty-one of 39 studies described treatments for allergic rhinitis, including perennial rhinitis, 9 for adenoid hypertrophy, 2 for the common cold, 5 for septal deviation, and 2 for chronic rhinosinusitis.

Conclusion: This systematic review provides good evidence regarding the causes and treatments of nasal obstruction. Allergic rhinitis is the most common cause of acquired nasal obstruction, and cetirizine, fexofenadine, fluticasone furoate nasal spray, and mometasone furoate monohydrate nasal are the commonly used treatments to alleviate the symptoms.

Keywords: Nasal obstruction, Paediatric, ENT, Children, Adolescents

Background

Paediatric nasal obstruction induces various degrees of respiratory distress and impairs various daily and social activities [1]. The condition worsened when the patient is a neonate as the neonates are generally nasal breathers [2]. Nasal obstruction is also associated with a decrease in lip-closing force, especially with the increased severity. Nasal obstruction is one of the primary clinical manifestations of mouth breathing [3]. Chronic cough in children can also be due to nasal obstruction [4]. A study conducted on ninety paediatric patients found a correlation of chronic cough in pre-school children with nasal obstruction with adenoid hyperplasia. In contrast, in other children, it appeared to be mainly associated with allergic rhninitis [4].

Nasal obstruction, a symptom in itself, can be due to congenital or acquired disease. Moreover, there are different types of nasal obstruction, including that caused due to the shape of the inside of the nose, a deformity or inflammation. Although not an urgent diagnosis, nasal obstruction certainly affects the quality of life [5]. A variety of treatments are available for managing various causes of nasal obstruction, including surgical repair; however, the disease management and treatment regimen depend on the obstruction's cause, severity, and location.

This review is therefore conducted to identify the causes and treatments reported in the literature to

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inform the practitioners to consider different causes of nasal obstruction when making the diagnosis and choose the most effective and safe treatment for their patients. In addition, this review will also inform the public to learn their treatment options and make an informed decision for their care.

Objective

The objective of the present systematic literature review was to identify the causes and treatments of nasal obstruction.

Methods

This systematic literature review was conducted to identify evidence demonstrating the causes and treatments of nasal obstruction in the paediatric population. We followed PRISMA reporting guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) for this review [6].

Eligibility criteria

We included studies assessing the potential causes and evaluating the effective treatments of nasal obstruction. Studies only conducted on the pediatric population and published in the English language were included in this systematic review.

A detailed eligibility criterion is reported below in Table 1.

Data sources and search strategy

We searched Medline and Embase to identify and retrieve the relevant articles. The search strategy used for Embase and Medline is reported in the Additional file 1: Appendix and was developed from search terms relating to nasal obstruction and the pediatric population. The search was limited to the studies published in English; however, we did not apply any geographical location. The search results were managed using reference management software 'Zotero' [7].

Study selection

Abstracts were assessed against the eligibility criteria shown in Table 1. The studies were screened in abstract screening software 'Rayyan' [8] by two researchers by title and abstracts, and disagreements were resolved through discussion.

The full texts were obtained for all studies that met the inclusion criteria according to title and abstract screening. Full texts were then assessed using the same inclusion criteria as abstract screening but focused on identifying studies with relevant outcomes. Two reviewers independently conducted full-text screening and resolved the discrepancies through discussion.

Data extraction

We extracted the relevant data into a pre-agreed Microsoft Excel template. Following data were extracted for each eligible study:

1. Study characteristics: Study name, authors, the title of the study, objectives of the study, study design, year of publication, study setting, country, patients' sampling design, and sample size
2. Patients characteristics: Study population (diagnosis), age, gender

Table 1 Inclusion and exclusion criteria

Category	Inclusion criteria	Exclusion criteria
Population	• Paediatric patients • Studies with adult and paediatric patient populations if they report the data separately for adults and children	• Adult population • Studies with adult and paediatric patient populations if paediatric data could not be separated from adults • Studies not reporting the age of the patients
Epidemiologic outcomes	• Causes of nasal obstruction • Available treatments for nasal obstruction	• Articles without relevant outcomes data • Genetic profiling studies • Palliative care studies
Study design	• Cohort studies • Case-control studies • Cross-sectional studies • Randomised controlled trials • Database studies • Case series	• Letters to the editor • Narrative reviews • Editorials • Expert opinions • Case studies
Year of publication	Inception to 16 January 2021	Studies published after 16 January 2021
Language	English language	Non-English language
Filters applied	Human, paediatric	

3. Outcomes: Causes, treatments or techniques, efficacy

Synthesis of findings

A narrative synthesis was performed to synthesise the findings of the included studies. A narrative synthesis constituted the best instrument to synthesise the findings of the studies as the studies were heterogeneous due to the variations in the age groups, interventions assessed and analytical approaches.

A preliminary synthesis was conducted in the form of a thematic analysis that involved study characteristics and results in tabular form. The results were then discussed again and structured into themes. Finally, included studies were summarised narratively in each theme.

The themes were based on the causes and treatments. The outcomes were summarised in groups within each theme as our outcome measures varied considerably among various studies. This framework comprised of the following factors: the cause of nasal obstruction (congenital, seasonal etc.) and the interventions (pharmacological, surgical etc.).

Results

The database search identified 4463 citations, of which 1342 were duplicates, leaving 3121 unique citations for screening. Ninety-seven articles were identified as potentially meeting the inclusion criteria and were retrieved as full texts; 38 of these were excluded for not meeting our inclusion criteria. The remaining 59 studies were subsequently included in this systematic review (Fig. 1).

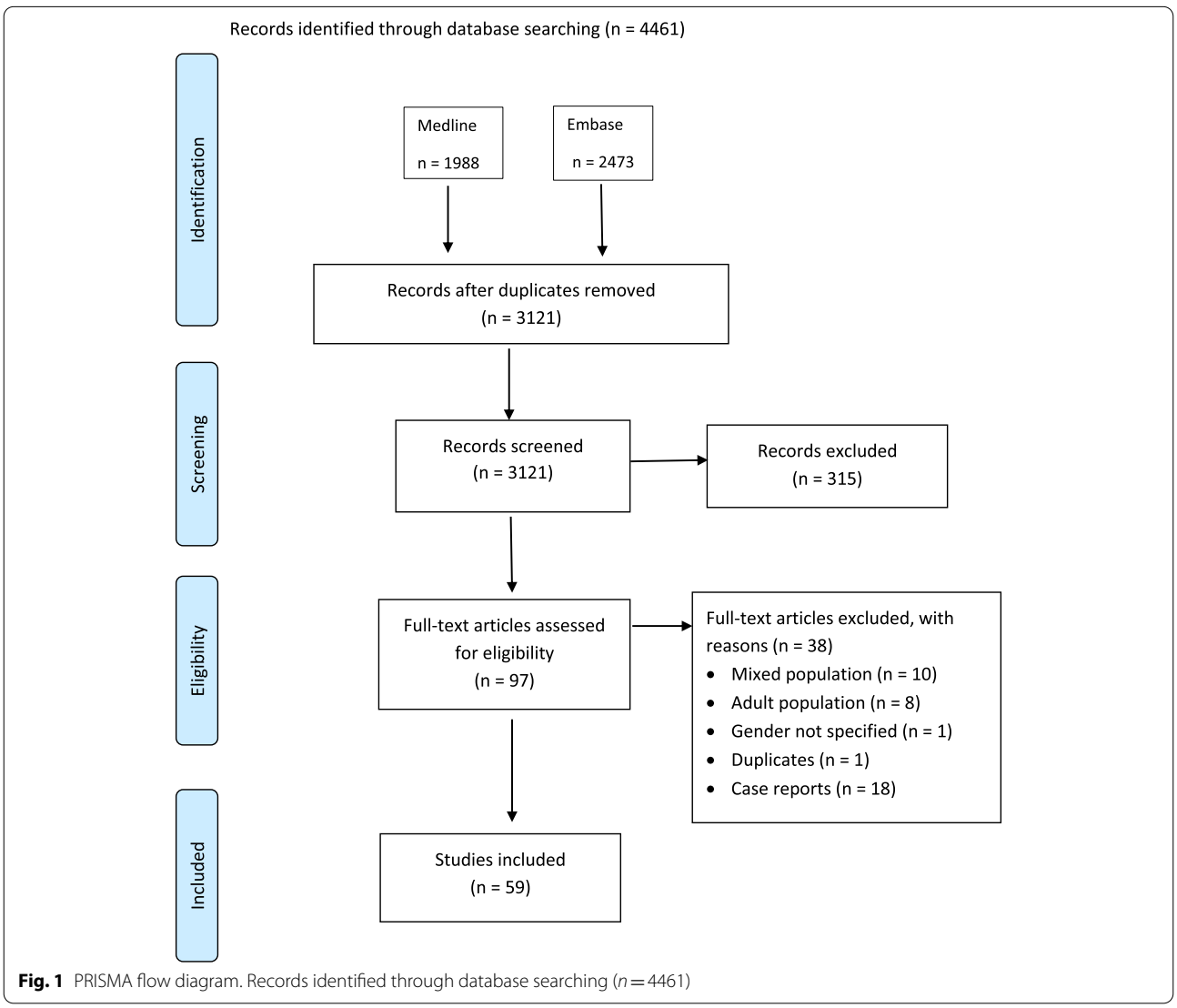

Fig. 1 PRISMA flow diagram. Records identified through database searching (*n* = 4461)

Twenty of these were classified into various etiologies, and the remaining 39 demonstrated treatments for various causes of nasal obstruction. Twenty-one of these studies described treatments for allergic rhinitis, including perennial rhinitis, nine for adenoid hypertrophy, including one for AdenoAmigdalina hypertrophy (HAA); two for the common cold; five for septal deviation including one for septal perforation; and two for chronic rhinosinusitis.

Study characteristics

Fifty-nine studies included in this systematic review all assessed primary research either on the causes of nasal obstruction or the treatment interventions for the same. All 59 studies included paediatric participants only. All twenty studies describing the causes of nasal obstruction used observational cross-sectional or retrospective chart review methodologies, while the studies on nasal obstruction treatments were a mix of randomised controlled trials and observational studies.

Of twenty studies reporting the causes of nasal obstruction, seven were conducted in the USA, two each in China and Poland, and one in each Colombia, Israel, Ireland, Brazil, Guatemala, Egypt, Romania, Italy, and UK. All studies were published in the English language.

All twenty studies reporting on etiologies of nasal obstruction enrolled a total of 2343 participants. Cleft lip and palate were the most reported cause for nasal obstruction, reported in 3 of 20 studies. Congenital nasal pyriform aperture stenosis (CNPAS), nasopharyngeal carcinoma, and antrochoanal polyps (ACPs) were reported twice, while all other causes were only reported once. The summary of included studies is reported in Table 2.

Of thirty-nine studies reporting the treatments for nasal obstruction, eight were conducted in Turkey, 5 in Italy, 3 in the USA, two each in South Korea, England, Thailand, Egypt, and Romania and one in each of China, Brazil, Genoa, Netherlands, Mexico, Thailand, France, Malaysia, Serbia, Japan, South Africa, India, Israel, and Argentina. The country was not reported in 3 studies. All studies were published in the English language. The summary of included studies is reported in Table 3.

Participants' characteristics

All studies enrolled paediatric participants only; ages ranged from 0 to 18 years.

Summary characteristics of the studies included in nasal obstruction causes are reported in Table 2, while

Table 2 Summary of included studies

Study name	Country	Cause	Age (mean/range)	Sample size
Pardo (2020) [9]	Colombia	Congenital nasal pyriform aperture stenosis (CNPAS)	Neonates	13
Reeves (2013) [10]	USA	Congenital nasal piriform aperture stenosis (CNPAS)	Neonates (< 30 days old)	13
Levi (2020) [11]	Israel	Congenital midnasal stenosis	Neonates (birth to 3 months)	9
Patel (2017) [12]	USA	Congenital nasal obstruction in neonates	Neonates	34
Cavazza (2008) [13]	Italy	Congenital dacryocystocele	Neonates (7 to 60 days)	5
Benoit (2008) [14]	USA	Cancer of nasal cavity	7 months to 17 years	16
Weber (2017) [15]	Brazil	Nasal polyposis (in cystic fibrosis)	3 to 16 years	23
Manole (2014) [16]	Romania	Chronic rhinosinusitis (in asthmatic children)	4 to 12 years	248
Liu (2014) [17]	China	Nasopharyngeal carcinoma	62.5 months	158
PoddÄ (2019) [18]	Poland	Adenoid hypertrophy	7 to 12 years	NR
Giron (2017) [19]	Guatemala	Juvenile nasopharyngeal angiofibroma (JNPAF)	8 to 17 years	350
Zheng (2019) [20]	China	Antrochoanal polyps (ACPs)	9 (8 to 11) years	43
Kasprzyk (2017) [21]	Poland	Antrochoanal polyp (ACP)	9 to 16 years	15
Sobol (2016) [22]	USA	Cleft lip and palate	9 to 17 years	176
Zhang (2018) [23]	USA	Cleft lip and palate	9.8 years	63
Zhang (2019) [24]	USA	Cleft lip and palate	10 years	1028
Crealey (2018) [25]	Ireland	Allergic rhinitis (in asthmatic children)	Not reported	89
Abdel-Aziz (2017) [26]	Egypt	Maxillary sinus mucocele (MSM)	15 to 52 years	36
Venkatramani (2016) [27]	USA	Esthesioneuroblastoma (ENB)	14 (0.6 to 20) years	24
Brennan (2006) [28]	UK	Nasopharyngeal carcinoma (NPC)	0 to 18 years	NR

Table 3 Characteristics of included studies (treatments)

Study	Country	Sample size	Age (mean) range years	Disease	Intervention drug/device/technique	Conclusion
Wang (2020) [29]	China	96	NR	Allergic rhinitis	Ketotifen fumarate and budesonide administered as nasal sprays	Ketotifen fumarate and budesonide have promising therapeutic effects on allergic rhinitis. Therefore, combining these two drugs is clinically effective in treating allergic rhinitis and relieving allergic symptoms
Carboni (2020) [30]	Italy	59	NR	Allergic Rhinitis	TS (GrazaxÂ® and OralairÂ® (28 with GrazaxÂ® and 31 with OralairÂ®)	ITS represents the only disease-modifying therapy for AR. Sublingual tablets were well tolerated and have improved AR symptoms. Reduction of medication dispensing was observed especially for systemic and nasal antihistamines
Brindisi (2020) [31]	Italy	76	6 to 12	Allergic rhinitis (AR) sensitised to dust mites	Pidotimod	Pidotimod is effective in relieving nasal obstruction in AR children
Zujovic (2019) [32]	Serbia	237	2 to 18	Allergic rhinitis	PropoMucilÂ® allergy nasal spray	The combination treatment including quercetin, propolis, N-acetylcysteine, thyme, and eucalyptus essential oil and vitamin D3 and E in nasal spray is an excellent choice for treating allergic rhinitis in children. Approximately 80% of parents reported an improvement in the condition of the child
Yoshihara (2017) [33]	Japan	40	2 to 14	Allergic Rhinitis	Leukotriene receptor antagonists (LTRAs)	Long-term administration of LTRA to manage asthma may improve nasal symptoms of pollinosis during the pollen season in children with pollinosis and asthma
Park (2016) [34]	South Korea	14	NR	Allergic rhinitis + house dust mite	SLIT	SLIT for house dust mite is effective and safe in house dust mite sensitised children with allergic rhinitis and does not cause any serious adverse effects

Table 3 (continued)

Study	Country	Sample size	Age (mean) range years	Disease	Intervention drug/device/technique	Conclusion
Park (2015) [35]	South Korea	19	NR	Allergic rhinitis + house dust mite	SLIT	SLIT for house dust mite is effective in polysensitised allergic rhinitis children. SLIT for house dust mite improved nasal symptoms and decreased antiallergic medications use with time. SLIT for house dust mites could also be recommended to polysensitised allergic rhinitis children and house dust mites mono sensitised allergic rhinitis children
Zicari (2015) [36]	Italy	60	6 to 10	Allergic rhinitis	Intranasal budesonide and isotonic nasal saline	Intranasal budesonide is effective in increasing nasal patency in children
Potter (2013) [37]	South Africa	266	6 to 11	Allergic rhinitis	Rupatadine (RUP) oral solution	Rupatadine oral solution (1 mg/ml) was substantially more effective than placebo in improving nasal and ocular symptoms at 4 and 6 weeks
YaÅŸar (2013) [38]	Turkey	60	7 to 16	Allergic rhinitis	Mometasone furoate nasal spray, intranasal azelastine, and isotonic sea water nasal spray	Mometasone furoate and azelastine, which decrease nasal congestion and increase nasal volume, are effective in managing allergic rhinitis in children
Moustafa (2013) [39]	Egypt	40	7 to 18	Allergic rhinitis	LED phototherapy and laser acupuncture	LED phototherapy and laser acupuncture are equally safe, reliable, non-invasive and successful
Manole (2012) [40]	Romania	158	6 to 16	Allergic rhinitis	Fluticasone furoate nasal spray	Intranasal fluticasone furoate spray in an effective and safe treatment for children with symptomatic seasonal allergic rhinoconjunctivitis
Mansi (2012) [41]	Italy	20	5 to 18	Allergic rhinitis	NariventÂ®, an osmotically acting medical device with anti-oedematous and anti-inflammatory effects	NariventÂ® is effective for nasal congestion and other major symptoms in children with AR
Manole (2010) [42]	Romania	38	10 to 16	Allergic rhinitis and sinus disease	Mometasone furoate monohydrate nasal spray 50 mcg	Mometasone furoate monohydrate nasal spray is an effective and well-tolerated treatment in children aged 10–16 with perennial allergic rhinitis

Table 3 (continued)

Study	Country	Sample size	Age (mean) range years	Disease	Intervention drug/device/technique	Conclusion
Rudenko (2009) [43]	England	22	9 to 14	Seasonal allergic rhinitis	Cetirizine 10 mg once a day orally + DerinatÂ® highly purified sodium salt of desoxyribonucleic acid 0.25% intranasally two drops in each nostril, six times per day	The improvement of symptoms was achieved faster in the first arm compared with the second one. There was a decrease in symptoms score: rhinorrhea 85.7%, nasal itch 71.4%, sneezing and lacrimation 90.4%, nasal blockage 76.1%, oedema of the nasal mucosa (confirmed by rhinoscopy) 80.9%. The use of suggested anti-inflammatory medication decreases the severity of symptoms, especially in patients who have poor control with antihistamines and improves their quality of life
Ngamphaiboon (2005) [44]	Thailand	100	6 to 11	Allergic rhinitis	Fexofenadine HCl	Fexofenadine 30 mg bid effectively reduces the total symptom score of allergic rhinitis, including blocked nose and is generally well tolerated. It is not cardiotoxic and is safe for pediatric patients as young as 6 years of age
Ciprandi (2004) [45]	Genoa	20	13.4	Allergic rhinitis	Cetirizine	Cetirizine effectively exerts anti-inflammatory activity by modulating cytokine pattern and reducing inflammatory infiltration in children with perennial allergic rhinitis
Fokkens (2004) [46]	Netherlands	12	2 to 4	Perennial rhinitis	Fluticasone propionate aqueous nasal spray (FPANS) and oral ketotifen	FPANS is an effective treatment to control rhinitis symptoms in children between 2 and 4 years old
Sienra-Monge (1999) [47]	Maxico	80	2 to 6	Allergic rhinitis	Cetirizine and loratadine	Cetirizine and loratadine provided effective, well-tolerated relief of the symptoms of perennial allergic rhinitis in small children. Cetirizine was more effective than loratadine in inhibiting the wheal response to histamine challenge and afforded greater reductions in most individual symptoms assessed daily by the parent

Table 3 (continued)

Study	Country	Sample size	Age (mean) range years	Disease	Intervention drug/device/technique	Conclusion
Ngamphaiboon (1997) [48]	Thailand	106	5 to 11	Allergic rhinitis	Fluticasone propionate aqueous nasal spray	Fluticasone propionate is an effective and safe treatment for children with perennial rhinitis
Herman (1997) [49]	France	125	5 to 12	Perennial rhinitis	Azelastine nasal spray	Azelastine is an effective treatment for perennial rhinitis in children aged 5–12 years and successfully relieved all symptoms, namely sneezing, nasal blockage, nasal itch, and rhinorrhea
Ghafar (2020) [50]	Malaysia	74	7 to 17	Adenoid hypertrophy (AH)	Mometasone furoate (MF) intranasal spray	MF intranasal spray effectively alleviates the symptoms associated with AH and reduces the adenoid size, hence should be considered before adenoidectomy
Ahmed (2019) [51]	Egypt	26	NR	Adenoid hypertrophy	Mometasone furoate aqueous nasal spray (Nasonex)	The use of intranasal mometasone furoate aqueous nasal spray (Nasonex) for one month reduced adenoidal tissue reactive cellular changes and its vascularity
Solmaz (2019) [52]	Turkey	55	6 to 12	Adenoid hypertrophy	Mometasone furoate	The use of mometasone furoate for 6 weeks in pediatric patients with chronic nasal obstruction due to AH is an effective treatment modality in alleviating symptoms and decreasing adenoid volume without causing systemic side effects
Tuhanıoğlu (2017) [53]	Turkey	120	4 to 10	Adenoid hypertrophy	Mometasone furoate, montelukast, and a combination of mometasone furoate and montelukast	Both montelukast and mometasone furoate therapies were similarly successful in treating adenoid hypertrophy. Combined therapy was not superior to single-therapy treatment
Hassanzadeh (2014) [54]	NR	40	4 to 12	Adenoid hypertrophy	Mometasone nasal spray treatment (100 µg per nostril every 12 h) for 4 weeks	Treatment with mometasone furoate nasal spray substantially improved nasal obstruction symptoms and reduced adenoid size in children with AH and may prevent the need for surgery in these patients

Table 3 (continued)

Study	Country	Sample size	Age (mean) range years	Disease	Intervention drug/device/technique	Conclusion
Gupta (2014) [55]	India	55	4 to 12	Adenoid hypertrophy	Mometasone nasal spray	Intranasal steroids are an easy and effective method to improve nasal obstruction, snoring, and OSA among children with adenoid hypertrophy
Berkiten (2014) [56]	Turkey	60	Under 18 (no age group reported)	Adenoid hypertrophy	Azelastine nasal spray	Azelastine nasal spray may be useful in decreasing adenoid pad size and the severity of symptoms related to adenoidal hypertrophy
Yilmaz (2013) [57]	Turkey	28	12 to 18	Adenoid hypertrophy	Mometasone furoate nasal spray	Mometasone furoate nasal spray has a significant advantage over placebo for adolescents' adenoid hypertrophy symptoms
Figueroa (2019) [58]	Argentina		2 to 18	AdenoAmigdalina hypertrophy (HAA)	Triple therapy with azithromycin, betamethasone and nasal budesonide	Triple therapy improved the symptoms and signs associated with HAA-snoring
Tropi (2019) [59]	Italy	40	under 12 years	Common cold	Pirometaxineâ„¢ (Narlisimâ„¢) nasal spray	Narlisimâ„¢ can be considered as a short-term option to control nasal congestion in children under 12 years
Köksal (2016) [60]	Turkey	109	< 2 years	Common cold	Saline (0.9%) and seawater (2.3%) nasal drops	Adding seawater or saline drops to standard treatment protocols helps to relieve nasal congestion, weakness, and sleep quality
Taylor (2020) [61]	USA	23	14.3 (3 to 18)	Nasal septal perforation	Septal perforation repair using a bilateral mucosal flap technique	Septal perforation repair using a bilateral mucosal flap technique can be successfully used in the adolescent patient
Hernandez [62] (2019)	NR	8	20 to 39 months	Septal deviation	Endoscopic septoplasty	Neonatal endoscopic septoplasty is safe and effective for the conservative management of nasal obstruction, normalising the nasal flow required in newborns without compromising the septal anatomy and its future development
Salturk (2014) [63]	Turkey	76	3 to 14	Nasal septal deviation	External nasal dilator	External nasal dilator use relieved nasal septal deviation, which narrows the nasal valve

Table 3 (continued)

Study	Country	Sample size	Age (mean) range years	Disease	Intervention drug/device/technique	Conclusion
Costa (2013) [64]	Brazil	16	13	Caudal septal deviation	The Metzenbaum septoplasty	The Metzenbaum septoplasty is a safe technique to correct caudal septum deviations with no substantial impact on the facial growth of the patients
Moore (2005) [65]	England	9	neonates	Nasal septal deformity	Septopalatal protraction	Septopalatal protraction in the newborn appears to provide a means for correcting nasal septal deviation in complete unilateral cleft palate infants. Septopalatal protraction in the newborn is relatively easy and safe
Pepe (2012) [66]	NR	50	3 to 13	Chronic nasal obstruction and sinusitis	Laser-assisted turbinoplasty RFQ adenoidectomy and sinus washes	Laser-assisted turbinoplasty RFQ adenoidectomy and sinus washes are successful approaches for treating pediatric chronic nasal obstruction and sinusitis
Ozturk (2011) [67]	Turkey	40	6 to 17	Chronic rhinosinusitis (CRS)	Oral methylprednisolone	Oral methylprednisolone is a well-tolerated treatment option and provides added benefit to treatment with antibiotics for children with CRS

the characteristics of the studies included in nasal obstruction treatments are reported in Table 3.

Outcomes

Causes

Congenital nasal pyriform aperture stenosis (CNPAS) CNPAS, a rare cause of nasal obstruction in neonates, is associated with narrowing the anterior 75% of the nasal cavity [10]. CNPAS can be fatal; hence, it must be thoroughly evaluated and adequately treated with conservative management or surgery which has very high success rates. Pardo [9] conducted a retrospective, analytical study of CNPAS patients surgically managed for seven years. The authors evaluated 13 patients, of which 31% also had congenital midnasal stenosis. Although medical treatment failed for all the patients and required surgical enlargement of the pyriform aperture, no complications were seen, and all patients improved in symptoms and development. Similar findings were reported by Sesenna [68], Berlucchi [69], Tagliarini [70], and Losken (2002) [71].

Congenital midnasal stenosis In neonates with nasal obstruction, stenosis of the midnasal area should be considered, especially when choanal atresia and pyriform aperture stenosis are excluded. Levi [11] conducted a study to illustrate midnasal stenosis (MNS), a rare etiology of nasal obstruction in neonates. The authors retrospectively reviewed medical charts and computerised tomography (CT) imaging of 9 neonates diagnosed with stenosis in the midnasal area. Of nine, four had isolated unilateral stenosis, two unilateral MNS and contralateral choanal atresia, and three bilateral MNS. Compared to their healthy counterparts, the median bony width was 1.7 mm vs 3.2 mm, respectively ($p < 0.00001$). All patients were treated with nasal saline irrigation, local steroids and topical antibiotics.

Congenital nasal obstruction Broad differential diagnosis of congenital nasal obstruction in terms of the onset, timing, and symptoms can provide insights into the cause of upper airway compromise. Patel [12] reviewed charts of 34 patients diagnosed with a nasal obstruction within the first 6 months of life to describe clinical practice patterns in evaluating, diagnosing, and treating symptomatic infants. The authors found that most infants improved through conservative management (i.e. suctioning, humidification) and medical therapies (i.e. intranasal drops, nasal sprays).

Congenital dacryocystocele True dacryocystocele is relatively rare, and evidence has described a variable natural course of these lesions. However, the opinions vary regarding their management. Cavazza [13] reviewed five neonates diagnosed with congenital dacryocystocele and with a unilateral cystic lesion. All patients were treated with digital massage and topical and systemic antibiotics. Probing under general anaesthesia was performed in the event of dacryocystitis or lack of resolution after a short trial period with digital massage, which was successful in all patients.

Cancer of nasal cavity Nasal cancer in the paediatric population frequently presents with nonspecific signs and symptoms. Therefore, a timely diagnosis is crucial. Benoit [14] conducted a retrospective cohort analysis to investigate the clinical signs and symptoms of malignant entities presenting as a nasal mass in children. Unilateral nasal congestion was the main presenting symptom. Moreover, the authors found that soft tissue sarcomas and esthesioneuroblastoma were common in these patients.

Nasal polyposis The incidence of nasal polyposis is relatively high in children and adolescents with cystic fibrosis. Weber [15] assessed the incidence of nasal polyposis in a three-year follow-up. The authors found at least one event of nasal polyposis in 56.52% of patients. Therefore, the authors recommended monitoring through routine endoscopy in patients with cystic fibrosis, especially in the absence of nasal symptoms.

Chronic rhinosinusitis Rhinosinusitis is alarming in asthmatic children as both are correlated. In addition, evidence suggests that the severity of asthma increases in children also suffering from rhinosinusitis. Manole [16] evaluated the prevalence of chronic rhinosinusitis in 4-12 years old children with various pulmonary diseases. The authors found that 33.8% asthmatic children had some alteration in sinuses. The authors also found that in children with other atopic disorders, chronic catharal rhinosinusitis was observed in 16.6% individuals compared to 6.25% children with other non-atopic pulmonary diseases. However, in severely asthmatic children, the abnormality of sinuses was found in over 65% of individuals.

Nasopharyngeal carcinoma (NPC) Nasopharyngeal carcinoma, a tumour arising from the epithelial cells, is another cause of nasal obstruction. The yearly incidence of NPC in the UK is 0.3 per million in 0–14 years old and 1 to 2 per million among 15–19 years old [28]. Liu [17] evaluated the clinical features, treatment results, prognostic factors, and late toxicity of nasopharyngeal carcinoma in children and adolescents. Again, nasal

obstruction (15%) was one of the symptoms. Although most patients had locally advanced disease at first diagnosis, they were treated with radiotherapy, with or without chemotherapy.

Adenoid hypertrophy (AH) Nasal obstruction caused by adenoid hypertrophy (AH) can lead to malocclusion. In addition, the evidence suggests that children with hypertrophy suffer from open frontal bites compared to those without hypertrophy and correctly breathing through the nose [18].

Juvenile nasopharyngeal angiofibroma (JNPAF) Juvenile nasopharyngeal angiofibroma (JNPAF) is a pathological benign vascular tumour with aggressive and destructive behaviour that usually affects male adolescents. Giron [19] described a 16-year institutional experience in treating JNPAF in Guatemala. The authors reported that nasal obstruction was the most common symptom (in 93% patients). Although JNPAF represented a small subset of all malignancies, given the aggressive and destructive nature of JNPAF, patients presented with diagnostic and therapeutic challenges. The main treatment modalities were Surgery and chemotherapy.

Antrochoanal polyps (ACPs) Nasal obstruction is the most common symptom in children with ACPs. Zheng [20] conducted a study on 33 ACP patients and ten healthy controls to investigate the effect of atopy on the pathogenesis of pediatric ACPs and to characterise the inflammatory profiles. The authors found that IL-6 plays a crucial role in the pathogenesis of neutrophilic inflammation in patients with ACPs. They also found that Treg cell-associated cytokine IL-10 was involved in the inflammatory pathophysiological process of ACPs and played a specific regulatory role; however, the role of allergic conditions on ACPs pathogenesis was negligible. Thus, complete removal of the ACP is the key to successful treatment [21].

Cleft lip and palate Nasal obstructive symptoms are more frequently reported in cleft lip with cleft palate. Sobol [22] compared 176 affected and 333 unaffected children to describe the frequency and severity of obstructive nasal symptoms. The authors noted that nasal obstruction was more frequently reported in patients than controls ($p < 0.0001$). Children with unilateral cleft lip with cleft palate were more severely affected than bilateral cases, and the severity of nasal obstruction increased with age. Zhang [23] reported a 46% prevalence of nasal obstruction in children with cleft lip and palate. However, Zhang [24] initially reported 67% prevalence, which came down to 49% at the follow-up stage of their cross-sectional study.

Allergic rhinitis Allergic rhinitis (AR), a nose disorder, is characterised by sneezing, rhinorrhoea, nasal discharge and nasal blockage. Rhinitis is particularly common among asthmatic children. The evidence suggests that over 80% of asthmatics have rhinitis, and 10-40% of patients with rhinitis have asthma [25]. Crealey (2018) conducted a study on asthmatic patients with AR attending the respiratory clinic and found that 73% were prescribed AR treatment.

Maxillary sinus mucocele (MSM) Maxillary sinus mucocele (MSM), an uncommon lesion, is another cause of nasal obstruction. MSM can present with various symptoms (nasal obstruction, nasal discharge) that cause expansion and subsequent pressure on the surrounding structures. The transnasal endoscopic approach is an effective and safe method for the treatment of the lesion [26].

Esthesioneuroblastoma (ENB) Esthesioneuroblastoma (ENB), a rare cancer of the nasal cavity in children, is a chemosensitive disease. Venkatramani [27] conducted a retrospective review of 24 patients. Nasal obstruction was the second most common symptom among these patients. Therefore, the authors recommended radiation therapy for local control with lower radiation doses in children.

Treatment interventions

Allergic rhinitis Allergic rhinitis (AR) is a public health problem that substantially affects the quality of life and exerts significant pressure on healthcare.

Wang [29] evaluated the clinical efficacy of ketotifen fumarate and budesonide nasal sprays to treat allergic rhinitis. The authors selected 96 allergic rhinitis patients and treated them with ketotifen fumarate and budesonide nasal sprays. The authors found that the symptoms of nasal obstruction, nasal itching, sneezing, and runny nose significantly improved ($p < 0.05$). Moreover, the eosinophils and IgE in peripheral blood of patients reduced after treatment ($p < 0.05$). Thus, the authors concluded that the combination treatment using ketotifen fumarate and budesonide nasal sprays effectively treated allergic rhinitis and could rapidly relieve allergic symptoms.

Grass pollen ITS is considered an effective disease-modifying treatment of AR. Carboni [30] conducted a study to explore the clinical features of patients treated with grass pollen ITS (GrazaxÂ® and OralairÂ®). The authors found that sublingual tablets were not only well tolerated by the patients but also improved AR symptoms.

Allergic rhinitis (AR) and adenoidal hypertrophy (AH) are frequent causative disorders of nasal obstruction in children, leading to recurrent respiratory infections. Brindisi [31] conducted a clinical study to evaluate the efficacy of an immunomodulator (Pidotimod) on nasal obstruction in children with AR or AH. The authors enrolled 76 children and grouped them into AR and AH groups. The children with both conditions were placed in the AR/AH group and those without AR Â ± AH in controls (CTRL). The authors noted that mean nasal flow (mNF) improved in all patients with respect to the baseline. In AR children, Pidotimod improved nasal obstruction and mNF reached that one of CTRL. In AH children Â ± AR, the mNF was lower in respect to CTRL and AR group.

Zujovic [32] evaluated the efficacy of PropoMucilÂ® allergy nasal spray in 237 children suffering from allergic rhinitis. Fifty-five percent subjects had no nasal itching after 30 days use of PropoMucilÂ®. The side effects reported by 7% of study participants included watery eyes, itchy or tingling nose, nasal bleeding, and sneezing. The authors concluded that combining quercetin, propolis, N-acetylcysteine, vitamin D3 and E, and thyme and eucalyptus essential oils in nasal spray is an effective treatment for AR in children. Approximately 80% of parents said that this nasal spray led to an improvement in the child's symptoms.

Leukotriene receptor antagonists (LTRAs) are regarded as a monotherapy for asthma and AR. Evidence suggests that the long-term administration of LTRA for the management of asthma improves nasal symptoms of pollinosis in children with pollinosis and asthma during the pollen season [33].

Sensitivity to house dust mite aggravates nasal symptoms in children with allergic rhinitis. Sublingual immunotherapy (SLIT) is considered as an effective and safe treatment for children with house dust mite sensitivity and allergic rhinitis. Park [34] tested safety and efficacy of SLIT on fourteen children. The authors noted that the symptoms of allergic rhinitis started to improve after 1 month of SLIT and significantly improved after 12 months of SLIT ($p < 0.05$). The patients' use of antiallergic medications significantly decreased with time ($p < 0.05$). The authors concluded that SLIT for house dust mite is effective and safe in children sensitised to house dust mite and have allergic rhinitis. The study found no serious adverse effects with SLIT. Similar results were reported by Lee [72] and Park [35], who recommended SLIT to poly-sensitised allergic rhinitis children as well as house dust mite mono-sensitised allergic rhinitis children.

Intranasal steroids are an effective treatment for AR and to increase nasal patency in children. Zicari [36] compared intranasal budesonide and isotonic nasal saline and isotonic nasal saline in 60 children aged 6 to 10 years. The authors found that nasal patency improved in children treated with intranasal budesonide for 2 weeks.

Potter [37] assessed the efficacy and safety of rupatadine (RUP) oral solution in 6 to 11 years old AR children. During 6 weeks of the clinical trial, patients were allocated to either RUP oral solution (1 mg/ml) or placebo solution. Rupatadine was significantly more effective than placebo in improving nasal and ocular symptoms at 4 and 6 weeks.

LED phototherapy and laser acupuncture are safe and successful techniques to treat allergic rhinitis in children. Moustafa [39] conducted a clinical trial on 40 patients with perennial allergic rhinitis to compare the outcomes of these two therapies. The results of this randomised controlled study showed a significant improvement in the severity of the symptoms in both groups.

YaÅŸar [38] evaluated the efficacy of mometasone furoate nasal spray, intranasal azelastine, and isotonic seawater nasal spray to treat nasal obstruction caused by AR in 60 children (aged 7 to 16). The authors found that azelastine and mometasone furoate decreased nasal congestion and increased nasal cavity volume more effectively than isotonic seawater nasal spray. Similar results were reported by Manole [40] and Manole [42] regarding the efficacy of fluticasone furoate nasal spray in treating seasonal allergic rhinitis in children. The studies found intranasal fluticasone furoate spray an effective and safe treatment for children with symptomatic seasonal allergic rhinoconjunctivitis.

NariventÂ® is another effective treatment for nasal congestion and other primary symptoms in children with AR. Mansi [41] evaluated the clinical effectiveness of NariventÂ® to treat allergic rhinitis in a paediatric population. The authors used this an osmotically acting medical device with anti-oedematous and anti-inflammatory effects in twenty patients. The authors noted that nasal

congestion, rhinorrhoea and sneezing significantly improve after four weeks of treatment ($p < 0.001$).

Anti-inflammatory medication decreases the severity of symptoms, especially in patients who have poor control with antihistamines and improves their quality of life. Evidence suggests that non-steroid anti-inflammatory medications given together with oral antihistamines can improve seasonal allergic rhinitis. Rudenko [43] conducted a randomised controlled trial to compare Cetirizine and DerinatÂ® nasal drops with Cetirizine only. The authors found a decrease in symptoms of rhinorrhea, nasal itching and blockage, sneezing and lacrimation, and oedema of the nasal mucosa. The authors also noted that the improvement of symptoms was achieved faster in the intervention group compared with the control group.

Fexofenadine is a well-tolerated and effective treatment in reducing symptoms of allergic rhinitis. Ngamphaiboon [44] tested fexofenadine 30 mg on 100 children to relieve allergic rhinitis symptoms. The authors found a statistically significant improvement ($p < 0.01$) for all the symptoms including nasal blockage.

Cetirizine has proven ability in reducing nasal inflammation in children with AR. Ciprandi [45] conducted a double-blind, randomised controlled trial to evaluate the effectiveness of cetirizine in children with perennial AR. The authors allocated the patients to either cetirizine or placebo for a 2-week treatment regimen. The authors found that cetirizine treatment effectively reduced inflammatory levels ($p < 0.01$) and nasal obstruction ($p = 0.007$).

Fokkens [46] compared the safety and efficacy of fluticasone propionate aqueous nasal spray (FPANS) and oral ketotifen in 12 toddlers with perennial rhinitis. The authors found that the children treated with FPANS had a significant reduction in rhinitis symptoms. In addition, a significant reduction in nasal blockage was observed in 4 to 6 weeks ($p = 0.027$). The authors also found that 75% of the patients taking FPANS showed substantial improvement compared with only 21% taking ketotifen; hence, concluded FPANS an appropriate treatment for rhinitis in 2–4 years old children. The safety and efficacy of FPAND [48] were also reported by Ngamphaiboon (1997) for children aged 5 to 11 years with perennial allergic rhinitis.

Cetirizine and loratadine are effective and well-tolerated in young children with perennial AR. Sienra-Monge [47] compared the efficacy and safety of cetirizine and loratadine in 2 to 6 years old children suffering from perennial AR caused by house dust mites or plant pollens. Patients received the treatment for 28 days, and histamine skin tests and eosinophil counts from nasal smears were performed before and after treatment. The authors found that cetirizine significantly inhibited the wheal response compared with loratadine ($p < .0001$). In addition, eosinophil counts were improved to a comparable level with both treatment arms. Although both agents substantially reduced symptoms, cetirizine was more effective than loratadine in relieving nasal obstruction, rhinorrhea, sneezing, and nasal pruritus ($p < .0001$) and in inhibiting the wheal response to histamine challenge.

Herman [49] assessed the effectiveness of azelastine nasal spray in comparison to placebo nasal spray in children with perennial AR and sensitive to house dust mites or cat or dog dander. The authors found that all four symptoms, sneezing, nasal blockage, nasal itch, and rhinorrhea, were statistically lower for the azelastine group compared to the placebo group.

Adenoid hypertrophy (AH) Adenoid hypertrophy (AH) is another common cause of upper airway obstruction. The incidence of AH is 2% to 3% in children, and adenoidectomy is the most frequently performed operation in children. However, recurrence of adenoid tissue after adenoidectomy is 10% to 20%, and that of postoperative respiratory problems is 27%. Therefore, medical therapy alternatives to adenoidectomy must be adopted, keeping surgery as a last resort. MF intranasal spray is endorsed as a treatment option before adenoidectomy as the evidence suggests this as an effective treatment in improving AH symptoms as well as reducing the adenoid size. Ghafar [50] conducted a study to evaluate the effect of MF intranasal spray in children and adolescents with AH. The authors noted significant improvements in nasal obstruction, rhinorrhoea, cough, and snoring in patients after 12 weeks treatment with MF intranasal spray ($p < 0.001$). A significant reduction was observed in AH size ($p < 0.001$) as well.

Topical nasal steroids can act directly on nasopharyngeal lymphoid tissue to decrease its reactive inflammatory changes and potentially reduce its size. Ahmed [51] conducted a trial on children with AH scheduled for adenoidectomy. The patients were allocated to receive either mometasone furoate aqueous nasal spray (Nasonex) or a nasal normal saline 0.9%. The authors found that adenoidal tissue from the mometasone group had less reactive germinal centres and less spongiosis compared to the control group. The authors concluded that the use of intranasal mometasone furoate aqueous nasal spray (Nasonex) for 1 month reduced adenoidal tissue

reactive cellular changes and its vascularity. Another study conducted by Solmaz [52] concluded that the use of mometasone furoate for 6 weeks in paediatric patients with chronic nasal obstruction due to AH was an effective treatment modality in relieving symptoms and reducing adenoid volume without causing systemic side effects.

Tuhanıoğlu [53] evaluated the effects of montelukast, mometasone furoate, and combined therapy on adenoid size in paediatric patients with AH for who surgery was not an option. One hundred twenty children aged between 4 and 10 years were randomly assigned to one of the four groups: montelukast, mometasone furoate, montelukast + mometasone furoate, and no treatment (control group). The authors reported an improvement of 21.76% in the montelukast group, 22.51% in the mometasone furoate group, 21.79% reduction in adenoid size in the montelukast + mometasone furoate group, and 12.46% in the control group. Pre- and post-treatment differences were statistically significant in the three treatment groups ($p < 0.05$). The authors concluded that all three treatment montelukast, mometasone furoate and montelukast+mometasone furoate therapies were equally successful in treating AH.

The use of intranasal steroids mometasone is an easy and effective method to improve nasal obstruction, snoring, and OSA among children having adenoid hypertrophy [55]. Hassanzadeh [54] conducted a trial on forty 4 to 12 years old children to compare mometasone nasal spray treatment and placebo spray to assess its effectiveness in reducing the adenoid size and nasal obstruction symptoms. The authors found that reduction in adenoid size was significantly greater in the intervention group compared with the control group (70% versus 20%, $p = .001$). The authors also reported significant improvement in other symptoms, including nasal obstruction, snoring and mouth breathing ($p < .05$).

Azelastine nasal spray helps reduce the adenoid size and the severity of symptoms related to AH. Berkiten [56] evaluated the effects of topical azelastine treatment on AH symptoms and the size of adenoid tissue in children. The authors found that the severity of symptoms, endoscopic grade, and adenoid size significantly decreased in all 60 patients after 4 weeks of treatment with azelastine.

Yilmaz [57] evaluated intranasal mometasone furoate in adolescents with AH to learn its effectiveness in reducing adenoid size. Although the researchers found a significant reduction in all symptoms except rhinorrhea, no change was detected in adenoid size.

AdenoAmigdalina hypertrophy (HAA) AdenoAmigdalina hypertrophy (HAA), the most common cause of snoring in children, is also associated with obstructive sleep apnea syndrome (OSAS) in about 10% of the affected patients. Although adenotonsillectomy is the treatment of choice, the evidence suggests that a triple therapy involving azithromycin, betamethasone, and nasal budesonide is effective in many children with OSAS. Figueroa [58] conducted a prospective observational study to evaluate the effectiveness of triple therapy for children with HAA and without OSAS. The patients were treated with azithromycin (5 days), betamethasone (7 days), and nasal budesonide (4 weeks). Pre-and post-treatment evaluations showed an improvement in the total version as well as in the day and night subscales of the Pediatric Sleep Questionnaire (PSQ-Chervin) ($p < 0.005$). The study concluded that triple therapy improved the symptoms and signs associated with HAA-snoring.

Common cold Nasal congestion is a troublesome health problem that is especially problematic in children, mainly because effective nasal drugs are usually not recommended for children under 12 years of age because of their potential adverse effects. Hypertonic nasal physiological solutions have proven effective in decongesting nasal mucosa in children and are considered a safe and effective treatment. Tropi [59] retrospectively analysed a case series of 40 children treated for 96 hours with nasal hypertonic spray containing Pirometaxineâ„¢ (Narlisimâ„¢) in patients affected by nasal congestion due to common cold. The authors evaluated the children on a 3-point symptom assessment scale (ranging from 0 to 3 with 0 as no symptoms and three as severe symptoms). The authors found that this hypertonic nasal solution was effective in controlling nasal obstruction ($p < 0.0001$) and nasal secretion ($p < 0.0001$). The authors recommended Narlisimâ„¢ as a useful short-term option to prevent nasal congestion in children under 12 years of age.

Köksal [60] conducted a randomised controlled trial on 109 children to compare the safety and efficacy of saline (0.9%) and seawater (2.3%) as nasal drops (the patient group) and the control group (no treatment). The authors found a significant improvement between the control group and both intervention groups ($p < 0.05$). In addition, nasal congestion and sleep quality were improved with both nasal drops (saline and seawater) in children with the common cold.

Septal deviation Septal deviation, associated with the pressure exerted on the fetus during delivery and appearing less frequently in cesarean deliveries, can be

presented in up to 58% of newborns. Neonates may experience difficulty with feeding. Although the role of the nasal septum in craniofacial growth suggests adopting a cautious approach to correct the nasal septum deformity in childhood, the traumatic severe septal deviation must be corrected to prevent future complications. Hernandez [62] evaluated the clinical effectiveness of septoplasty under endoscopic visualisation for septal deviation in neonates. The authors studied case series of 8 neonatal patients who presented with severe nasal obstruction and failure in nasal probe placement. The authors noted that in 3 cases, an orotracheal intubation was required because of respiratory failure. A closed septoplasty was performed. The authors reported that all patients, including the intubated patients, improved and were discharged with adequate nasal ventilation. The authors concluded that neonatal endoscopic septoplasty was safe and effective for nasal obstruction management without compromising the septal anatomy and its future development.

Salturk [63] conducted a study to assess the efficacy of external nasal dilator in pediatric nasal septal deviation patients. The researchers allocated the patients either to an external nasal dilator or to control group who had no treatment. The authors found that the results were significantly different at the beginning of the study between both groups (i.e. when patients in the external nasal dilator group were still using their dilators, $p = 0.000$). However, the difference did not remain significant after the patients in the external nasal dilator group stopped using their external nasal dilator ($p = 0.670$). The authors concluded that external nasal dilator use relieved nasal septal deviation and prevented the nasal valve's narrowing.

Costa [64] assessed the effects of the Metzenbaum septoplasty on the nasal and facial growth in children, including those referred for surgery. The authors found Metzenbaum septoplasty a safe technique to correct caudal septum deviations with no significant impact on the facial growth of the patients. Moore [65] tested septopalatal protraction in the unilateral cleft palate infant and found it as a means for correcting nasal septal deviation in complete unilateral cleft palate infants, hence relieving nasal airflow obstruction and its detrimental sequelae.

Children with nasal obstruction and submucous cleft palate usually are not subjected to adenoidectomy because of the fear of postoperative velopharyngeal insufficiency. Transnasal endoscopic horizontal partial adenoidectomy is believed to relieve nasal obstruction while preserving the velopharyngeal valve's function. Finkelstein [73] conducted a study to evaluate the efficacy of transnasal endoscopic horizontal partial adenoidectomy in patients with submucous cleft palate and adenoidal hypertrophy. The study included ten children aged 3.5 to 13 years with submucous cleft palate and hypertrophic adenoids. Endoscopic partial adenoidectomy was accomplished to open the lower third of the choanae. Nasal breathing was achieved in all the patients, and only mild snoring remained in two patients. The authors concluded that transnasal endoscopic horizontal partial adenoidectomy was an effective surgical method for relief of nasal obstruction while preserving velopharyngeal valve function in patients with submucous cleft palate who suffer from obstructive adenoids.

Chronic rhinosinusitis Ozturk [67] assessed the effectiveness and tolerability of oral methylprednisolone in children with chronic rhinosinusitis. The authors randomly assigned patients to either amoxicillin/clavulanate (AMX/C) and methylprednisolone or AMX/C and placebo twice daily for 30 days. The authors found that before and after treatment comparison demonstrated significant improvements in both groups' symptom and sinus CT scores ($p < .001$). At the end of treatment, 14% of children in the methylprednisolone group had abnormal findings on CT scans versus 48% in the placebo group ($p = .013$). The authors also found Methylprednisolone significantly more effective than placebo in reducing rhinosinusitis ($p = .001$), postnasal discharge ($p = .007$), nasal obstruction ($p = .001$) and cough ($p = .009$). Laser-assisted turbinoplasty RFQ adenoidectomy and sinus washes are proven to treat chronic nasal obstruction and sinusitis in children [66].

Discussion

This systematic review evaluated the available literature and compiled the evidence regarding the causes and available treatment for nasal obstruction. We identified 20 studies describing the causes of nasal obstruction and 39 studies evaluating the safety and efficacy of the potential treatment. These studies were a mix of observational and interventional studies, and the overall quality of the studies was good. Twenty studies describing the causes of nasal obstruction reported 17 different causes. Thirty-nine studies assessing the performance of medical interventions reported pharmacological interventions for six causes. Twenty-one of 39 studies reported the safety and efficacy of the interventions to treat allergic rhinitis. The remaining 18 studies reported the treatment interventions for adenoid hypertrophy, adenoamigdalina hypertrophy, common cold, septal deviation, and chronic rhinosinusitis.

Nasal obstruction causes distressing symptoms that affect their quality of life and constitutes a burden on

national healthcare. Nasal obstruction can be congenital or acquired and has several types. Treatment and cure of nasal obstruction depend on its cause. Some causes of nasal obstruction can be cured permanently through treatments; for instance, endoscopic septoplasty normalises nasal flow in newborns without compromising the septal anatomy and its future development. However, there is no proven cure for the common cold or associated blocked nose, and the treatment aim is only to relieve the symptoms.

Limitations

We used a comprehensive search strategy to identify studies for this review. We applied no language or geographical restrictions, and the searches are up to date to 16 January 2021. However, this is possible that we could have missed any relevant studies as we searched only two databases (Medline and Embase).

Conclusions

This systematic review provides good evidence regarding the causes and treatments of nasal obstruction. Allergic rhinitis is the most common cause of acquired nasal obstruction, and cetirizine, fexofenadine, fluticasone furoate nasal spray, and mometasone furoate monohydrate nasal are the commonly used treatments to alleviate the symptoms.

Supplementary Information

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Additional file 1: Appendix. Search strategy for Medline and Embase.

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