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Research Article

Clinical, Diagnostic, and Therapeutic Features of Nasopharyngeal Stenosis in Cats: A Retrospective Evaluation of Modified Balloon Dilation Procedures

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Abstract

Nasopharyngeal stenosis is a rare cause of upper respiratory tract obstruction in cats and may be difficult to treat. This retrospective study evaluated the clinical and diagnostic features of affected cats and the outcomes of modified balloon dilation. Records of 52 cats diagnosed between May 2021 and May 2026 were reviewed. Diagnosis was established under general anesthesia using pharyngeal examination, computed tomography, and/or retroflex nasopharyngoscopy. Dilation was performed by progressively inflating cuffed red rubber endotracheal tubes with internal diameters of 2.5, 3.0, and 3.5 mm at the stenotic site. Median age was 24 months, and sex distribution was equal. Stertor occurred in all cats, while purulent rhinorrhea occurred in 24 (46.2%). Computed tomography was used in 38 (73.1%) cases, pharyngeal examination in 36 (69.2%), and nasopharyngoscopy in 18 (34.6%). Dilation was performed in 30 cats (57.7%); treatment was declined for 22 cats. Thirteen treated cats underwent one session, 17 underwent multiple sessions, and eight required additional surgery. Early complications occurred in 10.0%. After a mean follow-up of 2.9±2.7 months, sustained clinical improvement was observed in 29 cats (96.7%), whereas one cat developed restenosis. Age and initial stertor severity were not associated with the number of sessions. Modified balloon dilation appears feasible and clinically effective; however, longer follow-up is required to determine its long-term efficacy.

Keywords: Modified balloon dilation, Nasopharyngeal stenosis, Nasopharyngoscopy, Restenosis, Throat examination

Introduction

The nasopharynx is the portion of the upper respiratory tract located dorsal to the soft palate and caudal to the choanae [1]. Nasopharyngeal stenosis (NPS) is a general term describing congenital or acquired pathological conditions characterized by partial or complete narrowing or obliteration of the nasopharyngeal lumen by fibrous, membranous, or osseous tissues [1-6]. While congenital NPS may be associated with developmental anomalies such as choanal stenosis or atresia, acquired stenosis can develop secondary to infectious, inflammatory, traumatic, or iatrogenic processes [1,2,4].

Nasopharyngeal stenosis is a rare upper respiratory tract disease in cats that can markedly compromise quality of life [2,4,7]. In a substantial proportion of cases, the condition is reported to develop secondary to scar tissue formation during the resolution of chronic upper respiratory tract infections and nasopharyngeal inflammation [4,6]. Feline herpesvirus and feline calicivirus infections, chronic rhinitis, gastroesophageal reflux-induced aspiration, nasopharyngeal trauma, and previous surgical interventions represent the primary etiologies that may contribute to stenosis development [1,4,6].

The most frequently reported clinical sign in cats with nasopharyngeal stenosis is stertor, which becomes particularly pronounced during closed-mouth breathing. Depending on the severity of the disease, stertorous breathing, increased inspiratory effort, open-mouth breathing, dyspnea, sneezing, reverse sneezing, and chronic serous or purulent rhinorrhea may be observed [1,2,4,7]. In cases with advanced obstruction, dysphagia, regurgitation, exercise intolerance, and intermittent respiratory crises can also develop [1].

Although skull radiographs can be utilized for the preliminary assessment of the nasopharyngeal region in the diagnostic approach, they provide limited information due to the superimposition of anatomical structures [3,6].

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Computed tomography (CT) enables the determination of the localization, length, and grade of the stenosis, as well as the evaluation of choanal atresia, sinonasal disease, nasal meatus obliteration, middle ear disease, and concurrent craniofacial anomalies [3,5]. Retroflex nasopharyngoscopy (RN), on the other hand, allows for direct visualization of the stenotic aperture, assessment of mucosal and membranous changes, and simultaneous intervention when necessary [1,2]. However, because thick CT slices or the presence of dense secretions within the nasopharynx can hinder visualization of the stenotic area, the combined use of CT and endoscopic evaluation may enhance diagnostic accuracy [4].

Mechanical dilation, surgical resection of the stenotic membrane, laser ablation, transpalatal or longitudinal palatal approaches, choanoplasty, and metallic or silicone stenting have been described for the treatment of NPS [2,4]. Balloon dilation is a less invasive therapeutic option compared with open surgical approaches, providing controlled expansion of the stenotic tissue. Nevertheless, due to the risk of restenosis, repeated sessions, additional surgical interventions, or antifibrotic therapies may be required [2,4,7]. Treatment selection should be individualized according to the location and extent of the stenosis, whether the stenotic membrane is perforate or imperforate, the presence of concurrent anatomical abnormalities, and the response to previous interventions [1,2,4]. Minimally invasive dilation may be preferred for perforate stenoses, whereas surgical reconstruction may be required for caudally located or imperforate lesions and for cases in which previous minimally invasive treatment has been unsuccessful [1,2,4].

Published evidence on feline NPS remains limited and consists largely of individual case reports and retrospective case series focusing on selected diagnostic or therapeutic aspects [2-7]. Consequently, data integrating demographic and clinical characteristics, diagnostic findings, anatomical features of the stenosis, treatment modalities, complications, and clinical outcomes within the same cohort remain limited. The primary objective of this study was to retrospectively evaluate the demographic and clinical features, computed tomography and endoscopic examination findings, applied therapeutic modalities, complications, and clinical outcomes of cats diagnosed with NPS. The secondary objective was to analyze the number of sessions, concurrent surgical interventions, developing complications, and treatment outcomes in cases undergoing balloon dilation, as well as to determine potential associations between initial clinical characteristics and treatment requirements.

Materials and Methods

Ethical Approval

This retrospective study was reviewed by the Istanbul University-Cerrahpaşa Local Ethics Committee for Animal Experiments, which determined that additional ethical approval was not required (decision date: 29 November 2024; decision no.: 2024/94). Signed informed consent forms were obtained from the owners of all cats included in the study.

Study Design and Case Selection

In this retrospective study, clinical records of 52 cats diagnosed with NPS that presented to the Ear, Nose, and Throat Clinic, Department of Surgery, Faculty of Veterinary Medicine, Istanbul University-Cerrahpaşa between May 2021 and May 2026 were evaluated. Recurrent examination, follow-up, imaging, and treatment records belonging to the same patient were merged under a single case.

Cats that were diagnosed with NPS via pharyngeal examination under general anesthesia, CT, RN, or a combination of these modalities, and whose records included demographic characteristics, clinical findings, diagnostic evaluations, therapeutic procedures, and follow-up outcomes, were included in the study. Cases with only suspected NPS whose stenosis presence could not be confirmed in available physical examination, imaging, or endoscopic records, as well as patients with insufficient clinical data for evaluation, were excluded from the study.

For each case, age, breed, sex, initial stertor score, presence of purulent rhinorrhea, diagnostic modalities used, presence of choanal atresia, treatment modality performed, number of modified balloon dilation sessions, additional operative interventions, complications, restenosis status, and clinical outcomes were recorded. Follow-up outcomes were obtained from follow-up examination records and/or telephone interviews with the owners. The duration between the initial presentation date and the last recorded clinical examination or telephone interview was defined as the total clinical follow-up period.

Clinical Evaluation

The medical history and clinical examination records of the cases at initial presentation were retrospectively reviewed. Initial stertor severity and the presence of purulent rhinorrhea were evaluated.

The presence of purulent rhinorrhea was assessed based on anamnesis and clinical examination records. Cases documented to have purulent nasal discharge were classified as “purulent rhinorrhea present,” whereas those explicitly noted to lack purulent nasal discharge were classified as “purulent rhinorrhea absent.”

Stertor severity was graded from 0 to 4 using a semi-quantitative scoring system developed for this retrospective study, based on findings documented in the medical

history and clinical examination records. Cases with an absence of stertor and normal respiratory sounds at rest and during sleep were scored as 0; cases where stertor occurred only during sleep, excitement, stress, or physical activity and was inconspicuous at rest were scored as 1; cases where stertor was present at rest and audible near the patient without marked respiratory effort or open-mouth breathing were scored as 2; cases with continuous and prominent stertor at rest audible from a distance accompanied by increased inspiratory effort were scored as 3; and cases where severe stertor was accompanied by open-mouth breathing, marked dyspnea, cyanosis, or intermittent respiratory crises were scored as 4.

Diagnostic Evaluation

Pharyngeal examination under general anesthesia, CT, RN, or different combinations of these modalities were used in the diagnostic evaluation of the cases.

Pharyngeal Examination Under Anesthesia

Pharyngeal examination was performed under general anesthesia. During the examination, the oral cavity, soft palate, oropharynx, tonsils, epiglottis, larynx, and nasopharyngeal opening were evaluated. To visualize the nasopharyngeal region, the soft palate was carefully retracted rostrodorsally using tissue forceps, and the nasopharyngeal aperture was directly inspected. The nasopharyngeal opening and the stenotic segment were directly evaluated during the examination.

Computed Tomography

CT images were retrospectively reviewed to confirm NPS and evaluate the presence of choanal atresia.

During CT examinations, patients were positioned in sternal recumbency to ensure symmetrical alignment of the cranial region. Scans were performed using a 128-slice Siemens SOMATOM AS+ scanner (Siemens Healthineers, Erlangen, Germany) with a slice thickness of 0.6 mm. Axial images were evaluated in conjunction with dorsal and sagittal multiplanar reconstructions.

Retroflex Nasopharyngoscopy

During RN, a single-use flexible videoendoscope (FIVE S, 3.5 × 65; outer diameter 3.5 mm; working channel 1.2 mm; REF 091361-01; KARL STORZ SE & Co. KG, Tuttlingen, Germany) was advanced through the oral cavity and directed caudodorsally over the soft palate into the nasopharyngeal region. The nasopharyngeal opening and the stenotic segment were directly evaluated.

Because of the retrospective design, the three diagnostic modalities were not applied systematically to every cat. The diagnostic approach was influenced by clinical requirements, owner financial constraints, availability of the CT and endoscopy units, and the feasibility of performing repeated procedures under general anesthesia. When more than one modality was used, the findings were reviewed descriptively; formal concordance analysis was not performed because the records did not contain a standardized grading system applicable across modalities.

The degree of stenosis was not quantified using aperture diameter, cross-sectional area, or a standardized grading system. Because body size and craniofacial anatomy varied among cats and no validated grading system for feline NPS was available, severity was assessed subjectively from clinical signs and the visual findings obtained during pharyngeal examination and/or RN. In some cats, patency was also assessed qualitatively by instilling sterile saline through the nostril and observing its passage into the nasopharynx. This was used only as an adjunctive clinical assessment and was not considered an objective or standardized measurement of stenosis severity.

Classification of Treatment Modalities

Cases were classified according to the treatment modality performed as follows:

1. Cases treated with modified balloon dilation alone,
2. Cases treated with modified balloon dilation and case-specific operative procedures performed during the subsequent treatment course,
3. Cases in which modified balloon dilation was recommended but the owner declined treatment. Additional operative procedures were recorded as case-specific interventions and were not assumed to have been performed during the same anesthetic session as the initial dilation.
4. Modified balloon dilation was preferred as the initial intervention when a residual nasopharyngeal opening permitted safe passage of the dilation tube. In Case 13, complete membranous occlusion prevented initial tube placement; therefore, the stenotic membrane was surgically removed to create an opening, and modified balloon dilation was performed during subsequent treatment sessions. In Case 26, choanal atresia required initial transpalatal choanoplasty, followed by modified balloon dilation of the nasopharyngeal opening during later sessions. Other operative procedures were selected individually according to concurrent disorders, including otitis media, inflammatory aural polyps, and chronic rhinosinusitis, and according to case-specific anatomical findings.

Preanesthetic Evaluation and Anesthesia Protocol

In cases undergoing pharyngeal examination under general anesthesia, RN, or surgical treatment, the general health status and anesthetic risk were assessed prior to the procedure. Complete blood count, serum biochemistry

analysis, thoracic radiography, and other deemed necessary preanesthetic evaluations were performed according to available clinical records.

In cases undergoing modified balloon dilation, intravenous access was established. For premedication, medetomidine HCl (40 µg/kg, IV; Delax®, AlbaFarma İlaç San. ve Tic. A.Ş., Istanbul, Türkiye) was administered, and ketamine HCl (2 mg/kg, IV; Keta-Control®, Doğa İlaç, Istanbul, Türkiye) was used for anesthetic induction. Following induction, endotracheal intubation was performed, and anesthesia was maintained with isoflurane (Isoflurane USP®, Piramal Critical Care, Pennsylvania, USA).

Heart rate, respiratory rate, peripheral oxygen saturation, end-tidal carbon dioxide, noninvasive arterial blood pressure, and body temperature were monitored throughout anesthesia using a uMEC12 Vet® patient monitor (Shenzhen Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, China).

Modified Balloon Dilation Technique

In this study, the term "modified balloon dilation" was used to define the pneumatic dilation technique performed by progressively inflating the cuffs of cuffed red rubber endotracheal tubes instead of a conventional balloon catheter. Cases scheduled for modified balloon dilation were placed in sternal recumbency. The mouth was maintained open using gauze strips positioned around the canine teeth. The soft palate was retracted rostrodorsally with an appropriate instrument to ensure visibility of the nasopharyngeal aperture.

The five-min inflation duration was selected with reference to the protocol described by Champetier et al.[4], in which each stepwise balloon pressure was maintained for five min. Initially, a cuffed red rubber endotracheal tube with an internal diameter of 2.5 mm (Endotracheal Red Rubber Tubes®, KRUUSE A/S, Langeskov, Denmark) was placed into the stenotic opening. Because cuffed red rubber endotracheal tubes were used instead of a pressure-calibrated balloon catheter, inflation pressure could not be objectively standardized or recorded. Each cuff was manually inflated with air using a syringe until its maximum achievable expansion was reached, as judged by resistance to further injection, and remained continuously inflated throughout the five-minute application.

Each selected tube size was used for a single inflation only; repeated inflation cycles were not performed with the same tube. The procedure was continued sequentially, when appropriate, using cuffed endotracheal tubes with internal diameters of 3.0 and 3.5 mm. Thus, each five-minute inflation was followed by one five-minute resting interval before the next selected tube size was used *(Fig. 1)*. At the end of each inflation, the cuff was completely deflated, the dilation tube

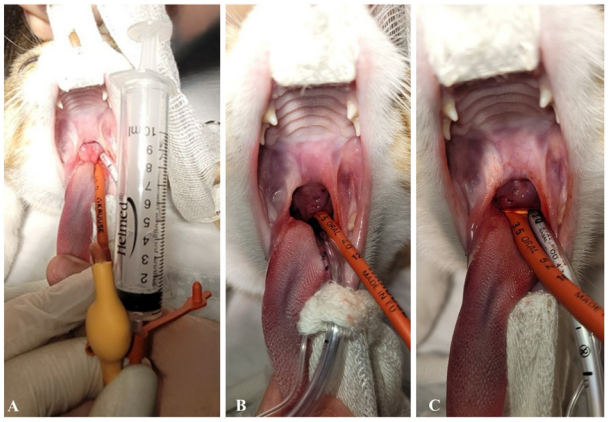

Fig 1. Placement of the endotracheal tubes in modified balloon dilation and sequential performance of the procedure using tubes with internal diameters of 2.5 **(A)**, 3 **(B)**, and 3.5 **(C)** mm

was removed, the gauze strips maintaining mouth opening were released, and the jaw was allowed to return to a near-closed position around the orotracheal tube. This position was maintained for five minutes to permit reperfusion of compressed tissues, interrupt prolonged mouth opening, and allow assessment for hemorrhage, edema, or mucosal injury. The same stepwise inflation-resting protocol was used in all treated cats; however, the initial and maximum tube sizes were individualized according to the width of the stenotic aperture, patient anatomy, tissue resistance, and tissue response. Progression to a larger tube was discontinued if marked resistance, hemorrhage, edema, or suspected mucosal injury was observed.

At the end of the procedure, the nasopharyngeal aperture was inspected via pharyngeal examination and/or RN. Aperture diameter and cross-sectional area were not measured objectively. Immediate procedural response was assessed qualitatively from the visually observed increase in luminal patency and the ability to introduce progressively larger dilation tubes.

The number of modified balloon dilation sessions and the intervals between sessions were not standardized across all cases. The requirement for repeated sessions was determined by the persistence of stertor and other clinical signs, insufficient nasopharyngeal aperture on follow-up pharyngeal examination or RN, or the development of restenosis. The total number of modified balloon dilation sessions performed for each case was recorded.

Following modified balloon dilation, all cats routinely received ceftriaxone (30 mg/kg, IM, q24h), methyl-prednisolone (1 mg/kg, PO, q24h), and sucralfate (250 mg/cat, PO, q24h) for seven days because of the potential for mucosal injury or tearing at the dilation site. In cats undergoing additional operative procedures, further medical treatment was selected individually according

to the concurrent disease, procedure performed, and postoperative clinical findings; therefore, these additional treatments were not standardized across cases.

Evaluation of Complications and Clinical Outcomes

Soft palate laceration, hemorrhage, nasopharyngeal and lingual edema, subcutaneous or generalized emphysema developing during the procedure or in the early postoperative period, and the requirement for tracheostomy due to these complications were recorded as complications. Restenosis was evaluated as a late adverse treatment outcome rather than a perioperative complication.

A marked reduction or complete resolution of clinical signs such as stertor, respiratory distress, open-mouth breathing, and purulent rhinorrhea following the procedure was considered clinical improvement.

Treatment outcomes in cases undergoing modified balloon dilation were classified as clinical improvement and restenosis. Restenosis was defined as recurrent narrowing documented during follow-up pharyngeal examination and/or RN, together with recurrent clinical signs when recorded. Restenosis was not quantified using standardized aperture measurements. Due to variability in follow-up duration, clinical outcomes were assessed from the status documented at the last follow-up examination or final telephone interview with the owner. In cases followed solely via telephone interview, the outcome was recorded as owner-reported clinical improvement. Cases in which modified balloon dilation was recommended but declined by the owner were evaluated separately.

Statistical Analyses

Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 31.0 (IBM Corp., Armonk, NY, USA). Continuous variables were presented as mean ± standard deviation or median, interquartile range, and minimum-maximum values according to their distribution characteristics, whereas categorical variables were presented as frequencies and percentages.

The relationship between age and initial stertor score was evaluated using Spearman's rank correlation analysis. Ages of cases with and without purulent rhinorrhea were compared using the Mann-Whitney U test. Breeds were categorized as purebred and crossbred/domestic; the associations between breed group and severe stertor (scores 3-4) and purulent rhinorrhea were examined using Fisher's exact test. Odds ratios (OR) were reported with 95% confidence intervals.

In cases undergoing modified balloon dilation, the relationships between initial stertor score and number of sessions, as well as between age and number of sessions, were evaluated using Spearman's rank correlation analysis. Analyses regarding the number of sessions were performed exclusively on cases undergoing modified balloon dilation (n=30).

All tests were two-tailed. Analyses were considered exploratory, and the Benjamini-Hochberg correction was applied for multiple comparisons. An adjusted $P<0.05$ was considered statistically significant.

Results

A total of 52 cats diagnosed with NPS were evaluated in the study. Of the cases, 26 (50.0%) were female and 26 (50.0%) were male. The ages of the cases ranged from 4 to 144 months. The median age was 24 months, and the mean age was 37.4±37.2 months. Ten cases (19.2%) were under one year of age, 21 (40.4%) were 1 to <3 years old, 15 (28.8%) were 3 to <7 years old, and 6 (11.5%) were seven years of age and older.

During the standardization of breed records, cats documented by coat color or pattern rather than breed -such as Tabby, Ginger, Tuxedo, Calico, or Dark Calico- along with cats specified as crossbred, were combined into the crossbred/domestic group. Accordingly, 46 cases (88.5%) were included in the crossbred/domestic group, and 6 cases (11.5%) were in the purebred group. The purebred group comprised four British Shorthairs, one Scottish Fold, and one Turkish Angora.

Initial stertor score was evaluated as 2 in 41 cases (78.8%), 3 in 10 cases (19.2%), and 4 in 1 case (1.9%). Purulent rhinorrhea was present in 24 cases (46.2%) and absent in 28 cases (53.8%) *(Table 1)*.

In the diagnostic evaluation of NPS, pharyngeal examination under general anesthesia was utilized in 36

Table 1. *Demographic and Initial Clinical Characteristics of the Cases*

Variables	Categories	n (%)
Age group	<1 year	10 (19.2)
	1 to <3 years	21 (40.4)
	3 to <7 years	15 (28.8)
	≥7 years	6 (11.5)
Breed group	Crossbred/Domestic	46 (88.5)
	Purebred	6 (11.5)
Sex	Female	26 (50.0)
	Male	26 (50.0)
Initial stertor score	2 - Moderate	41 (78.8)
	3 - Severe	10 (19.2)
	4 - Very severe	1 (1.9)
Purulent rhinorrhea	Present	24 (46.2)
	Absent	28 (53.8)

cases (69.2%), CT in 38 cases (73.1%), and RN in 18 cases (34.6%) *(Fig. 2)*. Multiple diagnostic modalities could be applied in the same case. When the combinations of diagnostic modalities were analyzed, all three modalities were used in 15 cases (28.8%). Pharyngeal examination alone and CT alone were performed separately in 13 cases (25.0%) each, whereas pharyngeal examination combined with CT was utilized in 8 cases (15.4%), CT combined with RN in 2 cases (3.8%), and RN alone in 1 case (1.9%) *(Table 2)*. Choanal atresia was detected in only one case (1.9%; Case no. 26) *(Fig. 3)*. In these 15 cats, the findings were not clinically contradictory and were considered complementary. Because stenosis severity was not documented using a standardized grading system for all modalities, formal concordance or correlation analysis was not performed.

The available retrospective records did not permit reliable classification of the cases as congenital or secondary NPS. Information regarding the presence of clinical signs since birth and previous infectious, inflammatory, traumatic, or iatrogenic events was not documented consistently. Therefore, etiology-specific treatment outcomes were not calculated. The single case of CT-confirmed choanal atresia was recorded separately as an anatomical developmental abnormality and was not used alone to establish an etiological subgroup.

Modified balloon dilation was performed in 30 cases (57.7%) *(Fig. 4)*. In 22 cases (42.3%) where modified balloon dilation was not performed, the treatment had been recommended, but the owner declined the procedure *(Table 3)*.

In 8 of the 30 cases (26.7%) undergoing modified balloon dilation, at least one case-specific operative procedure was performed during a subsequent treatment session. Case 13 underwent surgical removal of a completely occluding stenotic membrane before subsequent modified balloon dilation. Case 26 underwent transpalatal choanoplasty for choanal atresia before subsequent modified balloon dilation. Other recorded interventions reflected concurrent disease or case-specific anatomical findings and included vomer resection, soft palate reconstruction, ventral bulla

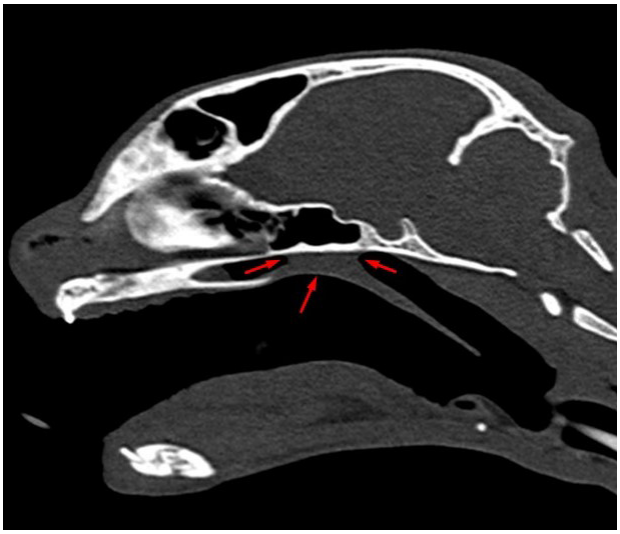

Fig 3. Sagittal-plane computed tomography image of a case diagnosed with choanal atresia. The nasopharyngeal lumen is obliterated by a soft-tissue-attenuating structure, and the choana is continuous with a bony framework. Choanal atresia and nasal secretions filling the nasal cavity secondary to the obstruction are indicated by the red arrows

Table 2. *Distribution of diagnostic modalities*

Variables	Category	n (%)
Diagnostic modality performed	Pharyngeal examination	36 (69.2)
	CT	38 (73.1)
	RN	18 (34.6)
Combination of diagnostic modalities	Pharyngeal examination alone	13 (25.0)
	CT alone	13 (25.0)
	RN alone	1 (1.9)
	Pharyngeal examination + CT	8 (15.4)
	CT + nasopharyngoscopy	2 (3.8)
	Pharyngeal examination + CT + nasopharyngoscopy	15 (28.8)

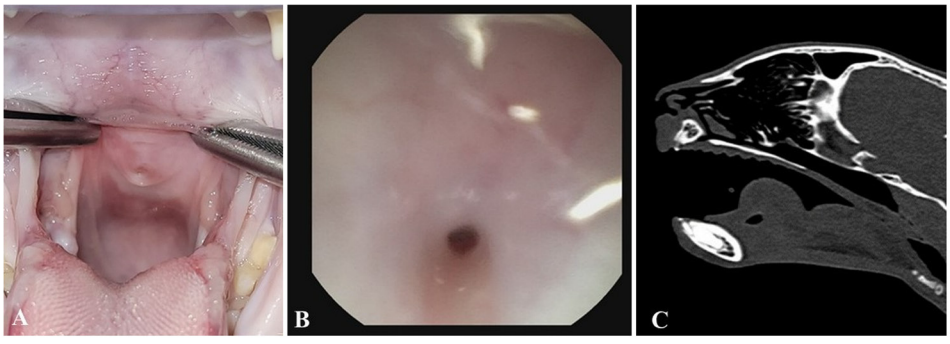

Fig 2. Diagnosis of nasopharyngeal stenosis via pharyngeal examination **(A)**, RN **(B)**, and sagittal CT view in the soft tissue window **(C)**

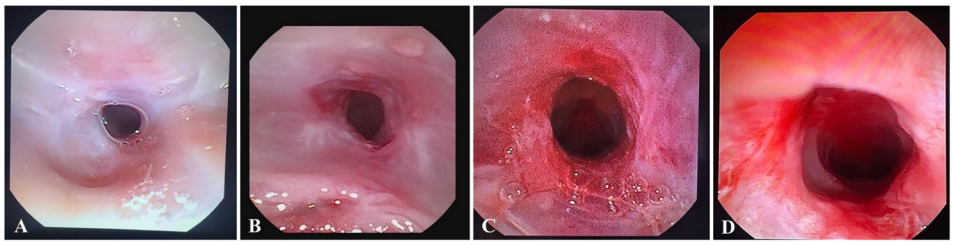

Fig 4. Gradual increase in nasopharyngeal patency following four balloon dilation sessions performed at two-week intervals: first session **(A)**, second session **(B)**, third session **(C)**, and fourth and final session **(D)**, demonstrating progressive widening of the nasopharyngeal meatus

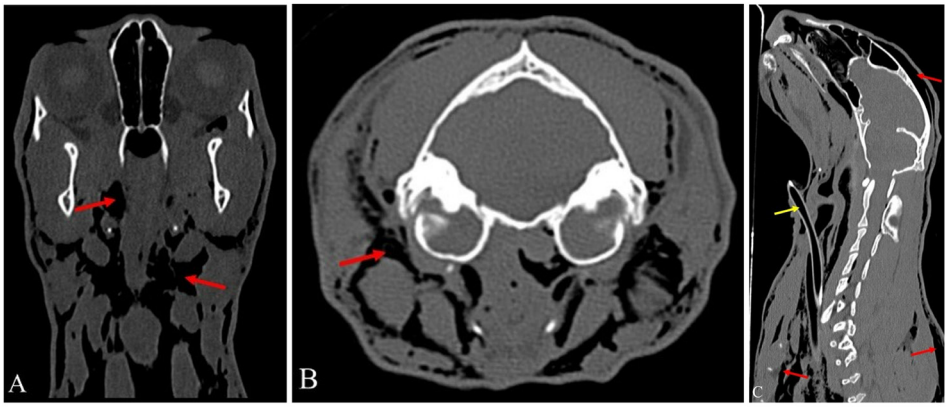

Fig 5. Sagittal **(A)**, axial **(B)**, and coronal **(C)** computed tomography images showing severe subcutaneous emphysema following balloon dilation in Case No. 26. The air accumulations extending from the nasopharyngeal region into the subcutaneous tissues of the neck and thorax are indicated by red arrows. The yellow arrow in panel C indicates the tracheostomy tube

osteotomy, polypectomy, epiglottectomy, staphylectomy, tonsillectomy, epiglottopexy, and sinonasal aspiration.

Early complications associated with the dilation procedure were recorded in 3 of the 30 cases (10.0%) undergoing modified balloon dilation. Intensive care support was required in Case 25 due to the development of widespread emphysema. Marked edema was observed in the nasopharyngeal region and tongue in Case 28. In Case 26, emphysema developed and tracheostomy tube placement was required *(Fig. 5)*.

Table 3. *Distribution of the number of sessions in cases undergoing modified balloon dilation*

Modified Balloon Dilation Session	**n (%)**
1 session	13 (43.3)
2 sessions	4 (13.3)
3 sessions	4 (13.3)
5 sessions	4 (13.3)
6 sessions	2 (6.7)
7 sessions	1 (3.3)
9 sessions	2 (6.7)

Furthermore, following nasopharyngeal reconstruction, which was evaluated separately from modified balloon dilation, bilateral mydriasis and transient vision loss developed in Case 13.

In the 30 cats that underwent modified balloon dilation, the mean total clinical follow-up period was calculated as 2.9±2.7 months. The median total clinical follow-up duration was determined to be 2.0 months (interquartile range: 1.5-3.4 months; range: 0.1-11.1 months).

In 29 of the 30 cases (96.7%) undergoing modified balloon dilation, clinical improvement persisted at the final follow-up evaluation. In Case 26, although clinical improvement was initially reported, recurrent narrowing was identified at the second treatment session, approximately one month after the initial intervention, and the case was classified as restenosis in the final assessment *(Table 4)*. The restenosis rate was therefore 1/30 (3.3%). Because only one restenosis event occurred, a mean time to recurrence was not calculated.

No significant correlation was found between age and initial stertor score (Spearman's ρ=-0.083; raw P=0.559). The median ages of cases with and without purulent rhinorrhea were 18 and 24 months, respectively, with no

Table 4. *Treatments, additional procedures, and clinical outcomes*		
Variable	**Category**	**n (%)**
Modified balloon dilation status[1]	Performed	30 (57.7)
	Recommended but declined by owner	22 (42.3)
Additional operative procedure during the treatment course[2]	Present	8 (26.7)
	Absent	22 (73.3)
Clinical outcome[2]	Clinical improvement	29 (96.7)
	Restenosis	1 (3.3)

[1] Percentages were calculated over all cases (n=52)
[2] Percentages were calculated over cases undergoing modified balloon dilation (n=30)

significant difference between the groups (Mann-Whitney U=302.5; raw P=0.541).

Severe or very severe stertor was detected in 2/6 purebred cats (33.3%) and 9/46 crossbred/domestic cats (19.6%). No significant association was found between breed group and severe or very severe stertor (OR=2.06; 95% CI: 0.32-13.04; raw P=0.595). Purulent rhinorrhea was observed in 4/6 purebred cats (66.7%) and 20/46 crossbred/domestic cats (43.5%). The association between breed group and purulent rhinorrhea was also not statistically significant (OR=2.60; 95% CI: 0.37-18.10; raw P=0.397).

In cats undergoing modified balloon dilation, initial stertor score was not significantly correlated with the number of sessions (Spearman's ρ=0.050; raw P=0.791). Age was also not significantly correlated with the number of sessions (Spearman's ρ=-0.104; raw P=0.586). After Benjamini–Hochberg adjustment for multiple comparisons, none of the evaluated relationships remained statistically significant *(Table 5)*.

Discussion

Mestrinho and Fonseca [3], Kang and Brash [5], and Masuyama et al.[6] documented NPS in cats from different age groups. Cats in the present study were generally younger than those in these previous populations. Earlier referral for advanced imaging or endoscopic evaluation may partly explain this difference. In addition, the specialized ENT referral setting of the present study may have increased the likelihood of identifying NPS in younger cats.

Congenital and secondary NPS may differ in anatomical configuration, tissue composition, response to dilation, and risk of restenosis. However, the retrospective records in the present study did not permit reliable etiological classification. Only one cat had CT-confirmed choanal atresia, whereas the presence of clinical signs since birth and previous infectious, inflammatory, traumatic, or iatrogenic events was not documented consistently in the remaining cases. Young age at diagnosis alone was not considered sufficient evidence of congenital NPS, and the absence of a documented preceding disorder was not interpreted as evidence against secondary disease. Consequently, subgroup-specific comparisons of clinical success, number of dilation sessions, recurrence, complications, additional treatment, and follow-up duration could not be performed without a substantial risk of etiological misclassification.

O'Neill et al.[7] found no difference in the overall prevalence of common disorders between purebred and crossbred cats, although they identified upper respiratory tract diseases more frequently in purebred cats. In contrast, crossbred/domestic cats constituted the great majority of the present population. The large regional stray-cat population and the predominance of crossbred cats within this population may explain this distribution. Therefore, the breed distribution in the present study probably reflects the geographic characteristics and referral population rather than a specific biological predisposition.

Stertor is an important clinical finding suggestive of nasopharyngeal airway obstruction; however, it is not specific to NPS, as nasopharyngeal polyps, neoplasia, foreign bodies, chronic rhinitis/rhinosinusitis, and brachycephalic upper airway syndrome can also present with stertor [8-10]. The reported frequency of stertor at approximately 90%-100% in previous NPS studies demonstrates

Table 5. *Relationships between demographic/clinical characteristics and treatment variables*				
Variables Compared	**Test**	**Test Statistic/Effect Size**	**Raw P**	**Adjusted P**
Age - initial stertor score	Spearman's correlation	ρ = −0.083	0.559	0.714
Age - purulent rhinorrhea	Mann-Whitney U	U = 302.5	0.541	0.714
Breed group - severe stertor	Fisher's exact test	OR = 2.06	0.595	0.714
Breed group - purulent rhinorrhea	Fisher's exact test	OR = 2.60	0.397	0.714
Initial stertor score - number of sessions	Spearman's rank correlation	ρ = 0.050	0.791	0.791
Age - number of sessions	Spearman's rank correlation	ρ = −0.104	0.586	0.714

[1] P-values were adjusted for six comparisons using the Benjamini-Hochberg procedure
[2] The analysis was performed on cases undergoing modified balloon dilation (n = 30)
CI, confidence interval; OR, odds ratio; ρ, Spearman's rank correlation coefficient

its importance in raising clinical suspicion [3,5,6]. Similarly, the presence of stertor in all cases in the present investigation supports this finding as a strong clinical indicator for the recognition of NPS and the referral of cases for advanced diagnostic workup. In addition to the presence of stertor, its severity was graded in the current records as mild, moderate, severe, and very severe based on subjective clinical observation. To our knowledge, no other study in the available literature has graded stertor severity in cats with NPS. This approach enabled the comparison of cases in terms of clinical severity and allowed the evaluation of a potential relationship between stertor severity and treatment requirement. Applying this grading system to obstructive airway diseases in the future may contribute to the differential diagnosis and help delineate variations in stertor severity across different conditions. However, because this system was developed within the scope of the present study, its inter-observer agreement, reproducibility, and clinical validity need to be verified in prospective studies.

Clinical signs such as stertor, nasal discharge, open-mouth breathing, and dyspnea are shared across various upper respiratory conditions; therefore, reaching a definitive diagnosis based only on clinical examination is challenging. Therefore, advanced diagnostic methods are required in the differential diagnosis of nasopharyngeal diseases [5,11,12]. CT, one of these methods, enables cross-sectional examination of the nasopharyngeal meatus and surrounding bone and soft tissue structures, providing detailed information regarding the localization, morphology, and anatomical extent of stenosis, choanal atresia, nasopharyngeal polyps, inflammatory disease, and neoplasia [5,11-14]. In cats with NPS, the most frequently reported CT finding is a marked and sudden meatal narrowing associated with a soft tissue density band in the caudal third of the nasopharynx. Focal dorsal deviation of the soft palate at the level of the stenosis has also been reported. The anatomical relationship between the soft palate and the stenotic membrane can be evaluated more clearly, particularly in sagittal reconstructions [5,12]. However, patient and mouth positioning during scanning, potential displacement of the soft palate by the endotracheal tube, secretions accumulating in the nasopharyngeal region, and concurrent neoplastic formations can affect the CT appearance and make accurate evaluation of the stenosis difficult. The use of CT in the majority of cases in the present study supports the importance of this method in the diagnosis and anatomical characterization of NPS. Furthermore, CT is considered to contribute to the differential diagnosis of conditions that can cause similar clinical signs and to the identification of pathologies accompanying NPS. Nevertheless, due to the potential limitations of the method, scans should be performed with the mouth open to allow a more objective examination of the nasopharyngeal meatus, and CT findings must always be interpreted in conjunction with clinical findings and other diagnostic methods.

Choanal atresia is a congenital anomaly characterized by partial or complete obliteration of the choana with bony, membranous, or mixed tissue [12,15,16]. CT allows the differentiation of choanal atresia from NPS by demonstrating in detail the composition of the obstruction, its anatomical extent, and its relationship with the surrounding bony structures [5,9]. This distinction is critically important because the surgical management of choanal atresia differs from that of classical NPS [17-19]. In the present study, the diagnosis of choanal atresia established in Case 26 via CT examination following pharyngeal inspection further underscores the clinical importance of CT in differential diagnosis and surgical planning.

CT measurements can be utilized for nasopharyngeal stent selection and for determining the target balloon diameter in conventional balloon catheter interventions [20,21]. However, in advanced stenosis, the very small residual lumen may reduce measurement reliability; relying strictly on these measurements to directly use a large-diameter balloon may increase the risk of mucosal trauma, fibrosis, and restenosis. Based on our clinical experience, initiating dilation with a small internal diameter cuffed endotracheal tube and gradually increasing the tube diameter according to tissue resistance and the achieved luminal patency provides a more controlled approach.

Pharyngeal examination under general anesthesia enables direct visualization of the caudal nasopharynx and the stenotic membrane in this region via soft palate retraction [9,22]. Nevertheless, the primary limitations of the method include a field of view predominantly restricted to the caudal nasopharynx and the masking of the stenotic aperture by secretions [23]. In the present study, the use of pharyngeal examination in the great majority of cases demonstrated that the method is useful for rapid, direct assessment, particularly of caudally located stenoses; however, it may remain inadequate on its own in rostral lesions and in the presence of copious secretions. Furthermore, uncontrolled retraction of the soft palate was observed to cause mucosal trauma, edema, and hemorrhage, underscoring the importance of careful manipulation. Conversely, its straightforward feasibility by an experienced team and lack of requirement for advanced instrumentation or specialized equipment were considered significant advantages of systematic pharyngeal examination.

RN has been reported to provide direct evaluation of the nasopharynx and choana by advancing a flexible endoscope transorally into the caudal oropharynx and

retroflexing it dorsally around the caudal free edge of the soft palate [23,24]. Through this modality, the morphology of the stenotic membrane, the location and approximate diameter of the residual lumen, as well as the presence of secretions, inflammation, polyps, and other soft tissue lesions can be assessed. Magnified, illuminated visualization combined with a deflectable endoscope tip enables the inspection of regions inaccessible on pharyngeal examination, whereas irrigation and suction facilitate clearer delineation of the stenotic site by clearing secretions [23]. However, the narrow nasopharyngeal space in cats restricts the usable endoscope diameter, and proper navigation of the scope demands technical proficiency [24]. In the current investigation, although RN offered more detailed visualization than pharyngeal examination, it was considered an operator- and equipment-dependent procedure. Performing the procedure under general anesthesia was deemed essential to ensure an adequate working field, patient immobility, and airway security, as well as to minimize the risks of gagging, coughing, and aspiration.

Diagnostic modalities complement one another in the evaluation of NPS. CT identifies the anatomical extent of the lesion and accompanying structural changes but does not replace direct assessment of nasopharyngeal patency. Pharyngeal examination enables direct clinical assessment of the nasopharyngeal opening, whereas RN provides magnified illumination and improved visualization of the affected region. In the 15 cats examined using all three modalities, no clinically contradictory findings were identified; however, formal concordance analysis was not possible because stenosis type and severity had not been recorded using a standardized grading system. The non-uniform use of the modalities reflected the retrospective clinical setting, including owner financial constraints, equipment availability, clinical need, and the feasibility of repeated general anesthesia.

In the literature, a case undergoing three balloon dilation sessions due to restenosis has been reported, whereas another study evaluating seven cats noted that acceptable clinical control was achieved following one or two interventions in cases with long-term follow-up [2,25]. In another study, the procedure was performed in 12 cats, with only two cases requiring a second intervention due to recurrence. In a more comprehensive investigation, dilations were scheduled as one to three sessions, and a planned serial dilation approach was reported to be potentially associated with a longer progression-free interval [6,26]. In the present study, the number of sessions reached five to nine in some cases, which was higher than the number of interventions reported in the literature. Because nasopharyngeal tissues are delicate and prone to tearing, increasing luminal patency in a controlled and staged manner was preferred over forcing dilation in a single session. Accordingly, the requirement for multiple dilations should not always be construed as restenosis or treatment failure, but rather as an outcome of a safe and stepwise therapeutic approach. Our clinical experience suggested that approximately five sessions may be necessary to achieve adequate nasopharyngeal patency in some cases. However, rather than adhering to a rigid protocol, the number of sessions should be determined on a case-by-case basis by evaluating the degree of patency, tissue response, clinical improvement, and complication risk prior to each intervention.

The treatment sequence was likewise individualized according to anatomical accessibility and concurrent disease. Modified balloon dilation was preferred when a residual opening permitted tube passage. Complete membranous occlusion in Case 13 required surgical removal of the membrane before later dilations, whereas choanal atresia in Case 26 required transpalatal choanoplasty before later dilation sessions. Additional procedures for otitis media, inflammatory aural polyps, chronic rhinosinusitis, or other anatomical abnormalities were performed during subsequent sessions as clinically indicated rather than as routine components of the primary dilation procedure.

In humans, prolonged pressure on the base of the tongue by mouth gags and retractors during palatal surgery has been reported to cause lingual edema due to venous congestion, ischemia, and impaired lymphatic drainage [27,28]. Subcutaneous emphysema developing after oropharyngeal interventions is explained by the passage of air into deep neck tissues through breaches in the pharyngeal mucosa and constrictor muscles [29,30]. In the present study, the observed nasopharyngeal and tongue edema was thought to be associated with temporary disruption of venous and lymphatic drainage caused by the pressure exerted on surrounding tissues during soft palate elevation. Widespread emphysema was considered to have developed as a result of air tracking into cervicofacial tissue planes through a small tear in the pharyngeal mucosa and underlying muscular layers. This complication represents the first similar case recorded following interventions in this region at the relevant clinic, and no directly comparable reports were found in the available veterinary literature. These findings highlight the importance of avoiding excessive tissue compression and uncontrolled deep trauma during the procedure, as well as the necessity of perioperative airway monitoring. Restenosis, on the other hand, is an expected outcome attributable to post-procedural inflammation, fibrosis, and recurrent scar tissue formation following dilation or reconstruction. Therefore, therapeutic efficacy should not be evaluated solely based on early clinical

improvement, but rather by taking into account the long-term preservation of nasopharyngeal patency.

Inflation durations reported for feline NPS vary considerably. Pollack et al. [24] used serial inflation periods of 30 or 60 sec whereas Champetier et al. [4] maintained each progressively increased balloon pressure for five minutes. The five-minute inflation period used in the present study was based on the latter protocol. Prolonged inflation may provide sustained radial pressure and facilitate gradual expansion of fibrotic tissue; however, it may also increase the risks of mucosal ischemia, tissue trauma, hemorrhage, edema, and inflammation. The five-minute resting interval between applications allowed the jaw to be returned to a near-closed position around the orotracheal tube and provided an opportunity to assess tissue response before further dilation. This precaution is relevant because maximal or prolonged mouth opening in cats can compress the maxillary arteries and reduce arterial supply to the brain and retina [31-33].

Previous investigations have reported stertor and rhinorrhea as frequent clinical findings, yet these findings have not been shown to predict the number of required dilations [6,25]. Similarly, although planned serial dilation has been suggested to be potentially associated with a longer progression-free interval, no significant correlation was identified between the total number of dilations and progression-free survival [26]. The findings of the present study suggest that age and initial stertor severity have limited value in predicting the number of modified balloon dilation sessions. The number of sessions is considered to be influenced more substantially by case-specific anatomical characteristics, such as the localization and length of stenosis, the subjectively assessed degree of narrowing, the fibrotic nature of the tissue, and the luminal caliber achieved at each intervention.

This study has several limitations. Its retrospective design resulted in incomplete or non-standardized clinical records and prevented uniform application of diagnostic, therapeutic, and follow-up protocols. The absence of a control or comparator group precludes any conclusion that the modified dilation technique is superior to previously reported balloon dilation protocols. Selection bias may have arisen because the study population was derived from a specialized ENT referral clinic and treatment was declined by a substantial proportion of owners. Treatment procedures, maximum tube diameter, number and timing of dilation sessions, adjunctive surgical interventions, and follow-up duration varied among cases. Clinical improvement was assessed partly from owner reports and was not consistently confirmed through repeat CT or RN. Objective, standardized measurements of stenosis diameter, length, severity, immediate post-treatment widening, and subsequent luminal patency were unavailable; the qualitative saline-passage assessment used in some cats was not a validated measurement method. Formal concordance analysis among CT, pharyngeal examination, and RN was therefore not possible. Furthermore, the available records did not permit reliable classification of most cases as congenital or secondary, which prevented robust etiological subgroup comparisons. The limited number of treated cats, low numbers of complications and restenosis events, and short and variable follow-up periods further restricted statistical analysis and assessment of long-term recurrence.

This study showed that pharyngeal examination under general anesthesia, CT, and RN can be used individually or in combination for the diagnosis of feline NPS. Modified balloon dilation with cuffed red rubber endotracheal tubes was followed by clinical improvement in most treated cats, although some required multiple dilation sessions or adjunctive surgical procedures and early procedure-related complications occurred. Age and initial stertor severity did not predict the number of dilation sessions. These findings support modified balloon dilation as a feasible treatment option but do not establish superiority over conventional balloon dilation or other treatments. Prospective controlled studies using standardized anatomical measurements, treatment protocols, and follow-up examinations are needed to compare therapeutic approaches and determine long-term efficacy.

Declarations

Availability of Data and Materials: The anonymized data supporting the findings of this study are available from the corresponding author upon reasonable request. Information that may identify animal owners will not be shared in accordance with the Turkish Personal Data Protection Law No. 6698 (KVKK).

Ethical Compliance Declaration: The authors declare that the study was conducted in accordance with all applicable animal welfare and research ethics principles, institutional and national/international regulations, and the requirements of the relevant ethics committees and funding/supporting institutions, where applicable. The authors accept full responsibility for the ethical integrity of the study.

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