*Original Article*

# Quantitative assessment of preoperative and postoperative brachycephalic airway obstruction syndrome surgery using clinical grading questionnaires and 6-minute walk test in French bulldogs

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*Abstract*

Brachycephalic airway obstructive syndrome (BAOS) is an anatomical abnormality of the upper airway commonly found in brachycephalic breeds, leading to clinical signs and physical capacity impairment. The degree of stenotic nares was reported to be related to BAOS severity in French bulldogs. This study aimed to compare clinical signs and physical capacity in French bulldogs before and after BAOS surgery using modified Roedler questionnaires and a 6-minute walk test (6-MWT). Twenty-seven French bulldogs were enrolled in this study (non-BAOS control (n=7), non-severe stenotic nares BAOS dogs (n=8), and severe stenotic nares BAOS dogs (n=12). BAOS surgery included staphylectomy using bipolar sealing device and vertical wedge alarplasty in all BAOS dogs. The non-severe and severe stenotic nares BAOS dogs before surgery had significantly higher overall BAOS severity scores assessed by owners using the questionnaire compared to the control dogs (vs 3(3.0-3.0) score, $p$<0.005) and their postoperative scores (17.5(15.25-19.0) vs 4.0(2.25-6.0) score; p=0.002 and 15.5(14.0-19.75) vs 6.0(5.0-6.0) score; p=0.01, respectively). The postoperative 6-MWT distances significantly increased in non-severe and severe stenotic nares BAOS dogs when compared with their preoperative walk distances (500.6±12.67 vs 408.5±15.25 meters; p=0.0003 and 509.8±9.16 vs 403.5±13.86 meters; p=0.0001, respectively). The 6-MWT distances did not show significant differences between non-severe and severe stenotic nares BAOS dogs both before and after surgery ($p$>0.05). However, the severe stenotic nares BAOS French bulldogs at resting state had significantly higher preoperative compared to postoperative heart rate (132±2.23 vs 120±2.17; p=0.0002) and respiratory rate (59.67±5.98 vs 42.0±4.45; p=0.003). Pain score after surgery was minimal, and no respiratory complications were found immediately after surgery and 4 weeks postoperatively. There were marked improvements in respiratory clinical grades and overall questionnaire scores after surgery in both BAOS groups. Walk distances significantly increased in both BAOS groups after surgery and were similar to the control dogs ($p$>0.05). In conclusion, short-term postoperative surgical outcomes and physical capacity were excellent in French bulldogs with and without severe stenotic nares assessed by owner's questionnaire scoring and 6-MWT in clinical settings. A quantitative assessment using 6-MWT as a noninvasive test was well-tolerated and feasible for monitoring exercise tolerance before and after BAOS treatment.

**Keywords:** *BAOS, brachycephalic airway obstruction syndrome, French bulldogs, surgery, quantitative assessment, 6-minute walk test*

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## Introduction

Brachycephalic airway obstructive syndrome (BAOS) is a respiratory syndrome related to conformational disorders commonly characterized by stenotic nares, elongated and thick soft palate, aberrant nasal turbinates, and other malformations of the skulls affecting the brachycephalic breeds. Studies have shown severity of BAOS associated with specific characteristics in different brachycephalic breeds, for instance, the severity of stenotic nares correlated with BAOS severity in French bulldogs (Lui *et al*., 2017b; Ekenstedt *et al*., 2020). Hypoplasia or absence of alae nasi in French bulldogs could attribute to stenotic nares (Virgilio et al., 2023), and they were presented with the most intense stenotic nares compared to other brachycephalic breeds (Mendes Junior *et al*., 2021). French bulldogs with severe stenotic nares could have more blockage of the nasal passageway than non-severe stenotic nares dogs. This increased the airflow resistance and reduced ventilation of sinuses, affecting physical capacity.

Surgical correction of BAOS aimed to alleviate the clinical signs rather than to correct all primary disorders, mostly recommended to reduce soft palate length and open the stenotic nares (Harvey, 1982; Davidson *et al*., 2001; Hughes *et al*., 2018; Mayhew *et al*, 2021). Vessel sealing device has been one of many surgical energy devices (such as CO2 lasers, radiofrequency blades, ultrasonic dissectors, etc.) widely used for staphylectomy (Knecht, 1979; Clark and Sinibaldi, 1994; Davidson *et al*., 2001; Elkins, 2005). These advanced tools reduced surgical time and intraoperative bleeding compared to conventional techniques (Davidson *et al*., 2001; Thunyodom *et al*., 2019). However, there were no quantitative assessments of clinical improvement after BAOS surgery utilizing these techniques. Surgical outcome evaluation was a clinical challenge due to the complexity of clinical signs and the influence of the excitement of the dogs in the clinical setting. Clinical monitoring was less accurate without quantitative assessments and direct comparison of the surgical success rate before and after surgery due to a lack of a standardized scoring system and objective measures (Packer and Tivers, 2015; Liu *et al*., 2015; Pohl *et al*., 2016). Clinical grading scores based on history along with clinical observation and modified questionnaires constructed specifically for BAOS answered by owners to reflect the severity of BAOS presented at home have been applied (Roedler *et al*., 2013; Pohl *et al*., 2016; Anyamaneecharoen *et al*., 2020). The 6-minute walk test (6-MWT) has been used in humans and dogs to test physical capacity using low-intensity submaximal exercise (Swimmer and Rozanski, 2011; Manens *et al*., 2014; Cerda-Gonzalez *et al*., 2016). The 6-MWT assessed the health status and therapy responsiveness of cardiovascular, pulmonary and neuromuscular diseases in dogs (Swimmer and Rozanski, 2011; Manens *et al*., 2014; Cerda-Gonzalez *et al*., 2016, Sutayatram *et al*., 2018). Studies have applied 6-MWT to assess BAOS in dogs (Lilja-Maula *et al*., 2017; Aromaa *et al*., 2019), and a recent study has shown a correlation between clinical signs and 6-MWT distances in French bulldogs (Anyamaneecharoen *et al*., 2020).

This study aimed to utilize quantitative assessment tools to assess BAOS French bulldogs before and after BAOS surgery. The 6-MWT was used to quantify the physical capacity before and after surgical correction. A bipolar sealing device and wedge resection alarplasty were used for BAOS surgery for all BAOS French bulldogs with various degrees of stenotic nares. The clinical signs were assessed by respiratory and digestive grading along with owners' perception using the modified Roedler BAOS questionnaire, respectively. Other potential factors such as heart rate (HR), respiratory rate (RR), and peripheral oxygen saturation (SpO2) were then compared between non-severe and severe obstruction of the nares BAOS dogs. A group of 7 healthy non-BAOS French bulldogs served as a reference control.

The 6-MWT might be an important tool to measure physical capacity in brachycephalic dogs before and after surgical treatment in BAOS dogs during clinical exam along with home-based clinical signs assessment by owner's observation and questionnaires.

## Materials and Methods

***Animals:*** Twenty-seven client-owned French bulldogs were enrolled in this study after approval of the protocol by the animal care and use committee at Chulalongkorn University (IACUC protocol #: 1931009). Twenty BAOS French bulldogs without other respiratory problems or who had previous respiratory surgeries were included in the study. Dogs with abnormalities that could affect physical walking abilities, including a history of syncope and cyanotic, obesity, cardiovascular diseases, neurological diseases, musculoskeletal diseases, and previous oxygen treatment, were excluded from the study. The dogs were divided into 2 BAOS groups according to the severity of stenotic nares described by Liu and colleagues (2016) (Group 1: non-severe stenotic nares were dogs with mild to moderate stenotic nares and Group 2: severe stenotic nares). Additionally, seven healthy French bulldogs with no stenotic nares and respiratory abnormalities served as the negative control group. All dogs included in the study were able to perform a 6-minute leash walk.

Data regarding age, gender, body weight, BCS, and preoperative blood profile were collected at the preoperative visit. In the BAOS groups, the respiratory and digestive clinical grading severity of the disease according to Poncet and colleagues (2006), scaling from 1 (absent of clinical signs) to 3 (severe clinical signs), were recorded preoperatively then at 1, 2, 3 and 4 weeks postoperatively. All owners received client education about BAOS, and then the modified Roedler questionnaires (Roedler *et al*., 2013; Anyamaneecharoen *et al*., 2020) were completed by the owners before further interventions to evaluate owners' perspectives of their French bulldogs. BAOS dogs included in this study received general anesthesia, and BAOS surgery was completed. Laryngeal and oropharyngeal examination in a sternal recumbency were performed during induction prior to intubation within 1 minute to assess the elongated soft

palate, degree of laryngeal collapse, everted laryngeal saccules, laryngeal edema, tonsillitis, tonsil enlargement and other secondary changes were reported.

***BAOS surgery:*** One of 2 experienced or board-certified surgeons led each BAOS surgery and was assisted by a master's degree student. Surgical correction of the elongated soft palate (staphylectomy) and stenotic nares (alarplasty) were performed in a sternal recumbency, and the mouth was kept open during staphylectomy. Surgical technique for staphylectomy utilized the bipolar sealing device (Ligasure® Small Jaw Instrument, Medtronic, USA). The elongated soft palate was transected laterally from the caudal aspect of the tonsillar crypt to another side in an arch shape not beyond the level of the middle tonsil, as previously described by Thunyodom and colleagues (2019). After staphylectomy, vertical wedge resection alarplasty, as previously described by Schmiedt and Creevy (2012), was done to increase the opening of both nares. The length of the base of the wedge determined the final size of the nares to resemble a normal opening, as shown in Figure 1A. Long-term absorbable sutures were placed to close the wedge defects.

Following the surgery, prednisolone (0.5 mg/kg) and famotidine (1 mg/kg) were prescribed once a day orally for 1 week, and sucralfate (1 g/dog) was prescribed twice a day orally for 2 weeks after surgery. Water and food were given within 8 hours after surgery. All dogs were fed with soft canned food and cool water and an Elizabeth collar worn at least 2 weeks postoperatively to prevent suture breakage from self-trauma. The clinical signs were monitored at 1 day, 1, 2, 3, and 4 weeks postoperatively. Post-operative complications and pain assessment scores were recorded. In the BAOS groups, the Modified Roedler questionnaire was then repeated by the owners 4 weeks after BAOS surgery.

***6-minute walk test (6-MWT):*** Physical capacity exercise test using the 6-MWT was done in all dogs prior to surgery. Before the 6-MWT (resting state), body temperature, heart rate (HR), respiratory rate (RR), and percentage peripheral oxygen saturation (SpO2) measured by pulse oximeter were recorded for each dog. The heart rate was measured by auscultation and indirectly by pulse rate from the pulse oximeter. The respiratory rate was measured by direct observation. Additionally, the respiratory rate in tachypneic dogs was reviewed using VDO records. After 20-30 minutes of acclimatization with a chest harness in a quiet 20-23 Celsius air-conditioned room, the dog was guided to walk at their own pace alongside the same veterinarian through an unobstructed 5x5 square meter corridor for 6 minutes. Immediately after the 6-MWT (post-walk), the HR, RR, body temperature, and SpO2 were remeasured. The total walk distances for each dog were reported in meters. The French bulldogs from both BAOS groups repeated the 6-MWT at 4 weeks postoperatively.

***Statistical analysis:*** All continuous variables were reported as mean ± the standard error of the mean, and ordinal variables were reported as median (interquartile range). Statistical analysis was performed using GraphPad Prism version 10.0 (GraphPad Software, CA, USA). A one-way ANOVA with a post hoc Tukey HSD test was used to compare the continuous data between the groups. Multiple comparisons within each group were made using one-way repeated measures ANOVA with Tukey's adjusted p-value. Wilcoxon sign rank test was used to compare pre-op and postoperative Modified Roedler questionnaire scores within each group. Kruskal-Wallis test with post hoc Dunn's multiple comparisons test was used for multiple comparisons of the Modified Roedler questionnaire scores between the groups. Mann Whitney U test was used for comparison between respiratory and digestive clinical grades between the BAOS groups. A comparison of the respiratory and digestive clinical grades for each BAOS group between each time point was done using the Friedman test and post hoc Dunn's multiple comparisons test. Results were considered significant when $p<0.05$.

## *Results*

Twenty-seven French bulldogs consisting of 18 males and 9 females aged between 8 and 58 months and weighing between 9 and 16.5 kg were included in the study. The severe stenotic nares BAOS dogs (34.42±4.37 months) were significantly older than the non-severe stenotic nares (21.75±4.11 months) and the healthy control dogs (14.29±1.96 months) ($p<0.05$ and $p<0.0001$, respectively). The characteristics of all dogs are shown in Table 1. The 7 healthy control French bulldogs had normal nostrils (Figure 1A) and no abnormal respiratory sounds. Three dogs in the control group had no primary and secondary BAOS disorders upon laryngoscopy. The majority of the healthy control dogs had absence or mild (less than once a month) respiratory and digestive clinical signs, which were graded respiratory and digestive clinical grade 1, except 1 dog had digestive clinical grade 2 due to previous medication. All 20 French bulldogs in both BAOS groups presented with pharyngeal stertor, and 9 dogs had mixed stertor and stridor sounds during physical examination. Eight BAOS French bulldogs had mild increased lung sound. Stenotic nares were present in all 20 BAOS dogs; 8 dogs had non-severe stenotic nares (Figure 1B and C), and 12 dogs had severe stenotic nares (Figure 1D). The most common secondary changes found were everted tonsils, 75% in the non-severe stenotic nares group and 92% in the severe stenotic nares group. Everted laryngeal saccules were predominately found in dogs with severe stenotic nares more than in dogs with non-severe stenotic nares (83% vs 37.5%). The blood profile levels for all dogs were within normal limits (Table 1). However, the severe stenotic nares BAOS group had significantly higher hemoglobin concentration when compared to the normal and non-severe stenotic nares BAOS group, p=0.017 and p=0.046, respectively.

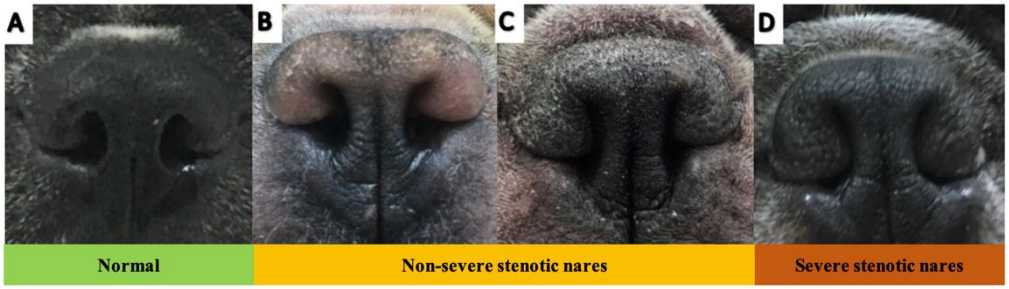


**Figure 1** Degree of stenotic nares in French bulldogs; A=normal nostril, B=mild stenosis, C=moderate stenosis and D=severe stenosis. B and C were categorized in the non-severe stenotic nares BAOS dogs group.

**Table 1** The characteristics and anatomical abnormalities of the control group (n=7), non-severe stenotic nares group (n=8) and severe stenotic nares group (n=12).

| Parameters | Control | Non-severe SN | Severe SN |
|---|---|---|---|
| Sex (number of dogs) | | | |
| Male | 2 (7.41%) | 6 (22.22%) | 10 (37.04%) |
| Female | 5 (18.52%) | 2 (7.41%) | 2 (7.41%) |
| Age (months) | 14.29±1.96 | 21.75±4.11 | 34.42±4.37 $^{b****}$ |
| Weight (kg) | 10.76±0.81 | 12.36±0.80 | 13.43±0.64 |
| BCS ¥ (5 scale) | 3 [2.90-3.25] | 3 [2.78-3.22] | 3 [3.05-3.37] |
| **Primary changes** (no. of dogs) | | | |
| Elongated soft palate | 0 | 8/8 | 12/12 |
| Hypoplastic trachea | 0 | 1/8 | 1/12 |
| Stenotic nares | | | |
| Mild | 0 | 2/8 | 0/12 |
| Moderate | 0 | 6/8 | 0/12 |
| Severe | 0 | 0/8 | 12/12 |
| **Secondary changes** (no. of dogs) | | | |
| Everted tonsils | N/A | 6/8 | 11/12 |
| Unilateral | N/A | 1/6 | 4/11 |
| Bilateral | N/A | 5/6 | 7/11 |
| Laryngeal saccules | N/A | 3/8 | 10/12 |
| Laryngeal collapse | N/A | 3/8 | 10/12 |
| Stage 1 | | 1/3 | 2/10 |
| Stage 2 | | 2/3 | 8/10 |
| Stage 3 | | 0/3 | 0/10 |
| **Blood parameters** | | | |
| RBC x$10^6$ (cells/uL) | 6.88±0.31 | 6.78±0.19 | 7.42±0.13 |
| Hb (g/dL) | 17.07±0.61 | 17.47±0.50 | 19.04±0.35$^{a*}$ |
| Hct (%) | 46.66±1.40 | 47.26±1.24 | 50.35±1.04 |
| WBC x$10^3$ (cells/uL) | 11.39±0.77 | 11.26±0.67 | 11.74±0.97 |
| Platelets x$10^3$ (cells/uL) | 356.00±37.12 | 266.70±26.37 | 305.70±18.03 |
| ALT (unit) | 43.00±6.11 | 61.43±13.62 | 48.00±5.97 |
| ALP (IU/L) | 40.14±5.06 | 33.86±5.29 | 33.17±2.54 |
| BUN (mg%) | 14.23±1.29 | 16.20±2.32 | 15.20±1.66 |

Data reported as number of dogs, Mean ± SE, ¥ Median (interquartile range) as appropriate.
Compared to control: *; $p$<0.05, **; $p$<0.005, ***; $p$<0.001, ****; $p$<0.0001
Compared between stenotic nares groups: a; $p$<0.05, b; $p$<0.005
Abbreviation: ALP; alkaline phosphatase, ALT; alanine transferase, BAOS; brachycephalic airway obstruction syndrome, BCS; body condition score, BUN; blood urea nitrogen, Hb; hemoglobin, Hct; hematocrit, RBC; red blood cells, SN; stenotic nares, WBC; white blood cells.

The owner's perspective of BAOS by using modified Roedler BAOS questionnaire scoring was shown in Table 2. The overall preoperative total questionnaire score of the BAOS groups was significantly higher than the control ($p$<0.0001), and there were no significant score differences between the BAOS groups. After 4 weeks postoperative BAOS surgery, the overall total questionnaire score of the non-severe and severe stenotic nares BAOS group significantly reduced from 17.5(15.25-19.0) to 4.0(2.25-6.0); p=0.002 and 15.5(14.0-19.75) to 6.0(5.0-6.0); p=0.01, respectively. No significant differences in the total questionnaire score were found between the control and both postoperative BAOS groups.

Preoperative 6-MWT distances compared between the non-severe and severe stenotic nares BAOS groups were not significantly different (408.5±15.25 vs 403.5±13.86 meters $p$>0.05), however, both preoperative distances were significantly shorter than the control (521.5±13.24 meters) with p=0.0001 and p=0.0001, respectively. French bulldogs with non-severe and severe stenotic nares could walk significantly longer distances after 4 weeks postoperative BAOS surgery when compared to their preoperative distances (500.6±12.67; p=0.0003 and 509.8±9.16 meters; p=0.0001, respectively). There was no significant difference in 6-MWT walk distances at 4 weeks postoperative BAOS surgery compared to the healthy control ($p$>0.05) (Figure 3).

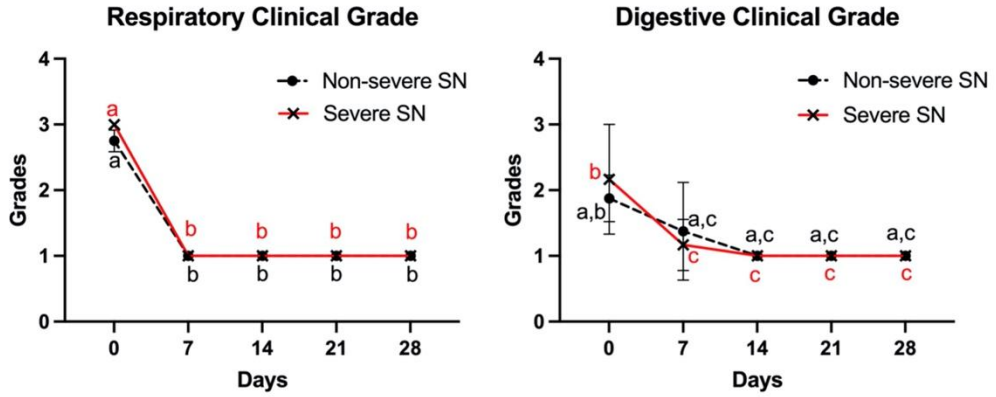


**Figure 2** These line graphs illustrated the respiratory and digestive clinical grades of the non-severe stenotic nares (dot on line) and the severe stenotic nares (cross on line) BAOS French bulldogs at pre-op (day=0) and 4 postoperative periods. The same alphabetical letters indicated no significant differences between points ($p$>0.05). The respiratory clinical grade significantly decreased within 1 week postoperatively in both groups, and the grades were stable through the follow-up periods. The severe stenotic nares BAOS French bulldogs had a significantly decreased digestive clinical grade at the first operative week and maintained the same grade.

**Table 2** Owner's perspective of BAOS by using modified Roedler BAOS questionnaire scores preoperative and 4 weeks postoperative BAOS surgery.

| Parameters | Control | Non-severe SN | Severe SN |
|---|---|---|---|
| **Breathing sound** | | | |
| Pre-operative | 1.0 (0-1.0) | 7.5 (5.5-8.0) $^{a***}$ | 6.0 (6.0-8.0) $^{a***}$ |
| Post-operative | - | 1.0 (0-3.0) | 2.0 (1.25-3.0) $^{b}$ |
| **Exercise / heat tolerance** | | | |
| Pre-operative | 0 (0-1.0) | 5.0 (4.25-6.0) $^{a**}$ | 6.0 (4.0-6.0) $^{a***}$ |
| Post-operative | - | 0 (0-1.75) | 1.5 (0.25-2.0) $^{b}$ |
| **Eating** | | | |
| Pre-operative | 2.0 (1.0-2.0) | 3.5 (3.0-4.0) $^{a*}$ | 3.0 (2.0-4.0) $^{a}$ |
| Post-operative | - | 2.0 (1.0-3.0) $^{a}$ | 1.5 (1.0-2.75) $^{a}$ |
| **Sleeping** | | | |
| Pre-operative | 0 (0-0) | 1.0 (0.25-2.5) $^{a}$ | 2.0 (0.25-2.75) $^{a**}$ |
| Post-operative | - | 0 (0-0) $^{a}$ | 0 (0-0) $^{b}$ |
| **Total questionnaire score** | | | |
| Pre-operative | 3 (3.0-3.0) | 17.5 (15.25-19.0) $^{a***}$ | 15.5 (14.0-19.75) $^{a***}$ |
| Post-operative | - | 4.0 (2.25-6.0) $^{b}$ | 6.0 (5.0-6.0) $^{b}$ |

Data reported as Median [interquartile range]. Kruskal-Wallis test with post hoc Dunn's multiple comparisons test (adjusted p-value) was used to compare between the groups. *$p$<0.05, ** $p$<0.005, *** $p$<0.005, **** $p$<0.0001 compared to control. Alphabetical letters annotated comparison within column group using Wilcoxon sign rank test. The same letters within the column indicated no significant differences.

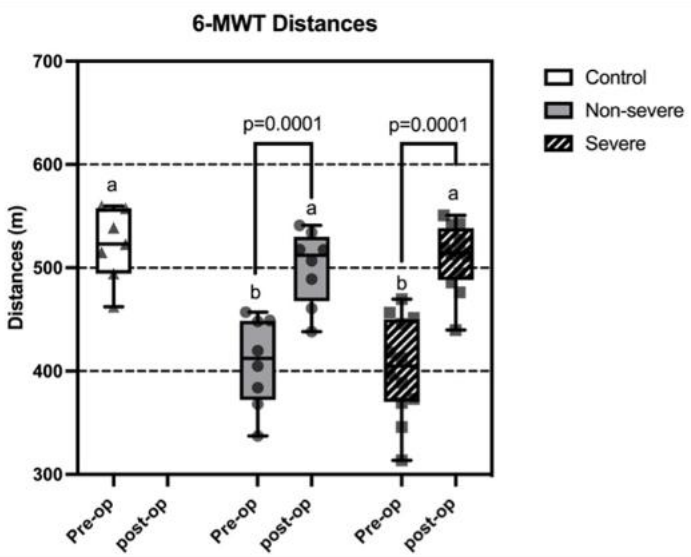


**Figure 3** Illustration of the 6-minute walk test (6-MWT) distances measured from the control (white bar), non-severe stenotic nares BAOS (grey bars), and severe stenotic nares BAOS groups (striped-black bars). Measurements were made pre-op and at 4 weeks postoperatively in the BAOS groups. Alphabetical letters annotated comparison between the BAOS and control groups. The same letters indicated no significant differences between the bar graphs. Abbreviations: Pre-op; preoperative measurements, Post-op; postoperative measurements.

**Table 3** Parameters before and after the 6-minute walk test of the normal group (n=7), mild-moderate stenotic nares group (n=8), and severe stenotic nares group (n=12).

| Parameters | Control | Non-severe stenotic nares BAOS dogs | | | Severe stenotic nares BAOS dogs | | |
|---|---|---|---|---|---|---|---|
| | | Preoperative | Postoperative | p-value‡ | Preoperative | Postoperative | p-value‡ |
| **HR (beat per minute)** | | | | | | | |
| Resting state | 118.9±5.14 [a] | 121.0±2.24 [a] | 114.0±2.73 [a] | ns | 132.3±2.23 [b] | 120.3±2.17 [a] | 0.0002 |
| Post 6-MWT | 128.6±5.41 [**b] | 138.5±3.02 [***b] | 125.0±4.12 [**b] | 0.01 | 156.0±3.27 [****c] | 138.7±2.11 [****b] | 0.0003 |
| **RR (breath per minute)** | | | | | | | |
| Resting state | 32.57±2.03 [a] | 39.5±6.02 [a] | 30.5±2.38 [a] | ns | 59.67±5.98 [b] | 42.0±4.45 [a] | 0.003 |
| Post 6-MWT | 48.00±1.95 [*c] | 60.5±10.83 [*c] | 42.5±3.46 [**c] | ns | 103.3±10.67 [***d] | 72.33±5.86 [****c] | 0.006 |
| **Body Temperature (F)** | | | | | | | |
| Resting state | 100.7±0.19 [a] | 101.1±0.26 [a] | 100.8±0.25 [a] | ns | 101.7±0.17 [a] | 101.0±0.15 [a] | 0.04 |
| Post 6-MWT | 101.0±0.20 [a] | 101.4±0.30 [a] | 101.1±0.23 [a] | ns | 102.3±0.23 [***b] | 101.4±0.13 [a****] | 0.008 |
| **$SpO_2$ (%)** | | | | | | | |
| Resting state | 97.86±0.34 [a] | 96.38±0.60 [a] | 96.88±0.40 [a] | ns | 96.42±0.23 [a] | 96.83±0.41 [a] | ns |
| Post 6-MWT | 97.71±0.29 [a] | 96.0±0.50 [a] | 96.88±0.44 [a] | ns | 96.67±0.38 [a] | 97.08±0.31 [a] | ns |

Data reported as Mean ± SE. Asterisks indicated significant differences comparing post-6-MWT and resting state within each column parameters (*; $p<0.05$, **; $p<0.005$, ***; $p<0.001$, ****; $p<0.0001$). ‡ ANOVA repeated measures followed by Tukey's multiple comparisons test were used for comparison between preoperative and postoperative parameters within each BAOS group before and after 6-MWT (adjusted p-value). Multiple comparisons between parameters at resting state and post-6-MWT with the control dogs were done by ordinary one-way ANOVA followed by Tukey's multiple comparisons test. The same alphabetical letters indicated no significant differences between points (adjusted $p>0.05$). Abbreviations: 6-MWT; 6-minute walk test, F; Fahrenheit, HR; heart rate, m; meters, ns; not significant, RR; rest rate, SpO2; peripheral oxygen saturation.

Table 3 shows physiological parameters of the HR, RR, body temperature, and SpO2 at resting state and after 6-MWT. All dogs had significantly increased heart rate and respiratory rate after 6-MWT. Postoperative heart rate in the severe stenotic nares BAOS group significantly decreased when compared to preoperative heart rate at resting state and post-6-MWT (120.3±2.17 vs 132.3±2.23 beat per minute; p=0.0002 and 138.7±2.11 vs 156.0±3.27 beat per minute; p=0.0003, respectively). Postoperative heart rate at resting and post-6-MWT in both BAOS groups were not significantly different from the control. The respiratory rate in the non-severe stenotic nares dogs did not differ before and after surgery. Moreover, no significance was found when compared to the control. At resting state, respiratory rate in the severe stenotic nares dogs significantly reduced after BAOS surgery (59.67±5.98 vs 42.0±4.45 breath per minute, p=0.003) and was not significantly different from the control (vs 32.57±2.03 breath per minute, $p>0.05$). Respiratory rate postoperative BAOS surgery in the severe stenotic nares dogs after 6-MWT significantly reduced from preoperative 103.3±10.67 breath per minute to postoperative 72.33±5.86 breath per minute (p=0.006) and was not significantly different from the control (vs 48.0±1.95 breath per minute, $p>0.05$). Body temperatures showed no significant changes at resting and after 6-MWT in the control, preoperative, and postoperative non-severe stenotic nares dogs ($p>0.05$).

In the severe stenotic nares dogs, after 6-MWT, the preoperative body temperature significantly increased to 102.3±0.23 F (p=0.0004) and was significantly higher compared to the control and non-severe stenotic nares dogs (p=0.001 and p=0.02, respectively). After BAOS surgery, the severe stenotic nares dogs' body temperature after 6-MWT significantly reduced to 101.4±0.13 F compared to preoperative body temperature (p=0.008) and did not differ from the control and non-severe stenotic nares dogs ($p>0.05$). Oxygen saturation at resting and after 6-MWT did not significantly change in all dogs ranging between 96 and 97.

## *Discussion*

The average age of the BAOS French bulldogs in this study that presented for surgical treatment were young adults with an average age of 29.35±3.34 months (approximately 2.5 years), and the severe stenotic nares dogs in this study were older than the other groups. Lui and colleagues (2016) reported that age was not significantly associated with BAOS severity; interestingly, they revealed that stenotic nares were significantly associated with BAOS severity in Pugs, French bulldogs, and bulldogs. Previous studies showed an association between obesity and the severity of BAOS (Lilja-Maula *et al.*, 2017; Lui *et al.*, 2017a) and obesity increased severity of respiratory and digestive clinical signs (Poncet *et al.*, 2005). Therefore, this study included French bulldogs with BCS between 2 to 4 to reduce obesity influencing the BAOS severity, and no significant weight differences were found between the groups, including the healthy controls. BAOS consists of abnormalities of upper airway anatomy that contribute to several clinical signs involved beyond the respiratory system and could be affected by the dog's behavior (Lilja-Maula *et al.*, 2017). This made clinical assessments more challenging, and clinical signs during hospital visits could not reflect true BAOS signs during daily activities. Therefore, multiple objective quantitative assessments should be used to evaluate BAOS severity before and after treatment.

After staphylectomy and nasal alarplasty, the respiratory clinical grades of all dogs in both BAOS groups significantly improved within one week, which maintained this score through the 4 weeks short-term follow-up period. In a previous long-term 6-month follow-up study, most French bulldogs with BAOS had respiratory clinical grade 3 before the conventional staphylectomy technique (Haimel and Dupre, 2015). However, not all dogs had improved respiratory clinical grades after surgery. Haimel and Dupre (2015) reported approximately 25% of dogs developed postoperative respiratory complications, including dyspnea, coughing, and aspiration pneumonia. Staphylectomy using the bipolar sealing device in this

study showed no severe acute postoperative respiratory complications. All dogs were discharged and able to eat and drink and had no noticeable pain within 24 hours postoperatively. This could be from reduced surgical time, minimal tissue manipulation, injury, and inflammation (Thunyodom *et al.*, 2019). In this study, the digestive clinical grades in most BAOS dogs reduced to grade 1 within the second week after surgery. The severe and non-severe stenotic nares dogs did not show significant differences in the digestive grades within each time point. However, 1 dog from the non-severe stenotic nares group had an increased frequency of vomiting in the first postoperative week, and 1 dog from the same group had no improvement until the second week. Other previous studies have shown various gastrointestinal signs and duration of improvement (Poncet *et al.*, 2006; Haimel and Dupre, 2015) and the most common signs were regurgitation, vomiting and dysphagia (Roedler *et al.*, 2013; Freiche and German, 2021). The respiratory and gastrointestinal tracts, both involved in the mechanism of breathing and swallowing, could affect each other (Grobman, 2021; Luciani *et al.*, 2022). Studies have shown that 80-97% of brachycephalic dogs with respiratory disorders had concurrent gastrointestinal disorders (Poncet *et al.* 2005 and 2006; Freiche and German, 2021). Therefore, gastrointestinal abnormalities involved in BAOS seem to be more problematic and have various outcomes after surgery compared to respiratory signs. Medical treatment for gastrointestinal disorders was suggested for BAOS dogs before and after BAOS surgery and is likely to be prescribed beyond improvement of respiratory signs.

The overall modified Roedler BAOS questionnaire scores before surgery were significantly higher in both BAOS groups compared to the control group, especially the breathing sound, exercise, and heat intolerance parts. Four weeks after surgical correction, the scores in both BAOS groups markedly improved in all parts and did not differ between the BAOS groups. This was in agreement with their respiratory and digestive clinical grades. However, the scores in the eating part showed some variations, such as regurgitation, vomiting, eating fast, and swallowing food without chewing, which are still present in several dogs. The modified Roedler BAOS questionnaire scores were used for the assessment of surgical clinical outcomes after conventional surgical correction (Pohl *et al.*, 2016). The previous study showed significantly improved scores, especially in breathing sound at different head positions and the exercise and heat intolerance evaluated in both summer and winter. Questionnaires with systematic scoring were beneficial for home-based BAOS severity assessments. However, the questionnaires were dependent on the owners' perceptions and recognition of BAOS, which could lead to underestimated or overestimated questionnaire scoring. Studies have shown approximately 60% of owners did not recognize the clinical signs of BAOS (Packer *et al.*, 2012; Lui *et al.*, 2015). Therefore, quantitative measurements that reduced the inter-observer variation should be added as adjunct assessment tools.

The physical capacity 6-MWT walk distances before surgical correction compared between the non-severe and severe stenotic nares BAOS dogs did not differ. However, both were significantly shorter than the control. This finding corresponded with previous studies in English bulldogs, French bulldogs and pugs, which reported BAOS dogs had shorter walk distances compared with healthy dogs in the same breed (Lilja-Maula *et al.*, 2017; Lui *et al.*, 2017a; Aromaa, 2019). Differences were seen in the physiological parameters. The severe stenotic nares BAOS dogs before BAOS surgery had significantly higher heart rates, respiratory rates, and body temperatures after low-intensity exercise. They also had higher hemoglobin concentrations compared to non-severe stenotic nares dogs. Therefore, these findings suggested that severe stenotic nares BAOS dogs needed more physiological workload to maintain a similar physical capacity compared to non-severe stenotic nares dogs. After 4 weeks of surgical correction, both BAOS groups had average 6-MWT distances similar to the control group and were significantly longer than before surgery. A previous study on BAOS surgical outcomes revealed that brachycephalic breeds showed 14% increased walk distances after conventional BAOS surgery (Villedieu *et al.*, 2018). The heart rate, respiratory rate, and SpO2 measured from the pulse oximeter reflected the oxygen delivery to maintain the physical capacity of the body. This study showed that dogs with severe stenotic nares, even during resting state, had higher heart rate and respiratory rate to maintain normal physical status. During physical examination, the clinical presentation of dogs could be interfered with by several factors, including stress and anxiety of the dog in the new environment. Therefore, assessments that relied primarily on clinical signs could not be accurately evaluated in most cases. The non-severe stenotic nares dogs maintained a stable body temperature after low-intensity exercise. In contrast, dogs with severe stenotic nares could not maintain body temperature after low-intensity exercise, and their body temperature significantly increased compared to that of their resting state. This study revealed that before BAOS surgery, body temperature raised significantly after 6-MWT in the completely obstructed nostril dogs. This emphasized the important function of the nasal cavity in regulating evaporative heat from air entering and exiting the body. Increased body temperature in these dogs was similar to a study in which English bulldogs with BAOS had higher body temperature both before and after performing 6-MWT compared with healthy dogs (Lilja-Maula *et al.*, 2017). Dogs with completely obstructed nostrils breathe with their mouth opened, which could have a negative effect on temperature regulation and oxygenation. In human studies, breathing through the nasal cavity slowed down the rate of breathing and contributed to humidifying and controlling the temperature of the air. This was crucial for the efficiency and maintenance of the healthy balance of your nervous system and blood gases (LaComb *et al.*, 2017). Despite the extra resistance during nose breathing, research showed 10 to 20% better oxygenation than mouth breathing (Trabalon and Schaal, 2012; Dallem *et al.*, 2018). Four weeks after surgical correction, all physiological parameters of 6-MWT in both BAOS groups had significantly

improved. Therefore, soft palate resection and correction of stenotic nares were recommended for elongated soft palate and all severity of stenotic nares in French bulldogs to reduce the risk of adverse events related to exercise and heat intolerance and to improve quality of life.

The limitation of this study included the anatomical abnormalities were not confirmed by laryngoscope in some healthy control dogs since most of these dogs presented to the hospital for annual check-ups or were appointed for other medical treatments without further surgical interventions. Therefore, the control dogs might not be normal and have a certain degree of respiratory abnormalities with subclinical BAOS signs. Moreover, surgical BAOS treatment in this study focused on staphylectomy and alarplasty without addressing the secondary lesions such as everted laryngeal saccules which could affect the opening into the trachea. Everted laryngeal saccules were found in 37.5% of non-severe and 83% of severe stenotic nares BAOS dogs. No dogs in this study had severe grade 3 laryngeal collapse, therefore, additional surgery to increase the rima glottidis size such as sacculectomy and arytenoidectomy were not necessary. Studies have shown mixed outcomes after sacculectomy and improvement was only found 40% of cases with the associated risk of moderate to severe complications (Lorinson *et al.*, 1997; Hughes *et al.*, 2018). Therefore, many surgeons omitted sacculectomy and arytenoidectomy as a standard for BAOS surgery and considered them as an option when severe grade 3 laryngeal collapse was diagnosed. Lastly, French bulldogs were mostly friendly and playful breed. They could tolerate leash walking during 6-MWT, which may not be feasible for certain dog breeds.

In conclusion, staphylectomy using bipolar sealing device and alarplasty gave excellent clinical outcomes in terms of minimal postoperative complication and marked improvement in clinical signs and physical capacity within 4 weeks postoperatively. The modified Roedler questionnaire and 6-MWT were simple assessment tools which did not required advanced tools and less manipulation on the dogs. These assessment tools should be applied for BAOS both before and after treatment to monitor treatment outcomes and the progression of BAOS in dogs.

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## *References*

Anyamaneecharoen T, Kradangnga K, Sutayatram S, Durongphongtorn S and Brikshavana P 2020. Clinical assessment of brachycephalic airway obstructive syndrome using questionnaire and 6-minute walk test in French Bulldogs. Thai J Vet Med. 50(3): 337–343.

Aromaa M, Lilja-Maula L and Rajamaki MM 2019. Assessment of welfare and brachycephalic obstructive airway syndrome signs in young, breeding age French Bulldogs and Pugs, using owner questionnaire, physical examination and walk tests. Anim welfare. 28(3): 287-298.

Cerda-Gonzalez S, Talarico L and Todhunter R 2016. Noninvasive assessment of neuromuscular disease in dogs: use of the 6-minute walk test to assess submaximal exercise tolerance in dogs with centronuclear myopathy. J Vet Intern Med. 30(3): 808-812.

Clark G and Sinibaldi K 1994. Use of a carbon dioxide laser for treatment of elongated soft palate in dogs. J Am Vet Med Assoc. 204(11): 1779–1781.

Dallam GM, McClaran SR, Cox DG and Foust CP 2018. Effect of nasal versus oral breathing on Vo2max and physiological economy in recreational runners following an extended period spent using nasally restricted breathing. Int J Kinesiol Sports Sci. 6(2): 22-29.

Davidson EB, Davis MS, Campbell GA, Williamson KK, Payton ME, Healey TS and Bartels KE 2001. Evaluation of carbon dioxide laser and conventional incisional techniques for resection of soft palates in brachycephalic dogs. J Am Vet Med Assoc. 219(6):776–781.

Ekenstedt KJ, Crosse KR and Risselada M 2020. Canine brachycephaly: Anatomy, pathology, genetics and welfare. J Comp Pathol. 176: 109–115.

Elkins, AD 2005. Soft palate resection in brachycephalic dogs. Vet Forum. (22): 43–46.

Freiche V and German AJ 2021. Digestive diseases in brachycephalic dogs. Vet Clin North Am Small Anim Pract. 51(1): 61–78.

Haimel G and Dupre G 2015. Brachycephalic airway syndrome: a comparative study between pugs and French bulldogs. J Small Anim Pract. 56(12): 714-719.

Harvey C 1982. Upper airway obstruction surgery. Soft palate resection in brachycephalic dogs. J Am Animal Hosp Assoc. 18: 538–544.

Hughes JR, Kaye BM, Beswick AR and Ter Haar G 2018. Complications following laryngeal sacculectomy in brachycephalic dogs. J Small Anim Pract. 59(1): 16–21.

Knecht C. 1979. Upper airway obstruction in brachycephalic dogs. Compend Contin Educ Pract Vet. 1: 25–31.

LaComb CO, Tandy RD, Lee SP, Young JC and Navalta JW 2017. Oral versus nasal breathing during moderate to high intensity submaximal aerobic exercise. Int J Kinesiol Sports Sci. 5(1): 8-16.

Lilja-Maula L, Lappalainen AK, Hyytiaïnen HK, Kuusela E, Kaimio M, Schildt K, Mo ̈lsa ̈ S, Morelius M and Rajama ̈ki MM 2017. Comparison of submaximal exercise test results and severity of brachycephalic obstructive airway syndrome in English bulldogs. Vet J. 219: 22-26.

Liu NC, Sargan DR, Adams VJ and Ladlow JF 2015. Characterisation of brachycephalic obstructive airway syndrome in French bulldogs using whole-body barometric plethysmography. PLoS One. 10(6): e0130741.

Liu NC, Adams V, Kalmar L, Ladlow J and Sargan D 2016. Whole-body barometric plethysmography characterizes upper airway obstruction in 3 brachycephalic breeds dogs. J Vet Intern Med. 30(3):853–65.

Liu NC, Oechtering GU, Adams VJ, Kalmar L, Sargan DR and Ladlow JF 2017a. Outcomes and prognostic factors of surgical treatments for brachycephalic obstructive airway syndrome in 3 breeds. Vet Surg. 46(2): 271–280.

Liu NC, Troconis EL, Kalmar L, Price DJ, Wright HE, Adams VJ, Sargan DR and Ladlow JF 2017b. Conformational risk factors of brachycephalic obstructive airway syndrome (BOAS) in pugs, French bulldogs, and bulldogs. PLoS One. 12(8):e0181928.

Lorinson D, Bright R and White R 1997. Brachycephalic airway obstruction syndrome: A Review of 118 Cases. Canine Pract. 22(5/6): 18–21.

Manens J, Bolognin M, Bernaerts F, Diez M, Kirschvink N and Clercx C 2012. Effects of obesity on lung function and airway reactivity in healthy dogs. Vet J. 193(1): 217–221.

Mayhew PD, Balsa IM, Marks SL, Pollard RE, Case JB, Culp WTN and Giuffrida MA 2021. Clinical and videofluoroscopic outcomes of laparoscopic treatment for sliding hiatal hernia and associated gastroesophageal reflux in brachycephalic dogs. Vet Surg. 50(1): o67–o77.

Mendes Junior AF, Santos GSLBD, Duarte PCDS, Hotz MR, Chalhoub FLL, Almeida VGFD, Mothe GB, Soares AMB and Almosny NRP 2021. Evaluation of the degree of stenosis of nostrils in brachycephalic dogs treated at the Nose Project of Flumimense Federal University. Research, Society and Development. 10(3): e13510313098.

Packer R, Hendricks A and Burn C 2012. Do dog owners perceive the clinical signs related to conformational inherited disorders as 'normal' for the breed? A potential constraint to improving canine welfare. Anim Welf. 21(1):81–93.

Packer RM and Tivers M 2015. Strategies for the management and prevention of conformation-related respiratory disorders in brachycephalic dogs. Vet Med Res Rep. 6:219–232.

Pohl S, Roedler FS and Oechtering GU 2016. How does multilevel upper airway surgery influence the lives of dogs with severe brachycephaly? Results of a structured pre-and postoperative owner questionnaire. Vet J. 210:39–45.

Poncet CM, Dupre GP, Freiche VG and Bouvy BM 2006. Long-term results of upper respiratory syndrome surgery and gastrointestinal tract medical treatment in 51 brachycephalic dogs. J Small Anim Pract. 47(3): 137–142.

Poncet CM, Dupre GP, Freiche VG, Estrada MM, Poubanne YA and Bouvy BM 2005. Prevalence of gastrointestinal tract lesions in 73 brachycephalic dogs with upper respiratory syndrome. J Small Anim Pract. 46(6): 273–279.

Roedler FS, Pohl S and Oechtering GU 2013. How does severe brachycephaly affect dog's lives? Results of a structured preoperative owner questionnaire. Vet J. 198(3):606–610.

Schmiedt CW and Creevy KE 2012. Nasal planum, nasal cavity and sinuses. In: Veterinary surgery: small animal. Volume 2. 1st ed. KM Tobias and SA Johnston (ed). St. Louis, Missouri: Elsevier. 1691-1706.

Sutayatram S, Buranakarl C, Kijtawornrat A, Soontornvipart K, Boonpala P and Pirintr P 2018. The effects of submaximal exercise training on cardiovascular functions and physical capacity in dogs with myxomatous mitral valve disease. Thai J Vet Med. 48(3): 433-441.

Swimmer RA and Rozanski EA 2011. Evaluation of the 6-minute walk test in pet dogs. J Vet Intern Med. 25(2): 405-406.

Thunyodom S, Kalpravidh M, Kalpravidh C, Banlunara W and Brikshavana P 2019. Efficacy of ultrasonic dissection device in staphylectomy surgery in brachycephalic airway obstructive syndrome (BAOS) dogs. Thai J Vet Med. 49(2): 113-120.

Trabalon M and Schaal B 2012. It Takes a Mouth to eat and a nose to breathe: Abnormal oral respiration affects neonates oral competence and systemic adaptation. Int J Paediat: 1-10.

Villedieu E, Rutherford L and Ter Haar G 2018. Brachycephalic obstructive airway surgery outcome assessment using the 6-minute walk test: a pilot study. J Small Anim Pract. 60(2): 132-135.

Virgilio F, Guelette V, Prata D, Boulouha L, Santos M, Belluzzi E, Caraty J, Bongartz A and Deneuche A 2023. Comparative histological analysis of the alae nasi in French bulldogs with brachycephalic obstructive airway syndrome and unaffected non-brachycephalic dogs. Vet Record. 193(4):