Comparison of the physical capacity using 6-minute walk test and questionnaire before and after resection of elongated soft palate by bipolar sealing device in French Bulldogs

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Veterinary Surgery
Department of Veterinary Surgery
FACULTY OF VETERINARY SCIENCE
Chulalongkorn University
Academic Year 2019

การเปรียบเทียบสมรรถภาพทางกาย โดยใช้การทดสอบเดิน 6 นาที และแบบสอบถามระหว่างก่อนและหลังการผ่าตัดแก้ไขเพดานอ่อนยาวด้วยเครื่องเชื่อมปิดหลอดเลือดในสุนัขพันธุ์เฟร้นบูลด๊อก

น.ส.ธมลวรรณ อัญมณีเจริญ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาศัลยศาสตร์ทางสัตวแพทย์ ภาควิชาศัลยศาสตร์
คณะสัตวแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2562

Thesis Title	Comparison of the physical capacity using 6-minute walk test and questionnaire before and after resection of elongated soft palate by bipolar sealing device in French Bulldogs
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กลุ่มอาการทางเดินหายใจส่วนต้นอุดตันเป็นความผิดปกติทางกายวิภาคของระบบทางเดินหายใจส่วนต้นที่พบได้มากในสุนัขพันธุ์หน้าสั้น ซึ่งทำให้เกิดอาการทางคลินิก และสมรรถภาพทางกายที่แย่ลง วัตถุประสงค์ของการศึกษานี้เพื่อเปรียบเทียบอาการทางคลินิกและสมรรถภาพทางกายในสุนัขพันธุ์เฟร้นบูลด๊อก โดยใช้แบบสอบถามและการทดสอบโดยการเดิน 6 นาที สุนัขพันธุ์เฟร้นบูลด๊อก 27ตัวถูกแบ่งออกเป็น 2 กลุ่ม คือ กลุ่มที่มีสุขภาพดี7 ตัว และกลุ่มที่มีอาการทางเดินหายใจส่วนต้นอุดตัน 20ตัว การซักประวัติ การตรวจร่างกาย และข้อมูลจากแบบสอบถาม รวมไปถึงการทดสอบเดิน6 นาที ได้มีการทำในทั้ง 2 กลุ่ม สุนัขกลุ่มที่มีอาการทางเดินหายใจส่วนต้นอุดตันจะมีอาการทางคลินิกที่รุนแรงกว่าอย่างชัดเจนจากแบบสอบถาม รวมไปถึงมีระยะทางเดินที่น้อยกว่าจากการทดสอบเดิน 6นาที เมื่อเทียบกับสุนัขกลุ่มปกติ สุนัขกลุ่มที่มีปัญหาทางเดินหายใจอุดตันได้รับการผ่าตัดแก้ไข โดยการผ่าตัดเพดานอ่อนยาวโดยการใช้เครื่องเชื่อมปิดหลอดเลือด และการผ่าตัดแก้ไขรูจมูกตีบแคบ ไม่พบว่ามีอาการข้างเคียงที่รุนแรงหลังการผ่าตัด จากนั้น 4 สัปดาห์หลังจากผ่าตัดจะทำการประเมินอาการทางคลินิกโดยการทำแบบสอบถามและการทดสอบเดิน6 นาทีอีกครั้ง สุนัขกลุ่มที่มีอาการทางเดินหายใจส่วนต้นอุดตันมีอาการทางคลินิกที่ดีขึ้นอย่างเห็นได้ชัด โดยเฉพาะอย่างยิ่งอาการทางระบบทางเดินหายใจเมื่อเทียบกับก่อนผ่าตัด นอกจากนี้ยังมีสมรรถภาพทางกายดีขึ้นเมื่อวัดโดยการทดสอบเดิน 6 นาที (406 ± 45 เมตร และ 506 ± 33 เมตร , $P<0.001$)โดยสรุป ทั้งแบบสอบถามและการทดสอบเดิน 6 นาทีมีความเหมาะสมที่จะใช้ทางคลินิกและสามารถประเมินอาการทางคลินิกและสมรรถภาพทางกายในสุนัขพันธุ์หน้าสั้นได้ ดังนั้นทั้งสองวิธีนี้ควรจะนำมาใช้ประกอบในการจัดการปัญหากลุ่มอาการทางเดินหายใจส่วนต้นอุดตันตั้งแต่การตรวจคัดกรองโรคจนถึงการประเมินผลหลังการผ่าตัด

สาขาวิชา	ศัลยศาสตร์ทางสัตวแพทย์	ลายมือชื่อนิสิต ....
ปีการศึกษา	2562	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....
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6075303231 : MAJOR VETERINARY SURGERY
KEYWORD: 6-minute walk test, bipolar sealing device, elongated soft palate, French bulldog, questionnaire

Tamolwan Anyamaneecharoen : Comparison of the physical capacity using 6-minute walk test and questionnaire before and after resection of elongated soft palate by bipolar sealing device in French Bulldogs. Advisor: Asst. Prof. SUMIT DURONGPHONGTORN, D.V.M., DVSc., D.T.B.V.S. Co-advisor: SAIKAEW SUTAYATRAM, D.V.M., Ph.D., KRISHAPORN KRADANGNGA, D.V.M., Ph.D.

Brachycephalic airway obstruction syndrome (BAOS) is an anatomical abnormality of upper airway commonly found in brachycephalic breeds leading to clinical signs and physical capacity impairment. The purposes of this study were to compare clinical signs and physical capacity in French bulldogs between before and after surgical correction using questionnaire and 6-minute walk test (6-MWT). Twenty-seven French bulldogs were enrolled in this study and divided into normal group (n=7) and BAOS group (n=20). History taking, clinical signs and questionnaire information were recorded and 6-MWT was performed in both groups. BAOS dogs had significantly higher severity of clinical signs from questionnaire with shorter walk distance from 6-MWT compared with normal group. BAOS group were surgically corrected including staphylectomy using bipolar sealing device and alarplasty. Serious post-operative complication was not found. Four weeks after surgery, questionnaire and 6-MWT were re-evaluated. There were marked improvements in severity of clinical signs, especially respiratory signs. Also, the BAOS dogs had better physical capacity measured by 6-MWT distance (406 ± 45 m. and 506 ± 33 m., $p<0.001$). In conclusion, both questionnaire and 6-MWT were clinically feasible and able to objectively assess clinical signs and physical capacity in brachycephalic dogs. Therefore, both of them should be included in BAOS management from screening to post-surgery evaluation.

Field of Study:	Veterinary Surgery	Student's Signature ....
Academic Year:	2019	Advisor's Signature ....
		Co-advisor's Signature ....
		Co-advisor's Signature ....

ACKNOWLEDGEMENTS

This study was supported by the 90th Anniversary of Chulalongkorn University, Rachadapisek Sompote Fund. I would like to deeply thank my thesis advisor, Asst. Prof. Sumit Drongphongtorn and my co-advisors, Dr. Saikaew Sutayatram and Dr. Krishaporn Kradangnga for their kindness, academic suggestions and helps during the research. I would like to thank all of the committees, Asst. Prof. Dr. Kumpanart Soontornvipart, Dr. Nicole Sirisopit Mehl and Assoc. Prof. Dr. Sukanya Manee-in for their valuable comments and useful suggestions on my thesis. I would like to express the highest gratitude to Asst. Prof. Pasakorn Brikshavana for giving me a great opportunity to study in master program, also giving me advices and supports in both thesis and clinical knowledge. Many thanks to all of the clinicians at the Surgical unit in the Small Animal Teaching Hospital, Faculty of Veterinary Science, Chulalongkorn University and my graduated colleagues for their helps and supports during the stressful and difficult times of this thesis. Finally, I would like to give appreciation to my dearest family for the greatest support of my life.

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CHAPTER I

INTRODUCTION

1.1 Importance and rationale

At present, brachycephalic breeds such as Pug, French bulldog, English bulldog and Boston terrier have gained their popularity worldwide due to their interesting appearances and energetic life style (Liu *et al.*, 2015). However, in these breeds, there are several respiratory structural deformities that lead to upper airway obstruction commonly known as brachycephalic airway obstruction syndrome (BAOS) (Oechtering *et al.*, 2016). Most of these dogs with BAOS, up to 86-100%, have elongated soft palate – a congenital primary malformation in which soft palate extends past the epiglottis (Pratschke, 2014). The degree of respiratory obstruction can be graded from severity of respiratory sign (Caccamo *et al.*, 2014). Moreover, the environmental temperature over than 19°C could increase severity of clinical sign (Roedler *et al.*, 2013). Average temperature in Thailand was estimated to be 28.1°C in 2019 (The Thai Meteorological Department, 2020), which could significantly impact clinical outcomes in many brachycephalic dogs. As recent study showed that brachycephalic dogs had shorter survival time than that of non-brachycephalic dogs and 16.7% of those brachycephalic dogs died from respiratory failure (O'Neill *et al.*, 2015).

Early correction of BAOS abnormalities, including elongated soft palate and stenotic nares, is recommended to stop progression of airway pathology (Meola, 2013; BOFAN *et al.*, 2015). Surgical correction is a treatment of choice for BAOS according to its superior long-term outcome (Trappler and Moore, 2011a). For elongated soft palate, staphylectomy can be performed using conventional incision technique or advanced surgical equipment technique. However, in clinical canine study, the disadvantage of conventional incision are more intrasurgical bleeding, longer operation time and more inflammation of soft tissue compared with advanced surgical equipment technique (Davidson *et al.*, 2001). Thus, advance surgical equipment technique was chosen for staphylectomy in this study.

Clinical signs are routinely assessed by physical examination. However, it can be interfered by excitement of the dog in unusual environment. Therefore, most of the recent studies used the questionnaires to assess frequency and severity of clinical sign in the normal environment (Roedler *et al.*, 2013; Pohl *et al.*, 2016)

In term of physical capacity evaluation, walking test is a clinical functional assessment that have been used in human medicine since 1960 (Manens *et al.*, 2014). The 6-minute walk test (6-MWT) can evaluate the degree of impairment, status of disease or responsibility of therapy in patients with diseases related with respiratory, cardiovascular and neuromuscular systems (Swimmer and Rozanski, 2011; Manens *et al.*, 2014). This test simply measures the distance that an individual can walk as fast as that person can in 6 minutes. It better reflects patient's ability to undertake daily activities than exercise capacity (Manens *et al.*, 2014; Cerda-Gonzalez *et al.*, 2016). Recently, the 6-MWT has been applied in dogs, as it is easy to perform in clinical settings, well-tolerated and able to differentiate clinical status (Manens *et al.*, 2014; Sutayatram *et al.,* 2018).

Although, the previous study showed the technical and clinical differences between two surgical techniques, there was no data on the difference in quantitative measurement of respiratory function. Clinical monitoring for disease progression is less accuracy without objective data on respiratory function (Liu *et al.*, 2015). Thus, 6-MWT might be an importance tool to measure physical capacity related with respiratory function in brachycephalic dogs and to compare respiratory efficiency between before and after surgical treatment in BAOS dogs.

1.2 Objectives of study

1. To compare physical capacity of French bulldogs with BAOS between before and after surgical correction using 6-MWT.

2. To compare respiratory clinical status of French bulldogs with BAOS between before and after surgical correction using modified Roedler BAOS questionnaire.

1.3 Research frame

Twenty-seven client owned French bulldogs were enrolled in this study. The dogs were divided based on full history taking and complete physical examination into two groups: healthy control group (n=7) and BAOS group (n=20). Cardiology and other respiratory abnormalities were rule out by experienced veterinarians. The modified Roedler BAOS questionnaire, respiratory clinical grades and digestive clinical grades according to Poncet *et al.* (2005) were answered by the owners. Then a 6-MWT was performed in all dogs by the same veterinarian and settings. All dogs were subjected to blood collection and thoracic radiography. On the surgical correction day, the BAOS dogs were anesthetized and upper respiratory tract was examined by laryngoscopy. All abnormalities of soft palate, larynx and tonsil were recorded. Bipolar sealing device (Ligasure™) was used for staphylectomy. Stenotic nares were corrected by nasal alar plasty. After full recovery, pain score was recorded and the dogs were discharged with medications and follow up appointments. Respiratory grade, digestive grade and pain score were re-evaluated at 1, 2, 3 and 4 weeks after surgery. The modified Roedler BAOS questionnaire and 6-MWT were repeated in BOAS group at 4 weeks after surgery.

1.4 Advantages of study

This study provides information on clinical signs and physical capacity in dogs with BAOS and evaluate the clinical outcomes of staphylectomy using bipolar sealing device incision technique, in terms of physical capacity and clinical signs assessed by 6-MWT and the modified Roedler BAOS questionnaire, respectively.

CHAPTER II
REVIEW OF LITERATURES

2.1 Definition of brachycephalic dogs

Dog breeds can be separated into dolichocephalic, mesocephalic and brachycephalic breeds using skull measurement. The craniofacial angles between the facial skull and the base of the skull are 9°-14° in brachycephalic, 19°-21° in mesocephalic and 25°-26° in dolichocephalic (Figure 1). For brachycephalic dogs, the ratio of skull width to length ratio is 0.81 or greater and the cranial length to the skull length ratio is 1.60 – 3.44 (Figure 2). This flatted-face and short nose appearance could be a result of chondrodysplasia of the longitudinal axis of the skull leading to early ankylosis in the basicranial epiphyseal cartilage (Meola, 2013). The brachycephalic breeds present a flat-face characteristic such as Pug, French bulldog, English bulldog and Boston terrier. Other dog breeds with short nose including Pekingese, Shih Tzu, Maltese, Boxers, Cavalier King Charles spaniels, Yorkshire terriers, Miniature Pinscher and Chihuahuas may develop brachycephalic problem.

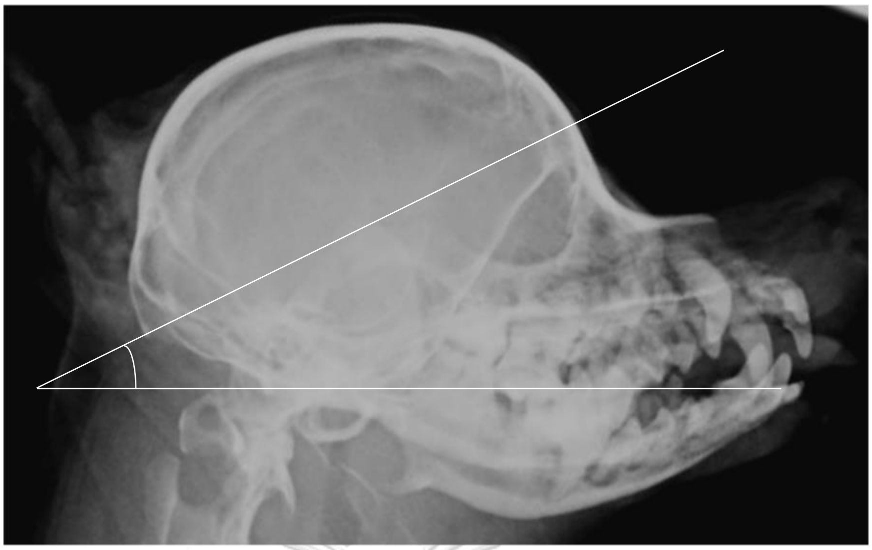

Figure 1. Skull measurement. The craniofacial angle between the base of the skull and the facial skull can be used to determine brachycephalic breeds.

Figure 2. The measurement of skull width (SW), skull length (SL), cranial length (CL), and facial length (FL).

2.2 Anatomical abnormalities of brachycephalic airway obstruction syndrome

BAOS composes of primary and secondary anatomical abnormalities. Primary lesions, congenital anatomical characteristics, include an elongated and thickening soft palate, stenotic nares, hypoplastic trachea and aberrated nasal conchae. Elongated soft palate is the most common primary disorder that has been reported in brachycephalic breeds (86-100%) (Pratschke, 2014). Normally, soft palate ends at the tip of epiglottis, but elongated soft palate is extended past the tip of epiglottis (Figure 3). Stenotic nares is an abnormality of under-sized nasal chambers due to medial alar nasal collapse and was found in 43-96% of brachycephalic breeds (Meola, 2013; Pratschke, 2014) (Figure 4). The aberrated nasal conchae is a malformed and aberrated growth of nasal conchae.

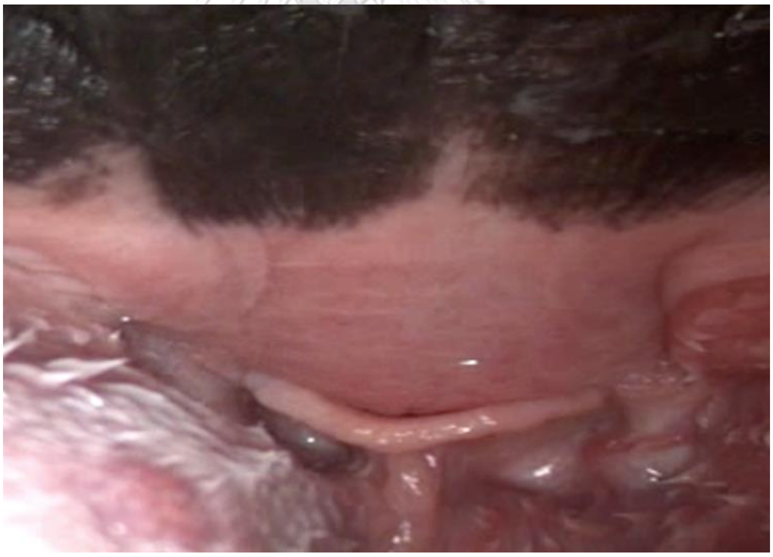

Figure 3. Laryngoscopic examination of a French bulldog indicated elongated soft palate that elongated beyond epiglottis leading to severe airway obstruction.

Figure 4. Stenotic nares of a French bulldog.

A hypoplastic trachea is caused by abnormal fetal development leading to tracheal narrowing. It was not commonly found in BAOS breeds (13%) (Pratschke, 2014). Hypoplastic trachea can be identified by measuring thoracic diameter (TD) to thoracic inlet (TI) ratio (TD:TI) on lateral view of thoracic radiograph (Figure 5). Hypoplastic trachea in brachycephalic breeds had TD:TI less than 0.16, except in Bulldogs that usually have more narrowing trachea. Thus, the TD:TI ratio less than 0.13 $\pm$ 0.03 indicates hypoplastic trachea in Bulldogs. While, hypoplastic trachea in non-brachycephalic breeds had TD:TI ration less than 0.2 $\pm$ 0.03 (Meola, 2013).

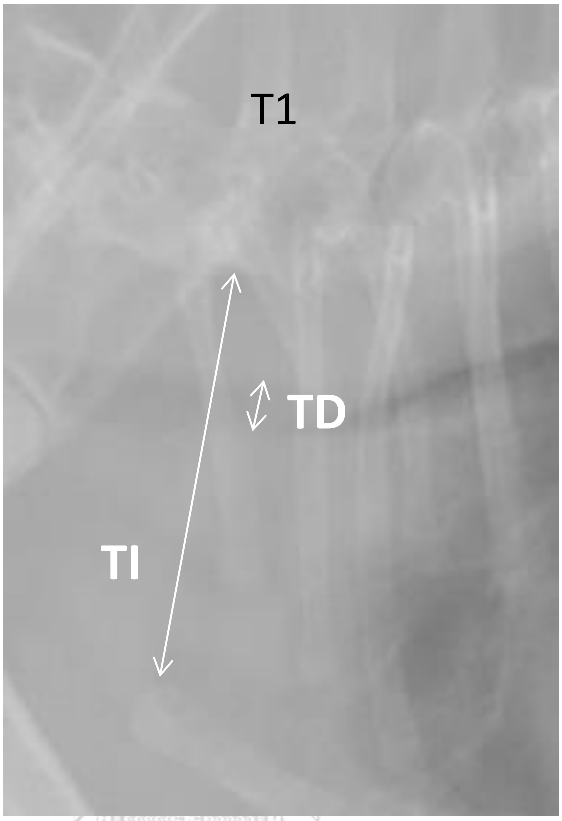

Figure 5. Trachea diameter (TD) to thoracic inlet (TI) ratio (TD:TI) measurement on lateral view of thoracic radiograph; TD is measured perpendicularly to long axis of the trachea, TI is measured from ventral of the first thoracic vertebrae (T1) to dorsal of the manubrium at the narrowest point of thoracic inlet.

Secondary lesions are induced by abnormal airflow from primary lesions. Secondary lesions and their incidents in BAOS are everted laryngeal saccules (55%-59%), everted tonsils (56%), laryngeal collapses (8-70%) (Figure 6) and bronchial collapse (rare) (Pratschke, 2014). Laryngeal collapse can be divided into 3 stages (Figure 7): stage I; eversion of laryngeal saccules, stage II; arytenoid cartilages loss of rigidity leading to medial displacement of the cuneiform processes and stage III; loss of the dorsal arch of the rima glottidis leading to collapse of corniculate processes of arytenoid cartilages (Pratschke, 2014).

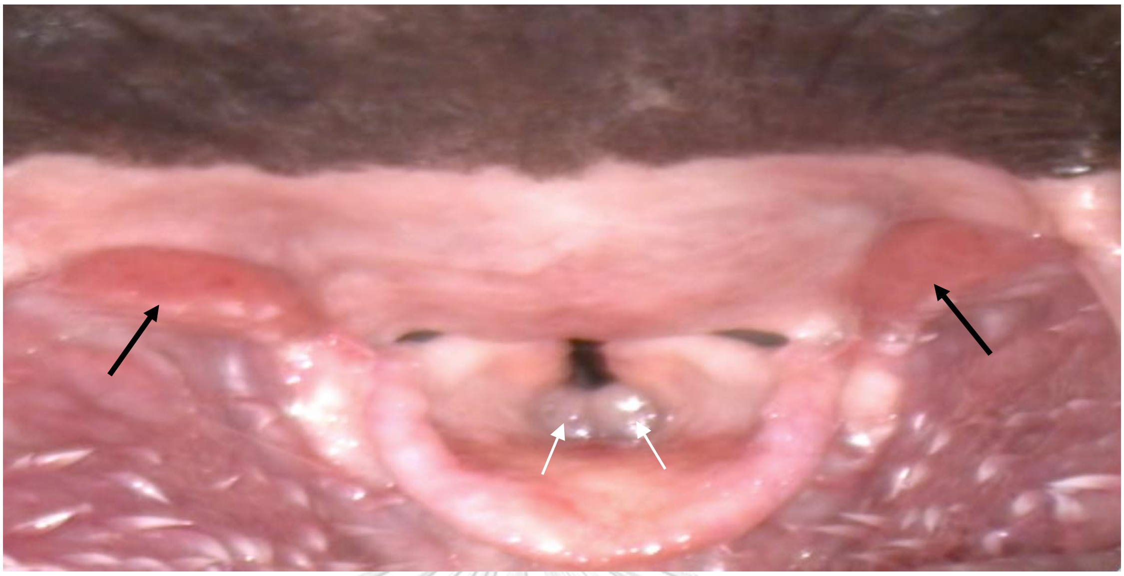

Figure 6. Laryngoscopic examination of a French bulldog indicated secondary lesions including everted tonsils (black arrows) and everted laryngeal saccules (white arrows).

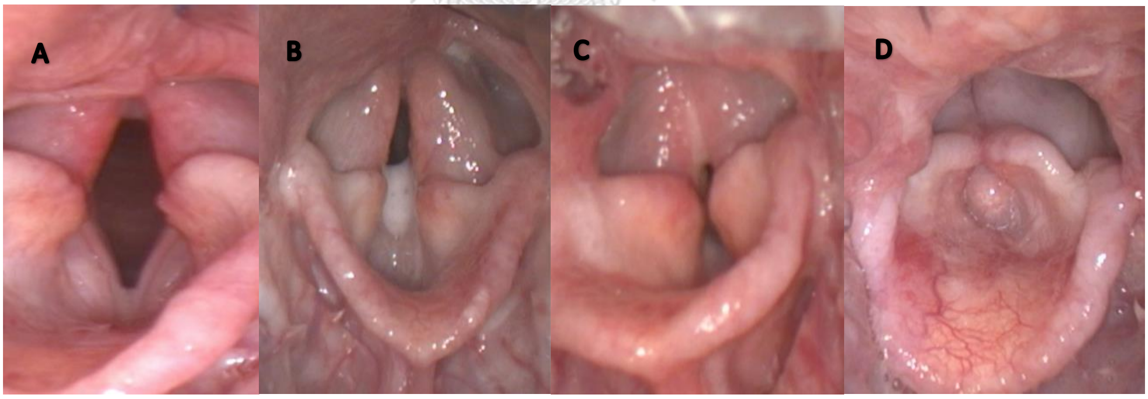

Figure 7. Laryngoscopic examination of four French bulldogs with normal larynx (A) and stage I (B), stage II (C) and stage III (D) laryngeal collapse.

2.3 Brachycephalic airway obstruction syndrome pathophysiology

The primary lesions including elongated soft palate, stenotic nares, hypoplastic trachea and aberrated nasal conchae, can lead to airway obstruction and breathing difficulty in brachycephalic dogs referred as BAOS. The affected dogs have narrowing of upper respiratory tract causing high airflow resistance and intraluminal pressure, especially during inhalation. From Poiseuille's law, 50% reduction of airway diameter causes 16 times increase in flow resistance. High resistance of respiratory tract results in increasing of intraluminal negative pressure and air turbulence leading to soft tissue inflammation and secondary lesion development. Secondary lesions are laryngeal edema and swelling, laryngeal saccule and tonsil eversion, as well as laryngeal collapse. All of these abnormality can develop life-threatening respiratory compromise (Meola, 2013; Liu *et al.,* 2015).

Besides tissue inflammation, the airway obstruction of upper respiratory tract can cause different breathing noise characteristics depended on the location. Pharyngeal obstruction due to thickening and elongated soft palate or abnormality organ in front of larynx produces low-pitched sound called 'stertor sound'. The obstruction of larynx (i.e., laryngeal saccules and laryngeal collapse) can cause a high-pitched sound called 'stridor'. Moreover, this airway obstruction can lead to gastrointestinal problems and exercise intolerance.

2.4 Clinical signs of brachycephalic airway obstruction syndrome

BAOS dogs exhibit typical respiratory signs such as abnormal breathing sounds (i.e. stertor, stridor, nasal sound and snoring), coughing, dyspnea and open mouth breathing. These common clinical signs are seen in both during awake and sleep. Also, sleep apnea has been mentioned in the literature (Poncet *et al.,* 2005; Bernaerts *et al.*, 2010; Meola, 2013). In moderate to severe cases, exercise intolerance, cyanosis and syncope are commonly reported. The degree of respiratory obstruction can be graded by the severity of respiratory signs in these brachycephalic dogs (Caccamo *et al.,* 2014). Moreover, Roedler and coworkers (2013) mentioned that the temperature above 19°C can increase severity of clinical signs. Thailand is a tropical country that has high temperature and humidity for most of the year. Last year, Thailand's temperature was estimated to be 28.1°C (The Thai Meteorological Department, 2020), so this high ambient temperature can significantly impact clinical outcomes in many brachycephalic dogs especially obesity dogs. Furthermore, upper respiratory tract inflammation and airflow obstruction can result in gastrointestinal signs such as difficult or painful swallowing, aerophagia, hypersalivation, regurgitation and vomiting (Poncet *et al.*, 2005; Meola, 2013).

Clinical signs are usually chronic and progressive, especially without proper management and treatment. Therefore, early diagnosis of BAOS is crucial for clinical management, especially surgical correction of primary lesions that can minimize the progression of secondary changes (Lodato and Hedlund, 2012b). Accordingly, the faster of definitive diagnosis and treatment initiation, the better quality of life of BAOS dogs. Definitive diagnosis in BAOS is derived from the history taking, physical examination, diagnostic imaging, blood gas analysis and upper airway and gastrointestinal endoscopy finding (Trappler and Moore, 2011a; Lodato and Hedlund, 2012b; Liu *et al.*, 2015).

2.5 History taking and questionnaire of brachycephalic airway obstruction syndrome

Clinical signs are routinely assessed by history taking and physical examination. In BAOS, clinical presentation usually involves with respiratory and gastrointestinal functions. To evaluate the severity of these clinical signs, respiratory grade and digestive grade were invented by Poncet and colleagues (2005). The Poncet respiratory clinical signs and digestive clinical signs grading can separate BAOS dogs into three grades for each system according to severity and frequency of clinical signs. This grading system was used to evaluate long-term surgical outcome in several brachycephalic breeds (Poncet *et al.,* 2006).

During physical examination, clinical presentation of dogs can be interfered by several factors including stress and excitement of the dog in unusual environment. For BAOS clinical assessment, objective surgical outcome evaluation is a clinical challenge due to the complexity of clinical signs with the influence of excitement of the dogs (Pohl *et al.*, 2016). Also, exposure to high ambient temperature during transportation to veterinary hospital can aggravate BAOS clinical sign. Therefore, heart rate and respiratory rate may increase in some dogs during physical examination, especially in dogs with over excitement and obesity. Some dogs that are scared or timid in nature, may not express their real clinical sign with the present of stranger. Therefore, clinical signs cannot be accurately evaluated in some cases. To control these factors, most of recent studies have been used questionnaires to reflex real clinical signs presented at home. With proper questionnaire, the clinical signs related with several daily activities such as sleeping, eating and performing exercise, as well as effect of season on BAOS severity can be evaluated (Roedler *et al.,* 2013; Pohl *et al.,* 2016). This questionnaire was performed to assess quality of life and severity of BAOS clinical signs in several clinical setting (Roedler *et al.*, 2013; Pohl *et al*., 2016; Aromaa *et al.*, 2019). Moreover, the questionnaires constructed specifically for BAOS could indicate clinical improvement in terms of exercise and heat intolerance in brachycephalic dogs after surgical correction (Pohl *et al.,* 2016). However, there is no information of short-term surgical outcome of Staphylectomy by bipolar sealing device in French bulldogs using the Poncet respiratory clinical signs and digestive clinical signs grading and BAOS questionnaire.

2.6 Physical assessment of brachycephalic airway obstruction syndrome

Various functional test procedures, such as spirometry, whole-body plethysmography, cardiac stress test and cardiopulmonary exercise test, are available for assessment of cardiopulmonary function and physical capacity but most of them require expensive equipment and are time consuming (Rick *et al.,* 2014). However, walking test, another functional test, has been routinely used in human medicine since 1960s to objectively assess disease status and therapy responsiveness (Swimmer and Rozanski, 2011; Manens *et al*., 2014). 6-MWT is a submaximal exercise test that measure the walking distance in 6 minutes. This test is non-invasive method of functional assessment in patient with chronic cardiopulmonary disease and in dogs with neuromuscular disease (Rick *et al.,* 2014; Cerda-Gonzalez *et al.,* 2016). The advantages of 6-MWT are simplicity, low cost and reproducibility with minimal technology requirement. Also, the vital signs and symptoms can be monitored during the test leading to its broad application (Heresi and Dweik, 2011; Cerda-Gonzalez *et al.,* 2016). However, 6-MWT has a limitation that it cannot specify the mechanism of exercise intolerance. The walking distance is influenced by several factors including age, sex, height and weight, that are unrelated to cardiopulmonary status. Besides, peripheral arterial disease, musculoskeletal problem, nutritional status, and cognitive function played a major role on walking test outcome (Heresi and Dweik, 2011; Morales-Blanhir *et al.*, 2011).

In dogs, physical capacity evaluation is also important to indicate health status and quality of life. Also, 6-MWT is easy to perform in clinics, well-tolerated and can separate between healthy and disease dogs (Boddy *et al.,* 2004; Manens *et al.,* 2014). So, 6-MWT has been adapted to use in dogs. Previous dog studies used 6-MWT to assess cardiopulmonary function (Boddy *et al*., 2004; Swimmer and Rozanski, 2011; Lilja-Maula *et al*., 2014; Manens *et al*., 2014; Sutayatram *et al.,* 2018) and neuromuscular disease (Cerda-Gonzalez *et al*., 2016), and to evaluate exercise tolerance in brachycephalic dogs (Lilja-Maula *et al.*, 2017). 6-MWT is also used to compare respiratory function in brachycephalic breeds between before and after surgical correction using conventional technique and it could indicate clinical improvement (Villedieu *et al*., 2018).

2.7 Medical treatment of brachycephalic airway obstruction syndrome

Treatment of BAOS is a combination of medical management and surgical treatment (Riecks *et al.*, 2007). The medical management or long-term conservative therapy for BAOS includes weight management, minimize stress, cool environment, exercise restriction and anti-inflammatory drugs such as short-acting glucocorticoid (Trappler and Moore, 2011b; Meola, 2013). Medical management can stabilize patient before surgical treatment and patient that suffer from clinical signs of BAOS, however, it cannot solve the primary problem.

2.8 Surgical treatment of brachycephalic airway obstruction syndrome

Surgical treatment is a reliable method that directly corrects the anatomical abnormalities of BAOS. Early surgical treatment of BAOS can attenuate development of secondary changes and cause better long-term outcomes (Trappler and Moore, 2011a; Meola, 2013). Goal of surgical treatment is to provide adequate airflow by decreasing airway obstruction such as elongated soft palate and stenotic nares (Lodato and Hedlund, 2012a). Staphylectomy, or soft palate excision, is performed to shorten an elongated soft palate to allow adequate airflow through the upper respiratory tract. Conventional or traditional technique requires sharp incision with scalpel blade or scissors, and suturing the incision with monofilament absorbable suture (Davidson *et al.,* 2001; Trappler and Moore, 2011a; Schlicksup, 2015). Disadvantages of conventional staphylectomy are bleeding, prolong surgical time and requiring suturing (Davidson *et al*., 2001). Complications of this technique include postoperative respiratory distress, pharyngeal edema, postoperative bleeding and aspiration pneumonia (Davidson *et al*., 2001). Other postoperative complications are pain, coughing and regurgitation. Recently, palate resection can be accomplished using advanced surgical equipment such as carbon dioxide laser, diode laser, monopolar electrocautery and bipolar sealing device, all of which can reduce surgical time and bleeding. Most importantly, these techniques do not require suturing (Davidson *et al*., 2001; Brdecka *et al*., 2008; Meola, 2013).

Electronic bipolar vessel sealer (Ligasure^{TM} Small Jaw Instrument, Medtronic, USA), one of the most widely used equipment today, has been developed as a substitute to suture ligatures, hemoclips, staplers and ultrasonic coagulation for sealing vessels and tissues (Takada *et al.*, 2005; Cortadellas *et al*., 2011). This instrument permanently seals blood vessel up to 7 mm in diameter, and tissue bundles by denaturing the collagen and elastin within the vessel wall and surrounding connective tissue (Carbonell *et al.,* 2003; Takada *et al.,* 2005; Brdecka *et al.,* 2008; Cortadellas *et al.,* 2011). This novel equipment achieves its effective hemostatic control with limited damage via minimal lateral thermal spread to surrounding tissue (Carbonell *et al.*, 2003; Entezari *et al.,* 2007; Lamberton *et al*., 2008). Advantages of the Ligasure^{TM} are less blood loss, tissue necrosis, pain, complications and surgical time compare with other conventional methods (Entezari *et al*., 2007; Brdecka *et al.*, 2008; Cortadellas *et al.*, 2011).

CHAPTER III
MATERIALS AND METHODS

3.1 Animals

Twenty-seven French bulldogs were enrolled in this study. They were divided into two groups: healthy control group (n=7) and BAOS group (n=20). In terms of inclusion criteria, French bulldogs with normal body condition score (BCS) (2.5-3.5/5) and age above 6 months were included in this study. History taking, physical examination and laboratory results were used to separate healthy and BAOS dogs.

In BAOS group, dogs with other respiratory problems such as rhinitis, nasopharyngeal polyp, tracheitis, bronchopneumonia, infectious pneumonia and pulmonary nodules and dogs with previous upper airway surgery were excluded. Furthermore, dogs with cardiac disease, neuromuscular disease and previous oxygen treatment were also excluded from the study.

The information including breed, gender, age, body weight, BCS, physical examination findings, respiratory clinical grade and digestive clinical grade (Poncet *et al.*, 2005) and degree of stenotic nares (Liu *et al.*, 2015) (Figure 8) were recorded in all dogs.

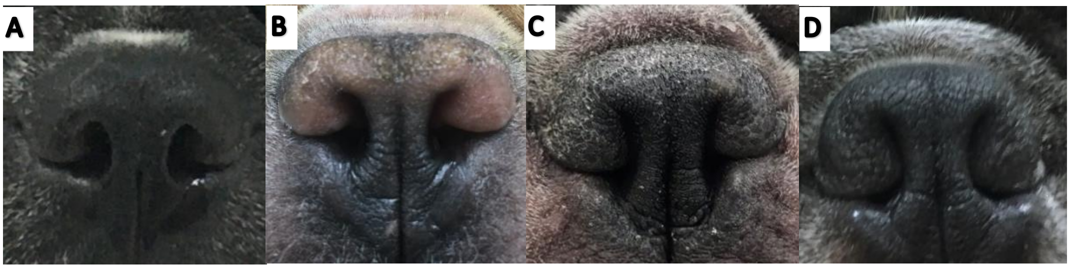

Figure 8. Degree of nostril stenosis in four French bulldogs; A=normal nostril, B=mild stenosis, C=moderate stenosis and D=severe stenosis

In BAOS group, respiratory and digestive grading severity of the disease were recorded at before surgery, 1, 2, 3 and 4 weeks after surgery. The respiratory and digestive clinical grades according to Poncet *et al*. (2005) were shown in Table 1 and 2.

Table **1.** Grading of respiratory clinical sings according to Poncet *et al*. (2005)

Respiratory grade	**Clinical signs**
Grade 1	- Absence of respiratory clinical sign (snoring, inspiratory efforts, stress or exercise intolerance and syncope) - Mild or intermittent snoring (less than once a month to once a day) and inspiratory efforts (less than once a month)
Grade 2	- Moderate or unusual soring (more than once a day), inspiratory efforts (once a week to more than once a day) and stress or exercise intolerance (less than once a month to once a week)
Grade 3	- Severe or continual snoring (all time), inspiratory efforts (all time), stress or exercise intolerance (once a day to more than once a day) and syncope (less than once a month to more than once a day) - Constant all respiratory clinical signs

Table 2. Grading of digestive clinical signs according to Poncet *et al*. (2005)

Digestive grade	Clinical signs
Grade 1	- Absence of digestive clinical sign (i.e. hypersalivation, regurgitation and vomiting) - Mild or intermittent hypersalivation and regurgitation (less than once a month)
Grade 2	- Moderate or unusual hypersalivation (once a week to once a day), regurgitation (once a week) and vomiting (less than once a month to once a week)
Grade 3	- Severe or continual hypersalivation (more than once a day), regurgitation (once a day to more than once a day) and vomiting (once a day to more than once a day) - Constant all digestive clinical signs

3.2 Modified Roedler questionnaire

All owners received the client education about BAOS at the first visit, they answered the questionnaire thereafter. This questionnaire was developed and modified from the previous study by Roedler and colleagues (2013), in which general and specific questions about breathing pattern, exercise and heat intolerance, eating and sleeping pattern were specifically included for brachycephalic breeds (Appendix). For the control group, the owners answered the questionnaire only one time after physical examination. The owners in BAOS group answered the questionnaire before and 4 weeks after surgical correction for clinical signs and surgical outcome assessment. Scoring of Modified Roedler questionnaire for each question was zero for never, one for 1-2 times per week, two for over 2 times per week and three for always. Then, the scores from all four parts (breathing sound, exercise and heat intolerance, eating and sleeping) were combined. Additional open-end questions regarding to dog walking or outdoor activities with frequency, duration of activity, and recovery time (i.e. resting duration that the dog required for recovery from exercise determined by respiratory rate and breathing pattern) were also included at the end of this questionnaire.

3.3 6-minute walk test (6-MWT)

Dogs in control group performed 6-MWT only once on the same date with physical examination and questionnaire. The dogs in BAOS group performed 6-MWT twice: before and 4 weeks after surgery. The results were used to assess physical capacity improvement associated with alterations in functional breathing and efficiency of breathing. Before start walking (pre-walk), body temperature, heart rate (HR), respiratory rate (RR) and oxygen saturation (SpO_2) measured by pulse oximeter were recorded for each dog. The pulse oximeter probe was placed on nonpigmented areas of buccal, vaginal or preputial mucosa.

After 20-30 minutes of acclimatization with chest harness in a quite air-conditioned room without other animals, the dog was guided to walk at their own pace together with the same veterinarian along unobstructed 5x5 meters square corridor for 6 minutes. Right after finishing the 6-MWT (post-walk), dog was stopped and immediately subjected to remeasurement of the HR, RR, body temperature and SpO_2. The total walk distance was measured and reported in meters. HR, RR, body temperature and SpO_2 were recorded as actual number and percent change (Δ). Percent change was calculated from the differences between post- and pre-walk divided by pre-walk and multiply by 100.

3.4 Preoperative assessment

All control dogs and BAOS dogs at before surgical time point were subjected to complete physical examination, blood collection for complete blood count (CBC) and serum blood chemistry analysis. Dogs' cardiac function from electrocardiography

(ECG), heart and lung sound, blood pressure measurement and thoracic radiograph in lateral and ventro-dorsal (VD) view were performed by experienced veterinarians.

3.5 Anesthetic technique

The recommended anesthetic protocol for brachycephalic dogs was used for all dogs undergoing surgery. Food and water were withheld for 8 to 12 hours before surgery. Each dog was sedated with acepromazine maleate (0.03 mg/kg) and morphine sulfate (0.5 mg/kg) intramuscularly. Pre-oxygenation by an oxygen mask at least 15 minutes was performed, then propofol (4 mg/kg) was administrated intravenously for induction. During induction of anesthesia, laryngeal and oropharyngeal examination by laryngoscope in sternal recumbency were performed to assess the elongation of soft palate, degree of laryngeal collapse, everted laryngeal saccules, laryngeal oedema, tonsillitis and tonsil enlargement within 2 minutes. Later, a cuffed endotracheal tube was placed. The anesthesia depth was maintained with isoflurane inhalation. Preoperative medicines such as cefazolin (25 mg/kg) and dexamethasone (0.5 mg/kg) were administered intravenously before surgery.

3.6 Surgery correction

3.6.1 Staphylectomy by Bipolar sealing device (Ligasure^{TM} Small Jaw Instrument, Medtronic, USA) incisional technique

BAOS dog was placed in ventral recumbency and the mouth was kept open during surgery. The middle free end of soft palate was held by Allis tissue forceps and retracted forward. Then, both of caudal tonsils were located and stay sutures were placed at corners of both free end of soft palate near caudal tonsils. Elongated soft palate was inserted between the jaws of the shear instrument which was activated until the soft palate cutting was completed. The elongated soft palate was transected laterally from caudal aspect of the tonsillar crypt to another side in an arch shape. The highest of soft palate cutting should not be higher than level of middle tonsil (Thunyodom *et al*., 2019).

3.6.2 Alarplasty of stenotic nares: vertical wedge resection technique

After staphylectomy, BAOS dogs with stenotic nares were also subjected to alarplasty for stenotic nares to increase the nares opening. Alarplasty procedure was performed as previous described (Schmiedt and Creevy, 2012). In brief, a pyramid shaped section of external nares was cut with scalpel blade No.11 in vertical wedge shape. Length of the base of the wedge determines the final size of nares opening. After wedge section removal, non-absorbable sutures were placed for closure the wedge defect.

3.7 Post-operative care and follow up

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) were 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 after surgery for 2 weeks. All dogs received alarplasty wore collar to prevent suture breakage from self-trauma. The clinical signs were monitored at 1 day, 1, 2, 3 and 4 weeks after surgery.

Respiratory and digestive grading score showed in table 1 and 2 were recorded at 1, 2, 3 and 4 weeks after surgery. Post-operative complications were also recorded. Pain scoring was recorded following the Colorado State University (CSU) canine acute pain scale.

3.8 Statistical analysis

The parameters such as age, body weight, respiratory grade, digestive grade, questionnaire score, HR, RR, body temperature, SpO_2 and walk distance for each time point were presented as mean $\pm$ standard deviation (SD) for parametric data or range and mode for ordinal data. Normal distribution of parametric data was confirmed by Shapiro-Wilk test. The parametric data with normal distribution were compared between normal group and BAOS group at before surgery using unpair t-test, and BAOS group at before and after surgery using pair t-test. Non-normal distributed parametric data were compared between normal group and BAOS group at before surgery using Mann Whitney U test, and BAOS group at before and after surgery using Wilcoxon Signed Ranks test. The ordinal data including respiratory grade, digestive grade in BAOS group were compared among time points (before and each week after surgery until one month) using Friedman's test. The questionnaire scores were compared between normal group and BAOS group at before surgery using Mann Whitney U test, and BAOS group at before and after surgery using Wilcoxon Signed Ranks test.

All statistical analyses were performed using commercial software SPSS version 22.0 (IBM Corp., Armonk, NY, USA) and GraphPad (PRISM® ver. 8, GraphPad, Inc). *P*-values less than 0.05 were considered statistically significant.

CHAPTER IV
RESULTS

4.1 Animals

Twenty-seven French bulldogs that came in the Surgery unit of the Small Animal Teaching Hospital, Faculty of Veterinary Science, Chulalongkorn University, Bangkok, from February 2019 to February 2020, were enrolled in this study. The characteristics of all dogs were shown in table 3. For physical examination, all dogs in both normal and BAOS group had normal heart sound. All normal dogs had normal breathing sound and lung sound. While, eight BAOS dogs had mild increased lung sound. All of BAOS dogs had stertor sound with nine dogs had mixed stertor and stridor sounds. Blood profiles of all dogs were within normal limit.

Table 3. The characteristics of normal group (n=7) and BAOS group (n=20).

Parameters	Normal group	BAOS group
Age (months)	14.3 ± 5.2	29.4 ± 14.6*
Sex [number (%)]		
Male	2 (28.57)	16 (80)
Female	5 (71.43)	4 (20)
Weight (kg)	10.8 ± 2.1	13.0 ± 2.3*
BCS (5-point score)	3 (3-3.5)	3 (2.5-3.5)

Data were presented as mean and standard deviation, except gender was presented as number with percentage and BCS was presented as median with range. * $P<0.05$ using t-test.
Abbreviation: BAOS: brachycephalic airway obstruction syndrome; BCS: body condition score.

4.2 Respiratory and digestive clinical grades according to Poncet *et al*. (2005)

Respiratory and digestive clinical grades according to Poncet *et al.* (2005) were recorded from the owners. Most of the dogs in normal group had grade 1 for both respiratory and digestive clinical grades. One normal dog had digestive clinical grade 2. Respiratory and digestive clinical grades in the BAOS group before surgery and each week after surgery until 4 weeks after surgery were shown in table 4 and table 5.

Most of the BAOS dogs had highest respiratory clinical grade before surgery. After surgery, respiratory clinical grade improved in all BAOS dogs within one week. Respiratory sign during physical examination showed marked improvement since day 1 after surgery in all dogs. Fourteen of BAOS dogs had improved digestive clinical grade within 1 week after surgery. While, only 1 dog had worse digestive clinical grade as the dog vomited more frequently during the first week after surgery. After the first week of post-operative period, vomiting was not seen in any dog.

Table 4. Respiratory clinical grade according to Poncet *et al*. (2005) of BAOS group (n=20) at before and each week after surgery until 4 weeks after surgery.

Parameters	Before Sx	1 week after Sx	2 weeks after Sx	3 weeks after Sx	4 weeks after Sx
Respiratory grade					
Grade 1	0	20†††	20†††	20†††	20†††
Grade 2	2	0	0	0	0
Grade 3	18	0	0	0	0

Data were presented as number of BAOS dog. ††† *P*<0.001 compared with before surgery, using Friedman's test.

Abbreviation: Sx: surgery.

Table 5. Digestive clinical grade according to Poncet *et al.* (2005) of BAOS group (n=20) at before and each week after surgery until 4 weeks after surgery.

Parameters	Before Sx	1 week after Sx	2 weeks after Sx	3 weeks after Sx	4 weeks after Sx
Digestive grade					
Grade 1	4	16†	20†††	20†††	20†††
Grade 2	11	3	0	0	0
Grade 3	5	1	0	0	0

Data were presented as number of BAOS dog. † $P<0.05$ and ††† $P<0.001$ compared with before surgery, using Friedman's test.

Abbreviation: Sx: surgery.

4.3 Modified Roedler BAOS questionnaire

Results from modified Roedler BAOS questionnaire assessing clinical signs at home were presented in table 6. Score of the questionnaires in each part of normal group, BAOS group at before and 4 weeks after surgery were presented in table 7. BAOS group had significantly higher score of breathing sound ($P<0.001$), exercise and heat intolerance ($P<0.001$), eating ($P<0.01$) and sleeping ($P<0.01$) than normal group.

Most of the owners in the normal group reported that their dogs never had clinical signs or had less than one time of clinical signs per week related with breathing sound, exercise and heat tolerance and sleeping disorder such as sleep apnea. All owners in the normal group reported their dogs had no loud breathing sound when awake, but they heard panting sound without stertor or stridor during exercise or when excited. However, most of the normal dogs had mild snoring while asleep in some positions. On the other hand, most of the BAOS dogs at before surgery had loud breathing sound during awake, sleeping and exercise or excited.

For exercise and heat intolerance, more than half of the owners of the dogs in normal group reported that their dogs had no breathing problem when exercised or stayed in non-air-conditioned room. None of the normal dogs collapsed or presented with cyanosis. All of the owners in BAOS group reported that their dogs always had difficult breathing when exercise in hot weather. While, 75% of the BAOS dogs had difficult breathing during exercise even in air-conditioned room. Only 10% of the owners in BAOS group noticed that the dogs had dyspnea before collapsed. Moreover, 20% of the owners in the BAOS group informed that the dogs exhibited cyanosis during excitement.

Regurgitation, vomiting and fast eating without chewing were reported by the owners in BAOS group greater than the normal group for both numbers of dogs and frequency of the signs. None of the normal dogs presented abnormal sleeping pattern. On the other hand, about half of the owners in BAOS group recognized that their dogs woke up to breathe or were unable to sleep without elevated the chin or use objects to open up their mouth. Sleeping in sitting position was reported in 10% of the dogs in the BAOS group.

Four weeks after surgery, the owners of the BAOS group reported that the respiratory signs improved in all dogs while the gastrointestinal signs improved in 14 dogs. All four scores from the questionnaire were significantly improved after surgery ($p<0.001$). Compared with before surgical correction, the owners still hear loud breathing sound of their dogs while awake, sleeping, exercise or excited but the loudness and frequency were lesser. None of the dogs collapsed or presented cyanosis after surgical correction. For exercise and heat intolerance, numbers of the dogs and frequency of difficult breathing in air-conditioned or hot weather were reduced compared with before surgical correction. Half of the dogs that presented regurgitation and vomiting before surgery had less frequency of these signs after surgery. The eating pattern for eat fast or swallow food without chewing had improved or still presented in some dogs. After surgery, most of the owners reported that the sleep patterns of their dogs had improved except only in 1 dog that still had to sleep in a sitting position.

Table 6. Results of modified Roedler BAOS questionnaire of normal group (n=7) and BAOS group (n=20) at before and 4 weeks after surgery.

Parameters	Normal group				BAOS group							
					Before Sx				4 weeks after Sx			
	Frequency											
	Never (n)	≤1/wk (n)	>2/wk (n)	Always (n)	Never (n)	≤1/wk (n)	>2/wk (n)	Always (n)	Never (n)	≤1/wk (n)	>2/wk (n)	Always (n)
Breathing sound												
1. Breathe loudly while awake at rest	7	0	0	0	2	2	10	6	8	12	0	0
2. Breathe loudly while sleeping	2	5	0	0	1	6	9	4	11	9	0	0
3. Breathe loudly while exercise/excited	7	0	0	0	0	0	4	16	5	15	0	0
Exercise and heat tolerance												
1. Difficulty breathing during exercise or when excited in air-conditioner room	7	0	0	0	0	5	8	7	12	8	0	0
2. Difficulty breathing during exercise or when excited outdoor/hot weather	4	3	0	0	0	0	2	18	8	12	0	0
3. Collapsed because of dyspnea	7	0	0	0	18	2	0	0	20	0	0	0
4. Cyanotic	7	0	0	0	16	1	2	1	20	0	0	0
Eating												
1. Regurgitation/vomiting	3	4	0	0	6	9	5	0	12	8	0	0
2. Eat fast or swallow food without chewing	0	5	2	0	0	5	4	11	3	7	5	5
Sleeping												
1. Wake up a few times during sleep/being almost unable to sleep	7	0	0	0	9	8	2	1	20	0	0	0
2. Only able to sleep with the chin in an elevated position	7	0	0	0	11	3	5	1	17	3	0	0
3. Attempting to sleep in a sitting position	7	0	0	0	18	1	1	0	19	1	0	0

Data were presented as number of dogs.

Abbreviation: BAOS: brachycephalic airway obstruction syndrome; Sx: surgery; wk: week.

Table 7. Scores of modified Roedler BAOS questionnaire in each part of normal group (n=7) and BAOS group (n=20) at before and 4 weeks after surgery.

Parameters	Normal group	BAOS group	
		Before Sx	4 weeks after Sx
Breathing sound	1 (0-1)	7 (3-9)***	2 (0-3)†††
Exercise and heat tolerance	0 (0-1)	5.5 (3-9)***	1 (0-2)†††
Eating	2 (1-3)	3 (1-5)**	2 (1-4)†††
Sleeping	0 (0)	1 (0-5)**	0 (0-2)†††

Data were presented as median with range. ** *P*<0.01 and *** *P*<0.001 compared with normal group, using Mann Whitney range test. ††† *P*<0.001 compared with BAOS group before surgery, using Wilcoxon Signed Ranks test.

Abbreviation: BAOS: brachycephalic airway obstruction syndrome; Sx: surgery.

From additional open-end questions, 4 out of 7 normal dogs exercised with their owner every day and the rest of the normal dogs exercised 2-3 days per week. For the BAOS group, the owners reported that they took their dogs out to exercise every day (9/20), 3-4 days per week (4/20) and 2-3 days per week (7/20). One owner that took the dog to perform outdoor activities with the lowest frequency informed that the dog always had loud breathing sound, dyspnea and exercise intolerance, therefore, the owner was concerned about the dog safety. Outdoor activities that were reported in this question were walking (16/20) and mixed activities of walking and swimming (4/20). The exercise duration per session and recovery time of all dogs were shown in figure 9 and figure 10.

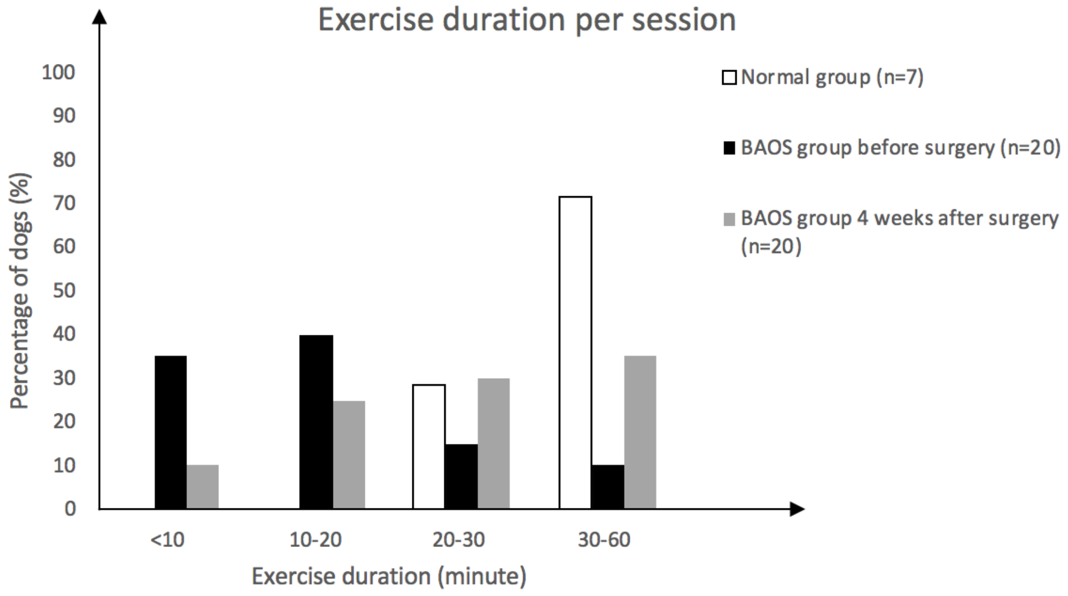

Figure 9. Approximated exercise duration in normal and BAOS groups.

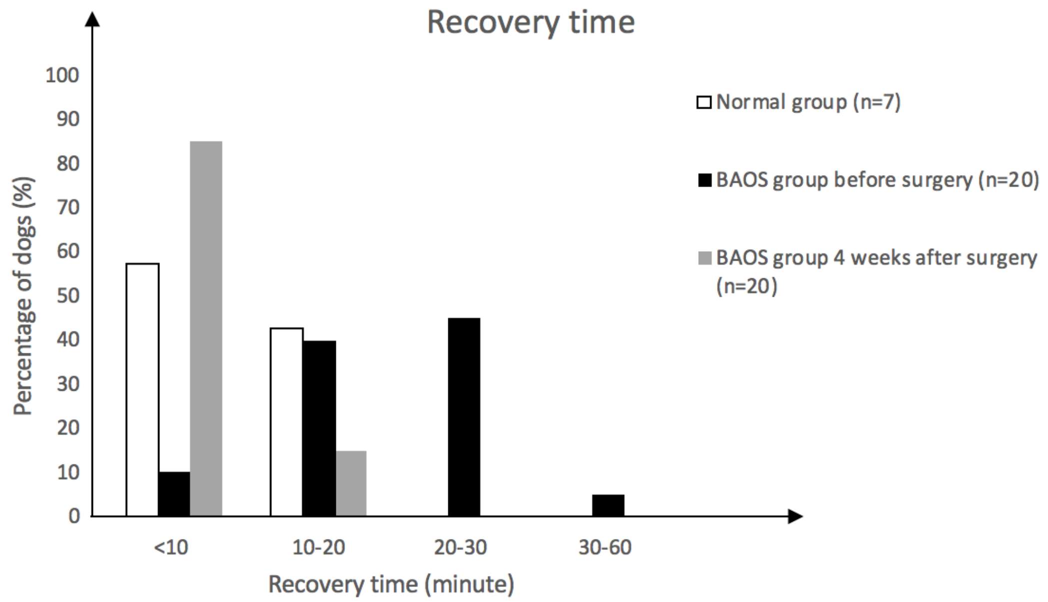

Figure 10. Approximated recovery time in normal and BAOS groups.

4.4 Upper respiratory examination

The distribution of stenotic nares, elongated soft palate, everted tonsil, laryngeal collapse, laryngeal saccule and hypoplastic trachea in BAOS group from physical examination, laryngoscopy and radiographic examination was shown in table 8.

All of the dogs in the BAOS group had both primary and secondary disorders. Eight dogs were categorized as severe BAOS cases in which their primary and secondary disorders were both severe. Two dogs with hypoplastic trachea also had severe secondary disorder. However, three dogs with mild primary disorders (i.e. elongated soft palate with mild stenotic nares or without stenotic nares) presented severe secondary disorder including laryngeal collapse stage II and everted tonsils.

Table 8. Primary and secondary disorders in BAOS group (n=20).

Parameters	BAOS group
Primary disorder	
Elongated soft palate	20 (100%)
Stenotic nares	
Mild	1 (5%)
Moderate	6 (30%)
Severe	12 (60%)
Hypoplastic trachea	2 (10%)
Secondary disorder	
Laryngeal saccules	13 (65%)
Laryngeal collapse	
Stage I	3 (15%)
Stage II	10 (50%)
Stage III	0 (0%)
Everted tonsils	
Single site	5 (25%)
Both sites	12 (60%)

Data were presented as numbers of dogs with percentage.

Abbreviation: BAOS: brachycephalic airway obstruction syndrome.

4.5 Canine acute pain scale

Post-operative pain scales following Colorado State University (CSU) canine acute pain scale at each week after surgery were non-noticeable (0/4) for all dogs. Also, all dogs were able to eat and drink within one day after surgery.

4.6 6-minute walk test

All dogs in the normal and BAOS groups were able to perform 6-MWT. Heart rate, respiratory rate, body temperature and oxygen saturation at pre- and post-walk of 6-MWT, as well as walk distance of dogs in normal and BAOS groups were shown in table 9. The distribution of walk distance in each group was shown in Figure 11. None of the serious complications (i.e. dyspnea, cyanosis and collapse) was found during or after 6-MWT. Most of the 6-MWT parameters were significantly different between normal group and BAOS group at before surgery, as well as between BAOS group at before surgery and 4 weeks after surgery. Oxygen saturation at before walk was not statistically different between BAOS group at before surgery and after surgery.

Compared with the normal group, BAOS dogs at before surgery had significantly higher percent change of heart rate ($P<0.05$) and body temperature ($P<0.05$). Percent change of body temperature was significantly higher in BAOS group at before surgery compared with at 4 weeks after surgery ($P<0.05$). However, there was no difference in percent change of respiratory rate, oxygen saturation or heart rate between BAOS group at before surgery and 4 weeks after surgery.

Average walk distances from 6-MWT were significantly longer in normal group compared with BAOS group at before surgery ($P<0.001$), as well as in BAOS group at 4 weeks after surgery compared with before surgery ($P<0.001$). There was improvement in walk distance in all BAOS dogs at 4 weeks after surgery (Figure 12). When calculated from improved distance in each dog, average improvement of walk distance was 25.73 ± 10.61% (range 10.86 to 49.12%).

Table 9. 6-MWT parameters in normal group (n=7) and BAOS group (n=20) at before and 4 weeks after surgery.

Parameters	Normal group	BAOS group	
		Before Sx	After Sx
Heart rate (beat/min)			
Pre-walk	119 ± 14	128 ± 9*	118 ± 8†††
Post-walk	129 ± 14	149 ± 13**	134 ± 10†††
ΔHR (%)	8.33 ± 5.91	16.14 ± 5.09**	13.81 ± 5.65
Respiratory rate (breath/min)			
Pre-walk	33 ± 5	52 ± 21*	37 ± 14†††
Post-walk	48 ± 5	86 ± 40*	60 ± 22†††
ΔRR (%)	50.24 ± 26.29	68.31 ± 40.72	61.75 ± 38.93
Temperature (F)			
Pre-walk	100.7 ± 0.5	101.4 ± 0.7*	101.0 ± 0.6†
Post-walk	101.0 ± 0.5	102.0 ± 0.9*	101.3 ± 0.5††
Δtemp (%)	0.26 ± 0.10	0.52 ± 0.40*	0.31 ± 0.20†
SpO_2 (%)			
Pre-walk	98 ± 1	96 ± 1**	97 ± 1
Post-walk	98 ± 1	96 ± 1*	97 ± 1†
ΔSpO_2 (%)	0.14 ± 0.92	0.01 ± 1.40	0.16 ± 1.10
6-MWT distance (meter)	521 ± 35	406 ± 45***	506 ± 33†††

Data were presented as mean and standard deviation. * *P*<0.05, ** *P*<0.01 and *** *P*<0.001 compared with normal group, using t-test for normal distribution or Mann-Whitney test for non-normal distribution. † *P*<0.05, †† *P*<0.01 and ††† *P*<0.001 compared with BAOS group at before surgery, using paired t-test for normal distribution or Wilcoxon Signed Ranks test for non-normal distribution.

Abbreviation: BAOS: brachycephalic airway obstruction syndrome; Sx: surgery; Δ: percent change; HR: heart rate; RR: respiratory rate; temp: temperature; SpO_2: oxygen saturation; 6-MWT: 6-minute walk test.

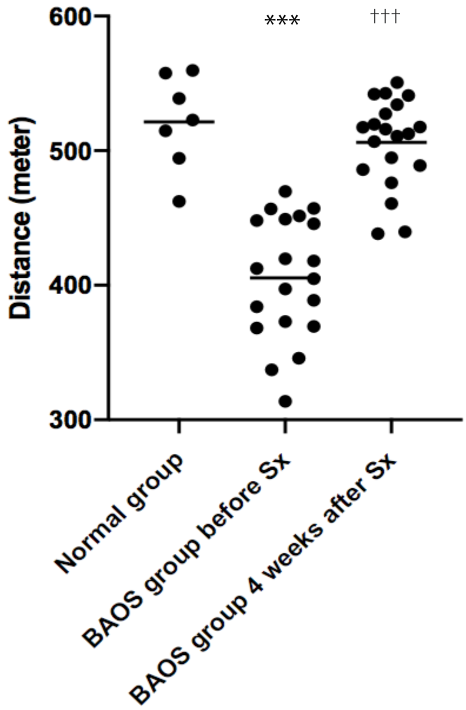

Figure 11. Scatter dot plot of walk distance distribution in normal group, BAOS group at before and 4 weeks after surgery. *** *P*<0.001 compared with normal group, using t-test. ††† *P*<0.001 compared with BAOS group at before surgery, using paired t-test. Abbreviation: BAOS: brachycephalic airway obstruction syndrome; Sx: surgery.

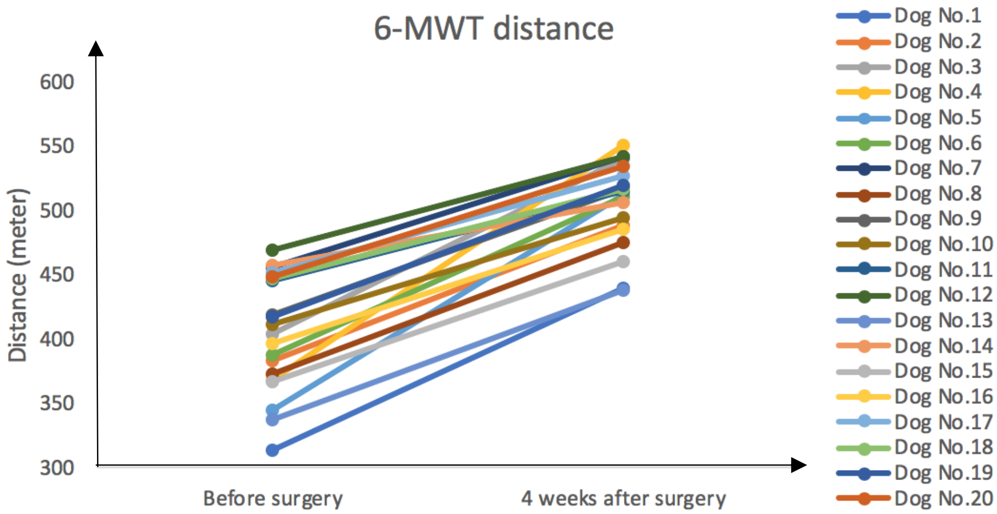

Figure 12. Line graph of walk distances in each BAOS dog at before and 4 weeks after surgery.

CHAPTER V
DISCUSSION AND CONCLUSION

Brachycephalic airway obstruction syndrome is the most common anatomical problem found in brachycephalic breeds (Oechtering *et al.,* 2016). This problem causes upper airway obstruction leading to increased airway resistance induced by soft tissue inflammation and malformation. In moderate to severe cases, affected dogs usually present abnormal breathing sound, heat and exercise intolerance, regurgitation and vomiting, sleep apnea, collapse and death (Poncet *et al.,* 2005; Bernaerts *et al.,* 2010; MacPhail, 2013; Meola, 2013). In this study, French bulldogs with BAOS had most of the signs from history taking, respiratory and digestive clinical grade according to Poncet et al. (2005), modified Roedler questionnaire and physical examination. Also, these BAOS dogs had lower physical capacity measured by 6-MWT, compared with normal French bulldogs. Most of these signs and walk distance were significantly improved at one month after surgical correction of elongated soft palate and stenotic nares.

This present study included only French bulldogs because it is a popular breed of brachycephalic dogs (The kennel club, 2020). Also, French bulldogs have high energy and always enjoy physical activities. Therefore, signs of exercise and heat intolerance were more obvious enough to be detected by the owners. In other BAOS clinical studies, French bulldogs were also one of the most common affected breeds (Roedler *et al.,* 2013; Ravn-Molby *et al.,* 2019). Average ages of normal and BAOS group in this study were not different and fell in the range of young adult. Our average age of BAOS cases was also similar with the previous studies (Roedler *et al.,* 2013; Pohl *et al.,* 2016). Most of the BAOS dogs that presented clinical signs and required veterinary consultation were reported to be 2-3 years of age (MacPhail, 2013; Meola, 2013). However, some owners in this study reported that they noticed the abnormal breathing sound since their dogs were less than 1 year old. This study found that male dogs was the majority of the cases (80%) which was similar to other clinical studies that reported male dogs had higher incidence than female dog

(Poncet *et al.,* 2005; Poncet *et al*., 2006). On the other hand, a welfare study in brachycephalic dogs found that female French bulldogs had more incident than male (25/44 dogs) (Aromaa *et al.*, 2019). However, there is no study that can confirm correlation between gender and BAOS. Nevertheless, gender of clinical cases may be influenced by owner preference and gender may affect the anatomical structures and dog activities. Male dogs had larger muscle mass surrounding the nasopharynx than female dogs, therefore, it could lead to more compression of airway (Roedler *et al.*, 2013). Moreover, male was associated with severity of respiratory and digestive clinical signs in dogs with BAOS (Poncet *et al.*, 2005). Average weight in BAOS group in this study was significantly greater than the normal group (P<0.05). Previous study showed that higher weight could increase severity of BAOS (Lilja-Maula *et al*., 2017) and increase severity of respiratory and digestive clinical signs (Liu *et al.*, 2015; Poncet *et al.*, 2005). Therefore, possible correlation between body weight or obesity and the severity of clinical sign was suggested (Roedler *et al.*, 2013). In this study, average age and body condition score were similar. All dogs in the BAOS group were within ideal body condition score. Thus, the difference of weight between groups could result from higher percentage of male dogs in the BAOS group (80% for BAOS group VS. 29% for normal group).

According to the severity evaluated by laryngoscopy examination, the gold standard for BAOS examination, all twenty BAOS dogs had elongated soft palate. Percentages of each primary disorder and secondary disorder that we found in this study, were similar to previous study (Meola, 2013; Pratschke, 2014). Most of severe primary disorder dogs also had severe secondary disorder and high severity of clinical signs. Thirteen BAOS dogs were presented severe clinical signs and seven BAOS dogs were presented moderate clinical signs. None of BAOS dogs in this study presented mild anatomical abnormality or clinical sign. As subtle abnormality of upper respiratory tract may not be able to induce obvious change in breathing pattern or other clinical signs that could be detected by the owners. Also, BAOS consists of multimodal abnormalities of upper airway anatomy that can contribute to several clinical signs involving beyond respiratory system and can be affected by dog behavior (Lilja-Maula *et al.,* 2017).

From history taking and physical examination, respiratory clinical grade according to Poncet *et al.* (2005) in all normal dogs was grade 1 (i.e. rarely have respiratory clinical signs associated with BAOS), while none of the BAOS dogs had grade 1. Most of the BAOS dogs at before surgery had grade 3 (90%) in which loud breathing sound when awake and sleep, inspiratory effort, stress/exercise intolerance and syncope were presented regularly. This result was consistent with other clinical studies that 74-83% of the BAOS dogs had respiratory clinical grade 3 and 13-25% of the BAOS dogs had grade 2 (Poncet *et al.,* 2005 2006). After surgical correction by staphylectomy using Ligasure™ and nasal alarplasty, the respiratory signs were immediately improved within one day also respiratory clinical grade reduced to grade 1 in all BAOS dogs at one week after surgery, which maintain at this score until 4 weeks follow up. In previous long-term follow up study, most of the French bulldogs with BAOS had respiratory clinical grade 3 at before conventional staphylectomy. However, the grades improved in only some dogs at six months after surgery (Haimel and Dupre, 2015). They also reported that approximately 25% of dogs developed post-operative respiratory complications including dyspnea, coughing and aspiration pneumonia. However, in the present study, acute post-operative respiratory complication was not found. All dogs were discharged and able to eat and drink within one day. These better outcomes in terms of respiratory signs could be a result of using advanced equipment that can cut the tissue and seal the vessel with minimal tissue injury and inflammation.

For gastrointestinal signs, most of the normal dogs presented digestive clinical grade 1. However, there was one dog that had history of occasionally vomiting (digestive clinical grade 2). While, half of the dog in BAOS group had digestive clinical grade 2 and the rest had grade 1 and 3 equally. However, the digestive clinical grade could be affected by both breed and BAOS severity. Compared with other brachycephalic breeds, French bulldogs with BAOS showed more gastrointestinal signs (Roedler *et al.,* 2013). Also, all dog with digestive clinical grade 3 has severe primary and/or secondary lesions.

After surgical correction, at day one, six dogs developed post-operative complication including regurgitation and vomiting. Similarly, regurgitation and vomiting were reported as post-operative complications in approximately 30% of BAOS dogs after conventional surgical correction which could lead to aspiration pneumonia (Haimel and Dupre, 2015). The digestive clinical grades improved in most of the dogs in our study at one week after surgery. However, one dog had worse grade due to increased frequency of vomiting. After two weeks, the digestive clinical grade was only grade 1 in all dogs. Other previous studies also found that the improvement of gastrointestinal sign in most dogs starting immediately after surgery while some dogs required more than two weeks for the clinical improvement (Poncet *et al.*, 2006). Furthermore, more than half of the dogs still had gastrointestinal signs (digestive clinical grade 2 and 3) at six months after conventional surgical correction (Haimel and Dupre, 2015). Therefore, gastrointestinal signs induced by BAOS seem to be more problematic and improve slower than respiratory signs.

The analysis of the modified Roedler BAOS questionnaire indicated that the scores of all parts including breathing sound, exercise and heat intolerance, eating and sleeping, were significantly higher in BAOS group at before surgery than those of normal group, especially breathing sound and exercise and heat intolerance parts. For example, BAOS dogs presented loud breathing sound in all situations and showed more cyanotic and dyspnea during exercise even in air conditioning room. This was in- agreement with their respiratory and digestive clinical grades. Four weeks after surgical correction, the scores markedly improved in all parts. However, the scores in eating part showed some variation as regurgitation, vomiting, eating fast and swallow food without chewing still presented in several dogs. This improvement of questionnaire scores was consistent with owner perception, physical examination and respiratory and digestive clinical grades. In previous study, after conventional surgical correction, the BAOS questionnaire scores significantly improved, especially in breathing sound at different situations and exercise and heat intolerance evaluated in both summer and winter (Pohl *et al.,* 2016). In that study, the result of questionnaire analysis also supported the improvement in surgical clinical outcome.

However, even at four weeks after staphylectomy and nasal alarplasty, the loud breathing sound still presented in some dogs. This could be a result of several factors. For instant, nasal aberrant conchae and secondary changes of larynx (i.e. laryngeal collapse and laryngeal saccule) that could be found in BAOS can lead to increased airway resistance and loudness of breathing sound. In this study, retroflex laryngoscopy or computed tomography scan (CT scan) was not performed to evaluate nasal aberrant conchae. Also, correction of either nasal aberrant conchae or secondary changes of larynx was not performed in this study. Another factor could be the relaxation of nasopharyngeal muscles that further compress upper respiratory tract resulting in snoring during sleep. Therefore, the BAOS dogs with severe primary and secondary lesions may still have snoring sound from persistence secondary lesions. Moreover, in severe BAOS cases, this compression of upper airway during sleep can induce sleep apnea and abnormal sleeping position. In this study, sleep apnea was also noticeably improved in all BAOS dogs after four weeks of surgical correction. However, abnormal sleeping positions such as dog sitting or chin rising were still presented in some dogs. Therefore, some dogs may still have secondary lesion or already establish preferred sleeping position that improve ventilation. Also, some brachycephalic dogs had an abnormal position or hold something in mouth during sleep to increase the airway (Pohl *et al.,* 2016).

Exercise and heat intolerance is the most important clinical signs related with BAOS. Most of the BAOS cases in this study presented severe exercise and heat intolerance and were unable to perform long duration of exercise in hot weather. This could be the combination of reduction of ventilation capacity and heat loss efficacy. According to anatomical abnormality of nasopharynx organs found in BAOS, ventilation is impaired due to narrowing of upper respiratory tract leading to increase of negative pressure in airway. In severe cases, some part of upper respiratory tract maybe completely collapses. Therefore, most of the dogs with BAOS cannot increased ventilation to meet high oxygen demand during exercise leading to exercise intolerance problems including cyanosis, early exhaustion, unable to perform strenuous exercise and collapse during exercise. For thermoregulation, in high ambient temperature, dogs can reduce body heat only in the form of evaporation through panting. During panting, heat from the body can be evaporative transfer to the colder air in oronasal cavity. With increasing air change per minute and surface of evaporation, heat loss is more effective. However, dogs with BAOS have narrowing nasal cavity with obstructed oropharynx, thus heat loss is significantly impaired (Roedler *et al.,* 2013). Thus, BAOS dogs usually exhibit vigorously breathing, dyspnea, hypersalivation, open-mouth breathing, hyperthermia and heat stroke during exercise or stay in hot weather.

From open ended question regarding to duration and frequency of exercise and recovery time, normal dogs had more outdoor activities for both duration and frequency and faster recovery time when looking at percentage of dogs in the group, compared with BAOS dogs at before surgery. After surgical correction, there were improved trends of exercise duration and frequency as well as recovery time. These findings were in the same fashion with clinical signs, respiratory and digestive clinical grade, questionnaire scores and 6-MWT.

For subjective physical capacity measurement using 6-MWT, normal dogs had significantly longer average walk distance than BAOS dogs at before surgical correction, approximately 521 and 406 meters, respectively. This finding was corresponding with previous studies in English bulldogs, French bulldogs and pugs that dogs with BAOS had shorter walk distance compared with healthy dogs in the same breed (Lilja-Maula *et al.,* 2017, Aromaa *et al.,* 2019). Therefore, 6-MWT was suggested that it can be used to assess BAOS severity and welfare in brachycephalic dogs for breeding (Ravn-Molby *et al.*, 2019). However, average walk distances in this study were lower than those studies. This could result from differences in severity of test subjects, familiarity with short-leashed walking and test setting especially in terms of ambient temperature and humidity, length of walk path and number of turns. Four weeks after surgical correction, all BAOS dogs were able to walk longer (approximately 25%) and the average walk distance was significantly higher than the values before surgery. This improvement was also found in previous brachycephalic breeds that received conventional surgical correction for BAOS and theses dogs had 14% increased walk distance (Villedieu *et al.*, 2018). However, degree of improvement in walk distance was range from 10% to 50% in this study. The wide variation in physical capacity alteration was also found in the study of Villedieu and coworkers (2018), in which the individual differences in walk distance at six weeks after surgical correction ranged from -31% to 67%. The differences in degree of physical capacity improvement after surgical correction could be a result of several factors such as base line physical capacity level, unsolved respiratory problems, other systemic diseases and dog behavior. Never the less, from our observation, most severe BAOS dogs that had low walk distance at the beginning and the surgical correction could resolve all major lesions trended to have better degree of walk test improvement. Therefore, absolute walk distance of individual dog may reflex physical capacity and surgical outcome better than percent of walk distance improvement.

Although, all of the physiological parameters from 6-MWT were statistically significant between normal dogs and BAOS dogs at before surgery, only respiratory rate and body temperature of some BAOS dogs were higher than normal limits at both before and after 6-MWT. 6-MWT is the low intensity physical capacity test. Therefore, alteration in physiological parameters including heart rate, respiratory rate, body temperature and oxygen saturation was minimal in healthy dogs (Lilja-Maula *et al.,* 2017). Also, arterial oxygen saturation is usually depressed in the cases that had moderate to severe cardiovascular and lower respiratory diseases such as in dogs with pulmonary fibrosis (Swimmer and Rozanski, 2011). Also, the oxygen saturation in this study was indirectly measured by pulse oxymeter. Thus, changing of oxygen saturation may be minimal and may not be necessary to measure, especially in partial or mild upper respiratory tract obstruction (Villedieu *et al.*, 2018). Using arterial blood gas may provide more accurate oxygen saturation but it is invasive and difficult to perform with excited dogs. However, from clinical observation in our surgical unit, arterial blood gas parameters could not reflex BAOS severity or clinical improvement after surgical correction of staphylectomy using bipolar sealing device in previous BAOS cases. The dogs that had high respiratory rate (60-80 breath per minute) presented with severe clinical sign and anatomical abnormality. However, some dogs in this study were excited which could lead to increase heart rate, respiratory rate and body temperature. Increased body temperature in these dogs was similar with the other reports in which English bulldogs with BAOS had higher body temperature at both before and after performing 6-MWT compared with healthy dogs (Lilja-Maula *et al.*, 2017). The higher body temperature found in BAOS dogs could cause by impaired evaporative heat loss. Four weeks after surgical correction, all physiological parameters of 6-MWT were significantly improved. Also, all dogs with clinically high respiratory rate and body temperature at before surgery had markedly decreased both respiratory rate and body temperature. This could indicate that the surgical outcome was good even in the severe cases. Therefore, surgical correction should be performed in all moderate to severe BAOS cases to reduce risk of adverse event related with exercise and heat intolerance and to improve dogs' quality of life.

The limitation of this study was a small number of included normal dogs due to most brachycephalic dogs presented BAOS clinical signs. Therefore, the correlation among parameters could not be identified. Moreover, anatomical abnormality was not confirmed by laryngoscope in normal dogs due to high risk of anesthesia in brachycephalic dogs. Also, secondary lesions such as everted laryngeal saccule were not corrected because sacculectomy showed mixed outcomes with moderate to severe complications (Hughes *et al.*, 2018). Lastly, questionnaire may depend on the owner knowledge, honestly, observation and recalled memory which could lead to less accuracy information.

In conclusion, French Bulldogs with BAOS had significant clinical signs and low physical capacity which could be evaluated by modified Roedler questionnaire and 6-MWT. Staphylectomy by Ligasure™ had excellent clinical outcome in terms of minimal post-operative complication and marked improvement in clinical signs and physical capacity. Therefore, both 6-MWT and modified Roedler questionnaire should be incorporated in clinical management for brachycephalic dogs.

REFERENCES

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. Animal Welfare. 28(3): 287-298.

Bernaerts F, Talavera J, Leemans J, Hamaide A, Claeys S, Kirschvink N and Clercx C 2010. Description of original endoscopic findings and respiratory functional assessment using barometric whole-body plethysmography in dogs suffering from brachycephalic airway obstruction syndrome. Vet J. 183(1): 95-102.

Boddy KN, Roche BM, Schwartz DS, Nakayama T and Hamlin RL 2004. Evaluation of the six-minute walk test in dogs. Am J Vet Res. 65(3): 311-313.

Bofan AB, Ionașcu I and Șonea A 2015. Brachycephalic airway syndrome in dogs. Scientific Works. Series C. Vet Med. 61(1): 103-112.

Brdecka DJ, Rawlings CA, Perry AC and Anderson JR 2008. Use of an electrothermal, feedback-controlled, bipolar sealing device for resection of the elongated portion of the soft palate in dogs with obstructive upper airway disease. J Am Vet Med Assoc. 233(8): 1265-1269.

Caccamo R, Buracco P, La Rosa G, Cantatore M and Romussi S 2014. Glottic and skull indices in canine brachycephalic airway obstructive syndrome. BMC Vet Res. 10(12): 1-7. https://doi.org/10.1186/1746-6148-10-12

Carbonell AM, Joels CS, Kercher KW, Matthews BD, Sing RF and Heniford BT 2003. A comparison of laparoscopic bipolar vessel sealing devices in the hemostasis of small-, medium-, and large-sized arteries. J Laparoendosc Adv Surg Tech A. 13(6): 377-380.

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.

Cortadellas T, Córdoba O, Espinosa-Bravo M, Mendoza-Santin C, Rodríguez-Fernández J, Esgueva A, Álvarez-Vinuesa M, Rubio IT and Xercavins J 2011. Electrothermal bipolar vessel sealing system in axillary dissection: a prospective randomized clinical study. Int J Surg. 9(8): 636-640.

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.

Entezari K, Hoffmann P, Goris M, Peltier A and Van Velthoven R 2007. A review of currently available vessel sealing systems. Minim Invasive Ther Allied Technol. 16(1): 52-57.

Fasanella FJ, Shivley JM, Wardlaw JL, and Givaruangsawat S 2010. Brachycephalic airway obstructive syndrome in dogs: 90 cases. J Am Vet Med Assoc. 237(9): 1048-1051.

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.

Heresi GA and Dweik RA 2011. Strengths and limitations of the six-minute-walk test: a model biomarker study in idiopathic pulmonary fibrosis. Am J Respir Crit Care Med. 183: 1122-1124.

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.

Lamberton GR, Hsi RS, Jin DH, Lindler TU, Jellison FC and Baldwin DD 2008. Prospective comparison of four laparoscopic vessel ligation devices. J Endourol. 22(10): 2307-2312.

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

Lilja-Maula L, Laurila H, Syrjä P, Lappalainen A, Krafft E, Clercx C and Rajamäki M 2014. Long-term outcome and use of 6-minute walk test in West Highland White Terriers with idiopathic pulmonary fibrosis. J Vet Intern Med. 28(2): 379-385.

Liu N-C, 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. https://doi.org/10.137/journal.pone.0130741

Lodato DL and Hedlund CS 2012a. Brachycephalic airway syndrome: management. Compend Contin Educ Vet. 34(8): E1-E7.

Lodato DL and Hedlund CS 2012b. Brachycephalic airway syndrome: pathophysiology and diagnosis. Compend Contin Educ Vet. 34(7): E1-E5.

MacPhail CM. 2013. Surgery of the upper respiratory system. In: Small animal surgery. 4th ed. LP Duprey and TG Huff (eds). Missouri: Elsevier, Inc. 906-957.

Manens J, Ricci R, Damoiseaux C, Gault S, Contiero B, Diez M and Clercx C 2014. Effect of body weight loss on cardiopulmonary function assessed by 6-minute walk test and arterial blood gas analysis in obese dogs. J Vet Intern Med. 28(2): 371-378.

Meola SD 2013. Brachycephalic Airway Syndrome. Top Companion Anim Med. 28(3): 91-96.

Morales-Blanhir JE, Palafox Vidal CD, Rosas Romero MdJ, García Castro MM, Londoño Villegas A and Zamboni M 2011. Six-minute walk test: a valuable tool for assessing pulmonary impairment. J Bras Pneumol. 37(1): 110-117.

O'Neill DG, Jackson C, Guy JH, Church DB, McGreevy PD, Thomson PC and Brodbelt DC 2015. Epidemiological associations between brachycephaly and upper respiratory tract disorders in dogs attending veterinary practices in England. Canine Genet and Epidemiol. 2(1): 1-10. http://doi.org/10.1186/s40575-015-0023-8.

Oechtering GU, Pohl S, Schlueter C, Lippert JP, Alef M, Kiefer I, Ludewig E and Schuenemann R 2016. A novel approach to brachycephalic syndrome. 1. Evaluation of anatomical intranasal airway obstruction. Vet Surg. 45(2): 165-172.

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 C, Dupre G, Freiche V, Estrada M, Poubanne Y and Bouvy B 2005. Prevalence of gastrointestinal tract lesions in 73 brachycephalic dogs with upper respiratory syndrome. J Small Anim Pract. 46(6): 273-279.

Poncet C, Dupre G, Freiche V and Bouvy B 2006. Long-term results of upper respiratory syndrome surgery and gastrointestinal tract medical treatment in 51 brachycephalic dogs. J Small Anim Pract. 47: 137-142.

Pratschke K 2014. Current thinking about brachycephalic syndrome: more than just airways. Companion Anim. 19(2): 70-78.

Ravn-Molby EM, Sindahl L, Nielsen SS, Bruun CS, Sandoe P and Fredholm M 2019. Breeding French bulldogs so that they breathe well-A long way to go. PLoS One. 14(12): e0226280. http://doi.org/10.1371/journal.pone.0226280

Rick O, Metz T, Eberlein M, Schirren J and Bölükbas S 2014. The six-minute-walk test in assessing respiratory function after tumor surgery of the lung: a cohort study. J Thorac Dis. 6(5): 421-428.

Riecks TW, Birchard SJ and Stephens JA 2007. Surgical correction of brachycephalic syndrome in dogs: 62 cases (1991–2004). J Am Vet Med Assoc. 230(9): 1324-1328.

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.

Schlicksup M 2015. Upper Airway Disease: Brachycephalic Airway Syndrome. In: Small Animal Surgical Emergencies. 1st ed. LR Aronson (ed). Chichester, UK: John Wiley & Sons, Inc. 270-278.

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). Missouri: Elsevier, Inc. 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.

Takada M, Ichihara T and Kuroda Y 2005. Comparative study of electrothermal bipolar vessel sealer and ultrasonic coagulating shears in laparoscopic colectomy. Surg

Endosc. 19(2): 226-228.

The kennel club. 2020, "Top 20 breeds 2018-2019" [Online]. Available: https://www.thekennelclub.org.uk/registration/breed-registration-statistics/. Accessed April 17, 2020.

The Thai Meteorological Department. 2020, "Thailand Annual Weather Summary, 2019" [Online]. Available: https://www.tmd.go.th/climate/climate.php?FileID=5,%20assessed%202020. Accessed April 17, 2020.

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.

Trappler M and Moore K 2011a. Canine brachycephalic airway syndrome: surgical management. Compend Contin Educ Vet. 33(5): E1-E8.

Trappler M and Moore K 2011b. Canine brachycephalic airway syndrome: pathophysiology, diagnosis, and nonsurgical management. Compend Contin Educ Vet. 33(5): E1-E5.

Villedieu E, Rutherford L and Ter Haar G 2019. Brachycephalic obstructive airway surgery outcome assessment using the 6-minute walk test: a pilot study. J Small Anim Pract. 60(2): 132-135.

APPENDIX

แบบสอบถามในสุนัขพันธุ์หน้าสั้น

(ดัดแปลงจากของ Roedler และคณะในปี 2013)

วันที่ : ______________________

ชื่อเจ้าของ : ____

เบอร์โทรศัพท์ : ____

HN : ______________________

ชื่อสุนัข : ____

พันธุ์ : ____

เพศ : ☐ ผู้ ☐ ผู้ทำหมันแล้ว

☐ เมีย ☐ เมียทำหมันแล้ว

อายุ : _________ ปี _________ เดือน

น้ำหนัก : ________________ กิโลกรัม

แบบสอบถามเพื่อประเมินการหายใจของสุนัขพันธ์หน้าสั้น

	0	1	2	3
1. สุนัขของคุณหายใจเสียงดังในขณะที่ไม่ได้นอนหลับ				
2. สุนัขของคุณหายใจเสียงดังในขณะที่นอนหลับสนิท				
3. สุนัขของคุณหายใจเสียงดังในขณะที่ออกกำลังกาย/ตื่นเต้น				
4. สุนัขของคุณหายใจลำบาก ในขณะที่ออกกำลังกาย หรือตื่นเต้น ตอนอยู่ในห้องแอร์				
5. สุนัขของคุณหายใจลำบาก ในขณะที่ออกกำลังกาย หรือตื่นเต้น ตอนอยู่ในที่อากาศร้อน หรืออบอ้าว				
6. สุนัขของคุณเป็นลมเนื่องจากหายใจลำบาก				
7. สุนัขของคุณมีปัญหาลิ้นม่วง				
8. สุนัขของคุณมีปัญหาต่อไปนี้ขณะทานอาหาร/น้ำ				
- สำรอก หรืออาเจียน				
- ทานเร็ว ไม่เคี้ยวอาหาร				
9. สุนัขของคุณมีปัญหาต่อไปนี้ขณะนอนหลับ				
- ตื่นขึ้นมาระหว่างนอน และอ้าปากงับอากาศ หรือหายใจหอบถี่หลังสะดุ้งตื่น				
- นอนได้เฉพาะเมื่อเชิดคางขึ้นสูง หรือคาบอะไรไว้ในปาก				
- นอนได้เฉพาะในท่าที่ผิดปกติ (นั่งหลับ)				

(0=ไม่เคย, 1=น้อยกว่าหรือเท่ากับอาทิตย์ละครั้ง, 2=มากกว่าอาทิตย์ละครั้ง, 3=ตลอดเวลา)

10. ใน 1 สัปดาห์ สุนัขได้ไปเดินเล่น/ออกกำลังกายบ่อยแค่ไหน________________________

กิจกรรมที่ทำ/ออกกำลังกาย คือ____

สุนัขของคุณเดินเล่น/ออกกำลังกายนานเท่าไหร่________________________นาที/ครั้ง

สุนัขของคุณใช้เวลานานเท่าไหร่ในการกลับมาหายใจได้ปกติหลังออกกำลังกาย_____นาที

Group	No.	Sex	Age (Months)	Weight (Kg.)	BCS	Respirotory clinical grade	Digestive clinical grade
Normal group	1	Female	13	10.6	3	1	1
	2	Male	16	15	3.5	1	1
	3	Female	13	9.5	3	1	1
	4	Female	25	9	3	1	1
	5	Female	13	10	3	1	2
	6	Female	9	9.2	3	1	1
	7	Male	11	12	3	1	1

Group	No.	Sex	Age (Months)	Weight (Kg.)	BCS
BAOS group	1	Male	56	16.5	3.5
	2	Male	13	12.8	3
	3	Male	8	10.5	3
	4	Male	58	16	3.5
	5	Male	34	13	3
	6	Male	55	13.6	3
	7	Male	28	16	3.5
	8	Male	30	14.5	3.5
	9	Female	19	9.5	3
	10	Male	30	13.2	3
	11	Male	14	13	3
	12	Male	40	10.6	3
	13	Male	29	13	3
	14	Female	40	11	3
	15	Female	11	9.2	2.5
	16	Male	35	14.5	3.5
	17	Female	25	11	3
	18	Male	29	16.7	3.5
	19	Male	19	13	3
	20	Male	14	12.5	3

Group	No.	Elongated soft palate	Stenotic nares	Hypoplastic trachea	Everted tonsil	Laryngeal saccule	Laryngeal collapse
BAOS group	1	/	severe	X	2 sides	/	1
	2	/	moderate	X	2 sides	x	x
	3	/	none	X	2 sides	/	2
	4	/	severe	X	2 sides	/	2
	5	/	severe	X	2 sides	/	2
	6	/	severe	X	2 sides	/	2
	7	/	severe	X	2 sides	/	1
	8	/	severe	X	1 side	x	x
	9	/	severe	/	2 sides	/	2
	10	/	moderate	X	2 sides	x	x
	11	/	severe	X	2 sides	/	2
	12	/	severe	X	1 side	x	x
	13	/	moderate	X	2 sides	x	x
	14	/	mild	/	None	/	2
	15	/	moderate	X	2 sides	x	x
	16	/	severe	X	1 side	/	2
	17	/	severe	X	1 side	/	2
	18	/	moderate	X	none	/	1
	19	/	severe	X	none	/	2
	20	/	moderate	X	1 side	x	x

Group	No.	Respiratory clinical grade				
		Before Sx	1 week after Sx	2 weeks after Sx	3weeks after Sx	4 weeks after Sx
BAOS group	1	3	1	1	1	1
	2	3	1	1	1	1
	3	3	1	1	1	1
	4	3	1	1	1	1
	5	3	1	1	1	1
	6	3	1	1	1	1
	7	3	1	1	1	1
	8	3	1	1	1	1
	9	3	1	1	1	1
	10	3	1	1	1	1
	11	3	1	1	1	1
	12	3	1	1	1	1
	13	2	1	1	1	1
	14	3	1	1	1	1
	15	3	1	1	1	1
	16	3	1	1	1	1
	17	3	1	1	1	1
	18	3	1	1	1	1
	19	3	1	1	1	1
	20	2	1	1	1	1

Group	No.	Digestive clinical grade				
		Before Sx	1 week after Sx	2 weeks after Sx	3weeks after Sx	4 weeks after Sx
BAOS group	1	3	1	1	1	1
	2	2	2	1	1	1
	3	2	1	1	1	1
	4	2	1	1	1	1
	5	3	1	1	1	1
	6	1	1	1	1	1
	7	1	1	1	1	1
	8	3	2	1	1	1
	9	1	1	1	1	1
	10	1	1	1	1	1
	11	3	1	1	1	1
	12	2	1	1	1	1
	13	2	1	1	1	1
	14	2	3	1	1	1
	15	2	1	1	1	1
	16	2	1	1	1	1
	17	2	1	1	1	1
	18	2	1	1	1	1
	19	3	2	1	1	1
	20	2	1	1	1	1

Group	No.	Heart rate (beat/minute)		Respiratory rate (breath/minute)		Temperature (F)		Oxygen saturation (%)		Distance (meter)
		Pre-walk	Post-walk	Pre-walk	Post-walk	Pre-walk	Post-walk	Pre-walk	Post-walk	
Normal group	1	120	128	36	48	101.4	101.6	97	98	462.24
	2	140	144	32	44	100.8	101	98	97	514.87
	3	120	128	24	48	100.4	100.8	99	98	557.56
	4	104	108	28	48	99.8	100	99	99	494.31
	5	128	136	36	52	100.8	101	98	97	522.87
	6	100	128	32	40	101	101.4	97	97	538.84
	7	120	128	40	56	101	101.2	97	98	559.71

Group	No.	Heart rate (beat/minute)			
		Before Sx		4 weeks after Sx	
		Pre-walk	Post-walk	Pre-walk	Post-walk
BAOS group	1	124	144	116	144
	2	112	132	108	112
	3	128	148	128	144
	4	120	152	112	140
	5	136	156	128	140
	6	136	152	128	136
	7	144	180	128	148
	8	136	152	124	140
	9	120	132	108	128
	10	136	160	128	144
	11	144	176	120	144
	12	124	148	116	140
	13	124	140	120	136
	14	120	132	104	116
	15	128	148	112	124
	16	128	144	104	120
	17	128	152	120	136
	18	124	148	116	132
	19	132	156	120	132
	20	120	128	116	124

Group	No.	Respiratory rate (breath/minute)			
		Before Sx		4 weeks after Sx	
		Pre-walk	Post-walk	Pre-walk	Post-walk
BAOS group	1	32	52	28	40
	2	24	40	32	48
	3	40	60	36	60
	4	32	68	28	64
	5	36	68	24	56
	6	80	100	28	68
	7	68	88	48	84
	8	52	92	44	84
	9	24	52	28	36
	10	84	124	64	100
	11	72	128	52	84
	12	88	172	68	96
	13	44	56	24	36
	14	24	28	20	36
	15	32	40	36	40
	16	40	108	32	52
	17	72	160	56	92
	18	68	124	40	52
	19	60	80	32	48
	20	60	84	28	32

Group	No.	Temperature (F)			
		Before Sx		4 weeks after Sx	
		Pre-walk	Post-walk	Pre-walk	Post-walk
BAOS group	1	101.4	101.6	100.6	100.8
	2	101.8	102	101.1	101
	3	101.4	101.8	100.4	100.8
	4	101.6	102.6	101	101.4
	5	100.2	100.6	100.4	101
	6	102.4	103	101.6	101.8
	7	102	102.6	101.6	101.8
	8	101.6	103	101	101.4
	9	99.8	100.2	101	101
	10	102.2	102.6	100	100.6
	11	101.4	101.8	101	101.2
	12	102.4	103.8	100.8	101.4
	13	101.8	102.2	101	101.6
	14	100.8	100.2	99.6	99.8
	15	100.6	101.2	101.2	101.4
	16	101.4	102	101.4	101.8
	17	101.6	102.2	101.2	101.6
	18	101.1	101.6	101.8	102
	19	101.6	102.2	101.6	102
	20	101.6	102	101	101.2

Group	No.	Oxygen saturation (%)			
		Before Sx		4 weeks after Sx	
		Pre-walk	Post-walk	Pre-walk	Post-walk
BAOS group	1	96	95	94	96
	2	98	97	96	96
	3	95	95	97	97
	4	96	96	97	96
	5	97	94	97	96
	6	95	98	99	98
	7	95	97	99	99
	8	97	98	96	98
	9	94	95	98	97
	10	97	98	97	98
	11	97	96	97	96
	12	97	96	97	98
	13	97	96	97	97
	14	99	99	98	99
	15	97	96	95	96
	16	97	97	95	97
	17	97	98	97	97
	18	96	95	96	95
	19	96	97	97	96
	20	95	95	98	98

Group	No.	Distance (meter)	
		Before Sx	4 weeks after Sx
BAOS group	1	313.69	439.72
	2	383.92	489
	3	404.86	541
	4	369.3	550.71
	5	345.79	512.58
	6	388.78	510.73
	7	456.75	542
	8	373	476.21
	9	419.75	517.57
	10	412.43	494.69
	11	445.69	516.08
	12	469.67	542.57
	13	337.23	438.25
	14	457.12	506.78
	15	368.1	460.7
	16	397.16	485.9
	17	451.58	527.43
	18	448	517.47
	19	418	519.53
	20	449	534.27

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