UNIVERSITI PUTRA MALAYSIA

COMPARISON OF THE EFFICIENCY OF LEAN BODY WEIGHT-BASED METHODS AND THORACIC RADIOGRAPH MEASUREMENT IN DETERMINING ENDOTRACHEAL TUBE SIZE IN MESOCEPHALIC DOGS

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DEDICATION

My supervisor and co-supervisors, for being my academic mentors and motivators. My family, for their unwavering support and belief in me, have been instrumental in achieving this milestone.

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I wish to express my sincere appreciation to Dr. Benedict Ong Huai Ern, my esteemed supervisor, for his enduring patience, invaluable guidance, insightful counsel, and unwavering dedication to our study.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
ACT	Actual inserted endotracheal tube size
BCS	Body condition score
BW	Body weight
BWT	Lean body weight-based formula method
LBW	Lean body weight
ETS	Endotracheal tube size
EDTT	Endotracheal tube
kg	Kilogram
mg	Milligram
mm	Millimeter
RAD	Thoracic radiographic measurement method
SEM	Standard error of mean
TAB	Lean body weight range table method
TID	Tracheal internal diameter
UPM	Universiti Putra Malaysia
e.g.	e.g. (abbr. Latin) exempli gratia (for example)
et al.	et al. (abbr. Latin) et alii (and others)
%	Percentage

ABSTRAK

Abstrak kertas projek yang dikemukakan kepada Fakulti Perubatan Veterinar untuk memenuhi sebahagian daripada kursus VPD 4999 - Projek Tahun Akhir.

PERBANDINGAN KEBERKESANAN KAEDAH BERASASKAN BERAT BADAN KURUS DAN PENGUKURAN RADIOGRAFI TORAKS DALAM PERAMALAN SAIZ TIUB ENDOTRAKEAL UNTUK ANJING MESOCEPHALIC.

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2023

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Peranan peramalan saiz tiub endotrakea (ETS) amat penting dalam pengelakkan komplikasi penggunaan saiz tiub endotrakea yang kurang berpadanan, pada masa yang sama memaksimumkan fungsinya. Namun begitu, kini tiada kaedah peramalan

ETS yang standard untuk anjing disebabkan kepelbagaian dalam baka, konformasi badan dan berat badan. Oleh itu, kajian ini dijalankan untuk menentukan kebolehan kaedah formula berasaskan berat badan kurus (BWT), kaedah pengukuran radiografi toraks (RAD) dan kaedah jadual julat berat badan kurus (TAB) dalam peramalan saiz sebenar tiub endotrakea (ACT). 12 anjing mesocephalic berlainan baka telah dipilih sebagai subjek kajian. Rekod berat badan telah diambilkan untuk pengiraan kaedah BWT dan TAB demi peramalan ETS. Untuk kaedah RAD, ETS telah diramalkan berasaskan ukuran diameter dalaman trakea subjek daripada radiografi toraks sisi digital. ACT ditentukan berasaskan tentangan semasa intubasi dan ujian kebocoran. Terdapat korelasi signifikan antara ACT dengan peramalan BWT (p = 0.000, r = 0.955), antara ACT dengan peramalan RAD (p = 0.000, r = 0.981) dan antara ACT dengan peramalan TAB (p = 0.000, r = 0.925). Dari segi ramalan yang betul bagi saiz tiub endotrakeal yang tepat, RAD mempunyai ketepatan yang paling tinggi (58%), diikuti BWT (41.6%) serta TAB yang mempunyai ketepatan paling rendah (16.67%). Manakala, tiga saiz tiub endotrakeal (saiz yang betul, satu 0.5mm lebih kecil, satu 0.5mm lebih besar daripada saiz yang diramalkan) meliputi 83.33% anjing dengan menggunakan kaedah RAD, 75% anjing dengan menggunakan kaedah BWT serta 50% anjing dengan menggunakan kaedah. Konklusinya, BWT dan RAD boleh digunakan sebagai panduan untuk meramal ACT untuk mesocephalic anjing.

Kata kunci: anjing, baka mesocephalic, berat badan, saiz tiub endotrakea, ukuran radiografi

ABSTRACT

An abstract of the project paper presented to Faculty of Veterinary Medicine in partial fulfillment of the course VPD 4999 - Final Year Project.

COMPARISON OF THE EFFICIENCY OF LEAN BODY WEIGHT-BASED METHODS AND THORACIC RADIOGRAPH MEASUREMENT IN DETERMINING ENDOTRACHEAL TUBE SIZE IN MESOCEPHALIC DOGS.

By

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Endotracheal tube size (ETS) estimation is vital to prevent undesirable complications of improper size endotracheal tube utilization while maximizing its functions. However, no standardized optimal ETS selection method is indicated for dogs currently due to a great variety in breeds, conformations, and body weights contributing to a wide individual tracheal diameter variation. Therefore, this study aimed to compare the ability of the lean body weight-based formula method (BWT), lean body weight range table (TAB), and thoracic radiographic measurement method (RAD) in estimating the actual inserted endotracheal tube size (ACT) for mesocephalic dogs. 12 mesocephalic dogs of different breeds were included as study subjects. The body weights and body condition scores were recorded for lean body weight-based formula calculation and lean body weight range table method to estimate BWT's and TAB's ETS respectively. The internal tracheal diameter was measured on digital lateral thoracic radiographs for RAD's ETS estimation. ACT was determined based on the resistance upon intubation and leak test. There was a high degree of significant positive correlation between ETS of BWT and ACT ($p = 0.000$, $r = 0.955$), ETS of RAD and ACT ($p = 0.000$, $r = 0.981$), as well as ETS of TAB and ACT ($p = 0.000$, $r = 0.925$). In terms of correct prediction of exact ETS, RAD (66.7%) had the highest accuracy, followed by BWT (41.7%), and TAB with the lowest prediction accuracy (16.7%). 83.3%, 75%, and 50% of the patients' ACT are within three sizes of endotracheal tubes (ETS, one 0.5mm smaller, one 0.5mm larger than the predicted size) using RAD, ACT, and TAB methods, respectively. In conclusion, BWT and RAD are practicable and suitable to be used as a guide to predict the ACT in mesocephalic dogs when three sizes of endotracheal tubes (ETS, one 0.5mm smaller, one 0.5mm larger than the predicted size) are prepared.

Keywords: body weight, dogs, endotracheal tube size, mesocephalic breed, radiographic measurement

1.0 INTRODUCTION

1.1 IMPORTANCE OF ENDOTRACHEAL INTUBATION IN VETERINARY ANESTHESIA

Endotracheal intubation, a fundamental procedure in veterinary anesthesia plays a crucial role in ensuring the safety of animals under general anesthesia. It refers to the process of inserting a tube into the trachea via the oral cavity. The correct selection and placement of an endotracheal tube (EDTT) ensure a patent airway in an unconscious patient (Muir *et al.*, 2013). Proper placement and size of an endotracheal tube (EDTT) in animal patients is critical for assisted or controlled ventilatory support, oxygen delivery, airway resistance minimization, induction and maintenance of inhalant anesthesia, as well as waste anesthetic gas exposure risk reduction in operator (Muir *et al.*, 2013).

1.2 ADVANTAGES AND RISKS OF ENDOTRACHEAL INTUBATION

Nonetheless, if endotracheal intubation is performed without proper caution, it can lead to several potential complications such as laryngeal spasm, tracheal damage, and over-insertion into the bronchus. While it is indisputable that endotracheal intubation may process certain risks, face masks can serve as an alternative means for administering oxygen and anesthetic gasses (Muir *et al.*, 2013), the advantages of utilizing endotracheal tubes with an inflated cuff may outweigh its disadvantages. The use of EDTT equipped with an inflated cuff offers several distinct advantages over face masks including easier securement, reduced atmospheric pollution from anesthetic gasses, improved maintenance of gas volume, prevention of aspiration and better lung inflation without the risk of gastric insufflation (Hughes, 2016).

1.3 SELECTION OF ENDOTRACHEAL TUBE SIZE

The selection of an appropriate endotracheal tube size (ETS) is a critical factor in mitigating the risk of adverse complications associated with the use of EDTT while optimizing their functionality. An improper EDTT size can lead to undesirable outcomes. For instance, the placement of an oversized EDTT may lead to inflammation of the laryngeal and tracheal, while the use of an undersized EDTT can increase breathing resistance and respiratory effort (Muir *et al.*, 2013). Therefore, a comprehensive understanding of optimal ETS determination is imperative to ensure an effective seal between tracheal mucosa and cuff, thereby enhancing patient safety and airway management efficacy.

1.4 ENDOTRACHEAL TUBE SIZE SELECTION CHALLENGES IN MESOCEPHALIC DOGS

Canines are traditionally categorized into three distinct cranial conformation groups: dolichocephalic, mesocephalic, and brachycephalic, as delineated by their cephalic indices (Hussien *et al*., 2012). Mesocephalic dogs, also known as mesaticephalic representing an intermediate head shape category characterized by cranial measurements that approximate equality in length and width, constitute a significant demographic within the clinical veterinary landscape (Bognár *et al*., 2021). Representatives of this category consists of breeds such as Labrador Retrievers and Cocker Spaniels. The accurate determination of the appropriate Endotracheal Tube Size (EDTT) for mesocephalic dogs assumes paramount importance, given the inherent diversity in body sizes exhibited by these individuals.

1.5 VARIABILITY IN ENDOTRACHEAL TUBE SIZE SELECTION METHODS AND NEED FOR STANDARDIZATION

Nevertheless, there is no standardized method for the selection of optimal ETS in dogs because of the great variety in age, breeds, and body weights which contribute to a wide tracheal diameter variation (Lish *et al.*, 2008; Mosley, 2015). Currently, the determination of ETS largely relies on the experience of individual practitioners as there are no established guidelines

(Tong and Pang, 2019). From the perspective of body weight, an overweight animal requires a smaller tube than another animal of the same species, breed, and weight, but with an ideal body condition score; vice versa for an emaciated animal (Thomas and Lerche, 2017). Consequently, most veterinary practitioners are advised to have at least three different-sized endotracheal tubes available for small animal intubation (Hughes, 2016).

1.6 DIVERSE APPROACHES TO ENDOTRACHEAL TUBE SIZE SELECTION IN VETERINARY MEDICINE

Various ETS selection methods are currently practiced in the veterinary medicine field based on the practitioner preferences. Veterinary textbooks often provide tables with overlapping ranges of body weights (Hughes, 2016). Some practitioners rely on external palpation of the trachea and assessment of the nasal septum width to determine the appropriate ETS size in dogs (Lish *et al.*, 2008; Shelby and McKune, 2014). In contrast, a more sophisticated approach using radiograph and ultrasound has been practiced in human pediatric ETS selection (Park *et al.*, 2013; Sutagatti *et al.*, 2017). Given the substantial inter-individual variation among veterinary patients in terms of species, breed, conformation, and body weight, there is a pressing need to develop individualized measurement methods for ETS selection. Commonly used methods such as nasal septum width assessment, externally palpated tracheal diameter, and approximate lean body weight are relatively subjective and rely solely on phenotypic parameters for optimal ETS determination (Shin *et al.*, 2018). Hence, recent research has explored the use of radiography as a basis for estimation, aiming to provide a visual representation of the tracheal diameter, thus overcoming some of the limitations associated with current ETS selection methods.

1.7 RESEARCH FOCUS

In this study, our primary objective was to compare the three methods of ETS prediction, namely the lean body weight-based formula method (BWT), thoracic radiographic measurement method (RAD) and lean body weight range table method (TAB). This study will determine the potential ability of body weight and tracheal internal diameter to estimate the actual inserted endotracheal tube size (ACT) from successful intubation with a proper seal in mesocephalic dogs. This study will provide insight into the accuracy of these three methods of ETS determination in ACT prediction.

2.0 LITERATURE REVIEW

2.1 ENDOTRACHEAL TUBE SIZE ESTIMATION METHODS

2.1.1 BODY WEIGHT

One of the most common methods used by veterinary practitioners for estimating ETS involves utilizing the body weight of the animals as the fundamental parameter. This approach assumes that the animal's body mass is directly proportional to its tracheal diameter (Lish *et al.*, 2008). Veterinary textbooks have introduced lean body weight range table (TAB) presenting a wide range of lean body weights corresponding to various ETS options as a reference for ETS selection in dogs (see Appendix Table 5), despite the considerable individual variability in tracheal diameter (Hughes, 2016). Nonetheless, the effectiveness of this method largely relies on the practitioner's personal experience (Lish *et al.*, 2008). In some cases, overlapping body weight ranges have resulted in as many as six potential optimal ETS estimations for a single patient (Hughes, 2016), indirectly contributing to an increased re-intubation rate in the absence of substantial experience. Additionally, there is limited literature available demonstrating a definitive correlation between body weight and tracheal size, especially in mixed-breed dogs (Lish *et al.*, 2008). Due to breed differences, using body weight as a generalized ETS estimation method may be challenging in clinical settings (Lish *et al.*, 2008).

Conversely, an alternative approach which is the lean body weight-based formula has been in use for several years at the University Veterinary Hospital, Universiti Putra Malaysia. According to this method, the optimal internal diameter of the endotracheal tube is determined as the square root of the product of the animal's current lean body weight and a constant factor of 5, irrespective of the animal's body condition score. Based on the author's experience, this formula has demonstrated practicality in clinical settings when applied to canine patients with ideal body conditions. However, it is important to note that the application of this formula lacks substantial validation in the published literature for estimating the optimal ETS.

2.1.2 WIDTH OF NASAL SEPTUM

The nasal septal width method relies on an external physical parameter of the animal to estimate the optimal ETS. In this approach, EDTT is positioned against a dog's nasal septum, precisely between the two nostrils at its narrowest point. The width of the nasal septum is then compared to the midportion outer diameter of the EDTT, allowing for the determination of the appropriate EDTT internal diameter as the optimal ETS (Lish *et al.*, 2008). Although this method is subject to variability due to differences in individual perspectives, it is quick and easy to carry out as no specialized skill or advanced equipment is needed. Nevertheless, the assumption of a direct anatomical correlation between tracheal diameter and the width of nasal septal width lacks strong support from published research (Lish *et al.*, 2008).

Furthermore, this method has demonstrated a relatively low accuracy rate, with only a 21.4% success rate in accurately estimating the optimal ETS (Lish *et al.*, 2008).

2.1.3 EXTERNAL DIGITAL TRACHEAL PALPATION

Direct palpation of the cervical trachea is often considered one of the simplest methods for estimating the appropriate ETS (Mosley, 2015). This technique is based on the assumption that the outer diameter of the trachea closely approximates the optimal outer diameter of EDTT (Shelby and McKune, 2014). The process involves manually palpating the tracheal diameter, located just cranial to the thoracic inlet, to provide an estimate of the closest outer diameter of the EDTT (Lish *et al.*, 2008). However, it depends on experience to a great extent as the palpation of the trachea includes the overlying tissues and hairs in the cervical region. Consequently, this method can be somewhat subjective, and results may vary among different assessors. The tracheal palpation method has demonstrated an accuracy rate of approximately 46.4% (Lish *et al*., 2008), which is relatively higher compared to the nasal septal width method.

2.1.4 RADIOGRAPHIC TRACHEAL DIAMETER MEASUREMENT

The utilization of thoracic radiographs for the estimation of the optimal ETS represents a relatively innovative approach in veterinary clinical practice. This method is based on the assumption that radiographic measured tracheal internal diameter is proportional to the outer diameter of optimal EDTT (Shin *et al.*, 2018). Despite its sophistication, involving a series of complicated steps, this method has demonstrated a commendable accuracy rate of up to 74.5% (Shin *et al.*, 2018).

Thoracic radiograph for tracheal diameter measurement should be ideally captured during maximum inspiration within one to two minutes of lateral recumbency under manual restraint. Proper positioning is crucial, with an emphasis on minimizing superimposition with the thorax by cranially pulling the thoracic limbs and ensuring that the neck is held neutral anatomically (Shin *et al.*, 2018). Preceding the internal tracheal diameter measurement, a reference line is drawn from ventral vertebral column at the center of most cranial rib to the dorsal manubrium's point of thickness, indicating the boundary of the thoracic inlet. Subsequently, another line is drawn perpendicularly to the tracheal long axis at the intersection with the previously drawn line at the tracheal lumen center. This second line is used to measure the tracheal internal diameter (Appendix Figure 9) (Hayward et al, 2008). The measured tracheal inner margin serves as a reference for estimating the EDTT outer diameter, thereby determining its corresponding internal diameter as the optimal ETS.

Despite the complexity involved in this procedure, the radiographic measurement method may offer superior ETS prediction capabilities, as evidenced by its lower re-intubation rate of 25.5% compared to the tracheal palpation method (53.6%) and nasal septal width method (78.6%) (Lish *et al.*, 2008). Moreover, the relationship between tracheal diameter and ETS appears more associated than that with the body weight of animals (Shin *et al.*, 2018). Supporting evidence can be gleaned from human medical research, which demonstrated that the radiograph-based method outperformed the standard age-based formula in estimating ETS for children aged three to six years old (Park *et al.*, 2013). These findings reinforce the potential of the radiographic method as a more accurate estimation option compared to the other conventional methods.

2.2 IMPORTANCE OF ESTIMATING OPTIMAL ENDOTRACHEAL TUBE SIZE

Ensuring proper endotracheal intubation is crucial to minimize potential risks associated with airway security and complications while optimizing its functional benefits. A critical concern in this regard is the appropriate sizing of ETS to achieve an effective seal between the cuff and the tracheal mucosa.

Using an undersized EDTT can lead to inadequate gas exchange due to increased respiratory effort resulting from higher breathing resistance

(Hughes, 2016; Lish *et al.*, 2008; Muir *et al.*, 2013). Furthermore, the utilization of an undersized EDTT often results in inefficient delivery of inhalant anesthetics, necessitating additional administration of anesthetic drugs that could have been avoided with proper ETS selection (Muir *et al.*, 2013). An undersized EDTT may also be more susceptible to blockage by mucus, obstructing patient ventilation (Thomas and Lerche, 2017). Additionally, undersized EDTT with proper inflated cuff still poses a higher risk of aspiration pneumonia in patients, as they fail to adequately protect the lower trachea and lungs from regurgitated stomach contents, foreign material, secretions, and fluids, as is the case with properly fitting EDTT (Tong and Pang, 2019). Another adverse effect includes the potential for atmospheric pollution in the workspace due to anesthetic gas leakage, posing risks to personnel surrounding (Lish *et al.*, 2008; Muir *et al.*, 2013). Moreover, the use of an undersized cuffed EDTT may necessitate overinflation of the cuff, leading to tracheal necrosis due to excessive pressure on the tracheal wall.

In contrast, patients intubated with oversized EDTTs are prone to tracheal mucosa pressure necrosis (Thomas and Lerche, 2017) resulting from perfusion injury due to disrupted blood flow in the tracheal mucosa capillaries (Sultan *et al.*, 2013). This is a consequence of the inflated cuff of the oversized EDTT exerting excessive pressure on the tracheal capillaries. The use of an oversized EDTT during intubation can also increase the risk of laryngotracheal trauma (Hughes, 2016; Lish *et al.*, 2008). Additionally, forced intubation with an oversized EDTT may lead to postoperative tracheitis and coughing due to mechanical irritation of the trachea (Thomas and Lerche, 2017). Furthermore, edema and inflammation of the trachea and larynx after removal of an overly large EDTT can significantly raise the likelihood of upper respiratory tract airway obstruction (Muir *et al.*, 2013). In extreme cases, an excessively large EDTT may even pose a grave risk of tracheal rupture, which could be fatal for the patient (Thomas and Lerche, 2017).

3.0 MATERIALS AND METHODS

3.1 RESEARCH DESIGN

The present study was approved by the Institutional Animal Care and Use Committee (IACUC) of UPM (Reference Number: UPM/IACUC/AUP - U027/2023). A prospective crossover study was conducted to compare the ability of lean body weight-based formula method (BWT), lean body weight range table (TAB), and thoracic radiographic measurement method (RAD) in the endotracheal tube size selection in mesocephalic dogs. The ability to predict the endotracheal tube size (ETS) using the lean body weight-based formula method (BWT), thoracic radiographic measurement method (RAD), lean body weight range table (TAB) was determined by comparing it with the actual inserted endotracheal tube size.

3.2 STUDY POPULATION

Patients that fulfilled the inclusion criteria of mesocephalic breeds that required endotracheal intubation under general anesthesia for surgery, and had performed lateral thoracic radiographic examination before surgery were included as study subjects. A total of 12 client-owned mesocephalic dogs of different breeds that underwent surgical intervention at University Veterinary Hospital, Universiti Putra Malaysia in 2023 were enrolled in this study. Data in the patient surgical anesthetic records and digital radiograph records were obtained from the study subjects.

3.3 METHOD AND DATA COLLECTION

3.3.1 LEAN BODY WEIGHT-BASED FORMULA METHOD (BWT)

During the pre-anesthetic examination, the current body weight (BW) and body condition score (BCS) of all the study subjects was recorded. The BCS of each subject was determined by using the American Animal Hospital Association (AAHA) Body Condition Scoring Systems (Appendix Figure XX). By using Becvarova's Common Body Condition Scoring Systems (Appendix Table XX), the percentage of BW below or above the ideal BW of each subject was determined. According to Becvarova (2011), the lean body weight (LBW) of the subjects was determined based on the formula:

$$LBW\ (kg) = \frac{BW\ (kg) \times 100}{(100 + BW\%\ below\ or\ above\ ideal)}$$

Then, the endotracheal tube size (ETS) for the respective subject was estimated using the BWT formula:

$$ETS\ (mm) = \sqrt{(BW\ (kg) \times 5)}$$

The internal diameter of the endotracheal tube (EDTT) in millimeters with the smallest difference with the result from the calculation using the BWT formula was recorded as the ETS of BWT.

3.3.2 THORACIC RADIOGRAPHIC MEASUREMENT METHOD (RAD)

The digital thoracic radiograph of each subject taken before the surgery was reviewed using Carestream Image Suite Software 11.3.2.0 (Carestream Health, Inc., United States of America). The inclusion criteria for radiography used include the cervical trachea with a clear margin taken at either right or left lateral recumbency. The internal diameter of the trachea at the level of the thoracic inlet was measured in millimeters (Shin *et al.*, 2018) using Carestream Image Suite Software 11.3.2.0 (Carestream Health, Inc., United States of America) (Appendix Figure 8) in order to estimate the outer diameter of EDTT in millimeters which had the smallest difference with the tracheal internal diameter. The internal diameter of EDTT (Appendix Table 7) corresponding to the outer diameter of EDTT predetermined for each subject was recorded as ETS of RAD (Shin *et al.*, 2018).

3.3.3 LEAN BODY WEIGHT RANGE TABLE (TAB)

During the pre-anesthetic examination, the current BW and BCS of all the study subjects were recorded for LBW calculation. Then, the ETS was estimated by an experienced veterinarian anesthetist referring to the table. The LBW which falls within the specific weight ranges was used to estimate the ETS. The internal diameter of the endotracheal tube (EDTT) in millimeters from the selection of ETS using the TAB formula was recorded as the ETS of TAB.

3.3.4 DETERMINATION OF ACTUAL INSERTED ENDOTRACHEAL TUBE SIZE (ACT)

The EDTTs planned for use were assessed for cuff leakage, lumen hygiene, and tube patency (Hughes, 2016). The insertion length of the EDTT was approximated by measuring the distance from the incisors to the thoracic inlet situated near the point of the shoulder of the subject with flexed neck (Hughes, 2016). Preoxygenation with 100% oxygen was done on subjects by facemask for three to five minutes. The study subjects were administered with propofol 1% intravenously (IV) at the rate of 1 - 2 mg/kg/min in mesocephalic dogs, titrated to effect until the subject lost its jaw tone.

The subject intended for intubation was positioned in sternal recumbency, and their mouth was gently held open. An appropriately sized laryngoscope was placed with its blade on the base of the tongue to facilitate the illumination of the larynx (Muir *et al.*, 2013). The tongue of the subject was pulled rostrally, while visually assessing the width of the arytenoid opening. Particular attention was given to ensuring that the observed width of the arytenoid opening was compatible with the size of the intended endotracheal tube (EDTT). Subsequently, the subject was intubated using the Rusch® Super Safety™ Magill Cuffed Endotracheal Tube (Teleflex®, United

Kingdom) lubricated with water-soluble lubricant KY jelly while ensuring that the EDTT's Murphy eye and bevel remained unobstructed (Hughes, 2016). To minimize potential bias, all intubations were consistently performed by the same qualified individual throughout the entirety of the study.

The primary criterion in the determination of ACT centered on assessing the resistance felt during intubation. Specifically, a notable high level of resistance was indicative of the utilization of an oversized endotracheal tube (EDTT). To further confirm the correct placement of EDTT within the trachea, verifications of water vapor detection within EDTT and neck palpation were conducted (Hughes, 2016). Upon successful intubation, the EDTT was secured to the maxilla of the subject using W.O.W. gauze. The cuff of the EDTT was inflated using a syringe of compatible volume while the EDTT was connected to the anesthetic machine. The second criterion in the determination of ACT was based on the leak test whereby a leak was no longer audible while maintaining airway pressures at the peak inspiratory pressure of 20 cmH_2O (Mosley, 2015). The occurrence of a "hissing sound" originating from the flow of air between the tracheal mucosa and the EDTT's cuff signified the usage of an undersized EDTT. The actual inserted endotracheal tube size (ACT) of each subject in the study fulfilled both of the ACT determination criteria stated above.

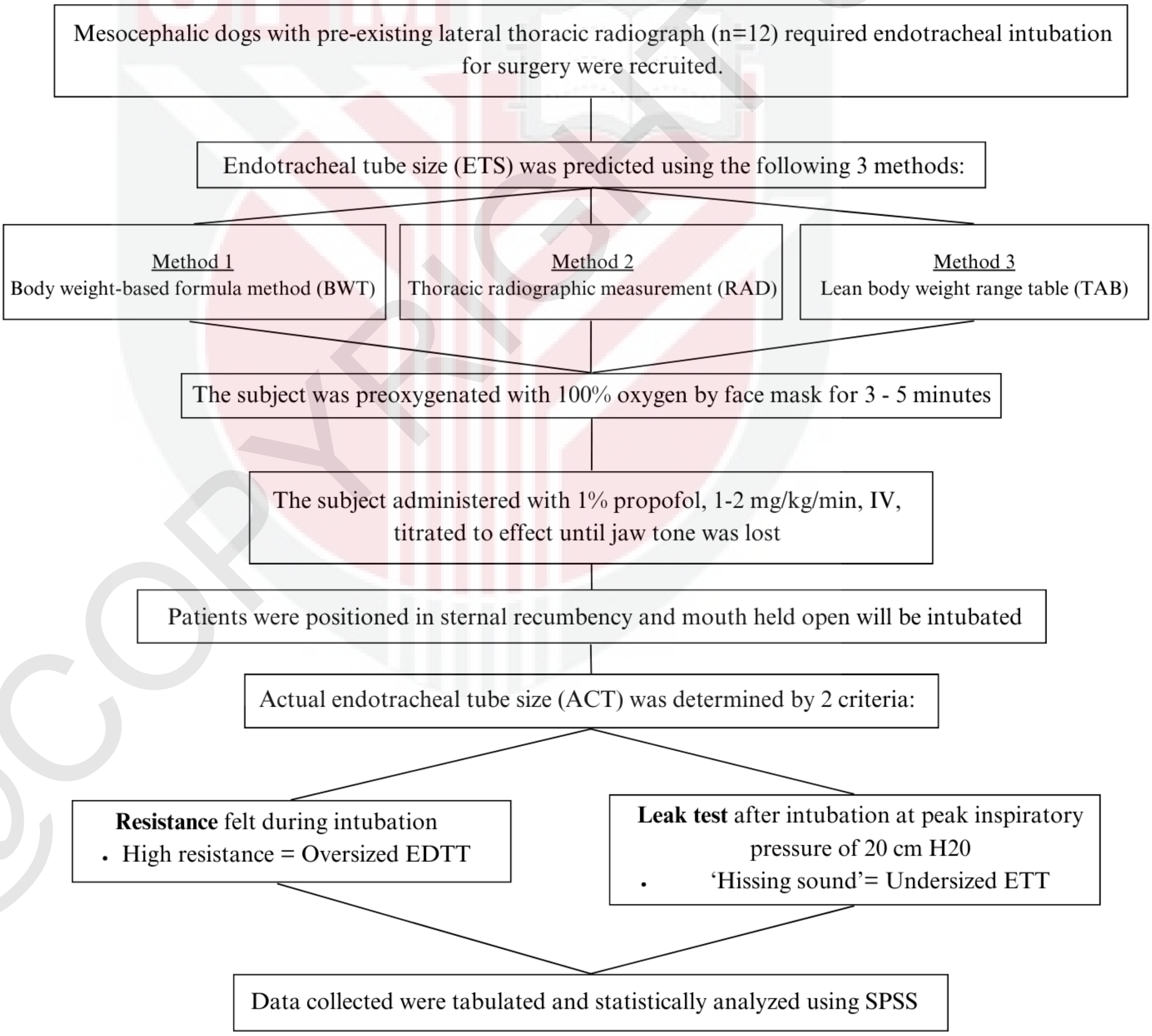
3.4 RESEARCH INSTRUMENTS

Patient records were referred to collect data on the mesocephalic dog breed who underwent endotracheal intubation at University Veterinary Hospital, Universiti Putra Malaysia. Anesthetic records were utilized for the data collection on BW to carry out calculations in BWT and estimation in TAB. Digital radiographic record in Carestream Image Suite Software 11.3.2.0 (Carestream Health, Inc., United States of America) was utilized to carry out tracheal diameter measurements in RAD. Tools and equipment used in endotracheal intubation and determination of ACT include Rusch® Super Safety™ Magill Cuffed Endotracheal Tube (Teleflex®, United Kingdom) of size two to ten, Jorgensen Laboratories Silicon Endotube without Cuff of size 47 to 57, KY jelly, W.O.W gauze, empty syringe, laryngoscope, and anesthetic machine; while propofol 1% was used to induce general anesthesia prior to endotracheal intubation. Data collected were tabulated and statistically analyzed using IBM SPSS Statistical Software 23.0 (IBM SPSS® Statistics, United States of America).

3.5 DATA ANALYSIS

The mean and the standard error of mean (SEM) were calculated for BW, tracheal internal diameter (TID), ETS of BWT, ETS of RAD, ETS of TAB and ACT. All data were analyzed statistically at the 95% confidence level. The Shapiro-Wilk's test was used to assess the normal distribution of ETS of BWT, ETS of RAD, ETS of TAB, and ACT while the Levene test was used to assess the homogeneity of variance prior to parametric approaches for further statistical analysis. To analyze the difference of mean between ETS of BWT, ETS of RAD, ETS of TAB and ACT, Paired Samples T-Test were performed. In order to analyze the correlation between ETS of BWT and ACT, ETS of RAD and ACT as well as ETS of TAB and ACT respectively; Pearson's correlation test was performed.

Figure 1: Flow chart of methodology.



4.0 RESULTS

A total of 12 client-owned mesocephalic dogs of different breeds were involved in the current study. The dogs that were enrolled in this study have a mean BW ± SEM of 20.26 ± 3.32 kg, a mean BCS ± SEM of 3.542 ± 0.23 out of 5, and a mean LBW ± SEM of 17.73 ± 2.48 kg (Table 1). The four groups of data recorded for all 12 subjects including ETS of BWT ($p = 0.654$), ETS of RAD ($p = 0.084$), ETS of TAB ($p = 0.567$), and ACT ($p = 0.201$) were shown to have a normal distribution through the Shapiro-Wilk test. ETS of BWT, ETS of RAD, ETS of TAB and ACT also have an equal population variance in the Levene test ($p = 0.908$) prior to further analysis using parametric tests.

Table 1: Mean and Standard Error of Mean of different parameters.

Parameters	Mean	Standard Error of Mean
BW (kg)	20.26	3.32
BCS	3.542	0.23
LBW (kg)	17.73	2.48

4.1 RELATIONSHIP BETWEEN LEAN BODY WEIGHT-BASED FORMULA METHOD AND THORACIC RADIOGRAPHIC MEASUREMENT METHOD

The ETS of BWT has a mean ± SEM of 9.35 ± 0.87 mm while ETS of RAD has a mean ± SEM of 9.54 ± 0.69 mm (Table 2; Figure 1). Based on Paired Samples T-test, there is no significant difference between ETS of BWT and ETS of RAD (p = 0.540) at 95% confidence level. Based on Pearson's correlation test, there is a significant correlation (p = 0.000) between ETS of BWT and ETS of RAD with a very high degree of correlation strength (r = 0.951) at 95% confidence level (Figure 2).

Table 2: Mean and Standard Error of Mean of ETS of BWT (mm) and ETS of RAD (mm).

	Mean	**Standard Error of Mean**
ETS of BWT (mm)	9.35	0.87
ETS of RAD (mm)	9.54	0.69

Figure 2: Comparison of Mean between ETS of BWT (mm) and ETS of RAD (mm).

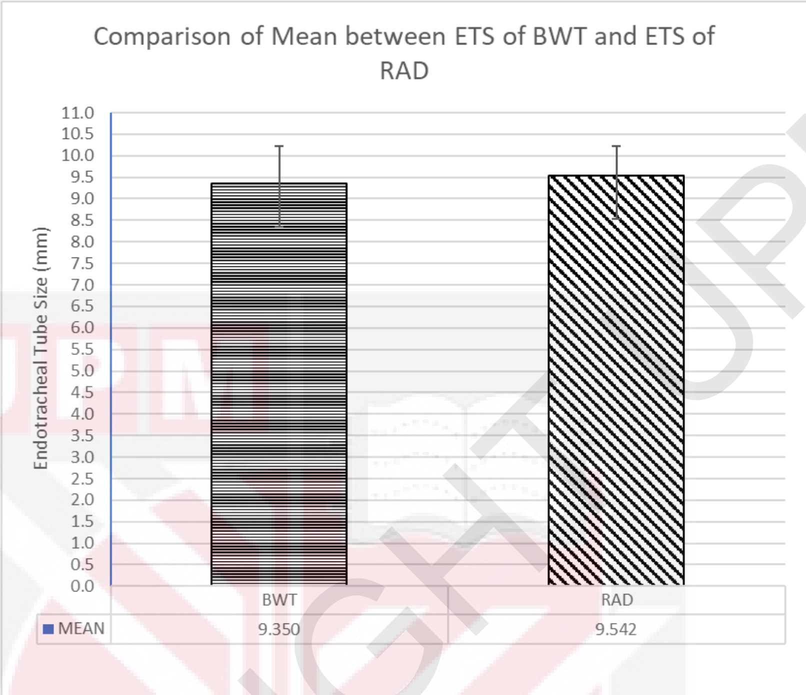
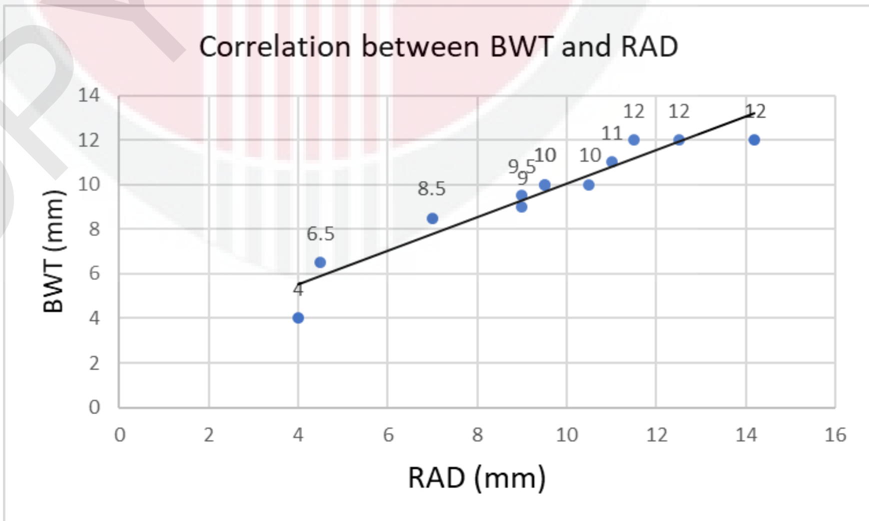


Figure 3: Correlation between BWT (mm) and RAD (mm).



4.2 RELATIONSHIP BETWEEN LEAN BODY WEIGHT-BASED FORMULA METHOD AND ACTUAL INSERTED ENDOTRACHEAL TUBE SIZE

The ETS of BWT has a mean ± SEM of 9.35 ± 0.87 mm while ACT has a mean ± SEM of 9.25 ± 0.73 mm (Table 3; Figure 3). Based on Paired T-test, there is no significant difference in ETS of BWT and ACT ($p = 0.726$) at 95% confidence level. Based on Pearson's correlation test (Figure 4), there is a significant correlation ($p = 0.000$) between ETS of BWT and ACT with a very high degree of correlation strength (r = 0.955) at 95% confidence level. Based on the contingency table (Appendix Table 8), BWT has shown an accuracy of 75% in giving estimates within the range of the nearest ETS to ACT (exact size, one size smaller, and one size larger), as well as an accuracy of 41.67% in predicting the exact ACT successfully.

Table 3: Mean and Standard Error of Mean of ETS of BWT (mm) and ACT (mm).

	Mean	**Standard Error of Mean**
ETS of BWT (mm)	9.35	0.87
ACT (mm)	9.25	0.73

Figure 4: Comparison of Mean between ETS of BWT (mm) and ACT (mm).

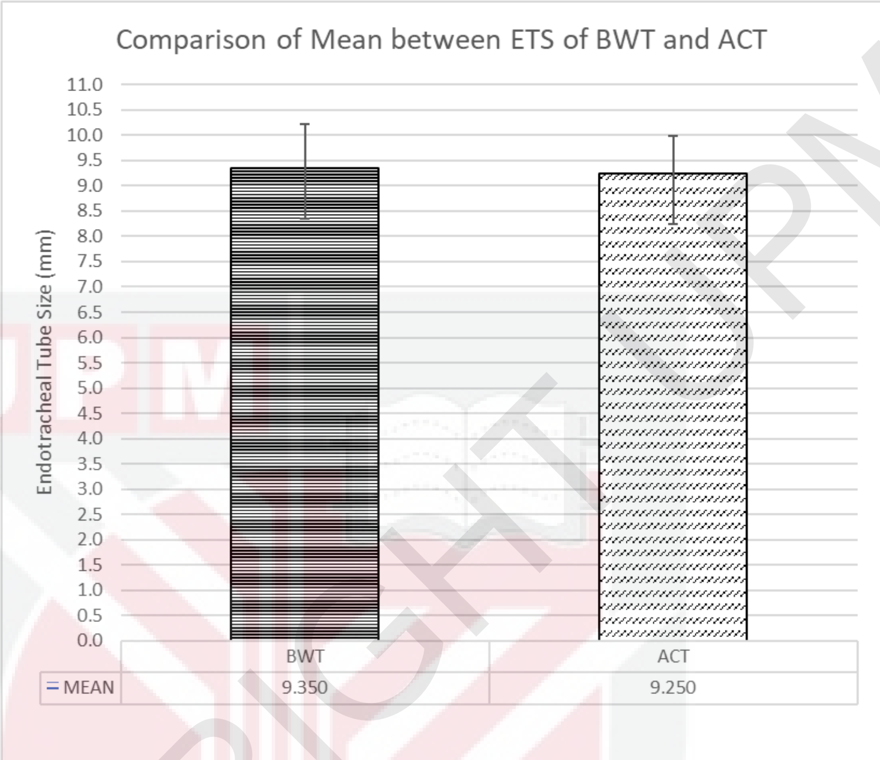
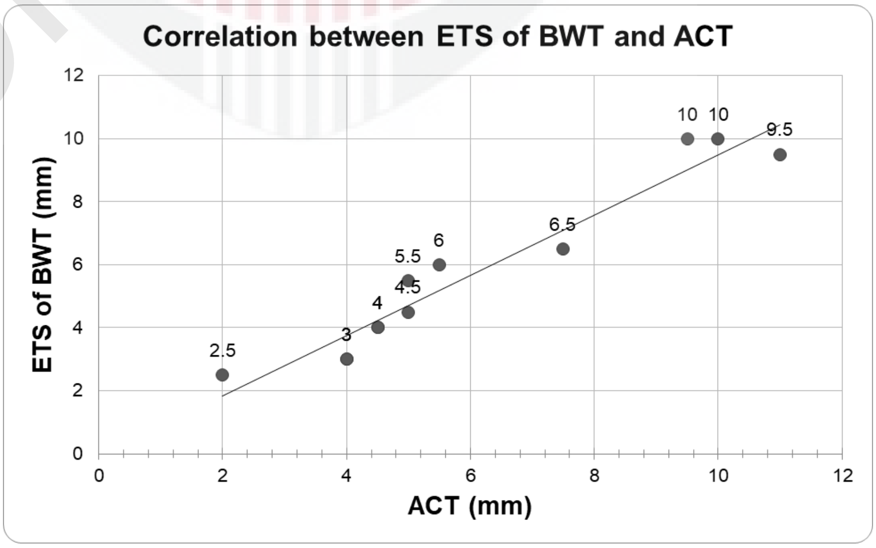


Figure 5: Correlation between ETS of BWT (mm) and ACT (mm).



4.3 RELATIONSHIP BETWEEN THORACIC RADIOGRAPHIC MEASUREMENT METHOD AND ACTUAL INSERTED ENDOTRACHEAL TUBE SIZE

The ETS of RAD has a mean ± SEM of 9.54 ± 0.69 mm while ACT has a mean ± SEM of 9.25 ± 0.73 mm (Table 4; Figure 5). Based on Paired T-test, there is no significant difference in ETS of RAD and ACT (p = 0.067) at 95% confidence level. Based on Pearson's correlation test (Figure 6), there is a significant correlation (p = 0.000) between ETS of RAD and ACT with a very high degree of correlation strength (r = 0.981) at 95% confidence level. Based on the contingency table (Appendix Table 9), RAD has shown an accuracy of 83.33% in giving estimates within the range of the nearest ETS to ACT (exact size, one size smaller, and one size larger), as well as an accuracy of 67% in predicting the exact ACT successfully.

Table 4: Mean and Standard Error of Mean of ETS of RAD (mm) and ACT (mm).

	Mean	**Standard Error of Mean**
ETS of RAD (mm)	9.54	0.69
ACT (mm)	9.25	0.73

Figure 6: Comparison of Mean between ETS of RAD (mm) and ACT (mm).

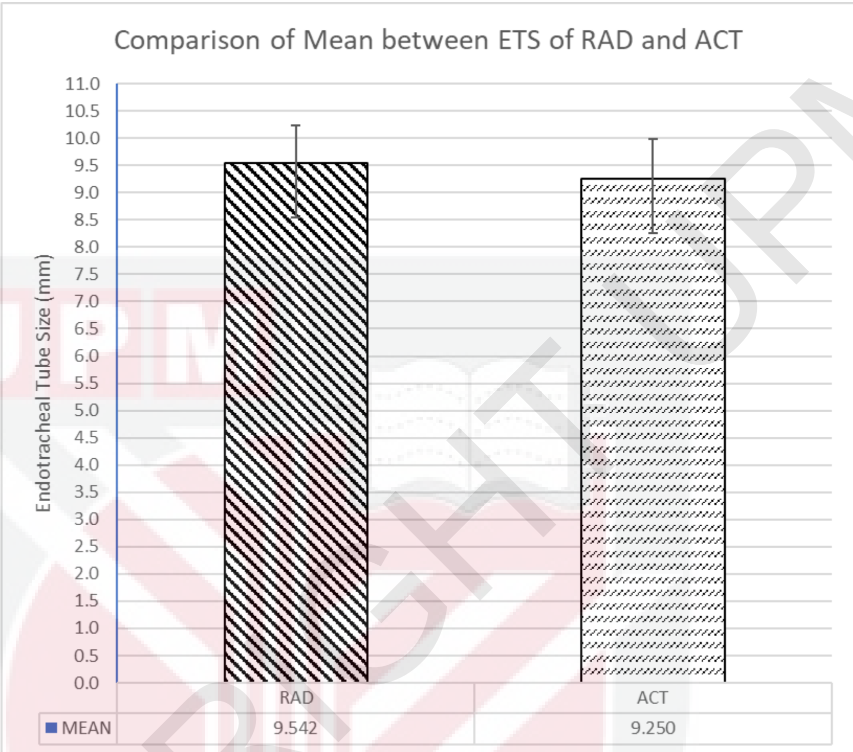
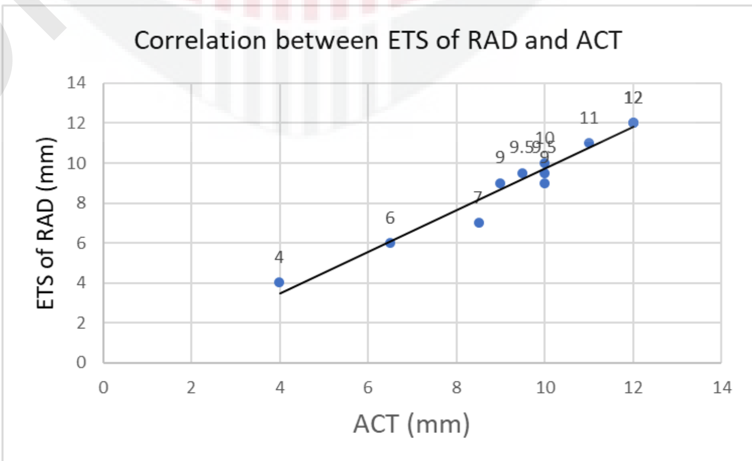


Figure 7: Correlation between ETS of RAD (mm) and ACT (mm).



4.4 RELATIONSHIP BETWEEN LEAN BODY WEIGHT RANGE TABLE METHOD AND ACTUAL INSERTED ENDOTRACHEAL TUBE SIZE

The ETS of TAB has a mean ± SEM of 9.13 ± 0.76 mm while ACT has a mean ± SEM of 9.25 ± 0.73 mm (Table 4; Figure 5). Based on Paired T-test, there is no significant difference in ETS of TAB and ACT ($p = 0.678$) at 95% confidence level. Based on Pearson's correlation test (Figure 6), there is a significant correlation ($p = 0.000$) between ETS of TAB and ACT with a very high degree of correlation strength ($r = 0.925$) at 95% confidence level. Based on the contingency table (Appendix Table 9), TAB has shown an accuracy of 50% in giving estimates within the range of the nearest ETS to ACT (exact size, one size smaller, and one size larger), as well as an accuracy of 16.67% in predicting the exact ACT successfully. The accuracy of TAB is the lowest compared to BWT and RAD.

Table 5: Mean and Standard Error of Mean of ETS of TAB (mm) and ACT (mm).

	Mean	**Standard Error of Mean**
ETS of TAB (mm)	9.13	0.76
ACT (mm)	9.25	0.73

Figure 8: Comparison of Mean between ETS of TAB (mm) and ACT (mm).

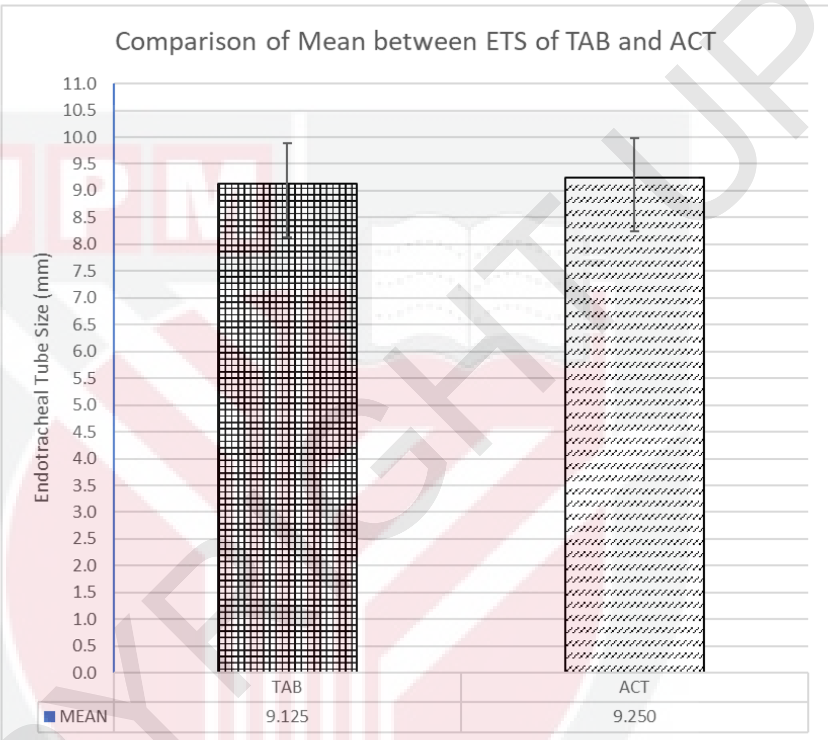
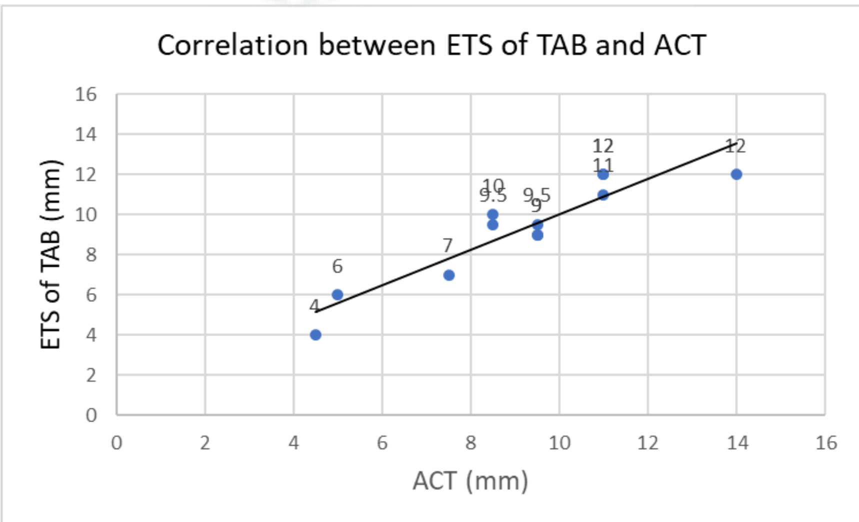


Figure 9: Correlation between ETS of TAB (mm) and ACT (mm).



5.0 DISCUSSION

5.1 RELATIONSHIP BETWEEN LEAN BODY WEIGHT-BASED FORMULA METHOD AND ACTUAL INSERTED ENDOTRACHEAL TUBE SIZE

Based on the findings in this study, there is an insignificant difference and a significant correlation between ETS of BWT and ACT. These outcomes imply that the lean body weight-based formula can effectively be used for prediction of ideal ETS. This finding aligns with prior research that has examined the correlation between body weight and tracheal diameter, as indicated by Haider *et al*. (2020) and Shin *et al.* (2018). The results indicate that as lean body weight increases, ETS of BWT increases as well. The accuracy of BWT (75%) in predicting ETS is notably high when aiming to estimate within one size of the actual ACT (BWT's ETS, one size smaller and one size larger). However, this accuracy diminishes when attempting to precisely predict the exact ACT (41.67%), which can be attributed to the inclusion of mixed breeds with varying anatomical conformations as study subjects. Consequently, it becomes imperative to have three EDTT sizes readily available to accommodate these variations. Considering the high accuracy demonstrated in this study, BWT appears to be a practical and cost-effective option for clinical practices. Such efficiency and accuracy are valuable attributes in clinical practice, where timely and precise decision-making is crucial for patient care. Other than that, this study exclusively involves mesocephalic dogs, a factor that contributes to a higher accuracy level in ETS estimation. This observation aligns with prior research findings that suggested body weight is accurate for ETS prediction in mesocephalic and dolichocephalic dogs only, not in brachycephalic dogs (Haider *et al.*, 2020). However, the ETS estimations obtained through the same formula might be influenced by confounding factors including anatomical variations which result in a wide range of tracheal diameter (Hughes, 2016; Thomas and Lerche, 2011), considering the subjects were not segregated according to breeds. Additionally, the determination of BCS may exhibit variations among assessors, stemming from differences in perception, which in turn leading to deviations in LBW from the ideal which impact the current findings.

In order to improve the precision of BWT as an indicator for ETS prediction, it is advisable to restrict the study to a single breed. This approach helps mitigate the inherent structural disparities that can arise when different breeds are included in the analysis. Additionally, for the purpose of attaining greater accuracy and consistency in results, the assessment of BCS in patients should be conducted consistently by a single assessor, utilizing both visual and palpation parameters derived from the same standardized scoring system.

5.2 RELATIONSHIP BETWEEN THORACIC RADIOGRAPHIC MEASUREMENT METHOD AND ACTUAL INSERTED ENDOTRACHEAL TUBE SIZE

Based on the findings of the present study, a significant correlation was observed between RAD's ETS and ACT. Furthermore, there was no significant difference between these two measures. These results support the utilization of radiographic measured tracheal diameter as a reliable method for accurately estimating the optimal ETS. The accuracy of RAD in predicting the ACT, at 41.67% was found to be comparable with the external tracheal palpation method which yielded a 46.4% accuracy rate (Lish *et al*, 2008).

However, it is important to acknowledge the limitations associated with RAD. This limitation arises from the variation in tracheal diameter observed in different radiographic positions. According to Shin *et al.* (2018), the trachea tends to deviate to the right at the thoracic inlet, resulting in a larger magnification factor and higher diameter measurements when the patient is positioned in left lateral recumbency. Moreover, RAD was observed to tend to either estimate the exact ACT or overestimate the ETS. The observation can be attributed to the magnifying effect caused by radiographic imaging. Similar phenomena have been noted in human studies where measurements of the tracheal diameter obtained from radiographs were observed larger than ACT. When the trachea was placed further away from the X-ray cassette, the magnifying effect became more pronounced (Issac, 2019). Additionally, the tracheal diameter increases during expiration in large-breed dogs (Scherf *et al.*, 2020). Leonard *et al.* (2009) also stated that the tracheal cross-sectional area changes approximately 24% between inspiration and expiration.

To enhance the accuracy of RAD in predicting ETS, several measures should be implemented. Firstly, the radiographic positioning of the patient should be standardized, either in right lateral or left lateral recumbency in order to minimize positional variations. The respiratory phase can be standardized too where radiograph images should be taken in inspiratory as tracheal diameter size can be overestimated when taken during expiratory. In addition, it is advisable to take at least three measurements of the tracheal margins for each subject and the mean value of the tracheal diameter will be calculated (Shin *et al.*, 2018). Furthermore, the delineation of the thoracic inlet boundary should be clearly marked using a standardized method before measuring the inner tracheal diameter (Hayward *et al,* 2008).

5.3 RELATIONSHIP BETWEEN LEAN BODY WEIGHT RANGE TABLE METHOD AND ACTUAL INSERTED ENDOTRACHEAL TUBE SIZE

Based on the findings in this study, there is an insignificant difference and a significant correlation between ETS of TAB and ACT. The results indicate that as lean body weight increases, ETS of TAB increases as well. However, the accuracy of TAB (50%) in predicting ETS is the lowest when aiming to estimate within one size of the actual ACT (TAB's ETS, one size smaller and one size larger). The accuracy diminished drastically when attempting to precisely predict the exact ACT (16.7%), which can vary among individuals, and its failure to account for variations in airway anatomy. This observation aligns with the previous research findings that nasal septal width has an accuracy of 21% to determine the exact ACT which is considered low (List *et al.*, 2008). The lack of precision results in a wide range of suggested ETS rather than a specific size which may lead to an increase in the complications risk during intubation. Overlapping body weight ranges can result in as many as size potential optimal ETS estimations for a single subject (Hughes, 2016).

5.4 COMPARISON OF THE PRACTICABILITY BETWEEN LEAN BODY WEIGHT-BASED FORMULA METHOD, THORACIC RADIOGRAPHIC MEASUREMENT METHOD, AND LEAN BODY WEIGHT RANGE TABLE

In comparison to the other two methods, TAB consistently demonstrates the lowest accuracy and reliability. Consequently, it is not practical for clinical use as it depends on the clinicians' personal experience (Lish *et al.*, 2008). In terms of time and skill requirements, BWT is quicker and more practical to be done when compared to RAD. BW and BCS in BWT are basic records routinely collected upon visit. Conversely, RAD requires thoracic radiograph images, involving manual restraint of animals by a few personnel to achieve the lateral radiographic position. Knowledge of X-ray machine operation is essential to ensure high-quality radiographic results. On top of that, certain small-scale veterinary clinics may face limitations in providing radiography services, potentially requiring patient referrals to external facilities. Moreover, concerns regarding radiation exposure may arise among certain clients (Shin *et al.*, 2018).

In terms of cost, BWT is relatively more economical as it primarily relies on the availability of a simple weighing machine and a calculator, while RAD can prove to be financially burdensome for cost-constrained clients (Shin *et al.*, 2018). Nevertheless, it is essential to recognize that a preoperative thoracic radiograph not only aids in ideal ETS prediction but also serves as a valuable tool for the early detection of unforeseen pathologies (Shin *et al.*, 2018); which would reclassification of patients into a higher class of American Society of Anesthesiologists Physical Status classification. Furthermore, RAD demonstrates a higher accuracy in predicting the exact ACT than BWT. This enhanced precision is particularly advantageous given the significant structural variations observed among diverse species and breeds. While BWT remains applicable to overweight and underweight patients (Thomas and Lerche, 2017), it tends to overlook the variation among different species, breeds, and body conformations (Hughes, 2016). RAD, with its visual representation of the trachea, enables direct and exact measurement of tracheal margins, enables direct and exact measurement of tracheal margins, outperforming estimations based on external phenotypic characteristics, the lean body weight which form the foundation of BWT (Shin *et al.*, 2018).

6.0 CONCLUSION AND RECOMMENDATION

In conclusion, the findings from the current study indicate that the lean body weight-based formula method (BWT) and thoracic radiographic measurement method (RAD) are suitable to be used as a guide to predict within 1 size from the actual endotracheal tube size (ACT) in mesocephalic dogs. RAD have the higher accuracy to predict the exact ACT but requires more complicated procedures compared to BWT. In contrast, lean body weight range table (TAB) is not suitable to be used as a guide in selecting ETT as it has the lowest accuracy to predict the ACT.

In addition to the limitations mentioned, a significant limitation of the study is having a small sample size. This was due to incomplete patient anesthetic records regarding patients' BCS and ACT. Furthermore, the study faced challenges in recruiting a sufficient number of patients with recent pre-existing thoracic radiographs. Additionally, instead of using all radiographic views, the study exclusively utilizes lateral radiographs. This was due to the presence of vertebrae and sternebrae in dorsoventral and ventrodorsal views superimposing the trachea causing difficulty in accurately measuring the tracheal diameter (Shin *et al.*, 2018). Moreover, only one type of EDTT (e.g. high-volume low-pressure cuffed EDTT) was utilized for intubation throughout the study. Therefore, the current findings may not be applicable to another type of EDTT (e.g. low-volume high-pressure cuffed EDTT). Consequently, future studies can benefit from several refinements. To increase the sample size while maintaining the standard of inclusion criteria, improvements should be made to the patient anesthetic recording system. Additionally, it is advisable to conduct radiography for every patient before the anesthesia procedure.

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APPENDIX

Figure 10: Tracheal internal diameter (mm) measurement (white arrow) and thoracic inlet boundary (black arrow) on a right lateral thoracic radiograph.

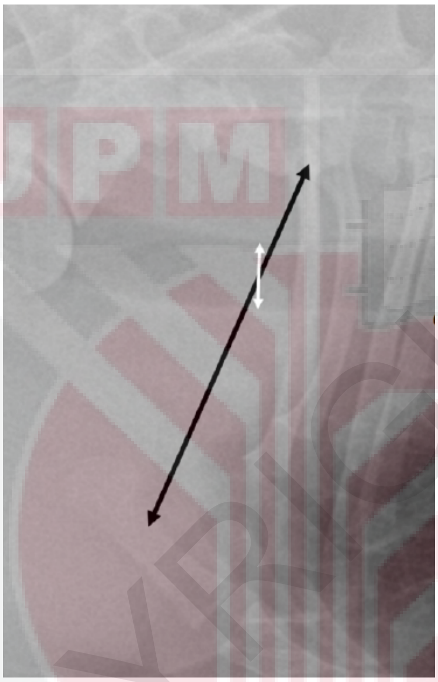

Table 6: Lean body weight range table (TAB) suggested by BSAVA.

Size (internal diameter) (mm)	Cuffed and/or uncuffed	Approximate Lean Body Weight (kg)
2.0, 2.5, 3.0	Cuffed and uncuffed	1 – 2.5
3.5, 4.0, 4.5	Cuffed and uncuffed	2.5 – 5
5, 6	Cuffed and uncuffed (size 5)	4 – 9
7, 8	Cuffed	7 – 15
9, 10	Cuffed	15 – 25
11, 12	Cuffed	25 – 45
14, 16	Cuffed	>40

Table 7: Internal diameter (ID) and outer diameter (OD) of Rusch® Super Safety™ Magill Cuffed Endotracheal Tube (Teleflex®, United Kingdom).

ID(mm)	OD(mm)
2.0	3.0
2.5	4.0
3.0	5.0
3.5	5.3
4.0	6.0
4.5	6.3
5.0	6.7
5.5	7.3
6.0	8.0
6.5	8.7
7.0	9.3
7.5	10.0
8.0	10.7
8.5	11.3
9.0	12.0
9.5	12.7
10.0	13.3

Table 8: Internal diameter (ID) and outer diameter (OD) of Jorgensen Laboratories Silicon Endotube

Size (fr)	ID (mm)	OD (mm)
47	11.0	15.7
51	12.0	17.0
57	14.0	18.0

Table 9: Contingency Table Representing Accuracy of BWT.

Contingency Table Representing Accuracy of Lean Body Weight-based Formula Method (BWT) of Endotracheal Tube Selection

Actual Inserted Endotracheal Tube Size (mm)	Endotracheal Tube Internal Diameter Size (mm) Selected by Lean Body Weight-based Formula Method																					Total No. of Subject
	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	
4.0	1*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
4.5	0	0*	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
5.0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
5.5	0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
6.0	0	0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
6.5	0	0	0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
7.0	0	0	0	0	0	0	1*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
7.5	0	0	0	0	0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
8.0	0	0	0	0	0	0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	**0**
8.5	0	0	0	0	0	0	0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	**0**
9.0	0	0	0	0	0	0	0	0	0	0	1*	1	0	1	0	0	0	0	0	0	0	**3**
9.5	0	0	0	0	0	0	0	0	0	0	0	1*	1	0	0	0	0	0	0	0	0	**2**
10	0	0	0	0	0	0	0	0	0	0	0	0	0*	0	0	0	0	0	0	0	0	**0**
10.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0*	0	0	0	0	0	0	0	**0**
11.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1*	0	0	0	0	0	0	**1**
11.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0*	0	0	0	0	0	**0**
12.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0*	1	0	0	1	**3**
Total No. of Subject	**1**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**2**	**1**	**1**	**1**	**1**	**0**	**1**	**0**	**0**	**1**	**12**

* **Note:** The numbers marked with an asterisk represent a correct match between the actual inserted endotracheal tube and the endotracheal tube selected by the lean body weight-based formula method.

Table 10: Contingency Table Representing Accuracy of RAD.

Contingency Table Representing Accuracy of Thoracic Radiographic Measurement Method (RAD) of Endotracheal Tube Selection

Actual Inserted Endotracheal Tube Size (mm)	Endotracheal Tube Internal Diameter Size (mm) Selected by Thoracic Radiographic Measurement Method																	Total No. of Subject
	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	
4.0	1*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
4.5	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
5.0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
5.5	0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
6.0	0	0	0	0	0*	1	0	0	0	0	0	0	0	0	0	0	0	**1**
6.5	0	0	0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	**0**
7.0	0	0	0	0	0	0	0*	0	0	1	0	0	0	0	0	0	0	**1**
7.5	0	0	0	0	0	0	0	0*	0	0	0	0	0	0	0	0	0	**0**
8.0	0	0	0	0	0	0	0	0	0*	0	0	0	0	0	0	0	0	**0**
8.5	0	0	0	0	0	0	0	0	0	0*	0	0	0	0	0	0	0	**0**
9.0	0	0	0	0	0	0	0	0	0	0	1*	0	1	0	0	0	0	**2**
9.5	0	0	0	0	0	0	0	0	0	0	0	1*	1	0	0	0	0	**2**
10	0	0	0	0	0	0	0	0	0	0	0	0	1*	0	0	0	0	**1**
10.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0*	0	0	0	**0**
11.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1*	0	0	**1**
11.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0*	0	**0**
12.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3*	**3**
Total No. of Subject	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**1**	**1**	**3**	**0**	**1**	**0**	**3**	**12**

* **Note:** The numbers marked with an asterisk represent a correct match between the actual inserted endotracheal tube and the endotracheal tube selected by the thoracic radiographic measurement method.

Table 11: Contingency Table Representing Accuracy of TAB.

Contingency Table Representing Accuracy of Lean Body Weight Range Table (TAB) of Endotracheal Tube Selection

Actual Inserted Endotracheal Tube Size (mm)	Endotracheal Tube Internal Diameter Size (mm) Selected by Lean Body Weight Range Table Method																					Total No. of Subject
	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	
4.0	0*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
4.5	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
5.0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
5.5	0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
6.0	0	0	1	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
6.5	0	0	0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
7.0	0	0	0	0	0	0	0*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
7.5	0	0	0	0	0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
8.0	0	0	0	0	0	0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	**0**
8.5	0	0	0	0	0	0	0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	**0**
9.0	0	0	0	0	0	0	0	0	0	0	0*	2	0	0	0	0	0	0	0	0	0	**2**
9.5	0	0	0	0	0	0	0	0	0	1	0	1*	0	0	0	0	0	0	0	0	0	**2**
10	0	0	0	0	0	0	0	0	0	1	0	0	0*	0	0	0	0	0	0	0	0	**1**
10.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0*	0	0	0	0	0	0	0	**0**
11.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1*	0	0	0	0	0	0	**1**
11.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0*	0	0	0	0	0	**0**
12.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0*	0	0	0	1	**3**
Total No. of Subject	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**2**	**0**	**3**	**0**	**0**	**3**	**0**	**0**	**0**	**0**	**0**	**1**	**12**

*** Note:** The numbers marked with an asterisk represent a correct match between the actual inserted endotracheal tube and the endotracheal tube selected by the lean body weight range table method.