UNIVERSITI PUTRA MALAYSIA

THE RELATIONSHIP BETWEEN IN-HOUSE LEAN BODY WEIGHT-BASED FORMULA AND THORACIC RADIOGRAPHIC MEASUREMENT IN PREDICTING THE ENDOTRACHEAL TUBE SIZE FOR DOGS AND CATS

CHONG WAN XIN

Ip
FPV 2022 100

THE RELATIONSHIP BETWEEN IN-HOUSE LEAN BODY WEIGHT-BASED FORMULA AND THORACIC RADIOGRAPHIC MEASUREMENT IN PREDICTING THE ENDOTRACHEAL TUBE SIZE FOR DOGS AND CATS

CHONG WAN XIN

A project paper submitted to the
Faculty of Veterinary Medicine, Universiti Putra Malaysia (UPM)
In partial fulfillment of the requirement for the
DEGREE OF DOCTOR OF VETERINARY MEDICINE
Universiti Putra Malaysia
Serdang, Selangor Darul Ehsan.

DECEMBER 2022

@COPYRIGHT UPM

CERTIFICATION

It is hereby certified that we have read this project paper entitled "The Relationship between In-house Lean Body Weight-based Formula and Thoracic Radiographic Measurement in Predicting the Endotracheal Tube Size for Dogs and Cats", by Chong Wan Xin and in our opinion it is satisfactory in terms of scope, quality, and presentation as partial fulfillment of the requirement for the course VPD4999 – Final Year Project.

____

DR. BENEDICT ONG HUAI ERN
DVM (UPM), MVM (UPM), PHD (MIYAZAKI)
Senior Lecturer,
Faculty of Veterinary Medicine,
Universiti Putra Malaysia.
(Supervisor)

____

DR. MICHELLE FONG WAI CHENG
DVM (UPM), PHD (UPM)
Senior Lecturer,
Faculty of Veterinary Medicine,
Universiti Putra Malaysia.
(Co-Supervisor)

____

DR. NURUL IZZATI UDA ZAHLI
DVM (UPM), MVSC (MIYAZAKI), PHD (MIYAZAKI)
Senior Lecturer,
Faculty of Veterinary Medicine,
Universiti Putra Malaysia.
(Co-Supervisor)

@COPYRIGHT UPM

DEDICATION

My supervisor and co-supervisors, for being my academic mentors and motivators. My family, for being my emotional supporters and pillar of strength.

ACKNOWLEDGEMENTS

I would like to express my gratitude to my supervisor, Dr. Benedict Ong Huai Ern, for all his guidance, advice, time, and dedication to our study.

The same goes for my co-supervisors, Dr. Michelle Fong Wai Cheng, and Dr. Nurul Izzati Uda Zahli, for their selfless sharing and patient assistance.

I would like to thank my family members and friends for their company and support throughout my study.

@COPYRIGHT UPM

CONTENTS

@COPYRIGHT UPM

LIST OF FIGURES — Page

LIST OF TABLES — Page

@COPYRIGHT UPM

LIST OF APPENDICES **Page**

@COPYRIGHT UPM

LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
ACT	Actual inserted endotracheal tube size
BCS	Body condition score
BW	Body weight
BWT	In-house lean body weight-based formula method
LBW	Lean body weight
ETS	Endotracheal tube size
ETT	Endotracheal tube
kg	Kilogram
mg	Milligram
mm	Millimeter
RAD	Thoracic radiographic measurement method
SEM	Standard error of mean
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

@COPYRIGHT UPM

ABSTRAK

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

HUBUNGAN ANTARA FORMULA BERASASKAN BERAT BADAN KURUS DAN PENGUKURAN RADIOGRAFI TORAKS DALAM PERAMALAN SAIZ TIUB ENDOTRAKEA UNTUK ANJING DAN KUCING.

Oleh

Chong Wan Xin

2022

Penyelia: Dr. Benedict Ong Huai Ern

Penyelia bersama: Dr. Michelle Fong Wai Cheng,

Dr. Nurul Izzati Uda Zahli

Peramalan saiz tiub endotrakea (ETS) memainkan peranan penting untuk mengelakkan komplikasi penggunaan saiz tiub endotrakea yang kurang berpadanan, pada masa yang sama memaksimumkan fungsinya. Namun begitu, kini tiada kaedah

@COPYRIGHT UPM

peramalan ETS yang standard bagi anjing dan kucing disebabkan kepelbagaian dalam baka, konformasi badan dan berat badan. Oleh itu, kajian ini dijalankan untuk menentukan kebolehan kaedah formula berasaskan berat badan kurus (BWT) dan kaedah pengukuran radiografi toraks (RAD) dalam peramalan saiz sebenar tiub endotrakea (ACT). Enam anjing dan enam kucing berlainan baka telah direkrut sebagai subjek kajian. Rekod berat badan dan skor keadaan badan subjek telah digunakan dalam pengiraan kaedah BWT 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. Hasil kajian menunjukkan bahawa tiada perbezaan signifikan antara purata ACT dengan purata peramalan BWT ($p = 0.952$), dan antara purata ACT dengan purata peramalan RAD ($p = 0.963$). Selain itu, terdapat korelasi signifikan antara ACT dengan peramalan BWT ($p = 0.000$, $r = 0.967$), dan antara ACT dengan peramalan RAD ($p = 0.000$, $r = 0.975$). Peramalan BWT dan RAD boleh menjangkakan ACT menerusi persamaan berikut: ACT = 0.609*ETS RAD + 0.419*ETS BWT - 0.476. RAD telah menunjukkan ketepatan yang lebih tinggi (75.0%) berbanding dengan BWT (66.7%) dalam peramalan saiz terdekat dari ACT. Konklusinya, BWT dan RAD boleh digunakan sebagai panduan untuk meramal ACT untuk anjing dan kucing.

Kata kunci*:* anjing, berat badan kurus, kucing, saiz tiub endotrakea, ukuran radiografi

@COPYRIGHT UPM

ABSTRACT

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

THE RELATIONSHIP BETWEEN IN-HOUSE LEAN BODY WEIGHT-BASED FORMULA AND THORACIC RADIOGRAPHIC MEASUREMENT IN PREDICTING THE ENDOTRACHEAL TUBE SIZE FOR DOGS AND CATS.

By

Chong Wan Xin

2022

Supervisor: Dr. Benedict Ong Huai Ern

Co-supervisor: Dr. Michelle Fong Wai Cheng,

Dr. Nurul Izzati Uda Zahli

Endotracheal tube size (ETS) estimation is crucial in preventing undesirable complications of improper size endotracheal tube utilization while maximizing its functions. However, there is no standardized optimal ETS selection method for dogs

@COPYRIGHT UPM

and cats 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 determine the ability of in-house lean body weight-based formula method (BWT) and thoracic radiographic measurement method (RAD) in predicting the actual inserted endotracheal tube size (ACT). Six dogs and six cats of different breeds were included as study subjects. The body weight and body condition scores were recorded for in-house lean body weight-based formula calculation to estimate BWT's ETS. 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 ($p = 0.000$, $r = 0.967$), as well as between ETS of RAD and ACT ($p = 0.000$, $r = 0.975$). ETS of BWT and ETS of RAD may predict ACT through the following equation: ACT = 0.609*ETS of RAD + 0.419*ETS of BWT - 0.476. In terms of prediction accuracy within the nearest ranges to ACT, RAD (75.0%) was superior to BWT (66.7%). In conclusion, BWT and RAD are suitable to be used as a guide to predict the ACT in dogs and cats.

Keywords: cats, dogs, endotracheal tube size, lean body weight, radiographic measurement

@COPYRIGHT UPM

1.0 INTRODUCTION

Endotracheal intubation refers to the insertion of a tube extending from the oral cavity into the trachea. It represents an essential constituent of veterinary medicine which ensures a patent airway in an unconscious patient (Muir *et al.*, 2013). Proper placement and size of an endotracheal tube (ETT) 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).

Nonetheless, if endotracheal intubation was done without proper caution, there may be a few possible complications such as laryngeal spasm, tracheal damage, and over-insertion into the bronchus. Although it is undeniable that endotracheal intubation may possess certain complications while a face mask may replace the function of an ETT in oxygen and anesthetic gas administration (Muir *et al.*, 2013), the advantages of using ETT compared to face masks may outweigh its drawbacks. Usage of ETT with an inflated cuff manifests several supremacies over face masks including easier securement, less atmospheric pollution by anesthetic gas, better gas volume maintenance, aspiration prevention, and better lung inflation without stomach inflation (Hughes, 2016).

Endotracheal tube size (ETS) can be considered to be one of the substantial elements in preventing undesirable negative complications of ETT usage caused by utilization

@COPYRIGHT UPM

of improper size ETT while maximizing its function. For instance, placement of an oversized ETT may result in laryngeal and tracheal inflammation while usage of an undersized ETT may increase breathing resistance and respiratory effort (Muir *et al.*, 2013). Therefore, the understanding of optimal ETS determination is crucial to ensure an effective seal between tracheal mucosa and cuff.

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). Selection of ETS largely depends on personal experience without established guidelines (Tong and Pang, 2019). The influence of species factor has been shown by the requirement of smaller ETS in cats when compared to dogs of similar body weight (Thomas and Lerche, 2017). Besides, brachycephalic breeds require a much smaller ETS than mesocephalic and dolichocephalic breeds of comparable weight (O'Dwyer, 2015; Haider *et al.*, 2020). 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). Thus, most veterinary practitioners are encouraged to prepare at least three ETT of different sizes for endotracheal intubation in small animals (Hughes, 2016).

Several ETS selection methods are being practiced currently in the veterinary medicine field based on the preferences of practitioners. In veterinary textbooks, a table with an overlapping range of body weight corresponding to a range of ETS was

@COPYRIGHT UPM

introduced (Hughes, 2016). Meanwhile, external palpation of the trachea and the width of the nasal septum have been used to select the optimal endotracheal tube size in dogs (Lish *et al.*, 2008; Shelby and McKune, 2014). In contrast, a more sophisticated measurement using radiographs and ultrasound has been practiced in human pediatric ETS selection (Park *et al.*, 2013; Sutagatti *et al.*, 2017). It is necessary to develop an individualized measurement method for veterinary patients because there is a large individual variation among species, breed, conformation, and body weight. The commonly used methods of using nasal septum width, externally palpated tracheal diameter, and approximate lean body weight are relatively subjective and solely depend on animals' phenotypic parameters in optimal ETS selection (Shin *et al.*, 2018). Hence, another method of ETS selection, which utilizes radiography as the basis for estimation, is being researched recently to overcome this limitation by providing a visual image of the trachea itself for diameter measurement.

Therefore, in this study, we aimed to compare the two methods of ETS prediction, namely the in-house lean body weight-based formula method (BWT) and the thoracic radiographic measurement method (RAD). This study will determine the potential ability of lean body weight and tracheal internal diameter in estimating the actual inserted endotracheal tube size (ACT) from successful intubation with a proper seal. This study will provide insight into the accuracy of these two methods of ETS determination in ACT prediction.

@COPYRIGHT UPM

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 in estimating ETS is to utilize the body weight of the animals as the basic fundamental parameter. This method assumes that the animal's body mass is directly proportional to its tracheal diameter (Lish *et al.*, 2008). In veterinary textbooks, a table with a wide range of lean body weights corresponding to a range of ETS was introduced as a guide for ETS selection in dogs and cats (Appendix Table 5), despite a large individual difference in tracheal diameter (Hughes, 2016). Nonetheless, the success rate of this method is very much dependent on personal experience (Lish *et al.*, 2008). Certain overlapping body weight ranges have resulted in up to 6 possible optimal ETS estimations for a single patient (Hughes, 2016), which would indirectly contribute to a higher re-intubation rate supposing there was a lack of experience. Besides, there has been a minimal review of literature showing a correlation between body weight and tracheal size in mixed-breed dogs (Lish *et al.*, 2008). Brachycephalic breeds such as English Bulldog and Boxer, are prone to tracheal hypoplasia. Thus, they typically require an ETT of a much smaller size, when compared to similarly sized patients of another breed (O'Dwyer, 2015). Therefore, body weight may not be an accurate ETS estimation method in the case of brachycephalic patients as in mesocephalic and

@COPYRIGHT UPM

dolichocephalic dogs (Haider *et al.*, 2020). Due to breed differences, using body weight as a generalized ETS estimation method may be difficult in clinical settings (Lish *et al.*, 2008).

On the other hand, an in-house body weight-based formula has been practiced for years at University Veterinary Hospital, Universiti Putra Malaysia, whereby the optimal endotracheal tube internal diameter is equal to the square root of the product of the animal's current body weight and a constant of 5, regardless of the body condition score. Up to the author's experience, it was practical to be used in canine and feline patients with optimal body conditions during clinical practice. However, there is a lack of published literature to validate its use in estimating the optimal ETS.

2.1.2 WIDTH OF NASAL SEPTUM

The nasal septal width method estimates ETS based on the animal's external physical parameter. To estimate the optimal ETS, an ETT is held against a dog's nasal septum between two nostrils at the narrowest point. The width of the nasal septum is matched with the ETT outer diameter at its midportion, in order to determine the corresponding ETT internal diameter as the optimal ETS (Lish *et al.*, 2008). Though the result may be subjected to the difference in individual perspective, this method is quick to carry out as no special skill or advanced equipment is required. Nevertheless, the speculation of a direct anatomical correlation between tracheal diameter and the width of nasal

@COPYRIGHT UPM

septal width has not been widely supported by published information (Lish *et al.*, 2008). This method has also shown only 21.4% accuracy in optimal ETS estimation (Lish *et al.*, 2008).

2.1.3 EXTERNAL DIGITAL TRACHEAL PALPATION

Direct palpation of the cervical trachea may be considered the easiest ETS estimation method (Mosley, 2015). This method assumes that the outer diameter of the trachea approximates the optimal ETT's outer diameter (Shelby and McKune, 2014). This method is performed by digitally palpating the tracheal diameter which locates immediately cranial to the thoracic inlet to give an estimate of the nearest outer diameter of ETT (Lish *et al.*, 2008). However, it depends on experience to a great extent as the palpation of the trachea includes together the overlying tissues and hairs in the cervical region. This method as well may be subjective and the result may differ among assessors. The tracheal palpation method has shown an accuracy of 46.4% (Lish *et al*., 2008), which is higher when compared to the nasal septal width method.

2.1.4 RADIOGRAPHIC TRACHEAL DIAMETER MEASUREMENT

The usage of thoracic radiographs for optimal ETS estimation is considered a novel method in veterinary clinical practice. This method is based on the

@COPYRIGHT UPM

assumption that radiographic measured tracheal internal diameter is proportional to the outer diameter of optimal ETT (Shin *et al.*, 2018). Although having an accuracy of up to 74.5% (Shin *et al.*, 2018), this method consists of a series of relatively sophisticated and complicated steps to retrieve a best-fit ETS estimate.

Thoracic radiograph for tracheal diameter measurement should be ideally taken at maximum inspiration within one to two minutes of lateral recumbency under manual restraint. Regarding the radiographic position of the animal, superimposition with the thorax should be minimized by pulling the thoracic limbs cranially; while the position of the neck should be anatomically neutral (Shin *et al.*, 2018). Prior to internal tracheal diameter measurement, a line is drawn from the ventral vertebral column at the most cranial rib's center to the dorsal manubrium at the point of minimum thickness to denote the boundary of the thoracic inlet. Then, another line is drawn perpendicularly to the tracheal long axis at the intersection with the previous line at the tracheal lumen center to measure the tracheal internal diameter (Appendix Figure 9) (Hayward et al, 2008). The measured tracheal inner margin is then used to estimate the ETT outer diameter to determine its corresponding internal diameter as the optimal ETS.

Despite the hardship in the procedure, the radiographic measurement method may be a greater ETS predictor for its re-intubation rate of 25.5% which is lower than of tracheal palpation method (53.6%) and nasal septal width method (78.6%) (Lish *et al.*, 2008). When compared with the body weight of

@COPYRIGHT UPM

the animal, tracheal diameter is shown to have a stronger relationship with ETS (Shin *et al.*, 2018). Additional support can be reviewed from a human medical research which showed that the radiograph-based method proved a higher success rate than the standard age-based formula when estimating ETS in children aged three to six years old (Park *et al.*, 2013). This statement reinforces the potential of the radiographic method as a better estimation option than other conventional methods.

@COPYRIGHT UPM

2.2 IMPORTANCE OF ESTIMATING OPTIMAL ENDOTRACHEAL TUBE SIZE

Appropriate endotracheal intubation is vital to minimize the potential risks of failing to secure the airway and complications while at the same time maximizing its functional effects. Endotracheal tube size (ETS) is therefore a key concern to ensure a proper seal between the cuff and the tracheal mucosa.

Endotracheal intubation with an undersized ETT may lead to a deficient gaseous exchange due to increased respiratory effort as a result of higher resistance to breathing (Hughes, 2016; Lish *et al.*, 2008; Muir *et al.*, 2013). Moreover, usage of an undersized ETT is more likely to result in ineffective maintenance of anesthesia depth due to inefficient inhalant anesthetics delivery, further causing an additional administration of anesthetic drugs which could have been avoided supposing an optimal ETS was selected instead (Muir *et al.*, 2013). A smaller ETT than ideal may also have a higher possibility of being blocked by mucus interfering with the ventilation for the patient (Thomas and Lerche, 2017). Furthermore, undersized ETT poses a higher risk of aspiration pneumonia in the patient. That is because the intubated undersized ETT, even with its cuff properly inflated, is unable to protect the lower trachea and lungs from the regurgitated stomach contents, foreign material, secretions, and fluids as it should be in the case of an ETT with a proper fit (Tong and Pang, 2019). Another negative impact may be the workspace atmospheric pollution due to the leakage of anesthetic gas putting personnel surrounding at risk (Lish *et al.*, 2008; Muir *et al.*, 2013). In

@COPYRIGHT UPM

addition, if an undersized cuffed ETT was used, overinflation of the cuff would be required in order to achieve a seal. As a consequence, it may lead to tracheal necrosis as the tracheal wall is under high pressure.

In contrast, patients intubated with an oversized ETT are predisposed to pressure necrosis of the tracheal mucosa (Thomas and Lerche, 2017) as a consequence of perfusion injury due to interrupted tracheal mucosal blood flow (Sultan *et al.*, 2013). This is caused by the high pressure exerted by the inflated cuff of the oversized ETT on the tracheal capillary. During the process of intubation, patients would be susceptible to laryngotracheal trauma due to the usage of an oversized ETT (Hughes, 2016; Lish *et al.*, 2008). Forced intubation using an oversized ETT may as well lead to tracheitis and coughing postoperatively resulting from mechanical irritation to the trachea (Thomas and Lerche, 2017). In addition, edema and inflammation of the trachea and larynx post removal of a larger than required ETT are highly likely to cause airway obstruction in the upper respiratory tract (Muir *et al.*, 2013). In extreme cases, an overly large ETT may even pose the risk of tracheal rupture which could be fatal for a patient (Thomas and Lerche, 2017).

@COPYRIGHT UPM

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 - U026/2022). A prospective crossover study was conducted to determine the relationship between the in-house body weight-based formula method (BWT) and thoracic radiographic measurement method (RAD) in the endotracheal tube size selection in dogs and cats; the actual inserted endotracheal tube size (ACT) and the endotracheal tube size (ETS) predicted using in-house body weight-based formula method (BWT); the actual inserted endotracheal tube size (ACT) and the endotracheal tube size (ETS) predicted using thoracic radiographic measurement method (RAD).

3.2 STUDY POPULATION

Patients that fulfilled the inclusion criteria of requiring 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 animals which consist of six dogs and six cats of different breeds that underwent surgical intervention at University Veterinary Hospital, Universiti Putra Malaysia in 2022 were enrolled in this study. Data in the patient surgical anesthetic records and digital radiograph records were obtained from the study subjects.

@COPYRIGHT UPM

3.3 METHOD AND DATA COLLECTION

3.3.1 IN-HOUSE 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 were recorded. BCS of the subjects was determined using the American Animal Hospital Association (AAHA) Body Condition Scoring Systems (Appendix Figure 7). The percentage of BW below or above the ideal BW of each subject was determined using Becvarova's Common Body Condition Scoring Systems (Appendix Table 6). According to Becvarova (2011), the lean body weight (LBW) of the subjects were determined based on 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 in-house BWT formula:

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

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

@COPYRIGHT UPM

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 ETT in millimeters which had the smallest difference with the tracheal internal diameter. The internal diameter of ETT (Appendix Table 7) corresponding to the outer diameter of ETT predetermined for each subject was recorded as ETS of RAD (Shin *et al.*, 2018).

3.3.3 DETERMINATION OF ACTUAL INSERTED ENDOTRACHEAL TUBE SIZE (ACT)

The ETTs intended to be used were checked for cuff leakage, lumen hygiene, and patency (Hughes, 2016). The length insertion of the ETT was estimated by measuring the endotracheal tube length from the incisors to the thoracic inlet near the point of the shoulder of the subject when the neck is flexed (Hughes, 2016). Preoxygenation was done on subjects by facemask for five

@COPYRIGHT UPM

minutes. The study subjects were induced with propofol 1% intravenously at the rate of 2 mg/kg/min in dogs and cats, titrated to effect until the subject lost its jaw tone.

The subject intended for intubation was placed on sternal recumbency with its mouth held open. A laryngoscope of appropriate size was placed with its blade on the base of the tongue and aid in the illumination of the larynx (Muir *et al.*, 2013). The larynx in cat subjects was desensitized by spraying with lidocaine 2% to prevent laryngospasm (Hughes, 2016). The tongue of the subject was pulled rostrally while the arytenoid opening width was visually inspected. The arytenoid opening width was ensured to be compatible with the size of the ETT intended to be used. The subject was intubated with Rusch® Super Safety™ Magill Cuffed Endotracheal Tube (Teleflex®, United Kingdom) lubricated with water-soluble lubricant KY jelly without occluding ETT's Murphy eye and bevel (Hughes, 2016). All the subjects were intubated by the same person throughout the study in order to minimize bias.

The first criterion in determining ACT was based on the resistance felt during intubation. A high resistance indicates the usage of an oversized ETT. The correct placement of ETT in the trachea was confirmed by the detection of water vapor within ETT and palpation of the neck (Hughes, 2016). Upon successful intubation, the ETT was secured to the maxilla of the subject using W.O.W. gauze. The cuff of the ETT was inflated using a syringe of compatible volume while the ETT was connected to the anesthetic machine.

@COPYRIGHT UPM

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). Usage of undersized ETT was indicated by the presence of a “hissing sound” originating from the flow of air between tracheal mucosa and ETT’s cuff. 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

Resources used to conduct the study include patient records to collect data on the species and breed of the study subjects who underwent endotracheal intubation at University Veterinary Hospital, Universiti Putra Malaysia. Anesthetic records were utilized for the data collection on BW and BCS to carry out calculations in BWT. 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, 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 and lidocaine 2% was used for desensitization of larynx. Data collected were tabulated and statistically analyzed using IBM SPSS Statistical Software 23.0 (IBM SPSS® Statistics, United States of America).

@COPYRIGHT UPM

3.5 DATA ANALYSIS

The mean and the standard error of mean (SEM) were calculated for BW, BCS, LBW, tracheal internal diameter (TID), ETS of BWT, ETS of RAD, 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, 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, and ACT, Paired Samples T-Test were performed. In order to analyze the correlation between ETS of BWT and ACT, as well as ETS of RAD and ACT respectively; Pearson's correlation test and multiple linear regression test were performed.

@COPYRIGHT UPM

4.0 RESULTS

A total of 12 client-owned animals consisting of six dogs and six cats of different breeds were involved in the current study. The dogs and cats that were enrolled in this study have a mean BW ± SEM of 9.17 ± 2.44 kg and a mean BCS ± SEM of 3.13 ± 0.14 out of 5, a mean LBW ± SEM of 8.68 ± 2.23 kg, and TID ± SEM of 8.28 ± 0.95 mm (Table 1). The 3 groups of data recorded for all 12 subjects including ETS of BWT ($p = 0.134$), ETS of RAD ($p = 0.072$), and ACT ($p = 0.069$) were shown to have a normal distribution through the Shapiro-Wilk test. ETS of BWT, ETS of RAD, and ACT also have an equal population variance in the Levene test ($p = 0.928$) 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)	9.17	2.44
BCS	3.13	0.14
LBW (kg)	8.68	2.23
TID (mm)	8.28	0.95

@COPYRIGHT UPM

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

The ETS of BWT has a mean ± SEM of 6.04 ± 0.81 mm while ETS of RAD has a mean ± SEM of 6.00 ± 0.75 mm (Table 2; Figure 1). Based on Paired Samples T-test, there is no significant difference between ETS of BWT and ETS of RAD ($p = 0.878$) 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 ($r = 0.945$) 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)	6.04	0.81
ETS of RAD (mm)	6.00	0.75

@COPYRIGHT UPM

Figure 1: Comparison of Mean between ETS of BWT (mm) and ETS of RAD (mm).

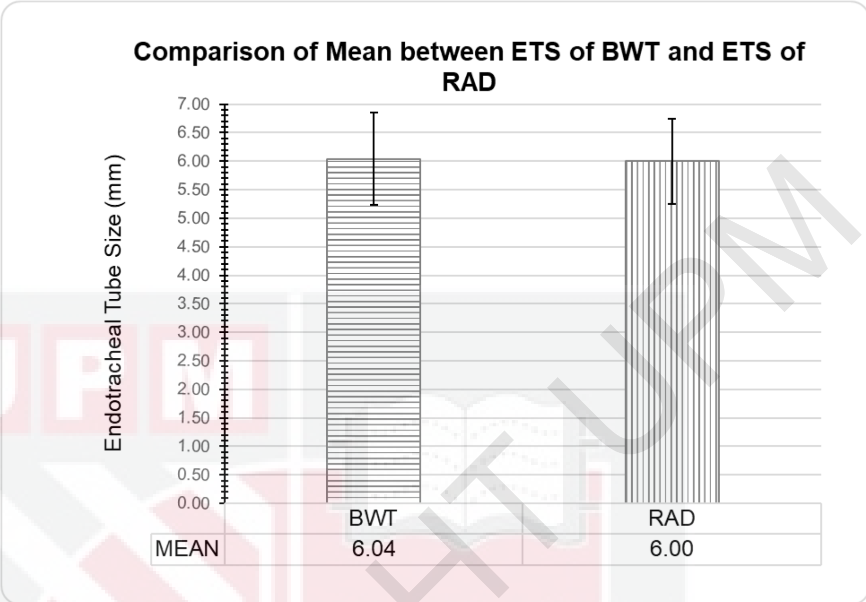
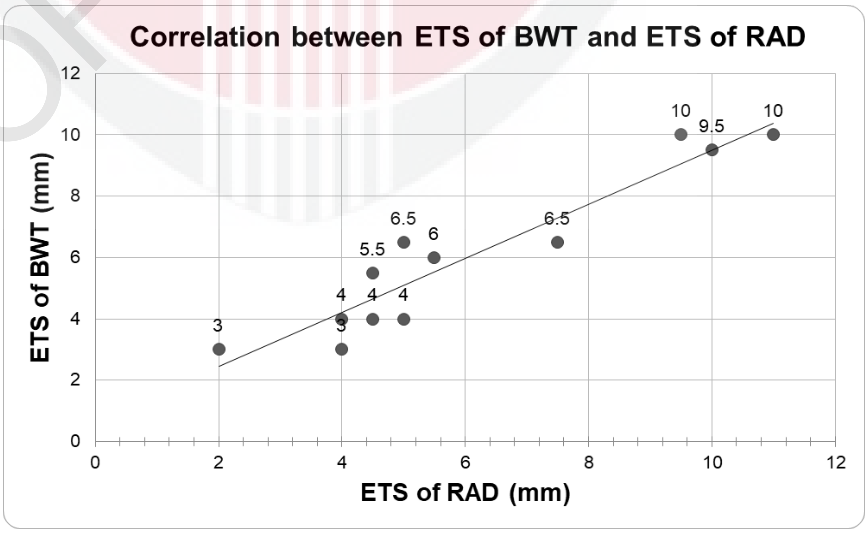


Figure 2: Correlation between ETS of BWT (mm) and ETS of RAD (mm).



@COPYRIGHT UPM

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

The ETS of BWT has a mean ± SEM of 6.04 ± 0.81 mm while ACT has a mean ± SEM of 5.71 ± 0.80 mm (Table 3; Figure 3). Based on Paired T-test, there is no significant difference in ETS of BWT and ACT ($p = 0.952$) 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 ($r = 0.967$) at 95% confidence level. Based on the contingency table (Appendix Table 8), BWT has shown an accuracy of 66.67% in giving estimates within the range of the nearest ETS to ACT, as well as an accuracy of 8.33% 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)	6.04	0.81
ACT (mm)	5.71	0.80

@COPYRIGHT UPM

Figure 3: Comparison of Mean between ETS of BWT (mm) and ACT (mm).

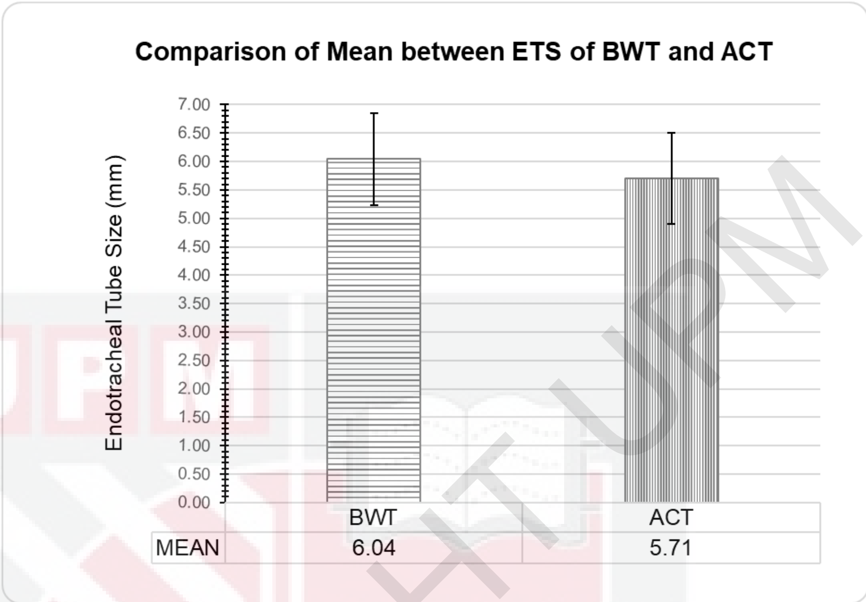
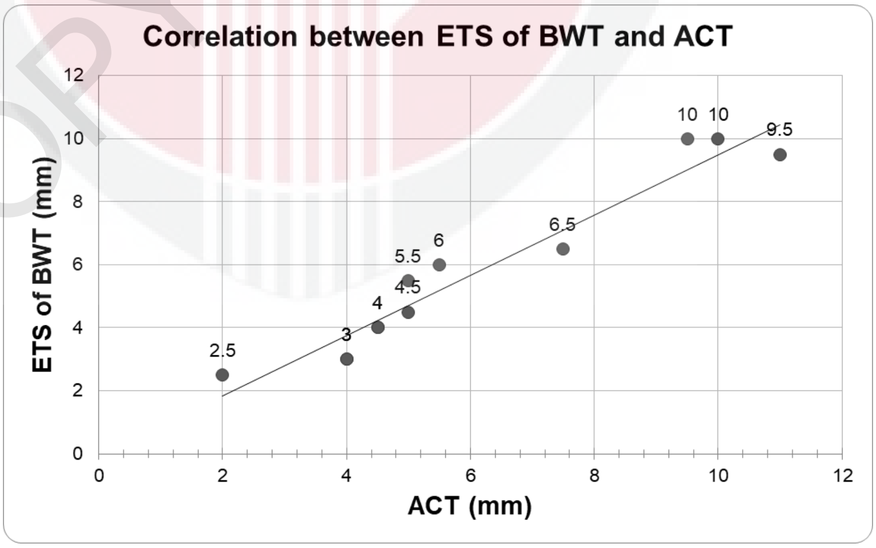


Figure 4: Correlation between ETS of BWT (mm) and ACT (mm).



@COPYRIGHT UPM

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

The ETS of RAD has a mean ± SEM of 6.00 ± 0.75 mm while ACT has a mean ± SEM of 5.71 ± 0.80 mm (Table 4; Figure 5). Based on Paired T-test, there is no significant difference in ETS of RAD and ACT ($p = 0.963$) 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 ($r = 0.975$) at 95% confidence level. Based on the contingency table (Appendix Table 9), RAD has shown an accuracy of 75.00% in giving estimates within the range of the nearest ETS to ACT, as well as an accuracy of 41.67% 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)	6.00	0.75
ACT (mm)	5.71	0.80

@COPYRIGHT UPM

Figure 5: Comparison of Mean between ETS of RAD (mm) and ACT (mm).

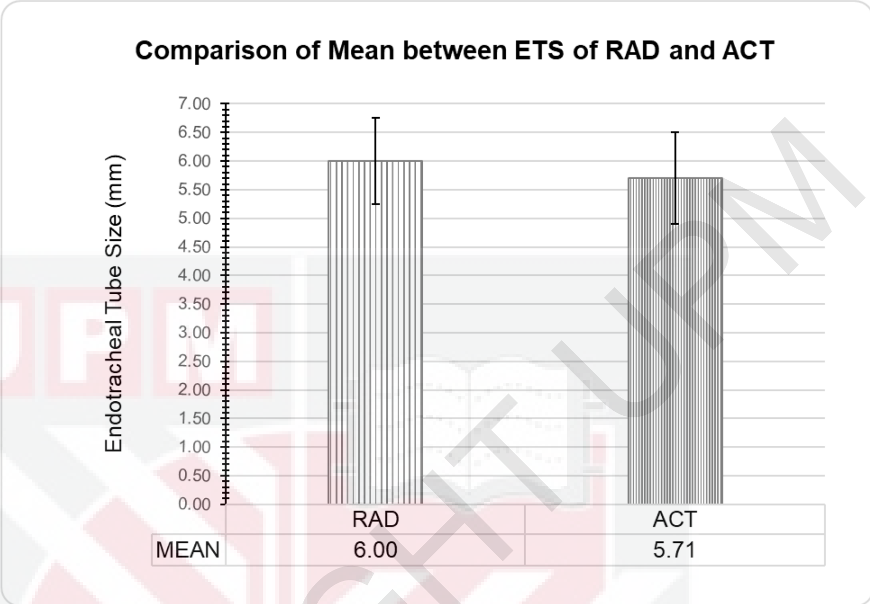
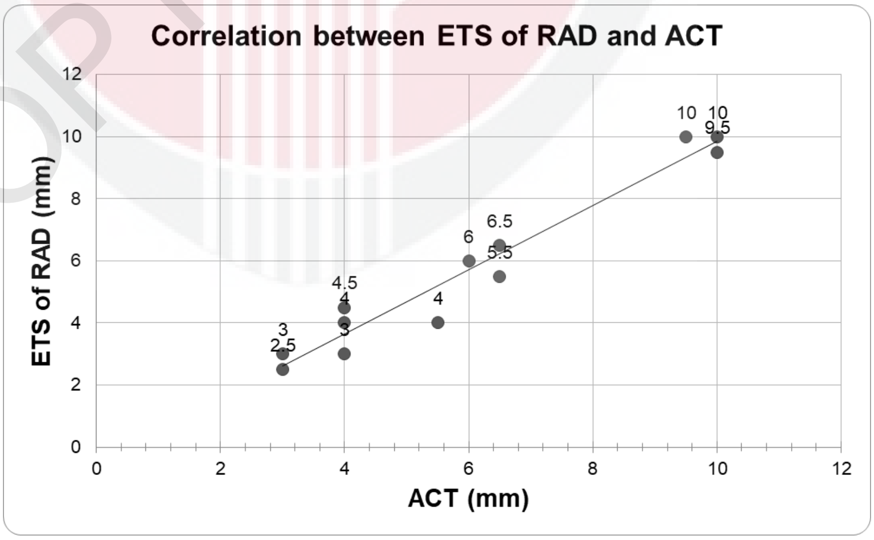


Figure 6: Correlation between ETS of RAD (mm) and ACT (mm).



@COPYRIGHT UPM

4.4 RELATIONSHIP BETWEEN IN-HOUSE LEAN BODY WEIGHT-BASED FORMULA METHOD AND THORACIC RADIOGRAPHIC MEASUREMENT METHOD AND ACTUAL INSERTED ENDOTRACHEAL TUBE SIZE

Based on the Multiple Linear Regression test, when ETS of RAD and ETS of BWT was used as the predictors, the ACT prediction model shows a statistically significant association between the dependent variable and predictors ($p = 0.000$), whereby 97.0% variability of ACT can be explained by ETS of RAD and ETS of BWT (r squared = 0.975). The model may predict ACT through the following equation: ACT = 0.609*ETS of RAD + 0.419*ETS of BWT - 0.476.

@COPYRIGHT UPM

5.0 DISCUSSION

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

Based on this study, there is an insignificant difference and a significant correlation between ETS of BWT and ACT. This suggests that the in-house lean body weight formula can be used for ideal ETS prediction. This finding may be coherent with the findings on the correlation between body weight and tracheal diameter (Haider *et al.*, 2020; Shin *et al.*, 2018). As lean body weight increases, the ETS of BWT increases. However, although having high accuracy in predicting within 1 size from ACT (66.67%), the accuracy of BWT decreases drastically towards the exact ACT prediction (8.33%). This may be due to a key limitation, which was involving mixed species and breeds having different conformations as the study subjects. Hence, the ETS estimations obtained through the same formula might be influenced by confounding factors including anatomical variations which result in a wide tracheal diameter variation (Hughes, 2016; Thomas and Lerche, 2011), considering the subjects were not segregated according to species and breeds. Furthermore, the determination of BCS may differ among assessors as a result of differences in perceptions, leading to a deviation in LBW from the ideal affecting current findings.

@COPYRIGHT UPM

To increase the accuracy of BWT, only one breed in one species should be involved to overcome the existing structural differences. Otherwise, subjects of different species and breeds should be grouped and analyzed separately to minimize the anatomical variation factors. To retrieve a more accurate and consistent result, the BCS of patients should be evaluated by the same assessor based on both visual and palpation parameters from the same scoring system.

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

Based on the current study, there is a significant correlation and no significant difference between ETS of RAD and ACT, thereby supporting the usage of radiographic measured tracheal diameter in optimal ETS estimation. The accuracy of RAD in ACT prediction (41.67%) was found to be comparable with the external tracheal palpation method (46.4%) (Lish et al, 2008).

Regarding RAD, there was a limitation due to the variation of tracheal diameter in different radiographic positions. This resulted from the tendency of the trachea to deviate to the right at the thoracic inlet thus leading to a larger magnification factor and higher diameter measurements when the patient was positioned on left lateral recumbency (Shin *et al.*, 2018).

@COPYRIGHT UPM

Likewise, variation of diameter along the trachea may also underestimate or overestimate the ETT's outer diameter due to the ambiguous location of the thoracic inlet.

To increase the accuracy of RAD, the radiographic position of the patient should be standardized, either right lateral or left lateral recumbency. Besides, at least three measurements of tracheal margins should be taken for each subject in order to calculate the mean value (Shin *et al.*, 2018). Other than that, the boundary of the thoracic inlet should be clearly denoted by a standardized method prior to measuring the inner tracheal diameter (Hayward et al, 2008).

5.3 COMPARISON OF THE PRACTICABILITY BETWEEN IN-HOUSE LEAN BODY WEIGHT-BASED FORMULA METHOD AND THORACIC RADIOGRAPHIC MEASUREMENT METHOD

Based on 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. In contrast, RAD requires a thoracic radiograph whereby the animals need to be restrained manually by a few personnel for lateral radiographic position. Knowledge of X-ray machine operation is also needed for good radiographic quality. On top of that, some small-scale clinics may not be able to provide radiography services thus patients would need to be referred elsewhere. Moreover, for certain clients,

@COPYRIGHT UPM

the risk of radiation exposure may be a concern (Shin *et al.*, 2018). In terms of cost, BWT is relatively more economical as it only requires a weighing machine and a calculator; while RAD may not be affordable for cost constraint clients (Shin *et al.*, 2018). Nevertheless, a preoperative thoracic radiograph may not only help in ideal ETS prediction but also in detecting unsuspected pathology (Shin *et al.*, 2018); which would categorize the patient into a higher class in the American Society of Anesthesiologists Physical Status classification. Additionally, having a much higher accuracy in predicting the exact ACT than BWT, RAD is more useful in consideration of individual structural differences among different species and breeds. Although BWT is applicable for overweight and underweight patients (Thomas and Lerche, 2017), BWT tends to overlook the variation among different species, breeds, and conformations (Hughes, 2016). The visual image of the trachea in RAD allows a more direct and accurate tracheal margin measurement when being compared to the estimation of ETS by lean body weight merely relying on the animals' external phenotypic parameters (Shin *et al.*, 2018). In addition, RAD has a potential clinical implication in brachycephalic breeds that tend to have hypoplastic trachea. A significantly narrowed trachea in brachycephalic patients causes them to require a smaller ETT than expected in other breeds of similar weight (O'Dwyer, 2015). Hence, body weight is not a reliable parameter for ETS estimation in brachycephalic, unlike in mesocephalic and dolichocephalic dogs (Haider *et al.*, 2020). Therefore, RAD is preferred over BWT under permitted circumstances.

@COPYRIGHT UPM

6.0 CONCLUSION AND RECOMMENDATION

In conclusion, the findings from the current study indicate that the in-house 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 dogs and cats, with RAD having higher accuracy to predict the exact ACT but requiring a more complicated procedure.

Apart from the limitations mentioned, one of the main limitations of this study is having a small sample size. This was due to incomplete patient anesthetic records regarding patients' BCS and ACT. A low number of patients having recent pre-existing thoracic radiographs also limits the recruitment of patients into the study population. Instead of using all views on radiographs, only lateral radiographs were utilized in this study. This was due to the presence of vertebrae and sternebrae superimposing the trachea on dorsoventral and ventrodorsal views causing difficulty in measuring tracheal diameter accurately (Shin *et al.*, 2018). Additionally, only one type of ETT (e.g. high-volume low-pressure cuffed ETT) was utilized for intubation throughout the study, so current findings may not be true for endotracheal tubes of another type (e.g. low-volume high-pressure cuffed ETT). Therefore, several refinements can be applied for future studies. To increase the sample size without lowering the standard of inclusion criteria, the patient anesthetic recording system should be improved, while radiography should be advised especially in brachycephalic patients before anesthesia.

@COPYRIGHT UPM

7.0 REFERENCES

Baldwin, K., Bartges, J., Freeman, L.M., Grabow, M., Legred, J. and Ostwald, D. (2010). AAHA Nutritional Assessment Guidelines for Dogs and Cats. J. Am. Anim. Hosp. Assoc. 46(4): 285-296. https://doi.org/10.5326/0460285

Becvarova, I. (2011). Canine and feline obesity: Frequently asked questions and their answers. Compend. Contin. Educ. Vet.. 33(11): E1-E5.

Haider, G., Lorinson, K., Lorinson, D. and Auer, U. (2020). Development of a clinical tool to aid endotracheal tube size selection in dogs. Vet. Rec. 186(5): 157-157. https://doi.org/10.1136/vr.105065

Hughes, L. (2016). Breathing systems and ancillary equipment. In: BSAVA Manual of Canine and Feline Anaesthesia and Analgesia. Duke-Novakovski, T., de Vries M. and Seymour, C. (Eds.) 3rd ed., British Small Animal Veterinary Association, Gloucester. pp. 45-64.

Lish, J., Ko, J.C. and Payton, M.E. (2008). Evaluation of two methods of endotracheal tube selection in dogs. J. Am. Anim. Hosp. Assoc. 44(5): 236-242. https://doi.org/10.5326/0440236

@COPYRIGHT UPM

Mosley, C.A. (2015). Anesthesia equipment. In: Lumb and Jones' Veterinary Anesthesia and Analgesia. Grimm, K.A., Lamont, L.A., Tranquilli, W.J., Greene, S.A. and Robertson, S.A. (Eds.) 5th ed., Wiley Blackwell, USA. pp. 23-85.

Muir, W.W., Hubbell, J.A.E., Bednarski, R.M. and Lerche, P. (2013). Anesthetic procedures and techniques in dogs. In: Handbook of Veterinary Anesthesia. Muir, W.W., Hubbell J.A.E., Bednarski, R.M. and Lerche, P. (Eds.) 5th ed., Elsevier Saunders, St. Louis. pp. 379-393.

O'Dwyer, L. (2015). Safe anaesthesia for brachycephalic dogs. BSAVA Congress Proceedings, Birmingham, British Small Animal Veterinary Association. pp. 361-362. https://doi.org/10.22233/9781910443521.43.8

Park, H.-P., Hwang, J.-W., Lee, J.-H., Nahm, F.S., Park, S.-H., Oh, A.-Y., Jeon, Y.-T. and Lim, Y.-J. (2013). Predicting the appropriate uncuffed endotracheal tube size for children: A radiograph-based formula versus two age-based formulas. J. Clin. Anesth. 25(5): 384-387. https://doi.org/10.1016/j.jclinane.2013.01.015

Shelby, A.M. and McKune, C.M. (2014). Anesthetic process. In: Small Animal Anesthesia Technique. Shelby, A.M. and McKune, C.M. (Eds.) 1st ed., Wiley-Blackwell, Ames. pp. 1-12.

@COPYRIGHT UPM

Shin, C.W., Son, W.-gyun, Jang, M., Kim, H., Han, H., Cha, J. and Lee, I. (2018). Selection of appropriate endotracheal tube size using thoracic radiography in Beagle Dogs. Vet. Anaesth. Analg. 45(1): 13–21. https://doi.org/10.1016/j.vaa.2017.10.002

Sultan, P., Carvalho, B., Rose, B.O. and Cregg, R. (2011). Endotracheal tube cuff pressure monitoring: A review of the evidence. J. Perioper. Pract. 21(11): 379-386. https://doi.org/10.1177/175045891102101103

Sutagatti, J.G., Raja, R. and Kurdi, M.S. (2017). Ultrasonographic estimation of endotracheal tube size in paediatric patients and its comparison with physical indices based formulae: A prospective study. J. Clin. Diagn. Res. 11(5): UC05–UC08. https://doi.org/10.7860/jcdr/2017/25905.9838

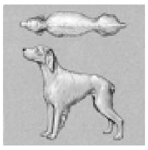
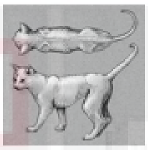
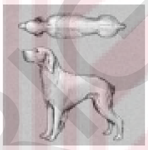
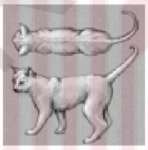
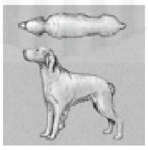
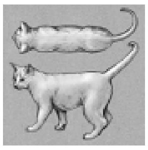
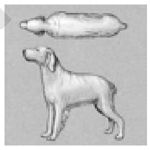
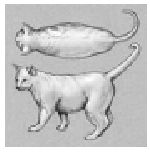
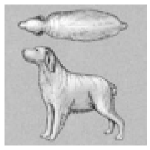
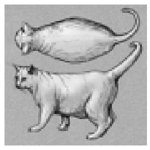
Tong, J. and Pang, D.S.J. (2019). Investigating novel anatomical predictors for endotracheal tube selection in dogs. Can. Vet. J. 60(8): 848-854. https://doi.org/10.7910/DVN/F4AQI0

Thomas, J.A. and Lerche, P. (2017). Canine and feline anesthesia. In: Anesthesia and Analgesia for Veterinary Technicians. Thomas, J.A. and Lerche, P. (Eds.) 5th ed., Elsevier Saunders, St. Louis. pp. 273-305

@COPYRIGHT UPM

APPENDIX

Figure 7: AAHA's body condition scoring systems.

5 Point	9 Point	Description
1/5	1/9	**Dogs:** Ribs, lumbar vertebrae, pelvic bones and all bony prominences evident from a distance. No discernible body fat. Obvious loss of muscle mass.  **Cats:** Ribs visible on short-haired cats; no palpable fat; severe abdominal tuck; lumbar vertebrae and wings of ilia obvious and easily palpable. 
1.5/5	2/9	**Dogs:** Ribs, lumbar vertebrae and pelvic bones easily visible. No palpable fat. Some evidence of other bony prominence. Minimal loss of muscle mass. **Cats:** Shared characteristics of BCS 1 and 3.
2/5	3/9	**Dogs:** Ribs easily palpated and may be visible with no palpable fat. Tops of lumbar vertebrae visible. Pelvic bones becoming prominent. Obvious waist.  **Cats:** Ribs easily palpable with minimal fat covering; lumbar vertebrae obvious; obvious waist behind ribs; minimal abdominal fat. 
2.5/5	4/9	**Dogs:** Ribs easily palpable, with minimal fat covering. Waist easily noted, viewed from above. Abdominal tuck evident. **Cats:** Shared characteristics of BCS 3 and 5.
3/5	5/9	**Dogs:** Ribs palpable without excess fat covering. Waist observed behind ribs when viewed from above. Abdomen tucked up when viewed.  **Cats:** Well proportioned; waist observed behind ribs; ribs palpable with slight fat covering; abdominal fat pad minimal. 
3.5/5	6/9	**Dogs:** Ribs palpable with slight excess fat covering. Waist is discernible viewed from above but is not prominent. Abdominal tuck apparent. **Cats:** Shared characteristics of BCS 5 and 7.
4/5	7/9	**Dogs:** Ribs palpable with difficulty; heavy fat cover. Noticeable fat deposits over lumbar area and base of tail. Waist absent or barely visible. Abdominal tuck may be present.  **Cats:** Ribs not easily palpable with moderate fat covering; waist poorly distensible; obvious rounding of abdomen; moderate abdominal fat pad. 
4.5/5	8/9	**Dogs:** Ribs not palpable under very heavy fat cover, or palpable only with significant pressure. Heavy fat deposits over lumbar area and base of tail. Waist absent. No abdominal tuck. Obvious abdominal distension may be present. **Cats:** Shared characteristics of BCS 7 and 9.
5/5	9/9	**Dogs:** Massive fat deposits over thorax, spine and base of tail. Waist and abdominal tuck absent. Fat deposits on neck and limbs. Obvious abdominal distention.  **Cats:** Ribs not palpable under heavy fat cover; heavy fat deposits over lumbar area, face and limbs; distention of abdomen with no waist; extensive abdominal fat pad. 

AAHA

©2010 Journal of the American Animal Hospital Association. All rights reserved.
Available at aahanet.org/PublicDocuments/NutritionalAssessmentGuidelines.pdf

@COPYRIGHT UPM

Figure 8: Tracheal internal diameter (mm) measurement (green line) on a right lateral thoracic radiograph.

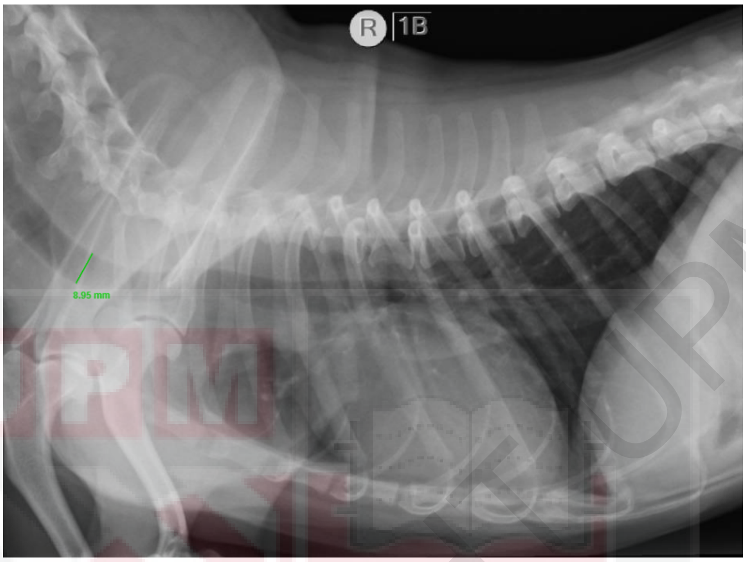
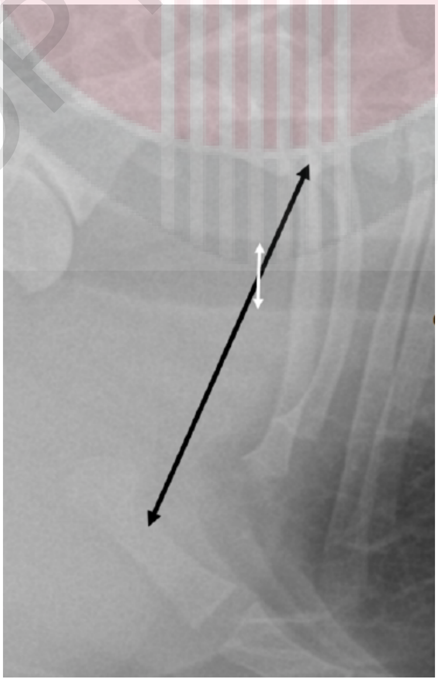


Figure 9: Tracheal internal diameter (mm) measurement (white arrow) and thoracic inlet boundary (black arrow) on a right lateral thoracic radiograph.



@COPYRIGHT UPM

Table 5: BSAVA's suggested sizes of endotracheal tubes for small animal practice.

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 6: Becvarova's common body condition scoring system.

Nine-Point System	Five-Point System	Body Weight Below or Above Ideal (%)
1	1	-40
2	1.5	-30
3	2	-20
4	2.5	-10
5	3	0
6	3.5	+10
7	4	+20
8	4.5	+30
9	5	+40

@COPYRIGHT UPM

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

@COPYRIGHT UPM

Table 8: Contingency Table Representing Accuracy of BWT.

Contingency Table Representing Accuracy of In-house 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 In-house Lean Body Weight-based Formula Method																			Total No. of Subject
	2.0	2.5	3.0	3.5	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	10.5	11	
2.0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
2.5	1	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
3.0	0	0	0*	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
3.5	0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
4.0	0	0	0	0	0*	2	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
4.5	0	0	0	0	0	0*	1	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**
5.5	0	0	0	0	0	0	1	0*	0	0	0	0	0	0	0	0	0	0	0	**1**
6.0	0	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	1	0	0	0	0	0	0	0	**1**
7.0	0	0	0	0	0	0	0	0	0	0	0*	0	0	0	0	0	0	0	0	**0**
7.5	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**
8.5	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	0	0	0	0*	0	0	0	0	**0**
9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0*	0	0	1	**1**
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1*	0	0	**2**
Total No. of Subject	**1**	**0**	**0**	**0**	**2**	**2**	**2**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**1**	**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 in-house lean body weight-based formula method.

@COPYRIGHT UPM

Table 9: 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
	2.0	**2.5**	**3.0**	**3.5**	**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**	
2.0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
2.5	0	0*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
3.0	0	0	1*	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**2**
3.5	0	0	0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
4.0	0	0	0	0	1*	0	0	1	0	0	0	0	0	0	0	0	0	**2**
4.5	0	0	0	0	1	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**
5.5	0	0	0	0	0	0	0	0*	0	1	0	0	0	0	0	0	0	**1**
6.0	0	0	0	0	0	0	0	0	1*	0	0	0	0	0	0	0	0	**1**
6.5	0	0	0	0	0	0	0	0	0	1*	0	0	0	0	0	0	0	**1**
7.0	0	0	0	0	0	0	0	0	0	0	0*	0	0	0	0	0	0	**0**
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	0	0	0	0	0*	0	0	**0**
9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0*	1	**1**
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1*	**2**
Total No. of Subject	**0**	**0**	**2**	**0**	**3**	**0**	**0**	**1**	**1**	**2**	**0**	**1**	**0**	**0**	**0**	**1**	**2**	**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.

@COPYRIGHT UPM