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Cardiac Autonomic Modulation and the Occurrence of Arrhythmic Events in Brachycephalic Dogs: A Scoping Review

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Abstract: Brachycephalic obstructive airway syndrome (BOAS) is a condition characterized by anatomical obstructions of the upper airways that impair airflow and lead to ventilatory dysfunction in dogs with broad and short skulls. This condition may also contribute to the occurrence of arrhythmias associated with increased vagal tone, such as sinus pauses or atrioventricular blocks. In advanced stages, pulmonary hypertension and cardiac remodeling may occur, predisposing affected dogs to more complex arrhythmias, including atrial fibrillation. This study aimed to map the available scientific evidence regarding autonomic cardiac activity and the presence of arrhythmias in brachycephalic dogs. This scoping review was conducted according to the standards of the Joanna Briggs Institute (JBI) and adhered to the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews methodological guidance (PRISMA-ScR). The databases CABI, BVS, Embase, MEDLINE/PubMed, SciELO, Scopus, and Web of Science were used to search for scientific evidence published to date. The search strategy included the terms: "airway obstruction", "brachycephalic dogs", "heart rate variability", "parasympathetic nervous system", and "respiratory sinus arrhythmia". The research identified 769 articles, of which 11 met the criteria and were included in the analysis. Each article was analyzed, and its information was characterized according to four domains of interest: general study information, methodological design of the studies, variables analyzed and diagnostic strategies applied, and main findings and conclusions. This scoping review emphasizes the increasing scientific interest in the relationship between brachycephalic breed morphology and cardiac autonomic modulation in dogs. Although there are a limited number of studies with methodological diversity, the evidence suggests that vagal overstimulation resulting from chronic upper airway obstruction in these breeds significantly influences heart rate and rhythm modulation. Future research should focus on achieving methodological standardization, detailed morphometric evaluations, and utilizing long-term monitoring techniques to improve diagnostic accuracy and clinical relevance.

Keywords: autonomic nervous system; brachycephaly; brachycephalic obstructive airway syndrome; bulldog; pug.

1. Introduction

The brachycephalic condition in dogs refers to a series of anatomical conformations characterized by a broad and shortened skull, which include an elongated soft palate, stenotic nares, everted laryngeal saccules, tracheal hypoplasia, and laryngeal collapse. Over time, these alterations lead to changes in ventilatory dynamics due to increased resistance to airflow through the upper airways (Dupré and Heidenreich, 2016; Liu et al, 2017; Junior et al., 2021). There are reports that these anatomical abnormalities may influence various cardiocirculatory conditions, including the presence of sinus pauses (Noszczyk-Nowak et al., 2017) and sinus arrhythmias (Dias et al., 2016; Canola et al., 2018). Likewise, it has been demonstrated that brachycephalic dogs exhibit higher values of the vasovagal tonus index (VVTI), a marker of heart rate variability (HRV), compared to non-brachycephalic breeds. These differences suggest a predominance of parasympathetic tone in these dogs, likely as a result of enhanced vagal stimulation associated with more pronounced respiratory sinus arrhythmia (SRA) (Doxey and Boswood, 2004; Dias et al., 2016; Canola et al., 2018). On the other hand, it has also been reported that such increased parasympathetic activity may be exacerbated, leading to marked bradycardia and even transient atrioventricular block following sympathetic activation events (Santilli et al., 2019).

Several mechanisms may explain the altered autonomic modulation observed in brachycephalic dogs. Fernandes et al. (2024) noted that the prolonged inspiratory phase and increased respiratory effort, characteristic features of brachycephalic syndrome, influence autonomic nervous system activity, promoting greater heart rate variability and higher VVTI values. However, when multiple brachycephalic breeds were compared, the differences were not significant, which may suggest that although a general pattern of vagal hyperstimulation exists, other morphological or physiological factors may modulate this response depending on the breed or individual. Additionally, chronic respiratory compromise caused by upper airway obstructions can lead to significant hemodynamic consequences. Canola et al. (2018) observed that dogs with brachycephalic syndrome exhibit elevated pulmonary pressures, likely secondary to chronic hypoventilation and hypoxemia, which may result in right-sided cardiac remodeling (*cor pulmonale*) and eventually in congestive heart failure. These structural and functional alterations of the cardiovascular system reflect the close interrelationship between brachycephalic morphology, respiratory physiology, and cardiac rhythm regulation.

Despite the above, the literature addressing the relationship between brachycephaly and electrocardiographic changes is limited. A search for information conducted in May 2025 across the databases CABI, BVS, Embase, MEDLINE/PubMed, SciELO, Scopus, and Web of Science revealed no evidence of syntheses, scoping reviews, or systematic reviews. Additionally, no relevant records were found on the Open Science Framework (OSF), the Database of Systematic Reviews for Animals and Food (SYREAF), the

Database of Veterinary Systematic Reviews (VetSRev), or the Journal/Author Name Estimator (JANE) (https://jane.biosemantics.org/) regarding the relationship between cardiac activity and the brachycephalic condition in dogs. Therefore, the aim of this scoping review is to characterize the published scientific evidence related to cardiac autonomic regulation and the occurrence of arrhythmic events in brachycephalic dogs.

2. Materials and Methods

2.1. Protocol and Registration

The present study adhered to the PRISMA-ScR (Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews) methodological guidance for scoping reviews (Tricco et al., 2018). The protocol used was registered on the Open Science Framework (OSF) and is accessible via the following link: https://doi.org/10.17605/OSF.IO/FESKR

2.2. Inclusion and Exclusion Criteria

This scoping review included published articles from the scientific literature available in various databases related to the research question. The research question was based on the PCC acronym (Population, Concept, and Context), where: P: Dogs, *Canis lupus familiaris*, C: Alterations in cardiac autonomic modulation and the occurrence of arrhythmic events, and C: Brachycephalic Obstructive Airway Syndrome (BOAS). The resulting question was: What scientific evidence is available regarding the relationship between brachycephalic conformation or the presence of Brachycephalic Obstructive Airway Syndrome (BOAS), and alterations in cardiac autonomic modulation and the occurrence of arrhythmic events in dogs (*Canis lupus familiaris*)?

Inclusion criteria encompassed articles focusing on dogs (*Canis lupus familiaris*) of brachycephalic breeds, with or without evidence of Brachycephalic Obstructive Airway Syndrome (BOAS), related to any electrocardiographic activity. Original articles based on observational, clinical, or experimental studies published in at least one electronic database included in this review were considered. No restrictions were applied regarding the date, geographical location, or language of publication, provided that the title and abstract were available in English.

Exclusion criteria included articles focusing on species other than the target species of this review (i.e., species other than *Canis lupus familiaris*), as well as studies that did not report variables related to heart rate or rhythm associated with the presence of BOAS in dogs. Narrative reviews, conference abstracts, letters to the editor, and opinion articles were also excluded, even if they addressed the topic of interest in this review.

2.3. Search Strategy

The search was conducted in the following databases: CABI, BVS, Embase, MEDLINE/PubMed, SciELO, Scopus, and Web of Science. The preliminary search utilized keywords from 10 reference articles and served as the basis for establishing the final search strategy. This search strategy was developed by a researcher with clinical experience (E.B.) and a librarian experienced in systematic searches (E.L.). It employed the descriptor terms “airway obstruction”, “arrhythmias, cardiac”, “arrhythmia, sinus”, “atrial fibrillation”, “atrioventricular block”, “autonomic nervous system”, “bradycardia”, “craniosynostoses”, “dog”, “dogs”, “electrocardiography”, “electrocardiography, ambulatory”, “heart rate”, “nasal obstruction”, “non-neuronal cholinergic system”, “parasympathetic nervous system”, “respiratory sinus arrhythmia”, “sleep apnea, obstructive”, “sympathetic nervous system”, and “tachycardia”, which are included in the platform DeSC/MeSH (https://decs.bvsalud.org/), as well as Emtree life science thesaurus terms in Embase, including “adrenergic system”, “ambulatory electrocardiography”, “atrial fibrillation”, “autonomic nervous system”, “brachycephaly”, “bulldog”, “cholinergic system”, “dog”, “electrocardiogram”, “electrocardiography”, “heart arrhythmia”, “heart rate”, “heart rate and rhythm”, “heart rate variability”, “holter monitoring”, “nose obstruction”, “obstructive sleep apnea”, “reflex bradycardia”, “respiratory sinus arrhythmia”, “tachycardia”, and “vagal bradycardia". Additionally, free-text terms were included: “BOAS”, “boston terrier”, “bulldog”, “brachycephalic dog”, “brachycephalic obstructive airway syndrome”, “brachycephalic syndrome”, “canine”, “heart rate monitor”, “holter”, “polar frequency”, “pug”, and “sinus pause”, and “VVTI”; all of which were combined using Boolean operators.

The following terms and Boolean operators were employed to search the titles, abstracts, and keywords of peer-reviewed journal publications, forming the general search strategy: ((“boston terrier” OR “brachycephalic” OR “bulldog” OR “craniosynostoses” OR “pug”) AND (“arrhythmia” OR “arrhythmia, cardiac” OR “bradycardia” OR “heart rate” OR “heart rate variability” OR “tachycardia” OR “vasovagal tone index”) AND (“airway obstruction” OR “autonomic nervous system” OR “parasympathetic nervous system” OR “respiratory sinus arrhythmia” OR “sympathetic nervous system”)). All strategies used for the various databases are clearly defined in the registered protocol in the OFS.

2.4. Selection of Studies

The initial selection and evaluation process of the articles was conducted using the Rayyan platform (Rayyan Systems Inc.), a tool specifically designed for screening studies in systematic reviews. Articles were imported into the platform in Research Information Systems format (.ris) from the databases used. Subsequently, two reviewers independently classified the studies into three groups: 1) include, 2) exclude, and 3) maybe, utilizing the available filters and labeling tools on the platform. Any discrepancies between the reviewers were resolved by a third reviewer (G.R.). Articles were then approved for further analysis through consensus. The screening process initially relied on title and abstract evaluation (E.B./F.A.), followed by a full-text review (E.B./F.A./G.R.).

2.5. Data extraction and data synthesis

Once the articles were selected for full-text analysis, a pre-designed Excel spreadsheet was created to document each reviewer’s findings and to construct the final data extraction sheet. Based on the objectives of this review, the existing scientific evidence

concerning the impact of brachycephalic obstructive airway syndrome (BOAS) on autonomic modulation and the occurrence of arrhythmias was analyzed descriptively, incorporating both quantitative and qualitative data. Accordingly, all extracted data were organized into four domains of interest. The first domain, general study information, included elements such as the authors' names, country of origin, and year of publication. The second domain referred to the methodological design of the studies, encompassing aspects such as sample size and study type, while the third domain focused on the variables analyzed and the diagnostic strategies applied. Finally, the fourth domain encompassed the main conclusions reported in each study.

3. Results

Out of a total of 769 articles identified across all the databases explored, 296 were excluded due to duplication. An additional 416 were excluded after title and abstract screening, and 46 were excluded for justified reasons. Ultimately, a total of 11 articles were selected, all of which met the study's eligibility criteria (Table 1). The flowchart detailing this process is presented in Figure 1.

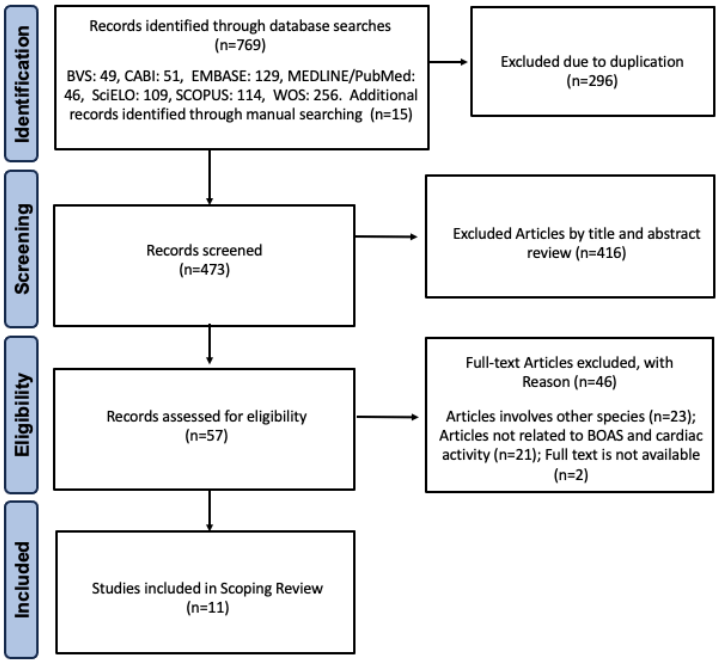

Figure 1 – PRISMA flow diagram for selecting studies for the scoping review, based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Moher et al., 2009).

Out of a total of 150 search terms most frequently used in the title, abstract, and keywords of the analyzed documents, the ten most commonly found terms were "dogs" 16/150 (10.7%), followed by "brachycephalic syndrome" 15/150 (10.0%), "heart rate" 9/150 (6.0%), "brachycephalic dogs" 8/150 (5.3%), "heart rate variability" 8/150 (5.3%), "VVTI" 7/150 (4.7%), "electrocardiographic" 7/150 (4.7%), "electrocardiography" 7/150 (4.7%), "bulldog" 6/150 (4.0%), and "vasovagal tone index" 6/150 (4.0%). Similarly, 56/150 terms (37.3%) corresponded to DeCS/MeSH or Emtree descriptors, while 94/150 terms (62.7%) were free. The most frequent keywords and their co-occurrence map are summarized in Figures 2 and 3, respectively.

Title	Autor	Year	Country	Study type, and sample size
Cardiorespiratory evaluation of brachycephalic syndrome in dogs	Canola et al.	2018	Brazil	Prospective and cross-sectional study, n=28
Anatomical, Cardiovascular, and Blood Gas Parameters in Dogs with Brachycephalic Syndrome	Dias et al.	2016	Brazil	Prospective and cross-sectional study, n=40
Differences between breeds of dog in a measure of heart rate variability	Doxey and Boswood	2004	United Kingdom	Retrospective study, n=92
Heart rate variability and vasovagal tone index in brachycephalic dogs	Fernandes et al.	2024	Brazil	Prospective and cross-sectional study, n=60
Electrocardiographic findings in healthy Cavalier King Charles Spaniels, Pugs, and English Bulldogs	Romito et al.	2023	Italy	Retrospective study, n=135
Study of heart rate variability in dogs with brachycephalic syndrome that underwent rhinoplasty	Santos Filho et al.	2020	Brazil	Prospective and cross-sectional study, n=16

Title	Autor	Year	Country	Study type, and sample size
Electrocardiographic findings in dogs with obstructive airway diseases	Silva et al.	2022	Brazil	Retrospective study, n=108
Baseline and post exercise electrocardiography in brachycephalic dogs	Tarelho et al.	2023	Brazil	Prospective and cross-sectional study, n=29
Establishing reference standards for the vasovagal tonus index in a cohort of healthy French Bulldogs	Trauffler et al.	2019	Switzerland	Prospective and cross-sectional study, n=60
Reference ranges for standard-echocardiography in pugs and impact of clinical severity	Wiegel et al.	2022	Germany	Retrospective study, n=42
The effect of the surgical treatment of brachycephalic obstructive airway syndrome on the thermoregulatory response to exercise in French bulldogs: a pilot study	Žgank et al.	2023	Slovenia	Prospective and cross-sectional study, n=13

Table 1 – Summary of the general characteristics of the documents analyzed in this scoping review concerning the relationship between brachycephalic conformation or the presence of Brachycephalic Obstructive Airway Syndrome (BOAS) and alterations in cardiac autonomic modulation and the occurrence of arrhythmic events in dogs.

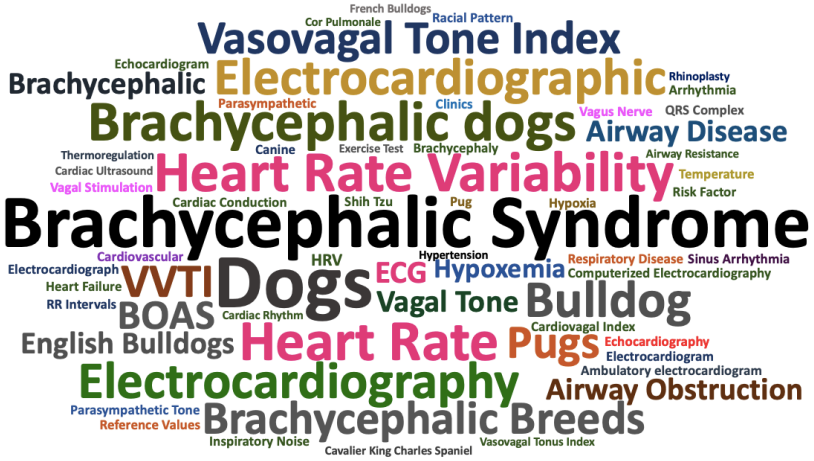

Figure 2 – Word cloud displaying the top 150 most frequently used words from the 11 articles selected for analysis in the scoping review. The terms were derived from the title, abstract, and keywords provided by the authors. The sizes reflect higher frequency, while the colors distinguish between various category terms.

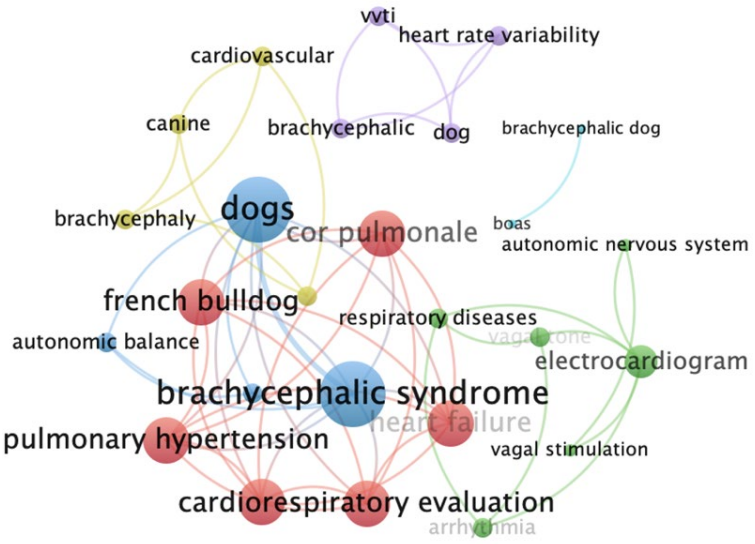

Figure 3 – Co-occurrence network map of the keywords identified in the titles and abstracts of the 11 analyzed articles. Out of a total of 191 keywords, and considering a minimum of 3 occurrences, 24 keywords met the threshold. A larger node size and shorter distance between nodes indicate a higher frequency and a stronger association strength between the terms.

The publications were issued in journals from Brazil in 6/11 (54.5%) of the cases, the United Kingdom in 2/11 (18.2%), Switzerland in 2/11 (18.2%), and the United States of America in 1/11 (9.1%). The origin of the research was Brazil in 6/11 (54.5%) of the studies, and 1/11 (9.1%) for each of the following countries: the United Kingdom, Italy, Switzerland, Germany, and Slovenia. The chronological range of the publications spanned from 2004 to 2024. The relationship between authors and publication years of the analyzed documents is summarized in Figures 4 and 5.

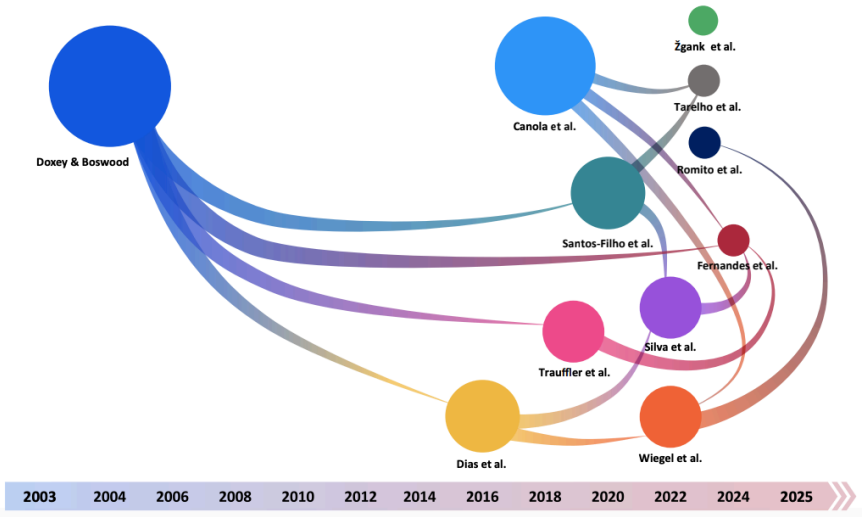

Figure 4 – Co-citation network map illustrating authors, publication years, and the proportion of references for the analyzed documents. The size of the circles reflects the proportion in which the author was referenced. Circle size represents the frequency with which each author was cited. Arrows indicate the relationship of each publication to other works addressing the same topic.

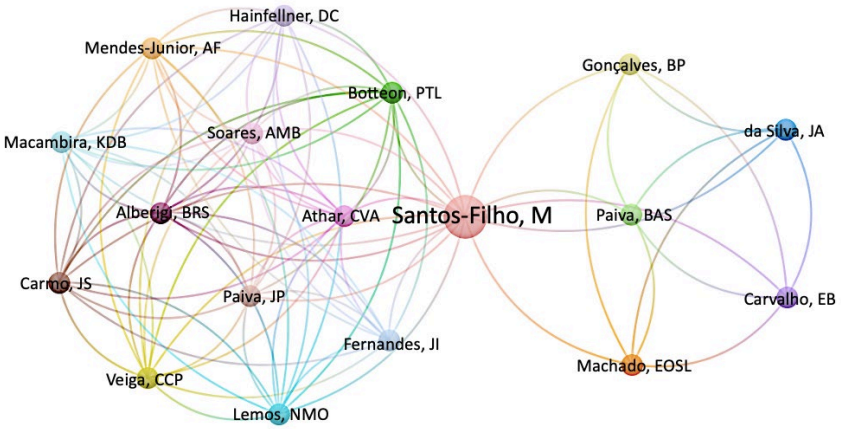

Figure 5 – The co-authorship network map is illustrated in the 11 analyzed articles. Out of a total of 64 authors, taking into account a minimum of 2 co-authorships, 18 authors met the threshold. A larger node size and a shorter distance between nodes indicate a higher frequency and a stronger association strength among the authors.

All analyzed documents corresponded to original scientific studies. Of the eleven papers, seven (63.6%) were prospective, cross-sectional, while four (36.4%) were retrospective studies. Prospective studies had an average sample size of 29 dogs (IQR 16.0–60.0), whereas retrospective studies included an average of 100 dogs (IQR 54.5–128.3).

The most frequently represented brachycephalic breed was the French Bulldog, featured in 7/11 (63.6%) studies, followed by the Pug in 6/11 (54.5%), English Bulldog in 5/11 (45.5%), Shih Tzu in 3/11 (27.3%), Boxer in 3/11 (27.3%), Cavalier King Charles Spaniel in 2/11 (18.2%), and finally Boston Terrier and Lhasa Apso, each represented in 1/11 studies (9.1%).

The classification of airway obstruction was performed using various strategies. In 6/11 studies (54.5%), brachycephaly was identified solely based on breed; 3/11 (27.3%) included measurements and anatomical evaluation of the nose; 1/11 studies (9.1%) relied on clinical signs and clinical examination and was confirmed with an endoscopic examination of the upper airways; and finally, 1/11 studies (9.1%) employed a functional grading system utilizing an exercise test.

The variables analyzed in the studies included Approximate Entropy (ApEn), Cardiac Sympathetic Index (CSI), Cardiac Vagal Index (CVI), Echocardiography (ECO), Electrocardiography (ECG), Heart Rate (HR), Heart Rhythm (HRhy), Root Mean Square of Successive Differences between Adjacent NN Intervals (rMSSD), Short-Term Scaling Exponent from Detrended Fluctuation Analysis (Alfa 1 and Alfa 2 DFA), Standard Deviation of All NN Intervals (SDNN), Standard Deviation of the Averages of NN Intervals in 5-Minute Segments (SDANN), and Vasovagal Tonus Index (VVTI). The most frequently analyzed variable in the documents was HR, with 10/11 (90.9%) occurrences, followed by the evaluation of HRym conducted in 6/11 (54,5%) studies. Evaluation of the timing and amplitudes of electrocardiographic deflections occurred in 3/11 (27.3%) studies, while 4/11 (36.4%) studies assessed metrics of autonomic modulation. The most frequently reported arrhythmia in the analyzed documents was RSA, present in 6/11 (54.5%), followed by sinus arrest and first-degree atrioventricular block, each reported in 1/11 cases (9.0%).

The analyzed documents estimated the studied variables using various diagnostic strategies. Surface electrocardiography was utilized in 9/11 (81.8%) of the documents, while 1/11 (9.1%) reported using echocardiography and surface electrocardiography when necessary. Additionally, 1/11 (9.1%) employed femoral pulse palpation for this estimation. The variables obtained through surface electrocardiography were measured with different monitoring durations: 3/9 (33.3%) were conducted by analyzing 10 or 20 RR intervals (less than 50 seconds), 1/9 (11.1%) analyzed monitoring periods of 1, 3, and 5 minutes each, and 3/9 (33.3%) did not report the analysis time utilized.

The main conclusions drawn from the analyzed documents indicate that the brachycephalic condition is associated with various changes in cardiac and autonomic activity in affected dogs, specifically alterations in HR, HRV, and VVTI values, which have implications for both rest and physical exercise. Furthermore, significant effects of stress, upper airway obstruction, and surgical interventions on the airways were observed in relation to the studied variables. The main findings of each analyzed study are summarized in Table 3.

Author, year	Conclusions
Canola et al., 2018	HR in Brachycephalic dogs were higher than in non-brachycephalic group, a fact that suggests a stress effect.
Dias et al., 2016	Alterations associated with brachycephalic syndrome result in significant cardiovascular abnormalities in brachycephalic dogs, mainly related to HR and HRym, as well as evident changes in blood pressure, blood gas parameters, and oxygen saturation.
Doxey and Boswood, 2004	Brachycephalic dogs showed higher VVTI values than non-brachycephalic dogs, though not always significantly across breeds. VVTI was negatively correlated with HR.
Fernandes et al., 2024	Dog's breed and morphology did not alter its electrocardiographic parameters or HRV. The VVTI showed no difference when compared separately in brachycephalic breeds.
Romito et al., 2023	Several ECG differences exist among Cavalier King Charles Spaniels, Pugs, and English Bulldogs and that a trend to QRS-MEA left shift physiologically occurs in Pugs and English Bulldogs but not in Cavalier King Charles Spaniels, likely as a consequence of their chest conformation
Santos Filho et al., 2020	Upper airway obstruction in brachycephalic dogs increases HRV through enhanced parasympathetic activity, as evidenced by higher SDANN, rMSSD, and cardiovagal indices. After rhinoplasty, this activity decreases, along with bradyarrhythmias and RSA, and mean heart rate increases.
Silva et al., 2022	RSA is frequent in animals diagnosed with bronchitis, suggesting its strong association with this disease as well as with chronic conditions. Association between autonomic regulation and the exacerbation of vagal tone in those with obstructive airway diseases that in some way affected cardiac bathmotropism.
Tarelho et al., 2023	Electrocardiography may be able to assess significant alterations in the cardiovascular physiology of brachycephalic dogs when subjected to physical exercise. These findings demonstrate that the anatomy of these dogs predisposes them to more pronounced alveolar hypoxia compared to non-brachycephalic dogs during physical activity, and that acute cardiac adaptations occur during exercise
Trauffler et al., 2019	VVTI values in French Bulldogs cover a relatively wide range and are negatively correlated with heart rate. Stress in dogs significantly affects VVTI and HR, highlighting the need to minimize its impact before and during ECG recordings.
Wiegel et al., 2022	BOAS did not show any significant influence on echocardiographic measurements, including heart rate.
Žgank et al. 2023	Surgery to reduce upper airway obstruction in French Bulldogs improved the HR profile during exercise and the recovery phase. This improvement suggests better thermal regulation following the intervention. Therefore, surgery is recommended for dogs with BOAS that exhibit evident clinical signs.

Table 3 – Summary of the main conclusions found in each analyzed document regarding the relationship between brachycephalic conformation or the presence of Brachycephalic Obstructive Airway Syndrome (BOAS) and changes in cardiac autonomic modulation, as well as the occurrence of arrhythmic events in dogs. Electrocardiogram (ECG), Heart Rate (HR), Heart Rate variability (HRV), Heart Rhythm (HRym), QRS-complex mean electrical axis (QRS-MEA), Root Mean Square of Successive Differences between Adjacent NN Intervals (rMSSD), respiratory sinus arrhythmia (RSA), Standard Deviation of the Averages of NN Intervals in 5-Minute Segments (SDANN), Vasovagal Tonus Index (VVTI).

4. Discussion

The objective of this study was to conduct a scoping review that maps the available scientific evidence regarding autonomic cardiac activity and the presence of arrhythmias in brachycephalic dogs. To our knowledge, this is the first scoping review specifically focused on this area of research. A total of 11 studies met the eligibility criteria and formed the basis of this analysis. Given the variability of responses observed across different experimental models, our work is particularly relevant as it identifies and synthesizes contradictory results, highlights common patterns, and points out methodological gaps to guide future research.

General study information – The bibliometric analysis revealed that the term "dogs" and the specific expression "brachycephalic syndrome" emerged as the most frequent and co-occurring terms related to the topic of this study. However, the former represents a formal descriptor, while the latter is a free term, highlighting the terminological heterogeneity present in the literature. To date, some frequently used terms in articles focused on this topic have only been designated as candidate terms, possibly due to the limited available evidence. Nevertheless, we believe that the use of candidate terms and even free terms employed in this scoping review could streamline literature search processes related to the subject. This is especially relevant, considering that searches based solely on controlled vocabulary may have limitations in retrieving all available information from the consulted databases (Salvador et al., 2019; DeMars & Perruso, 2022).

Since the pioneering publication by Doxey and Boswood (2004) and the most recent work by Fernandes et al. (2024), there has been an increase in scientific output, particularly concentrated between 2019 and 2023, during which Brazil has emerged as a leading contributor. This regional growth highlights a growing interest in understanding how airway obstruction impacts heart rate and autonomic balance in these popular breeds. Nevertheless, while the studies by Doxey and Boswood (2004) and Canola et al. (2018) laid the initial groundwork, their limited citation frequency suggests that the existing evidence remains fragmented and insufficient, despite the clear clinical relevance of the topic.

Methodological design of the studies – The predominance of prospective cross-sectional designs among the analyzed documents indicates a preference among researchers for collecting data under controlled conditions, which may enhance internal validity and measurement consistency. However, this type of study utilized smaller sample sizes compared to retrospective studies, which, although less frequent, included larger populations. This may improve statistical power but inherently carries a higher risk of selection bias and variability in the data used for analysis. Nonetheless, given the limited literature available on the subject, we find it valuable to integrate both types of evidence to build a broader and more robust perspective that can guide future research toward increasingly well-structured study designs, particularly in the field of small animal veterinary medicine, where access to large populations is constrained.

Although most of the analyzed studies included French Bulldogs, Pugs, and English Bulldogs as representative breeds of the brachycephalic condition, it is evident that brachycephalic breeds may encompass a wide range of individuals who may or may not exhibit ventilatory compromise. Reports indicate that a more extreme brachycephalic conformation is associated with a higher risk of BOAS (Liu et al., 2016), which in turn is linked to major associated complications (Carabalona et al., 2021) (Figure 6). However, there are limitations in the characterization of brachycephalic dogs in most of the reviewed studies, as none of them performed a detailed analysis of craniofacial morphometric indices. In our study, the brachycephalic condition was identified solely based on breed in more than 54.5% of the documents, followed by 27.3% that conducted measurements and anatomical evaluations of the nose, and only 9.1% that relied on clinical signs and physical examinations or employed a functional grading system utilizing an exercise test. Nonetheless, various methods have been proposed to characterize the presence of BOAS, primarily including the assessment of the craniofacial ratio (Packer et al., 2015), the evaluation of the degree of nasal stenosis (Liu et al., 2016), or its combination with regular clinical assessments of respiratory signs before and after exercise (Liu et al., 2017). These findings indicate a considerable methodological variance in the definition and classification of brachycephalic syndrome, which may influence the comparability of results and impede the accurate identification of its pathophysiological impact.

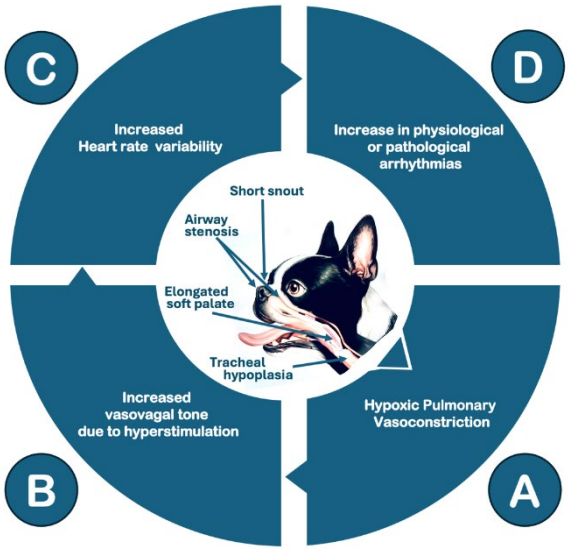

Figure 6 – Influence of different risk factors on cardiac modulation and the occurrence of arrhythmias in brachycephalic dogs. The illustration shows the main anatomical changes that promote brachycephalic obstructive airway syndrome (BOAS). Around the edges, in a counterclockwise direction, the effects of BOAS on autonomic modulation and heart rhythm are depicted: A) chronic intermittent hypoxia caused by airway blockage leads to hypoxic pulmonary vasoconstriction; B) this hypervagotonia increases parasympathetic activity and the risk of autonomic imbalance; C) persistent vagal stimulation results in greater heart rate variability; and D) these changes raise the likelihood of developing physiological or pathological arrhythmias.

Variables analyzed and the diagnostic strategies applied – In the studies analyzed, HR was the most commonly assessed variable. Although HR is an accessible and widely reported measure in the field of cardiology, we consider its isolated use may be insufficient, particularly in short-term recordings, since RR intervals in dogs do not typically follow a linear mathematical pattern and fluctuate throughout the day (Moïse et al., 2020), including inherent variations associated with the circadian rhythm (Matsunaga et al., 2001). In this context, the autonomic variability observed in dogs requires a more comprehensive approach that incorporates additional variables capable of capturing both sympathetic and parasympathetic dynamics. The limited number of studies evaluating HRV-derived metrics such as rMSSD, SDNN, DFA, or entropy indices highlights a significant opportunity for further research. This field remains in the process of consolidation, suggesting a promising area for more precise and robust assessments of autonomic modulation.

On the other hand, heart rhythm analysis was limited across the 11 reviewed documents. The most frequently reported arrhythmia was RSA, present in 6 out of 11 studies (54.5%), along with isolated reports of sinus arrest and first-degree atrioventricular block, each identified in only one of the analyzed documents. These findings support the idea that, although RSA is typically a physiological manifestation of autonomic modulation, its association with other bradyarrhythmias may indicate a more complex autonomic imbalance, which could be pathological in specific clinical contexts, such as sinus node disease (Flanders et al., 2024) or even in states of hypervagotonia secondary to respiratory conditions (Silva et al., 2022).

Although ECG was used in 81.8% of the studies analyzed, other diagnostic methods, such as heart rate estimation by ultrasound or pulse palpation, were also employed. Despite the variety of modalities, the gold standard for accurately determining heart rate and cardiac rhythm in dogs is ECG (Birettoni et al., 2004), as well as in other species (Abbott, 2005; Stracina et al., 2022; Calvet and Seebeck, 2023). While complementary methods, such as ultrasonographic estimation of cardiac activity, are viable as they incorporate additional electrocardiographic measurements or allow evaluation of interbeat intervals based on systolic and diastolic activity, we believe that exclusive reliance on femoral pulse palpation, although clinically convenient, could introduce bias if misinterpreted as the actual heart rate. This is due to reports indicating that peripheral pulse detection in conscious dogs is inconsistent, with success rates as low as 67% compared to 87% in anesthetized dogs (Dagnall et al., 2022). Furthermore, estimating heart rate variability indices from ECG segments that are too short could generate some problems in diagnosis. RR intervals in dogs show significant nonlinear fluctuations influenced by the circadian rhythm. Consequently, extrapolations based on brief recordings carry the risk of misinterpretation in clinical contexts. Future studies should standardize ECG monitoring durations, prioritize longer Holter recordings or multi-minute traces, and refrain from substituting pulse palpation with ECG-derived variables to ensure accurate evaluation of autonomic profiles and arrhythmias.

The main conclusions reported in each study – Although the literature regarding the influence of the brachycephalic condition on cardiac autonomic modulation and the occurrence of arrhythmic events in dogs remains limited, the analysis of the conclusions presented in the 11 reviewed articles consistently indicates that the respiratory alterations characteristic of brachycephalic syndrome can induce significant changes in various electrocardiographic monitoring parameters, such as HR, HRV, and autonomic tone indices like the VVTI. Generally, a negative correlation between HR and VVTI was observed, along with a trend toward higher VVTI values in brachycephalic dogs (Doxey and Boswood, 2004; Trauffler et al., 2019); however, these differences were not always statistically significant across breeds (Fernandes et al., 2024). This disparity in information may arise from variations in the experimental models used, primarily related to the characterization of brachycephalic breeds and the presence or absence of BOAS, as well as the methodological strategies applied in the acquisition of electrocardiographic variables.

The primary factor influencing cardiac activity in brachycephalic dogs seems to be vagal overstimulation resulting from chronic upper airway obstruction, a condition that improves following surgical interventions such as rhinoplasty (Santos Filho et al., 2020; Žgank et al., 2023). However, multiple complementary factors affect the relationship between brachycephaly and cardiac activity. In this context, the studies reviewed indicate that physical exercise produces more significant cardiac adaptations in brachycephalic breeds due to their heightened susceptibility to alveolar hypoxia (Tarelho et al., 2023), which is associated with both physiological arrhythmias, such as respiratory sinus arrhythmia (Doxey and Boswood, 2004; Dias et al., 2016; Canola et al., 2018), or pathological arrhythmias, such as those triggered by chronic hypoxemia (Canola et al., 2018). Therefore, we believe that, despite existing evidence, the relationship between brachycephaly and heart rhythm in dogs is influenced by various factors that must be considered when interpreting it. Furthermore, additional studies with enhanced methodological consistency are still needed to draw more robust and clinically applicable conclusions.

Despite the diversity of information gathered in this scoping review, several significant limitations were identified. First, the number of included studies was limited and exhibited substantial methodological heterogeneity, which prevented a quantitative analysis of the variables studied. Additionally, due to the selection criteria applied, it is possible that some studies were excluded because they did not explicitly address the topic of interest in their title, abstract, or keywords, even though they contained tangentially relevant information within the main body of the text. Lastly, although we searched grey-literature repositories like OSF, SYREAF, and VetSRev for non-indexed work, our synthesis was limited to peer-reviewed articles; therefore, unpublished or non-indexed materials may not have been systematically included. Future studies should consider these methodological issues to improve the scope and depth of the analysis.

5. Conclusion

This Scoping Review provides evidence regarding autonomic cardiac activity and the presence of arrhythmias in brachycephalic dogs. Although there are a limited number of studies with methodological diversity, the evidence suggests that vagal overstimulation resulting from chronic upper airway obstruction in these breeds significantly influences heart rate and rhythm modulation. Future

research should focus on achieving methodological standardization, detailed morphometric evaluations, and utilizing long-term monitoring techniques to improve diagnostic accuracy and clinical relevance.

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6. References

Abbott JA. Heart rate and heart rate variability of healthy cats in home and hospital environments. Journal of feline medicine and surgery, 7:195–202. 2005. https://doi.org/10.1016/j.jfms.2004.12.003

Birettoni F, Porciello F, Rueca F, Fruganti G. 24-hour ambulatory electrocardiography in the dog. Veterinary research communications, 28:323–325. 2004. https://doi.org/10.1023/b:verc.0000045437.71719.17

Calvet C, Seebeck P. What to consider for ECG in mice with special emphasis on telemetry. Mamm Genome, 34:166–179. 2023. https://doi.org/10.1007/s00335-023-09977-0

Canola RAM, Sousa MG, Braz JB, Restan WAZ, Yamada DI, Silva-Filho JC, Camacho AA. Cardiorespiratory evaluation of brachycephalic syndrome in dogs. Pesq. Vet. Bras, 38:1130-1136. 2018. https://doi.org/10.1590/1678-5150-PVB-5376

Carabalona JPR, Le Boedec K, Poncet CM. Complications, prognostic factors, and long-term outcomes for dogs with brachycephalic obstructive airway syndrome that underwent H-pharyngoplasty and ala-vestibuloplasty: 423 cases (2011-2017). Journal of the American Veterinary Medical Association, 260:S65–S73. 2021. https://doi.org/10.2460/javma.20.09.0534

Dagnall C, Wilson H, Khenissi L. An investigation into the detection of the pulse in conscious and anaesthetized dogs. Vet Anaesth Analg, 49: 589-596. 2022. https://doi.org/10.1016/j.vaa.2022.08.005

DeMars MM, Perruso C. MeSH and text-word search strategies: precision, recall, and their implications for library instruction. Journal of the Medical Library Association,110:23–33. 2022. https://doi.org/10.5195/jmla.2022.1283

Dias MLM, Morris CFM, Moreti BM, Espírito-Santo AV, McManus CM, Almeida RM, Galera PD. Anatomical, Cardiovascular, and Blood Gas Parameters in Dogs with Brachycephalic Syndrome**.** Acta Scientiae Veterinariae, 44:1356. 2016. https://doi.org/10.22456/1679-9216.80932

Doxey S, Boswood A. Differences between breeds of dog in a measure of heart rate variability. Veterinary Record, 154:713-717. 2004. https://doi.org/10.1136/vr.154.23.713

Dupré G, Heidenreich D. Brachycephalic Syndrome. Vet Clin North Am Small Anim Pract, 46:691–707. 2016. https://doi.org/10.1016/j.cvsm.2016.02.002

Fernandes SL, Conti LMC, Souza MR, Artuzo RM, Bascherotto JS, Gnoatto FLC, Champion T. Heart rate variability and vasovagal tone index in brachycephalic dogs. An Acad Bras Cienc, 96:e20231250. 2024. https://doi.org/10.1590/0001-3765202420231250

Flanders, W. H., Moïse, N. S., & Otani, N. F. (2024). Use of machine learning and Poincaré density grid in the diagnosis of sinus node dysfunction caused by sinoatrial conduction block in dogs. Journal of Veterinary Internal Medicine, 38:1305 1324. https://doi.org/10.1111/jvim.17071

Junior AFM, Vaz KF, Tanaka BMBS, Araújo JM, Mothé GN, Soares AMB, Almosny NRP. Anatomical and clinical aspects of brachycephalic syndrome: literature review, Research, Society and Development, 10: e269101321221. 2021. https://doi.org/10.33448/rsd-v10i13.21221

Liu NC, Adams VJ, Kalmar L, Ladlow JF, Sargan DR. Whole-Body Barometric Plethysmography Characterizes Upper Airway Obstruction in 3 Brachycephalic Breeds of Dogs. J Vet Intern Med, 30(3):853–865. 2016. https://doi.org/10.1111/jvim.13933

Liu NC, Troconis EL, Kalmar L, Price DJ, Wright HE, Adams VJ, Sargan DR, Ladlow JF. Conformational risk factors of brachycephalic obstructive airway syndrome (BOAS) in pugs, French bulldogs, and bulldogs. PLoS ONE, 12:e0181928. 2017. https://doi.org/10.1371/journal.pone.0181928

Matsunaga T, Harada T, Mitsui T, Inokuma M, Hashimoto M, Miyauchi M, Murano H, Shibutani Y. Spectral analysis of circadian rhythms in heart rate variability of dogs. AJVR,62:37-42. 2001. https://doi.org/10.2460/ajvr.2001.62.37

Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med, 6: e1000097. 2009. https://doi.org/10.1371/journal.pmed.1000097

Moïse NS, Flanders WH, Pariaut R. Beat-to-beat patterning of sinus rhythm reveals non-linear rhythm in the dog compared to the human. Front Physiol, 10:1548. 2020. https://doi.org/10.3389/fphys.2019.01548

Noszczyk-Nowak A, Michałek M, Kałuża E, Cepiel A, Pasławska A. Prevalence of arrhythmias in dogs examined between 2008 and 2014. Journal of Veterinary Research, 61:103-110. 2017. https://doi.org/10.1515/jvetres-2017-0013

Packer RM, Hendricks A, Tivers MS, Burn CC. Impact of Facial Conformation on Canine Health: Brachycephalic Obstructive Airway Syndrome. PloS one, 10:e0137496. 2015. https://doi.org/10.1371/journal.pone.0137496

Romito G, Castagna P, Sabetti MC, Cipone M. Electrocardiographic findings in healthy Cavalier King Charles Spaniels, Pugs, and English Bulldogs. Journal of the American Veterinary Medical Association, 261:688-695. 2023. https://doi.org/10.2460/javma.22.12.0542

Salvador-Oliván JA, Marco-Cuenca G, Arquero-Avilés R. Errors in search strategies used in systematic reviews and their effects on information retrieval. J Med Libr Assoc, 107:210-221. 2019. https://doi.org/10.5195/jmla.2019.567

Santilli R, Moïse NS, Pariaut R, Perego M. (2019) Electrocardiografía de perros y gatos, diagnóstico de arritmias. 2da edición. Editorial edra. Zaragoza - España. 360p

Santos Filho M, Hainfellner DC, Lemos NMO, Macambira, KDB, Carmo JS, Alberigi BRS, Athar CVA, Mendes Junior AF, Veiga CCP, Soares AMB, Botteon PTL, Fernandes JI, Paiva JP. Study of heart rate variability in dogs with brachycephalic syndrome that underwent rhinoplasty. Brazilian Journal of Veterinary Medicine, 42:e104920. 2020. http://dx.doi.org/10.29374/2527-2179.bjvm104920

Silva J da, Gonçalves BP, Machado E de OSL, Paiva BA dos S, Carvalho EB, Filho M dos S. Electrocardiographic findings in dogs with obstructive airway diseases. Acta Veterinaria Brasilica, 16:166-171. 2022. https://doi.org/10.21708/avb.2022.16.2.10838

Stracina T, Ronzhina M, Redina R, Novakova M. Golden Standard or Obsolete Method? Review of ECG Applications in Clinical and Experimental Context. Frontiers in physiology, 13:867033. 2022. https://doi.org/10.3389/fphys.2022.867033

Tarelho BB, Garcia Youssef A, Maingué AP, Benedito GS, Eugênio Luz P, Gava FN. Baseline and Post Exercise Electrocardiography in Brachycephalic Dogs. Acta Scientiae Veterinariae, 51:1907. 2023. https://doi.org/10.22456/1679-9216.128359

Trauffler L, Schuller S, Kovacevic A, Tichy A. Establishing reference standards for the vasovagal tonus index in a cohort of healthy French Bulldogs. Schweizer Archiv für Tierheilkunde, 161:821–829. 2019. https://doi.org/10.17236/sat00238

Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, Moher D, Peters MDJ, Horsley T, Weeks L, Hempel S, Akl EA, Chang C, McGowan J, Stewart L, Hartling L, Aldcroft A, Wilson MG, Garritty C, Lewin S, Godfrey CM, Macdonald MT, Langlois EV, Soares-Weiser K, Moriarty J, Clifford T, Tunçalp Ö, Straus SE. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Annals of internal medicine, 169:467–473. 2018. https://doi.org/10.7326/M18-0850

Wiegel PS, Nolte I, Mach R, Freise F, Bach JP. Reference ranges for standard echocardiography in pugs and impact of clinical severity of Brachycephalic Obstructive Airway Syndrome (BOAS) on echocardiographic parameters. BMC Vet Res, 18:282. 2022. https://doi.org/10.1186/s12917-022-03348-8

Žgank Ž, Nemec-Svete A, Lenasi H, Vodičar J, Erjavec V. The effect of the surgical treatment of brachycephalic obstructive airway syndrome on the thermoregulatory response to exercise in French bulldogs: a pilot study. Frontiers in Veterinary Science, 10:1229687. 2023. https://doi.org/10.3389/fvets.2023.1229687