Received: 16 June 2022 | Revised: 15 February 2023 | Accepted: 2 April 2023

DOI: 10.1111/vsu.13964

WILEY

CLINICAL RESEARCH

Influence of extreme brachycephalic conformation on perioperative complications associated with total ear canal ablation and lateral bulla osteotomy in 242 dogs (2010–2020)

Charlotte Banks BVMedSci (Hons), BVM BVS (Hons), PGDipVCP, MRCVS[1] | **Lee Beever BVetMed (Hons), MVetMed, PGCert, FHEA, DiplECVS, MRCVS**[2] | **Benjamin Kaye BVSc, MANZCVS (ECC), MVetMed, DipECVS**[3] | **Merianna Foo BA(Maths&Socio), PGDE (Math&Eng), BSc, DVM (Distinct)**[3] | **Gert ter Haar DVM, PhD, DiplECVS**[4] | **Lynda Rutherford BVM&S, MVetMed, PGCert VetEd, FHEA, DiplECVS, MRCVS**[1]

[1]Department of Clinical Science and Services, Queen Mother Hospital for Animals, Royal Veterinary College, London, UK

[2]Massey University, Palmerston North, New Zealand

[3]Southpaws Speciality and Referral Hospital, Melbourne, Australia

[4]Anicura Specialistische Dierenkliniek Utrecht, Utrecht, The Netherlands

Correspondence
Charlotte Banks, Department of Clinical Science and Services, Queen Mother Hospital for Animals Royal Veterinary College, London, UK.
Email: cbanks7@rvc.ac.uk

Abstract

Objective: To determine the influence of extreme brachycephalic conformation on presenting signs, imaging findings, intraoperative and perioperative complications following total ear canal ablation and lateral bulla osteotomy (TECA-LBO).

Study design: Cross-sectional retrospective study.

Animals: A total of 306 ($n = 242$ dogs) TECA-LBOs (extreme brachycephalic breeds [EBB] = 81, other breeds [OB] = 225).

Methods: Medical records of patients undergoing TECA-LBO at a single referral institution (2010–2022) were evaluated.

Results: Extreme brachycephalic breeds most commonly presented acutely, at a younger age with oto-neurological signs (46/81, 56.8%). Chronic otitis externa without neurological signs (171/225, 76.0%) was most common in OBs. Extreme brachycephalic breeds preoperatively presented more frequently with facial nerve paresis ($p = .001$), vestibular syndrome ($p = .001$), and Horner's syndrome ($p = .002$) compared to OBs. On diagnostic imaging, bilateral changes ($p = .038$), aural masses ($p = .045$), para-aural abscesses ($p = .011$), otitis interna ($p = .001$), and brainstem changes ($p = .001$) were more common in EBBs. The apparent difference in intraoperative complication rate between EBBs (9/81, 11.1%) and OBs (12/225, 5.3%) did not reach statistical significance ($p = .078$). Perioperative complications occurred in 85/306 (27.8%) of TECA-LBOs with no difference in perioperative complication rate between EBBs (19/81, 23.5%) and OBs (66/225, 29.3%) ($p = .586$).

ECVS Poster Presentation: Preliminary dataset displayed as a poster at ECVS Congress, July 2021.

Conclusion: Extreme brachycephalic breeds are more likely to present for TECA-LBO acutely, with neurological signs and more advanced diagnostic imaging abnormalities. Intra- and perioperative complication rates did not differ between EBBs and OBs.

Clinical significance: Despite being subjectively more technically challenging, TECA-LBO did not result in more surgical complications in EBBs. Reported data are useful for effectively informing clients of the specific risks of TECA-LBO surgery.

1 | INTRODUCTION

Total ear canal ablation with lateral bulla osteotomy (TECA-LBO) is a salvage surgery performed to treat end-stage otitis externa (OE), otitis media (OM), otitis interna (OI), auricular neoplasia or tympanokeratoma (cholesteatoma) in dogs.[1–3] TECA-LBO is technically challenging due to the anatomic complexity of the region. Poor access and visualization of critical neurovascular structures including the facial nerve, retroarticular vein, external carotid artery, and maxillary vein may lead to iatrogenic damage resulting in perioperative complications.[4,5] Incomplete debridement of the epithelial lining of the external acoustic meatus may result in latent para-aural abscessation, which typically manifests 5.5–10 months postoperatively.[1,6]

The most commonly encountered major intraoperative complication is severe hemorrhage from the retroarticular vein, maxillary vein, or external carotid artery during dissection around the external acoustic meatus.[1] Significant hemorrhage requiring a blood transfusion has been reported in 5.5%–15.6% of cases.[7,8] Overall postoperative complication rates range from 21% to 53%.[4,8–10] Wound-related complications include surgical site infection, fistulation, para-aural abscessation, and persistent drainage tracts (2%–50%).[1,7] Neurological complications include facial nerve paresis or paralysis (13%–36%), Horner's syndrome (3.3%), vestibular disease (1%–8%), and hypoglossal nerve dysfunction (3%–8%).[11–14]

French Bulldogs, English Bulldogs, and Pugs have been referred to as extreme brachycephalic breeds (EBBs).[15] Recent studies have demonstrated significant divergence of EBBs from other brachycephalic and non-brachycephalic breeds in terms of overall health and specific disease predispositions including stenotic nares, brachycephalic obstructive airway syndrome (BOAS), aural discharge, and lower respiratory disease.[16–18] Computed tomographic conformational studies carried out in these breeds have demonstrated distinct differences in the anatomy of the tympanic bullae in EBBs including bulla volume, wall thickness, and position in relation to the temporomandibular joint compared with all other breeds (OB).[19] Furthermore, stenotic malformation of the porous proximal external auditory canal resulting in a 50% reduction in the lumen compared with normocephalic dogs has been demonstrated on computed tomography (CT) examination.[20] This malformation may predispose to or complicate the treatment of OE and OM.[20] In the primary author's institution, the number of EBBs, primarily French Bulldogs, presenting for TECA-LBO has increased in recent years. Subjectively, otic surgery in EBBs is considered more technically challenging compared to OBs.

To the authors' knowledge, the complication rate following TECA-LBO in EBBs has not been reported. The purpose of our study was to investigate and compare presenting clinical signs and diagnostic imaging findings in a cohort of EBBs and OBs and to determine intraoperative and perioperative complication rates following TECA-LBO. The hypothesis was that EBBs would have higher complication rates than OBs.

2 | MATERIALS AND METHODS

2.1 | Patient and clinical data

The study was approved by the institutional Ethical Review Board at the lead institution (URN SR2019-0199) prior to commencement.

Electronic medical records were reviewed to include dogs that underwent TECA-LBO at a single institution between January 2010 and December 2020. Cases that presented for the management of complications resulting from TECA-LBOs performed at other institutions and cases with reports with inadequate detail regarding presenting signs, treatment, or perioperative outcome were excluded. Cases undergoing concurrent procedures including corrective multilevel upper airway surgery were excluded.

Case details were collected, including signalment, bodyweight, history, clinical signs, duration of presenting complaint, lateralization of clinical signs, and diagnostic

imaging findings (computed tomography, magnetic resonance imaging, or both). Breed data were categorized into two groups: EBBs (French Bulldogs, English Bulldogs, and Pugs) or all OBs. Duration of clinical signs was categorized into four groups: less than 2 weeks, greater than 2 weeks but less than 2 months, 2 to 6 months, and greater than 6 months. The primary presenting complaint was categorized into four groups: (1) Otitis externa without neurological signs, (2) otitis externa, OM, or OI with neurological signs (including peripheral vestibular syndrome, Horner's syndrome, facial nerve paresis or paralysis), (3) aural mass (including those affecting the pinna, vertical and horizontal canal) and (4) other (including maxillary pain, facial swelling, and fistulous tract). For this study, facial nerve deficits were referred to as paresis rather than paralysis as not all cases had a complete inability to move the muscles of the eyelid, ears, and lips. Clinical signs of BOAS including tachypnea, dyspnea, upper respiratory stertor or stridor, exercise intolerance, or cyanotic episodes were recorded.

Diagnostic imaging reports were assessed, and imaging modality and findings were recorded. Specific findings from the diagnostic imaging report included the presence of the following: unilateral or bilateral pathology, ear canal mineralization, an aural mass affecting the pinnal base, vertical canal or horizontal canal, para-aural abscessation, middle ear soft tissue opacity, OI and evidence of brainstem changes. Brainstem changes were described as T2-weighted ± fluid-attenuated inversion recovery (FLAIR) interaxial hyperintensity and meningeal enhancement on magnetic resonance imaging (MRI) and intracranial contrast enhancement on CT.

The surgical records were examined for each patient. TECA-LBO surgeries were either performed uni- or bilaterally. If bilateral surgery was performed, data for each ear were considered separately. Bilateral procedures were classified as single-session when left and right TECA-LBOs were performed under the same general anesthetic. Bilateral staged procedures were classified when left and right TECA-LBOs were performed separately within any time frame. The anesthetic record was examined to determine the surgical time for each operated ear. All surgeries were performed by a board-certified specialist in Small Animal Surgery or a resident under the direct supervision of a specialist.

Intraoperative complications, defined as complications occurring between skin incision to closure, were recorded in the medical records at the time of surgery. When available, microbiology results including the location from which the sample was obtained, and the culture result were recorded. If a surgical drain was placed before closure, the type of drain and time that it remained in place was recorded in days.

Duration of hospitalization and survival to discharge were recorded in days. Follow-up information was included up to the time of discharge. Patient hospitalization records were examined and the occurrence of new postoperative clinical examination findings including facial nerve paresis, vestibular signs, Horner's syndrome, hemorrhage, extensive focal swelling around the surgical wound, and incisional dehiscence was recorded.

Information regarding perioperative management was ascertained from detailed hospital sheets. Postoperative monitoring included 24-h monitoring in intensive care or surgery ward depending on respiratory and cardiovascular stability. Opioid analgesia was provided for all cases with the drug, frequency, and dose individualized to the patient based on pain scoring. Where intra- and perioperative antimicrobial and nonsteroidal anti-inflammatory drugs (NSAIDs) were prescribed, the drug and duration of treatment were recorded.

2.2 | Statistical analysis

All statistical analyses were performed using commercially available software (IBM SPSS, Statistics, version 28.0, IBM Corp, Armonk, New York). Data were assessed for normality using Shapiro–Wilk. Descriptive statistics were generated to report signalment; bodyweight; duration of clinical signs; primary presenting complaint; diagnostic imaging findings; surgical time; placement, duration, and type of drain; occurrence and nature of intra- and perioperative complications; type and duration of antimicrobial and anti-inflammatory medications; hospitalization duration and survival to discharge.

Comparison of outcomes for all variables between groups were assessed using independent sample *t*-test or Mann–Whitney U test for normally and non-normally distributed variables, respectively.

Chi-square test for independence assessed the association between breed group and presenting signs, imaging findings, intra- and postoperative complications, unilateral, bilateral single-session, and staged surgeries, medications, and survival to discharge. Significance was set at the 5% level and all tests were two-tailed.

3 | RESULTS

A total of 306 TECA-LBOs performed in 242 dogs were included. Eighty-one and 225 TECA-LBOs were performed in EBBs and OBs, respectively. Signalment data is reported in Table 1. Dogs in the EBB group were younger at the time of surgery compared to dogs in the OB group ($p = .000$). No difference was detected in the

TABLE 1 Summary of signalment data for extreme brachycephalic and other breeds.

Breed group	Dogs	TECA-LBOs performed (*n*)	Mean age (years, months)	Mean weight kg (range)	Laterality of operated ear		Gender category			
					Left	Right	FE	FN	ME	MN
Total	242	306	6y 5 m ± 2y 10 m	15.8 (3.7–73)	161	145				
Extreme Brachycephalic breeds	69	81	5y 3 m ± 2y 4 m	14.7 ± 6.7 kg	42	39	11	9	37	32
French Bulldog	44	49								
Pug	15	19								
English Bulldog	10	13								
Other Breeds	173	225	6 year 11 m ± 2y 11 m	22.3 kg ± 13.2 kg	119	106	61	35	84	45
Cocker Spaniel	27	38								
Cross Breed	22	25								
Labrador Retriever	15	18								
West Highland White Terrier	12	14								
Staffordshire Bull Terriers[a]	11	17								
English Springer Spaniel	9	11								
Shar Pei[a]	8	13								
Cavalier King Charles Spaniel[a]	7	8								
Boxer[a]	6	7								
Rottweiler[a]	5	7								
Shih Tzu[a]	4	4								
German Shepherd	4	5								
Basset Hound	3	4								
Welsh Terrier	3	4								
Jack Russell Terrier	2	3								
St Bernard	2	3								
Bichon Frise	2	2								
Border Terrier	2	2								
Flat-Coated Retriever	2	2								
Hungarian Vizsla	2	2								
Standard Poodle	2	2								
Tibetan Terrier	2	4								
Yorkshire Terrier	2	4								
Afghan Hound	1	2								
Airedale Terrier	1	1								
Beagle	1	1								
Blood Hound	1	2								
Chow Chow[a]	1	1								
Coton De Tulear	1	1								
Dachshund	1	2								
English Pointer	1	1								
Fox Terrier	1	2								
Golden Retriever	1	1								
Grand Basset Griffon Vendeen	1	1								
Irish Setter	1	1								

TABLE 1 (Continued)

Breed group	Dogs	TECA-LBOs performed (*n*)	Mean age (years, months)	Mean weight kg (range)	Laterality of operated ear		Gender category			
					Left	Right	FE	FN	ME	MN
Lhasa Apso[a]	1	1								
Mastiff[a]	1	2								
Newfoundland	1	1								
Patterdale Terrier	1	1								
Polish Sheepdog	1	2								
Sussex Spaniel	1	1								
Toy Poodle	1	2								

Abbreviation: TECA-LBOs, total ear canal ablation and lateral bulla osteotomy.
[a]Represents breeds included that are identified as brachycephalic but do not fall within the extreme brachycephalic breed group.

lateralization of the surgery between breed groups ($p = .790$). Thirty-eight cases were identified to be clinically affected by BOAS at the time of presentation, all were EBBs (38/81, 46.9%). Twenty-two cases (22/38, 57.9%) including 15 French Bulldogs, five Pugs, and two English Bulldogs had undergone previous BOAS surgery.

A total of 57 EBBs (57/81 TECA-LBOs, 70.4%) underwent unilateral surgery, four EBBs (8/81 TECA-LBOs 9.9%) underwent bilateral single-session surgeries, and eight EBBs (16/81 TECA-LBOs, 19.8%) underwent bilateral staged surgeries. A total of 121 (121/225 TECA-LBOs, 53.8%) OBs underwent unilateral surgery, 37 (74/225 TECA-LBOs, 32.9%) underwent bilateral single-session surgeries, and 15 (30/225 TECA-LBOs, 13.3%) underwent bilateral staged surgeries. Extreme brachycephalic breeds were more likely to undergo unilateral surgery compared to OBs ($p = .001$). When bilateral surgery was performed, EBBs were more likely to have staged surgeries compared to OBs ($p = .001$). The median interval between bilateral staged surgeries was 41 days (range 3–1670 days). No difference in surgical interval was detected between groups ($p = .580$).

The median perioperative follow-up period for all breeds was 3 days (range 1–18 days). The median hospitalization period was longer for EBBs than OBs: 4 days (range 1–18) and 3 days (range 1–15) respectively ($p = .026$).

3.1 | Presenting signs

The duration of clinical signs differed between groups ($p = .001$). Extreme brachycephalic breeds most commonly presented with clinical signs <14 days duration (35/81, 43.2%) whilst OBs most commonly presented with chronic signs >6 months duration (104/225, 46.2%). The presenting signs are summarized in Figure 1. The most common presenting signs differed between EEBs and OBs ($p = .001$). Extreme brachycephalic breeds most commonly presented with OE, OM, or OI with neurological signs (46/81, 56.8%) whereas OBs most commonly presented with OE alone (171/224, 76.0%). Other causes included maxillary pain in six cases, para-aural abscessation in five cases, and trauma to the ear canal in two cases. Specific preoperative neurological signs are summarized in Table 2. Extreme brachycephalic breeds were more likely to present with facial nerve paresis ($p = .001$), vestibular syndrome ($p = .001$), and Horner's syndrome ($p = .02$).

3.2 | Diagnostic imaging findings

Advanced diagnostic imaging studies were performed in 281/306 (90.0%) of ears. The imaging modality performed in EBBs and OBs is demonstrated in Table 3. A higher proportion of EBBs underwent both CT and MRI and MRI alone compared to OBs ($p = .01$). Specific imaging findings between breed groups are summarized in Table 4. Bilateral changes were more frequently identified in OBs. Canal mineralization, ear canal mass, para-aural abscess formation, OI, and brainstem changes were more frequently identified in EBBs (Figure 2).

When imaging findings were compared between presenting sign categories, dogs with neurological signs were more likely to have OI and brainstem changes than dogs presenting for other reasons ($p = .001$). No difference was detected in the presence of unilateral versus bilateral changes, middle ear effusion, or canal mineralization between presenting sign categories.

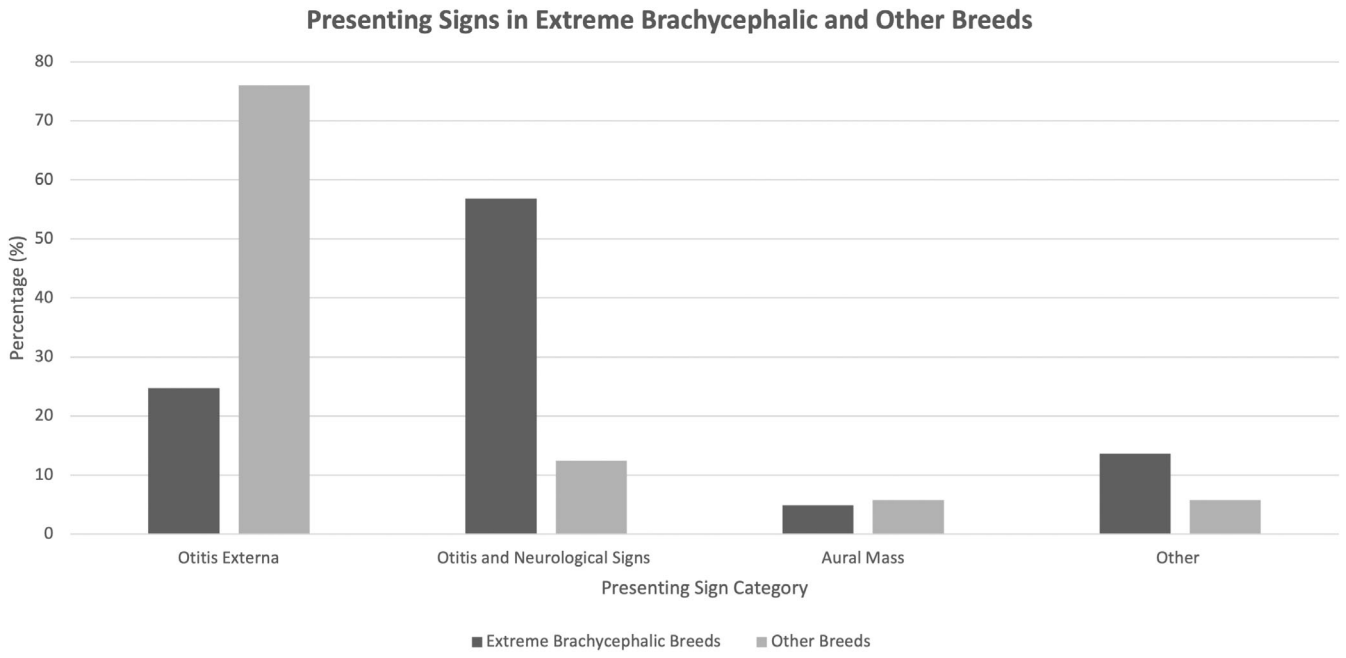

FIGURE 1 Bar chart demonstrating the percentage of extreme brachycephalic (n = 81) and other breeds (n = 225) presenting with each clinical sign.

TABLE 2 Pre- and perioperative neurological signs in extreme brachycephalic and other breeds.

	Preoperative neurological signs			Perioperative neurological signs		
	Extreme brachycephalic breeds (n = 81)	Other breeds (n = 225)	*p*-value	Extreme brachycephalic breeds	Other breeds	*p*-value
Facial nerve paresis	23 (28.4%)	12 (5.3%)	.001	17/58 (29.3%)	43/213 (20.2%)	.138
Vestibular signs	47 (58.0%)	26 (11.5%)	.001	0/34 (0%)	6/199 (3.0%)	.305
Horner's syndrome	6 (7.4%)	2 (0.9%)	.002	1/75 (1.3%)	0/223 (0%)	.084
Other Cranial nerve deficits	3 (3.7%)	2 (0.9%)	.087	0/1 (0%)	0/1 (0%)	.000

Note: *p*-value determined via Pearson's chi-square test.

3.3 | Surgical details and intraoperative complications

Intraoperative complications occurred during 21/306 (6.9%) TECA-LBOs including 9/178 (5.1%) unilateral surgeries, 8/82 (9.8%) bilateral single-session, and 4/46 (8.7%) bilateral staged surgeries. No difference in overall intraoperative complication rate between unilateral, bilateral single-session, and bilateral staged surgeries was detected ($p = .329$). Intraoperative complications included iatrogenic hemorrhage in 16/21 (76.2%) TECA-LBOs and difficulty in identifying bony landmarks reported to increase surgical time in 6/21 (28.6%) cases. Intraoperative complications were more frequent in EBBs (9/81, 11.1%) compared to OBs (12/225, 5.3%). The apparent difference in intraoperative complication rate did not reach statistical significance ($p = .078$). One French Bulldog required a packed red blood cell transfusion intraoperatively. All other hemorrhage was managed with either digital pressure or

TABLE 3 Imaging modality performed in extreme brachycephalic and other breeds.

	Study performed in each breed group	
Imaging modality	Extreme brachycephalic Breeds	Other breeds
CT only	58 (71.6%)	180 (80.0%)
MRI only	10 (12.3%)	14 (6.2%)
Both CT and MRI	12 (14.8%)	7 (3.1%)

Note: *p*-value determined via Pearson's chi-square test = 15.397. $p < .001$.

TABLE 4 Imaging findings in extreme brachycephalic and other breeds.

Imaging findings	Extreme brachycephalic breeds ($n = 81$)	Other breeds ($n = 200$)	p-value
Bilateral changes	49 (61.3%)	95 (47.5%)	.038
Mineralization of the external ear canal	33 (41.3%)	101 (50.5%)	.162
Aural mass	8 (10.0%)	40 (20.0%)	.045
Para-aural abscess	13 (16.3%)	13 (6.5%)	.011
Middle ear effusion	60 (75.0%)	133 (68.2%)	.263
Otitis interna	37 (46.3%)	17 (8.5%)	.001
Brainstem changes	14 (17.5%)	6 (3.0%)	.001

Note: p-value determined via Pearson's chi-square test.

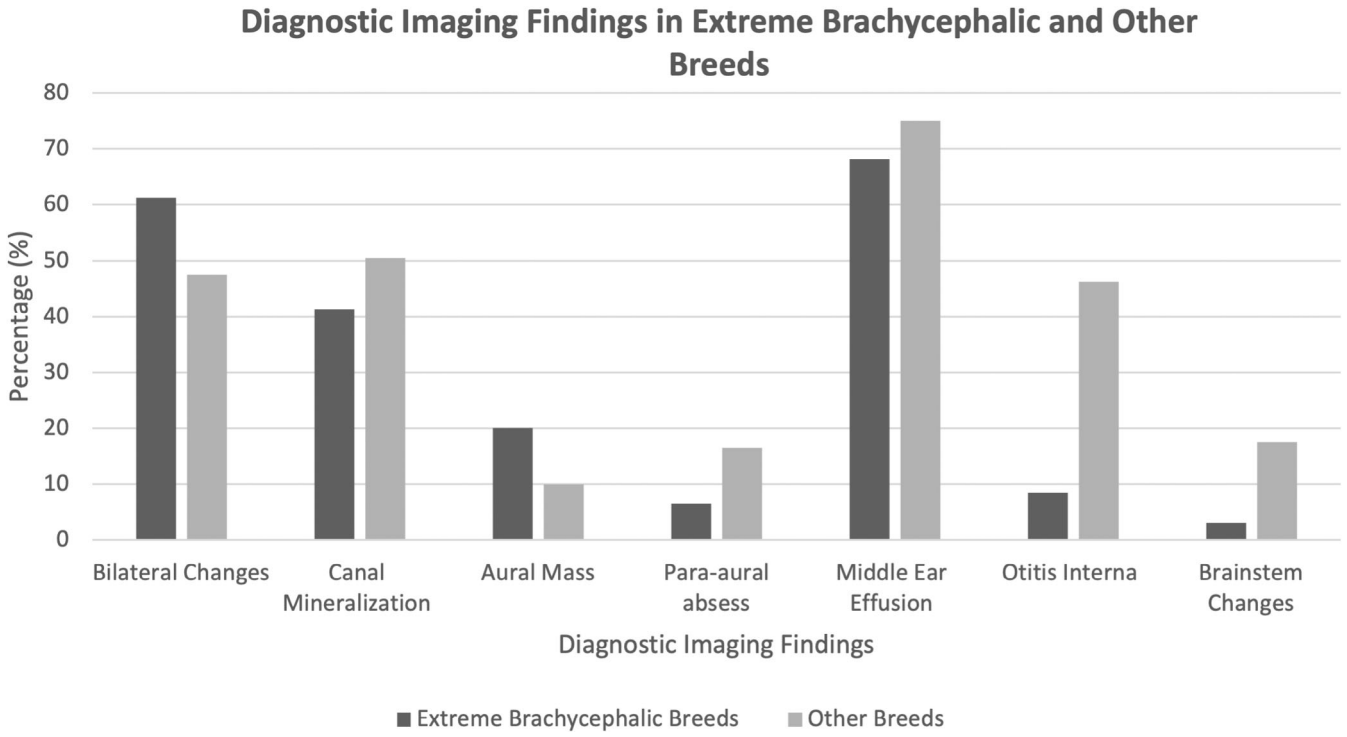

FIGURE 2 Bar chart demonstrating preoperative diagnostic imaging findings between extreme brachycephalic (n = 81) and other breeds (n = 225).

topical hemostatic agents. Overall median surgical time for each ear was 100 min (30–255). Median surgical time was longer in EBBs than in OBs; 115 min (35–242) versus 95 min (30–255) ($p = .011$) (Figure 3).

Surgical drains were placed in 113/306 (36.9%) TECA-LBOs. An active suction drain was placed in 2/113 (1.7%) and a Penrose drain was placed in the remaining 111/115 (96.5%). Drains were placed in 31/81 (38.3%) TECA-LBOs in EBBs and 82/225 (36.4%) TECA-LBOs in OBs. Drains were left in place for a median of 2 days in both EBBs and OBs with a range of 1–3 and 1–5 days respectively. No difference in drain placement or

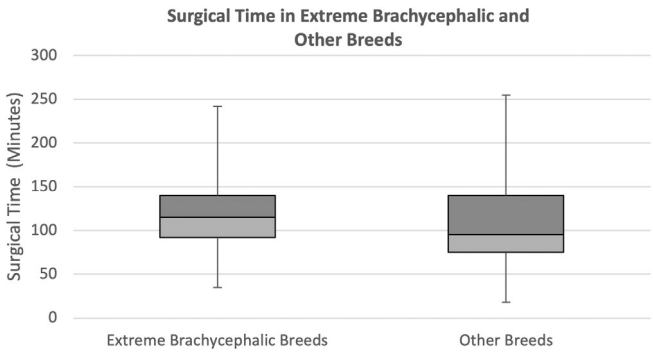

FIGURE 3 Box and Whisker plot demonstrating surgical times in extreme brachycephalic and other breeds.

TABLE 5 Microbiology isolates from positive middle ear or ear canal cultures in extreme brachycephalic and other breeds. Numbers represent individual total ear canal ablation and lateral bulla osteotomy (TECA-LBO) results.

Cultured organism	Extreme brachycephalic breed	Other breeds	Total count (all dogs)
Staphylococcus pseudintermedius	34	50	84
Enterococcus faecalis	22	50	72
Pseudomonas aeruginosa	7	48	55
Escherichia coli	7	32	39
Proteus mirabilis	10	15	25
Streptococcus canis	3	19	22
Bacteroides spp.	3	6	9
Staphylococcus aureus	4	3	7
Pasteurella spp.	3	3	6
Malassezia pachydermatis	0	6	6
Corynebacterium spp.	2	3	5
Staphylococcus schleiferi	2	2	4
Methicillin-resistant Staphylococcus pseudintermedius	4	0	4
Methicillin-resistant Staphylococcus aureus	0	1	1
Enterobacter spp.	0	1	1
Streptococcus dysgalactiae	0	1	1
Total	101	240	341

duration was detected between groups ($p = .646$ and $p = .535$, respectively).

Two EBBs (both English Bulldogs) and one OB (Staffordshire Bull Terrier) underwent an elective temporary tracheostomy postoperatively due to marked, pre-existing pharyngeal swelling resulting from paraaural abscessation. No dogs required emergency temporary tracheostomy.

Microbiology results were available for 270/306 TECA-LBOs (88.2%) and culture was positive in 204/270 TECA-LBOs (75.6%). Samples were taken from the tympanic bullae in 187 cases, the external ear canal in 24 cases and the site was unspecified in 15 cases. A total of 341 microbes were isolated in total, including 15 bacterial isolates and one fungal isolate. The microbiology results are demonstrated in Table 5.

3.4 | Perioperative complications

Overall perioperative complications occurred following 85/306 (27.8%) TECA-LBOs including 47/178 unilateral (26.4%), 20/82 bilateral single-session (24.4%), and 18/46 bilateral staged surgeries (39.1%). No difference in perioperative complication rate was detected between unilateral, bilateral single-session, and bilateral staged surgeries ($p = .166$).

Facial nerve paresis occurred postoperatively in 60/271 TECA-LBOs (22.1%); postoperative vestibular syndrome occurred in 6/233 TECA-LBOs (2.6%); postoperative Horner's syndrome occurred in 1/298 (0.3%) TECA-LBOs; postoperative hemorrhage occurred in 4/306 (1.3%) TECA-LBOs; postoperative wound swelling occurred in 10/306 (3.3%); wound dehiscence within the hospitalization period occurred in 13/306 (4.2%) surgeries (Figure 4). No difference in perioperative complication rate was detected between EBBs (19/81, 23.5%) and OBs (66/225, 29.3%) for any complication ($p = .311$) (Table 6).

3.5 | Perioperative medications

Broad-spectrum intravenous antimicrobials were administered intraoperatively to all cases. Postoperative antimicrobials were prescribed in 237/306 (77.5%) TECA-LBOs (64/81, 79.0% of EBBs and 173/225, 76.9% of OBs) with no difference between breed groups ($p = .274$). Amoxicillin clavulanate was prescribed in 125/237 (52.7%, cephalexin in 98/237) (41.4%), enrofloxacin in 12/237 (5.1%), and clindamycin in 2/237 (0.01%). Antimicrobials were prescribed for a median of 8 days postoperatively (range 1–56). No difference in the choice of antimicrobial or duration of prescription was detected between groups ($p = .552$ and $p = .271$ respectively).

TABLE 6 Perioperative complications in extreme brachycephalic and other breeds.

Perioperative complication	Extreme brachycephalic breeds (n = 81)	Other breeds (n = 225)	*p*-value
Hemorrhage	0 (0%)	4 (1.8%)	227
Swelling	1 (1.2%)	9 (4.0%)	.230
Wound complication	1 (1.2%)	3 (5.7%)	.093

Note: *p*-value determined by Pearson's chi-square test.

Intra- and perioperative complication rates did not differ when antimicrobials were prescribed ($p = .796$ and $p = .408$, respectively).

NSAIDs were prescribed in 228/306 (74.5%) of TECA-LBOs (58/81, 71.6% of EBBs and 170/225, 75.6% OBs) with no difference detected between groups ($p = .484$). NSAIDs were prescribed for a median of 7 days (3–14 days). No difference in NSAID course duration was detected between groups. Intra- or perioperative complication rates did not differ when NSAIDs were prescribed ($p = .078$ and $p = .311$, respectively).

3.6 | Survival to discharge

Reasons for prolonged hospitalization included wound management following surgical site dehiscence (7), the severity of neurological signs (2) and hospitalization for the duration between staged surgeries (2), and management of corneal ulceration (2) and upper respiratory obstruction (2). Prolonged hospitalization in one dog was due to an investigation of unrelated narcolepsy.

Two dogs did not survive to discharge including one EBB and one OB (0.70%). A 5-year 1-month-old female entire English Bulldog underwent bilateral single-session TECA-LBO for the treatment of chronic OE. The dog developed postoperative aspiration pneumonia and had a cardiopulmonary arrest 4 days postoperatively. The second case was a 7-year 5-month-old female neutered Bichon Frise who underwent unilateral TECA-LBO for treatment of a para-aural abscess. The dog developed sepsis and acute kidney injury and had a cardiopulmonary arrest 2 days postoperatively.

4 | DISCUSSION

This study is the largest to date exploring the presenting signs, diagnostic imaging findings, and intra- and perioperative complications in dogs undergoing TECA-LBO and the first to compare these factors amongst two groups: EBBs and OBs.[4,7,9,10,14]

The perioperative complication rate of 27.8% is at the lower end of the range of previously reported complications for TECA-LBO (21%–53%).[9,21] The occurrence of perioperative facial nerve paresis and vestibular signs were similar to previously reported values.[1] Wound complications occurred in 5.8% of cases which is lower than previously reported (11%–41%).[4,14,21] However, the duration of follow-up in this study varied from previous literature and direct comparisons should be interpreted with caution. Despite the perceived increase in the difficulty of TECA-LBO surgery and the apparent increase in intraoperative complication rates in EBBs compared with OBs, the difference did not reach statistical significance. Thus, our hypothesis was rejected. This may be a result of low numbers of intraoperative complications overall and type I statistical error.

Significant hemorrhage was the most encountered complication in this study. The rate and severity of intraoperative hemorrhage is consistent with previous reports.[4,7] The other intraoperative complication reported in the current study was difficulty in the identification of anatomical landmarks and performing the lateral bulla osteotomy. This was included as an intraoperative complication as the surgery diverged from the ideal course and may have prolonged surgical time. Obtaining intraoperative information was reliant on details in the surgical report due to the retrospective nature of this study. Complications may therefore be underreported. The increased intraoperative complication rate and prolonged surgical time in EBBs supports the anecdotal suggestion that TECA-LBO surgery is considered more challenging in these breeds. Aberrant bulla location, size, thickness of the bony wall, narrow external bony meatus diameter and proximity of neurovascular structures to the surgical site account for these perceived challenges.[19,22–24] The morphology and anatomic position of the tympanic bulla in relation to the temporomandibular joint in French Bulldogs, English Bulldogs, and Pugs differs significantly from all OBs.[19] This makes visualization of the interior of the tympanic bulla more difficult and could theoretically make removal of contents more complicated. Thicker bullae walls in French and English Bulldogs, a larger overlap between the temporomandibular joint and

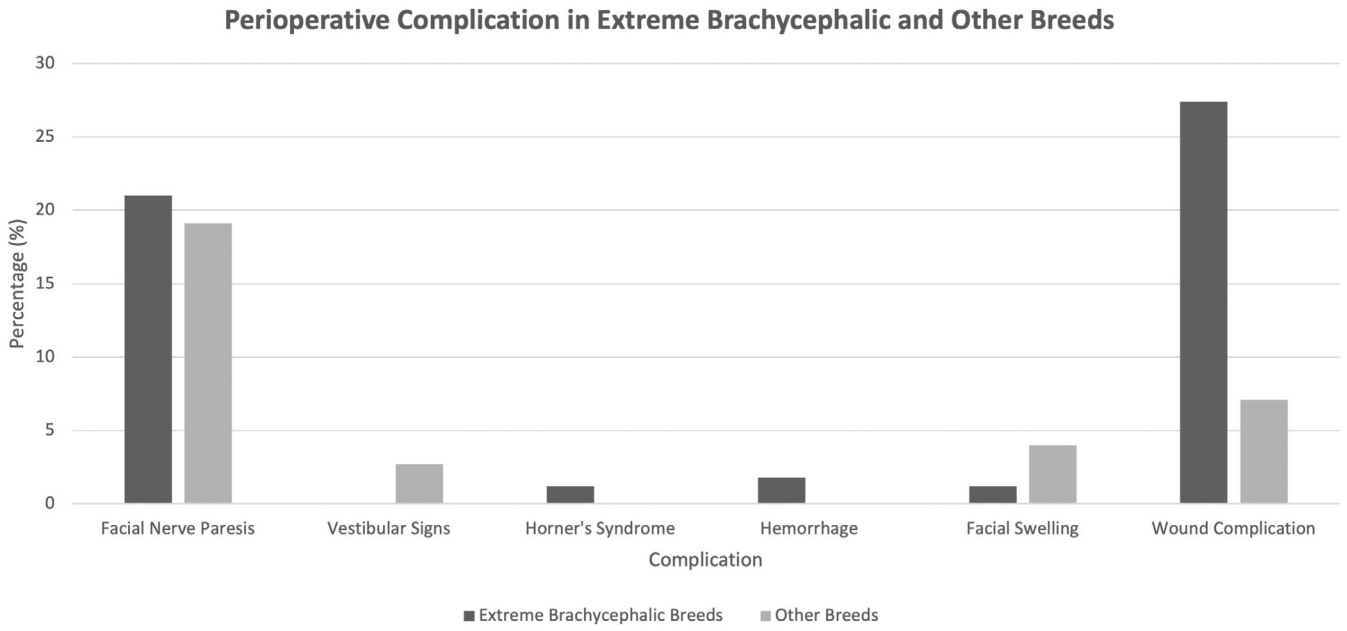

FIGURE 4 Bar chart demonstrating the perioperative complications in extreme brachycephalic (n = 81) and other breeds (n = 225).

tympanic bullae in Pugs and French Bulldogs, and smaller bullae volume: weight ratios have also been described in EBBs adding to difficulties in accessing the surgical sites in these breeds.[19]

Recent studies have also considered these three EBBs to be predisposed to similar conformation-related disease processes and therefore it was deemed appropriate to group them as a single category in our study.[25–28] French Bulldogs were the breed most frequently presented for TECA-LBO in our study, representing 49 of 306 total surgeries.[29] Previous studies have dichotomized breeds as either brachycephalic or nonbrachycephalic. However, recent literature suggests that brachycephaly is not binary.[17,18,22,30,31] Quantitative skull morphometry has demonstrated that dogs with more extreme brachycephalic conformations are at higher risk of conditions such as BOAS.[22] They are 3.5 times more likely to have at least one upper respiratory tract disorder and a significantly shorter life span than moderate brachycephalic or nonbrachycephalic dogs.[15] This is supported by our finding that all dogs reported to be clinically affected by BOAS were EBBs with almost half of these cases requiring previous BOAS surgery. Extreme brachycephalic breeds also presented more frequently for "other" reasons including jaw pain. This may be linked to the occurrence of para-aural abscessation, concurrent OM or the close anatomic association between the tympanic bullae and the temporomandibular joint.[22] This study compared EBBs to all OBs due to the morphological differences summarized above. The results could differ if all brachycephalic breeds were compared to nonbrachycephalic breeds.

One of our major findings was the difference in presenting signs between EBB and OBs. Excluding EBBs, most dogs presented for management of chronic OE without neurological signs. This suggests that TECA-LBO is most commonly performed in OBs as a salvage procedure for end-stage ear canal disease when medical management fails.[21] Conversely, EBBs were significantly more likely to present acutely, at a younger age, with predominantly neurological signs. This is consistent with findings from previous literature which demonstrated that younger age was significantly associated with a diagnosis of OM or OI.[32] Neurological signs were attributed to OM, OI, or intracranial extension of infection in these cases. Previous studies have demonstrated that two-thirds of dogs displaying vestibular signs have a chronic history of OE in addition to OM.[32] For that reason, cases with clinical or radiographic evidence of OE in addition to the primary neurological presenting complaint were still included in the neurological sign category. Fluid accumulation in the middle ear can be an incidental finding in brachycephalic dogs probably due to auditory tube or pharyngeal dysfunction.[33] Our study demonstrated no difference in the incidence of middle ear effusion between breed groups or presenting sign categories. However, given the predominantly neurological presentation in EBBs and the increase in the diagnosis of OI and brain stem changes, further investigation into the precise pathogenesis leading to oto-neurological signs in these breeds

is warranted. The increased incidence of neurological signs may explain the differences in imaging modalities performed in EBBs. Extreme brachycephalic breeds were more likely to have an MRI alone, or in conjunction with CT than OBs. Whilst CT is considered the modality of choice for evaluation of bony structures, MRI provides superior soft tissue contrast of the membranous labyrinth, cerebrospinal fluid, and neural structures, allowing effective differentiation between intra- and extracranial causes of the cranial nerve deficits.[34] The increased incidence of neurological deficits and identification of OI and brainstem changes in EBBs suggests that whilst ultimately the surgery is the same, TECA-LBO was performed for different reasons in these breeds.[27,31] This could have influenced our results.

Perioperative neurological signs were recorded when new abnormal neurological examination findings were evident postoperatively. Cases that presented with neurological signs were not considered to have neurological perioperative complications as it was not possible to determine statistically whether postoperative neurological deficits were due to pre-existing neurological damage or exacerbated by intraoperative trauma. A greater proportion of EBBs than OBs presented with neurological signs, and intraoperative trauma resulting in perioperative neurological complications may be underestimated. Iatrogenic trauma to the neural structures may have been more prevalent in these dogs due to the anatomical reasons discussed previously.

A greater proportion of EBBs underwent unilateral surgery and bilateral surgery was more commonly staged in these dogs, whereas OBs more commonly underwent bilateral single-session TECA-LBO. The surgeon's decision to perform a staged procedure may have been justified based on the anecdotal surgical complexity and increased surgical time in EBBs. However, in support of previous literature, there was no difference in perioperative complication rates between unilateral, single-session bilateral, and staged bilateral TECA-LBO.[7]

Although positive bacterial cultures were reported in 75.6% of cases where culture was taken from the surgical site, there was no significant increase in intra- or perioperative complications in cases that did not receive postoperative antibiotics. TECA-LBO should be considered a clean-contaminated surgery in cases where the infection is confined to the external ear canal. A large proportion of patients in this study may have received postoperative antibiotics unnecessarily if appropriate irrigation was performed before closure. The current study does not make conclusions regarding the impact of postoperative antibiotics on delayed surgical site infection and para-aural abscess formation. Further research into the use of postoperative antimicrobials in patients undergoing TECA-LBOs is warranted.

The median duration of hospitalization in EBBs was 1 day longer than for OBs. Due to retrospective data collection, it was difficult to accurately determine the reason for prolonged hospitalization from the clinical records. An explanation may be concern regarding upper respiratory obstruction, pharyngeal inflammation, regurgitation, or aspiration pneumonia which occur more frequently in brachycephalic breeds after general anesthesia.[35]

Two dogs did not survive to discharge. Both patients progressed to cardiopulmonary arrest following intensive management for severe systemic disease that developed postoperatively. A post-mortem examination was not performed in either case. However, based on antemortem clinical records the cause of death was not considered to be directly related to the TECA-LBO surgery.

One limitation of this study is the retrospective nature of the data collection. Whilst a large amount of relevant data has been obtained, data collection was reliant on details in patient records and surgical reports. This may have resulted in underreporting clinical examination findings or intraoperative challenges. In addition, all surgeries were performed at a single institution by diplomates or residents in small animal surgery, and so complication rates, whilst similar to those previously reported, may vary between institutions or based on surgeon experience. Finally, follow-up past the perioperative period was not carried out in this study, and conclusions regarding delayed postoperative complications such as para-aural abscessation cannot be drawn. Therefore, direct comparisons between the perioperative complications rate reported in this study and long-term postoperative complications reported elsewhere should be made with caution.

In conclusion, this is the first study comparing TECA-LBO in extreme brachycephalic and other canine breeds. Despite being considered more technically challenging, there was no increase in intra- or perioperative complications in EBBs compared to OBs. Extreme brachycephalic breeds are more likely to present acutely, with neurological signs, with a higher incidence of OI and brainstem changes. The complication rates reported in this study are useful for accurately informing clients of the specific risks of TECA-LBO surgery in extreme brachycephalic and OBs.

AUTHOR CONTRIBUTIONS

Banks C, BVMedSci (Hons), BVM BVS (Hons), PGDipVCP, MRCVS: Contributed to the study design, data acquisition, statistical analysis, and interpretation and wrote the manuscript. Beever L, BVetMed (Hons), MVetMed, PGCert, FHEA, DiplECVS, MRCVS: Contributed to the conception and design of the study, data acquisition, and interpretation and contributed to the

manuscript. Kaye B, BVSc, MANZCVS (ECC), MVetMed, DipECVS: Contributed to the statistical analysis, and interpretation of the data and reviewed the manuscript. Foo M, BA(Maths&Socio), PGDE (Math&Eng), BSc, DVM (Distinct): Contributed to the statistical analysis and interpretation of the data. ter Haar G, DVM, PhD, DiplECVS: Contributed to the interpretation of the data and contributed to the manuscript. Rutherford L, VM&S, MVetMed, PGCert VetEd, FHEA, DiplECVS, MRCVS: Contributed to the conception and design of the study, supervised the data acquisition and interpretation, and contributed to the manuscript. All authors approved the revised manuscript and are publically accountable for relevant content.

CONFLICT OF INTEREST STATEMENT

The authors confirm that there are no conflicts of interest to disclose.

ORCID

Charlotte Banks https://orcid.org/0000-0003-1920-388X

REFERENCES

1. Smeak DD. Management of complications associated with total ear canal ablation and bulla osteotomy in dogs and cats. *Vet Clin North Am Small Anim Pract*. 2011;41(5):981-994. vii.
2. Boothe HW. Surgical Management of Otitis Media and Otitis Interna. *Vet Clin North Am Small Anim Pract*. 1988;18(4):901-911.
3. Greci V, Travetti O, di Giancamillo M, et al. Middle ear cholesteatoma in 11 dogs. *Can Vet J*. 2011;52(6):631-636.
4. White RAS, Pomeroy CJ. Total ear canal ablation and lateral bulla osteotomy in the dog. *J Small Anim Pract*. 1990;31(11):547-553.
5. ter Haar G. Ear canal surgery. In: Griffon D, Hamaide A, eds. *Complications in Small Animal Surgery*. John Wiley & Sons, Inc; 2016.
6. Vogel PL, Komtebedde J, Hirsh DC, Kass PH. Wound contamination and antimicrobial susceptibility of bacteria cultured during total ear canal ablation and lateral bulla osteotomy in dogs. *J Am Vet Med Assoc*. 1999;214(11):1641-1643.
7. Coleman KA, Smeak DD. Complication rates after bilateral versus unilateral Total ear canal ablation with lateral bulla osteotomy for end-stage inflammatory ear disease in dogs: 79 ears. *Vet Surg*. 2016;45(5):659-663.
8. Doyle RS, Skelly C, Bellenger CR. Surgical management of 43 cases of chronic otitis externa in the dog. *Ir Vet J*. 2004;57(1):22-30.
9. Beckman SL, Henry WBJ, Cechner P. Total ear canal ablation combining bulla osteotomy and curettage in dogs with chronic otitis externa and media. *J Am Vet Med Assoc*. 1990;196(1):84-90.
10. Hardie EM, Linder KE, Pease AP. Aural cholesteatoma in twenty dogs. *Vet Surg*. 2008;37(8):763-770.
11. Spivack RE, Elkins AD, Moore GE, Lantz GC. Postoperative complications following TECA-LBO in the dog and cat. *J Am Anim Hosp Assoc*. 2013;49(3):160-168.
12. Smeak DD. Treatment of persistent deep infection after total ear canal ablation and lateral bulla osteotomy. *Vet Clin North Am Small Anim Pract*. 2016;46(4):609-621.
13. Matthiesen DT, Scavelli T. Total ear canal ablation and lateral bulla osteotomy in 38 dogs. *J Am Anim Hosp Assoc*. 1990;26(3):257-267.
14. Mason LKAY, Harvey CE, Orsher RJ. Total ear canal ablation combined with lateral bulla osteotomy for end-stage otitis in dogs results in thirty dogs. *Vet Surg*. 1988;17(5):263-268.
15. O'Neill DG, Jackson C, Guy JH, et al. Epidemiological associations between brachycephaly and upper respiratory tract disorders in dogs attending veterinary practices in England. *Canine Genet Epidemiol*. 2015;2(1):10.
16. O'Neill DG, Packer RMA, Francis P, Church DB, Brodbelt DC, Pegram C. French bulldogs differ to other dogs in the UK in propensity for many common disorders: a VetCompass study. *Canine Med Genet*. 2021;8(1):13.
17. O'Neill DG, Skipper A, Packer RMA, et al. English bulldogs in the UK: a VetCompass study of their disorder predispositions and protections. *Canine Med Genet*. 2022;9(1):5.
18. O'Neill DG, Sahota J, Brodbelt DC, Church DB, Packer RMA, Pegram C. Health of pug dogs in the UK: disorder predispositions and protections. *Canine Med Genet*. 2022;9(1):4.
19. Mielke B, Lam R, Ter Haar G. Computed tomographic morphometry of tympanic bulla shape and position in brachycephalic and mesaticephalic dog breeds. *Vet Radiol Ultrasound*. 2017;58(5):552-558.
20. Töpfer T, Köhler C, Rösch S, Oechtering G. Brachycephaly in French bulldogs and pugs is associated with narrow ear canals. *Vet Dermatol*. 2022;33(3):214.
21. Smeak DD, Kerpsack SJ. Total ear canal ablation and lateral bulla osteotomy for management of end-stage otitis. *Semin Vet Med Surg Small Anim*. 1993;8(1):30-41.
22. Packer RMA, Hendricks A, Tivers MS, Burn CC. Impact of facial conformation on canine health: brachycephalic obstructive airway syndrome. *PLoS One*. 2015;10(10):e0137496.
23. Salgüero R, Herrtage M, Holmes M, Mannion P, Ladlow J. Comparison between computed tomographic characteristics of the middle ear in nonbrachycephalic and brachycephalic dogs with obstructive airway syndrome. *Vet Radiol Ultrasound*. 2016;57(2):137-143.
24. Devitt CM, Seim HB, Willer R, McPherron M, Neely M. Passive drainage versus primary closure after total ear canal ablation-lateral bulla osteotomy in dogs: 59 dogs (1985–1995). *Vet Surg*. 1997;26(3):210-216.
25. Packer RMA, O'Neill DG, Fletcher F, Farnworth MJ. Great expectations, inconvenient truths, and the paradoxes of the dog-owner relationship for owners of brachycephalic dogs. *PLoS One*. 2019;14(7):e0219918.
26. Kaye BM, Rutherford L, Perridge DJ, Ter Haar G. Relationship between brachycephalic airway syndrome and gastrointestinal signs in three breeds of dog. *J Small Anim Pract*. 2018;59(11):670-673.
27. Caccamo R, Buracco P, La Rosa G, Cantatore M, Romussi S. Glottic and skull indices in canine brachycephalic airway obstructive syndrome. *BMC Vet Res*. 2014;10(1):12.
28. De Decker S, Packer RMA, Cappello R, et al. Comparison of signalment and computed tomography findings in French

bulldogs, pugs, and English bulldogs with and without clinical signs associated with thoracic hemivertebra. *J Vet Intern Med*. 2019;33(5):2151-2159.
29. The Kennel Club. Breed Registration Statistics. 2013 https://www.thekennelclub.org.uk/media-centre/breed-registration-statistics/
30. O'Neill DG, Baral L, Church DB, Brodbelt DC, Packer RMA. Demography and disorders of the French bulldog population under primary veterinary care in the UK in 2013. *Canine Genet Epidemiol*. 2018;5(1):3.
31. O'Neill DG, Pegram C, Crocker P, Brodbelt DC, Church DB, Packer RMA. Unraveling the health status of brachycephalic dogs in the UK using multivariable analysis. *Sci Rep*. 2020;10(1):17251.
32. Harrison E, Grapes NJ, Volk HA, De Decker S. Clinical reasoning in canine vestibular syndrome: which presenting factors are important? *Vet Rec*. 2021;188(6):e61.
33. Owen MC, Lamb CR, Lu D, Targett MP. Material in the middle ear of dogs having magnetic resonance imaging for investigation of neurologic signs. *Vet Radiol Ultrasound*. 2004;45(2):149-155.
34. Garosi LS, Dennis R, Schwarz T. Review of diagnostic imaging of ear diseases in the dog and cat. *Vet Radiol Ultrasound*. 2003;44(2):137-146.
35. Gruenheid M, Aarnes TK, McLoughlin MA, et al. Risk of anesthesia-related complications in brachycephalic dogs. *J Am Vet Med Assoc*. 2018;253(3):301-306.

How to cite this article: Banks C, Beever L, Kaye B, Foo M, ter Haar G, Rutherford L. Influence of extreme brachycephalic conformation on perioperative complications associated with total ear canal ablation and lateral bulla osteotomy in 242 dogs (2010–2020). *Veterinary Surgery*. 2023;52(5):661-673. doi:10.1111/vsu.13964