

Lateral ear canal resection and bulla osteotomy with marsupialization to treat otitis media in rabbits: forty-eight procedures

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Abstract

Objective: Describe lateral ear canal resection and bulla osteotomy with marsupialization (LECARBOM) in rabbits with otitis media (OM), and report outcomes, complications, bacteria cultured from middle ears, and their antimicrobial susceptibility testing (AST) results.

Study design: Retrospective clinical case series; single referral hospital.

Animals: Forty-two rabbits with naturally occurring OM.

Methods: Medical records (2011–2021) of rabbits with CT-confirmed OM undergoing surgery were reviewed for outcomes, complications, bacteria cultured from middle ears, and AST.

Results: Surgery was performed on 48 ears, and outcomes determined 21 days postoperatively. All rabbits survived the procedure. Otitis externa resolved in all lop-eared rabbits. Of 29 ears with OM-associated head tilt, eight (28%) resolved, nine (31%) improved, seven (24%) remained unchanged and five (17%) worsened. Outcome was not associated with head tilt duration nor OM severity. Postoperative complications occurred in 12 (25%) cases, seven of which had wound margin dehiscence that healed by 21 days. The most frequent bacteria isolated were *Pasteurella multocida* (16%), *Bordetella bronchiseptica* (14%) and *Staphylococcus aureus* (14%). Bacteria were sensitive to azithromycin, marbofloxacin or enrofloxacin and resistant to penicillin.

Conclusion: LECARBOM is a well-tolerated surgical procedure to treat OM. It also improved or stabilized 83% of cases with head tilt and resolved all cases with otitis externa.

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Clinical significance: LECARBOM with administration of an AST-sensitive antibiotic, or azithromycin when no AST is performed, should be effective in rabbits with OM. Postsurgically, it resolves or alleviates most secondary conditions such as otitis externa, head tilt and facial nerve paralysis.

1 | INTRODUCTION

Otitis media is a common condition in rabbits. Post-mortem examination of 583 adult meat rabbits with no overt signs of clinical disease found purulent otitis media in 32% of cases.¹ Similarly, necropsies of 102 and 31 laboratory rabbits with upper respiratory clinical signs found 32% had subclinical otitis media.^{2,3}

Otitis media is difficult to diagnose based only on clinical signs such as vestibular syndrome and facial hemiparalysis.⁴ The most reliable method of identifying otitis media is by computed tomography (CT) examination.⁵ CT evidence of otitis media was identified in 12 of 21 (57%) rabbits with clinical signs of ear disease and 18 of 67 (27%) rabbits without clinical signs of ear disease.⁶

Rabbits are the third most common mammal pet in US households, and their owners expect high levels of medical and surgical care.⁷ For rabbits with clinical otitis media, medical treatment with antibiotics yields poor results,⁸ not only because of inadequate drug penetration into the middle ear but also because of inappropriate antimicrobial selection. Sampling the tympanic cavity to identify bacteria and determine their antibiotic susceptibility is rarely performed because it requires anesthesia and a myringotomy.

In the past 10 years, four surgical techniques have been described to treat otitis media in rabbits. These techniques involve removal of all or most of the external acoustic meatus (ear canal) and include ventral bulla osteotomy,⁹ total ear canal ablation and lateral bulla osteotomy/ostectomy (TECALBO),^{10–12} and partial ear canal ablation and lateral bulla osteotomy (PECALBO).^{8,13} Complications, bacteria isolated, and antibiotics used were described in a case series of six lop-eared rabbits,⁸ two case reports,^{9,11} and postoperative complications between TECALBO in 13 rabbits and PECALBO in eight rabbits were described in a conference abstract.¹³ Because of the small number of rabbits reported in the former references, and the brevity of the conference abstract, data on actual rates of complications are not available in rabbits.

This retrospective study, which describes a less invasive surgical technique called lateral ear canal resection and bulla osteotomy with marsupialization (LECARBOM), reports (1) outcomes of 48 surgeries performed to treat otitis media in rabbits, (2) the incidence of postsurgical complications, (3) the bacteria isolated from the rabbits' middle ears during surgery, (4) their

susceptibility to antimicrobials, and (5) broad-spectrum antimicrobials recommended for use against bacteria causing otitis media in pet rabbits.

2 | MATERIALS AND METHODS

2.1 | Case selection

Medical records of rabbits seen at the teaching hospital of the National Veterinary School of Alfort between February 1, 2011, and September 30, 2021, were reviewed. The inclusion criteria were a diagnosis of otitis media by CT scan (“Otitis media” AND “Computed tomography”), lateral ear canal resection and bulla osteotomy (“Middle ear surgery” OR “Osteotomy”), and at least 3 weeks postoperative follow-up. Rabbits with incomplete medical records, follow-up less than 3 weeks after surgery, treated using a different surgical procedure, and lacking a diagnosis of otitis media on CT scan were excluded. Institutional Animal Care and Use Committee approval or owner consent was not required.

2.2 | Medical record review and CT scan

Data collected included age and bodyweight at presentation, sex, ear conformation, presenting complaint, physical examination findings of head tilt, otitis externa, facial nerve paralysis, rhinitis and diagnostics performed (CT scan, bacteriology). Otitis externa was diagnosed by video-otoscopy and confirmed on CT scan (80-slice multidetector, helical system, Aquilion Lightning 80, Canon Medical Systems). Rabbits were anesthetized for CT with 2.5% isoflurane (Vetflurane, Virbac, Carros, France) in oxygen (1 L/min) via facemask after 5 min of preoxygenation. An IV catheter was placed to inject iohexol (2 mL/kg; Omnipaque 350, GE Healthcare SAS, Velizy Villacoublay, France). The severity of otitis media was graded by a European board-certified diagnostic imaging veterinarian (Table 1).¹⁴

2.3 | Anesthesia and analgesia during surgery

All rabbits were premedicated with an analgesic and sedative. Anesthetic induction and endotracheal intubation

Grade	Description	No	%
I	Incomplete fill of material in tympanic cavity. No tympanic bulla involvement, with normal anatomical shape and wall thickness.	5	10
II	Complete fill of material in tympanic cavity. No tympanic bulla involvement, with normal anatomical shape and wall thickness.	18	38
III	Material (either complete or incomplete fill) in the tympanic cavity. Tympanic bulla involvement without change to bulla shape, but areas of bone lysis and/or wall thickening.	13	27
IV	Tympanic bulla derangement with change to bulla shape and areas of bone lysis or expansile anatomical distortion.	12	25

Abbreviation: LECARBOM, lateral ear canal resection and bulla osteotomy with marsupialization.

^aGrading scheme of Richardson et al.¹⁴

TABLE 1 Grading of otitis media on CT scan for rabbit ears before LECARBOM surgery^a.

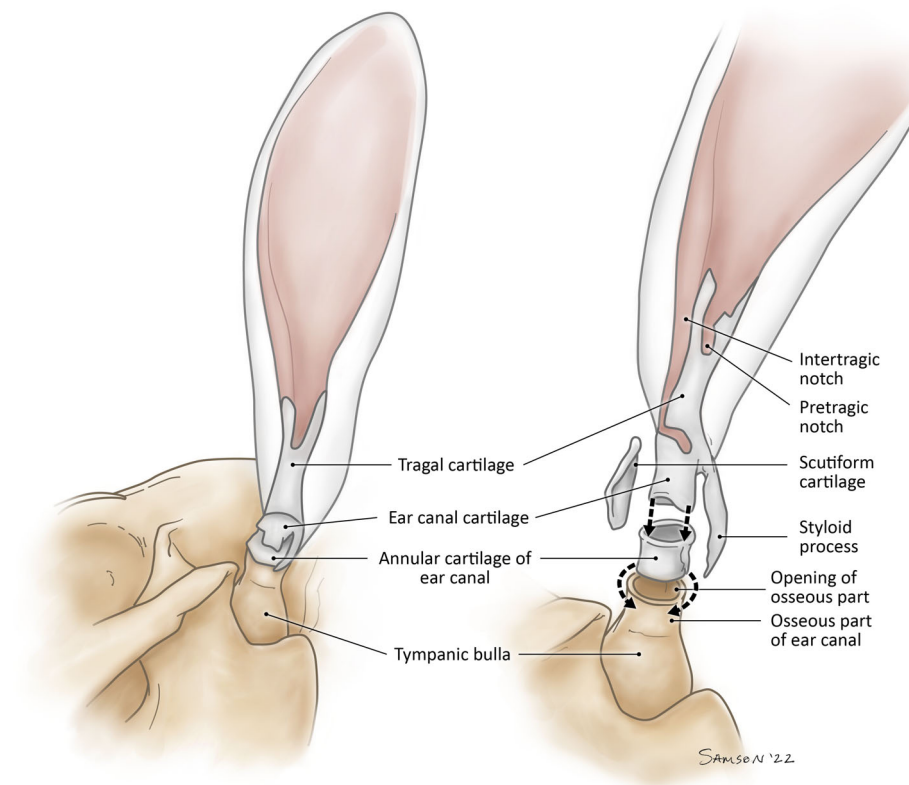


FIGURE 1 Cartilages of the rabbit ear. The left figure shows the auricular cartilages in situ and the right ex-situ. The ear canal is supported by three auricular cartilages that interlock and provide rigidity. It is formed distally by the tragus and centrally by the ear canal cartilage. Arising vertically from the tympanic bulla is the osseous part of the ear canal, which interlocks with the annular cartilage. This figure was modified from drawings by Barone R, Pavaux C, Blin PC, Cuq P. *Atlas d'anatomie du lapin*. Masson et Cie; 1973, and Barone R, Simoens P. *Anatomie comparée des mammifères domestiques*. Vol 7. Neurologie II. Vigot Freres; 2010.

were performed with an intravenous anesthetic or isoflurane via face mask. Anesthesia was maintained with isoflurane in oxygen. Rabbits received a continuous rate infusion of analgesia during anesthesia and some rabbits also received auricular nerve blocks. Rectal temperature, heart activity, blood oxygen saturation, expired carbon-dioxide and noninvasive blood pressure were monitored during anesthesia in all rabbits.

2.4 | Perioperative considerations

Before 2018, all rabbits had a sterile lubricating gel (Ocry-gel, TVM, Kirtlington, Oxfordshire, UK) applied every 10–20 min to their eyes from intubation to extubation. After 2018, a temporary blepharorrhaphy was placed. Rabbits had fluorescein stain applied to their corneas at extubation and 24 h post-surgery to check

for corneal lesions. A topical solution of broad-spectrum ophthalmic antibiotic was applied to all post-extubation fluorescein-positive eyes. Eyes that

remained fluorescein-positive at 24 h were referred to a European board-certified veterinary ophthalmologist for treatment.

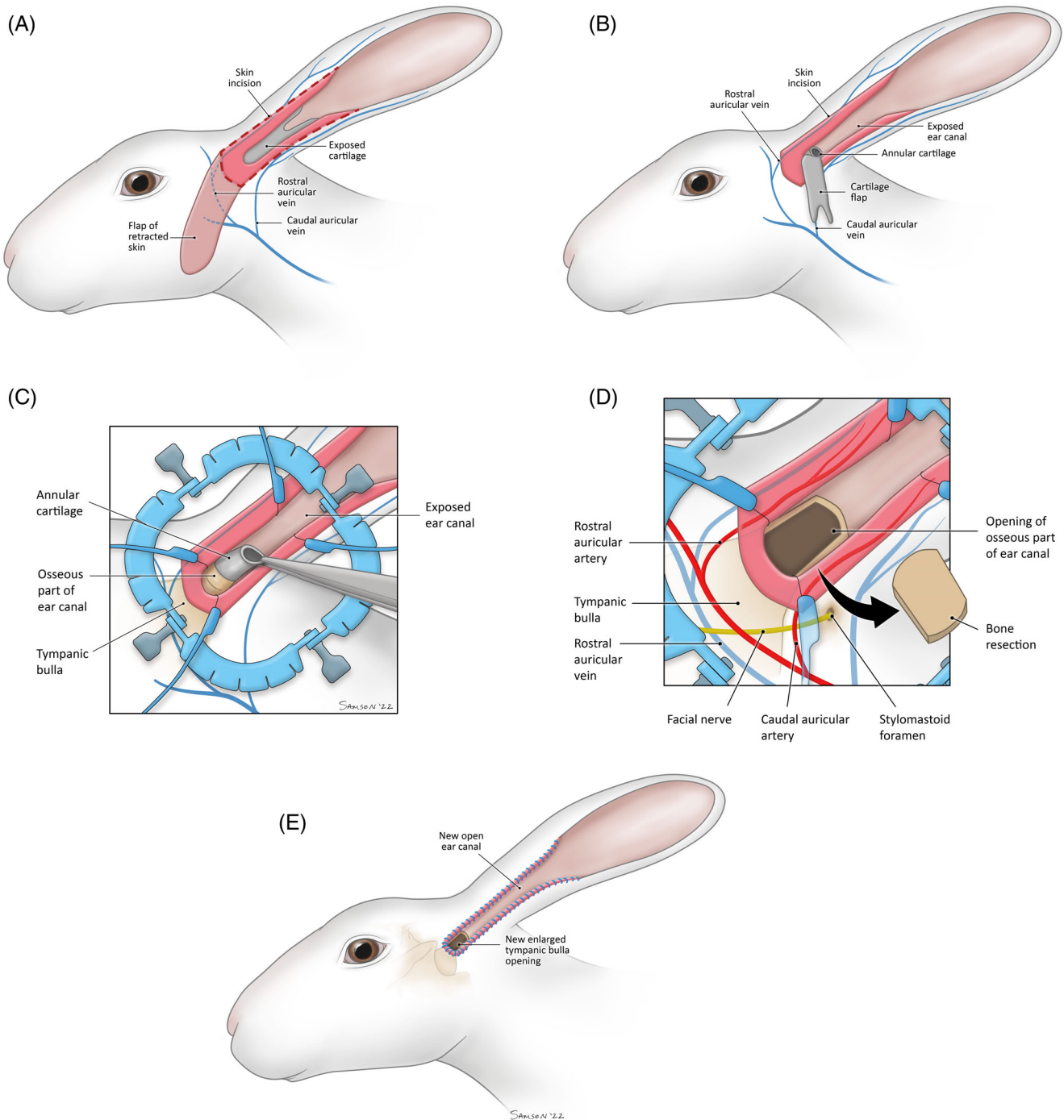


FIGURE 2 Lateral ear canal resection and bulla osteotomy with marsupialization (LECARBOM) in the rabbit. (A) Skin incisions are made over the ear canal to create an isolated skin flap that is resected. (B) The lateral surface of the ear canal cartilage is cut to the opening of the annular cartilage to create an isolated cartilage flap that is resected. (C) A lone star retractor is used to retract the subcutaneous tissues. The annular cartilage is exposed and excised. (D) The lateral aspect of the osseous ear canal is removed (generally as fragments) and the opening of the tympanic bulla is enlarged to allow curettage and flushing of the tympanic cavity. (E) The epithelial lining of the exposed ear canal is sutured to the surrounding skin overlying the pinna. Subcutaneous tissue around the tympanic bulla opening is marsupialized to the surrounding skin. The skin wound around the enlarged tympanic bulla opening generally heals by 2–3 weeks.

2.5 | Surgical technique

All rabbits underwent the same surgical procedure performed by a European board-certified zoological medicine veterinarian (author CP) or his resident (author EM). After the rabbits were positioned in lateral recumbency, the side of the face and both sides of the pinna were clipped and prepared with povidone-iodine. Figure 1 depicts the anatomy of the rabbit ear canal cartilages and bone. Two parallel skin incisions were made lateral to the ear canal from the base of the ear to the pretragic notch and intertragic notch (Figure 2A). Care was taken not to damage the blood vessels that supply the pinna (Figure 2A,D). Bipolar electrosurgery was used to control hemorrhage.

A 6" cotton tip swab was passed into the ear canal to the junction of the ear canal cartilage and annular cartilage. The swab was tilted laterally to create a slight protuberance in the skin, which serves as a reference point to localize the tympanic bulla opening. A mark was made over the protuberance and an incision was made 1.0–1.5 cm ventral to the mark to join the lateral parallel skin incisions. The subcutaneous tissues were dissected from the auricular cartilage, and the skin flap was excised (Figure 2A). The tragal and ear canal cartilages were exposed using Stevens scissors for dissection. Straight blunt Mayo scissors were used to create two parallel cuts in the lateral wall of the tragal and ear canal cartilages. The cartilage flap was transected ventrally at the opening of the annular cartilage and excised (Figure 2B). Care was taken to separate the ear canal epithelial lining from the tragal and ear canal cartilages along the cut edge of the ear canal so that it can be reattached to the skin without tension on the wound.

A plastic lone star retractor (14.1 × 14.1 cm with 5 mm sharp hooks, model 3307G, CooperSurgical, Trumbull, Connecticut) was placed to expose the annular cartilage (Figure 2C). The annular cartilage was bluntly freed from the surrounding tissue and excised using Stevens scissors, exposing the osseous part of the ear canal (Figure 2C). Micro-Friedman rongeurs were used to remove the lateral aspect of the osseous ear canal and enlarge the tympanic bulla opening (Figure 2D). Care must be taken during this step to avoid damaging the facial nerve. If there was bone lysis or tympanic wall thickening (grades III and IV) based on 3-D images of the CT scan, the affected fragments were resected using micro-Friedman rongeurs. The tympanic cavity was curetted (Volkman curette, single-ended oval 3 mm scoop, 18 cm) to remove debris, pus, and epithelial lining, which were submitted for bacterial culture and antibiotic susceptibility. Care was taken to avoid aggressive curettage dorsomedially where the vestibular or oval window of the inner ear is located. The tympanic cavity was then gently



FIGURE 3 The ear of a lop-eared rabbit immediately after lateral ear canal resection and bulla osteotomy with marsupialization (LECARBOM).

flushed with warm sterile saline and inspected with a 1.9- or 2.7-mm diameter rigid endoscope to ensure remaining debris and pus were removed. The epithelial layer of the exposed ear canal was sutured to the skin overlying the pinna. Subcutaneous tissue around the bulla osteotomy opening was marsupialized to the surrounding skin using polydioxanone 3–0 suture (PDS II; Ethicon Inc., Issy-les-Moulineaux, France) in a simple interrupted pattern (Figures 2E and 3). The skin wound around the tympanic bulla opening heals by 2–3 weeks. Fibrous tissue from the surrounding scar begins lining the tympanic bulla and eventually covers the opening.

2.6 | Postoperative care

Postoperatively the rabbits were offered hay, fresh green vegetables and commercial pellets after they regained consciousness. All rabbits were syringe-fed during hospitalization using an energy-rich herbivore formula (Intensive Care Herbivore, Emeraid, Cornell, Illinois). Pain was assessed during hospitalization using a rabbit pain scale,¹⁵ which includes activity level, behavior, posture, general appearance, and food consumption. Postoperatively, methadone (1 mg/kg IM every 4 h for 1–3 days) and then buprenorphine (30–50 µ/kg every 6 h SC for 1–6 days) were administered until discharge, based on the rabbit's pain scale. Rabbits were administered a first-line antibiotic for 4 weeks after surgery. Before April 2016, enrofloxacin was used. After that date, changes in European regulations for prescribing antibiotics to animals dictated that penicillin-G (40,000 IU/kg every 24 h) or azithromycin (30 mg/kg orally every 24 h) be given. If the antimicrobial susceptibility testing (AST) showed resistance to the first-line antibiotic, it was replaced with one to which the bacteria were susceptible. All rabbits received meloxicam (1 mg/kg orally every 12 h) for

2 weeks after discharge from the hospital. Owners were trained to flush with gentle pressure the surgical wound and tympanic cavity with normal saline twice daily using a 3 mL syringe until the marsupialized opening of the tympanic bulla closed by secondary intention. Physical assessments were made twice a day during hospitalization.

2.7 | Follow-up and complications

Owners were requested to return their rabbits for follow-up examinations on days 7 and 21 post-surgery. The resolution of physical examination abnormalities was noted. Rabbits with postoperative complications not resolved by or seen after 21 days returned for additional follow-up between 1 and 9 months. The complications were documented and treated.

2.8 | Bacterial identification and antibiotic susceptibility testing

The contents of the tympanic bulla (pus, debris and epithelial lining) were immediately transported in Amies Agar Gel (Transystem, 108C Copan, Brescia, Italy) to the institution's microbiology service for aerobic and anaerobic culture, bacterial identification and AST. Bacterial culture was performed on Columbia Blood Agar at 37°C for 24 to 72 h. Bacteria were identified using matrix-assisted laser desorption ionization–time of flight (MALDI-TOF) mass spectrometry. AST to eight antibiotics (marbofloxacin, enrofloxacin, azithromycin, benzylpenicillin, doxycycline, trimethoprim-sulfamethoxazole, gentamicin, and tobramycin) was performed on Mueller-Hinton agar.

2.9 | Statistical analysis

Descriptive statistics used to analyze the data were performed on XLSTAT[®] software (Addinsoft, New York). Continuous variables data were analyzed using the Shapiro–Wilk test and expressed as a mean and standard deviation for normally distributed data and as a median and range when not normally distributed. At the 21-day postoperative follow-up, Fisher's exact test was used to assess the association between categorical data, and $p < .05$ was considered significant.

A binary logistic regression model was used to evaluate the impact of the duration of head tilt before surgery on the outcome, defined as positive (resolution, improvement) or negative (no improvement,

deterioration). First, potential confusion parameters (breed, age, sex, CT grade and duration of hospitalization post-surgery) were evaluated against outcome individually in univariate binary logistic regression models. A parameter was included in the final multivariate binary logistic regression model with the duration of head tilt before surgery only if the p -value for this parameter in the univariate model was $< .2$. In all models, linearity of continuous independent variables was verified using the Box-Tidwell method. In the final model, presence of outliers was verified using standardized residual standard deviation evaluation.

3 | RESULTS

3.1 | Case selection-signalment and history

Forty-two rabbits met the inclusion criteria. Twenty-six (62%) rabbits were males, and 16 (38%) were females. Their ages ranged from 7 months to 8 years, with a median age of 4 years and bodyweight range from 0.6 to 3.0 kg (mean 2.0 ± 0.5 kg).

Thirty-three (79%) rabbits were lop-eared, and nine (21%) were erect-eared. While eight (19%) rabbits presented for otitis externa, only four rabbits (1 lop-eared and 3 erect-eared; 10%) did not have otitis externa on the otitis media-affected ear. Of the 38 rabbits with otitis externa, 32 were lop-eared, and six were erect-eared. Otitis externa was diagnosed bilaterally in 29 rabbits. Lop-eared rabbits were significantly more often affected by otitis externa than erect-eared rabbits ($p < .01$). However, there was no difference in prevalence of head tilt in lop-eared rabbits versus erect-eared rabbits ($p = 1.0$).

Six rabbits had staged bilateral LECARBOM; thus, 48 ears were operated on 42 rabbits. The presenting complaint for 29 (60%) ears was a head tilt that ranged from a slight cocked-head position to a near upside-down (180° rotation) configuration. Ten (21%) ears were associated with facial nerve paralysis. For seven (17%) ears, the presenting complaint was facial nerve paralysis without head tilt, and clinical examination revealed both facial nerve paralysis and head tilt for three (6%) ears. Two rabbits (4 ears; 8%) presented for chronic rhinitis with otitis media and had surgery on both ears. The time between the initial presentation and development of a head tilt varied from 0.5 to 210 days (median 10 days).

3.2 | CT scan

Head CT scans were graded from I to IV based on severity of otitis media (Table 1).

3.3 | Anesthesia and analgesia during surgery

All rabbits were premedicated with midazolam (0.3–1.0 mg/kg IM). Anesthetic induction and endotracheal intubation were accomplished with ketamine (1–10 mg/kg IV) in 20 rabbits, alfaxalone (1–5 mg/kg IV) in 19, or isoflurane via face mask in 3. Anesthesia was maintained with isoflurane in oxygen. Analgesia premedication was with fentanyl (2.5 µg/kg IM) and then a continuous rate infusion of fentanyl (0.5–2.5 µg/kg/h), lidocaine (3–6 mg/kg/h) and ketamine (0.3–0.6 mg/kg/h) in 38 animals, or methadone (1 mg/kg IM) in seven. In 15 rabbits, greater auricular and auriculopalpebral nerve blocks were performed with 0.3 mL/kg of 0.5% preservative-free bupivacaine.¹⁶ During surgery, rabbits generally remained normothermic (37.5–40.0°C) with normal sinus rhythm, had >95% blood oxygen saturation, were normocapnic (35–45 mmHg) and normotensive (>80 mmHg), and fully recovered from anesthesia.

3.4 | Perioperative considerations (exposure keratopathy)

At extubation, 17/31 (55%) rabbits that had sterile lubricating gel applied to their eyes (before 2018) showed positive fluorescein staining corneas, but no rabbits were fluorescein-positive at 24 h post-surgery. In the 17 rabbits with temporary suture blepharorrhaphy (after 2018), fluorescein staining of the cornea was negative after extubation.

3.5 | Lateral ear canal resection and bulla osteotomy with marsupialization

All rabbits survived the surgery. Surgery was performed 32 times by author CP and 16 times by author EM. CP assisted with all surgeries performed by EM. There were no differences in the complication rate or the persistence of head tilt ($p > .05$).

3.6 | Postoperative care

After 48 ear surgeries, 31 cases (65%) ate within 24 h, and nine (19%) ate between 24 and 48 h. For the other eight cases (17%), three ate after 48–72 h, one after 9 days, three died within 48 h after surgery, and one was euthanized 15 days after surgery. Twice daily flushing was well-tolerated by all rabbits. In some rabbits, the saline exiting the tympanic cavity was pink and contained tiny pieces of tissue but became clear within 2 days. The

hospitalization time after surgery ranged from 2 to 15 days, with a median time of 3 days.

3.7 | Complications

Thirty-eight rabbits (44/48 ear surgeries) returned for follow-up examinations between days 7–9 and 21–24. Post-operative complications occurred with 12 ears (Table 2). In seven (15%) ears, partial dehiscence occurred within 7 days. A 2–4 mm margin of necrosis was noted along the incision extending less than 1 cm on the pinna. Necrotic tissue was debrided and healing by secondary intention was complete by 21 days. In one rabbit head tilt not seen before surgery was noted at the 7-day postsurgical follow-up, but had resolved by the 21-day follow-up. In the two rabbits that developed para-auricular abscesses after surgery, CT scans were obtained, bacteria from the abscess were cultured, and AST was determined. Treatment involved marsupialization of the abscess, enrofloxacin, meloxicam and local wound care with saline flushing. Healing occurred for both by 3 weeks.

3.8 | Outcome

Three rabbits died within 48 h of the surgery. One died from an undiagnosed dilated cardiomyopathy confirmed on necropsy, and two necropsies were declined. However, petrous osteolysis (grade IV) was noted on their CT scans. One rabbit was electively euthanized after 15 days of hospitalization because the presenting clinical signs of severe head tilt, inability to walk and anorexia never improved.

For 29 ear surgeries where the presenting complaint was head tilt, a positive outcome (head tilt resolution in 8/29 ears or improvement in 9/29 ears) was seen in 59% and stabilization (no improvement, but no deterioration in 7/29 ears) in 24% at 21 days. Worsening of the head tilt (5/29 ears) was seen in 17% at 21 days. Duration of head tilt before surgery was not associated with outcome ($p = .28$), and an unfavorable outcome was not associated with severe otitis media compared to milder grades ($p = .52$).

Facial hemiparesis due to facial nerve damage was associated with 10 ears before performing surgery. By 21 days, five cases had resolved, by 2 months three cases had resolved, and two cases did not resolve. Two rabbits presented for chronic rhinitis and had staged bilateral surgery. Upper respiratory tract clinical signs were resolved 21 days after the second surgery.

In lop-eared rabbits, LECARBOM resulted in resolution of otitis externa in all affected rabbits by 2–3 weeks post-surgery. The marsupialized opening of the tympanic bulla usually closed by 21 days. However, in 3/44 cases,

TABLE 2 Complications after surgery on 44 ears.

Complications	Number	First noted	Resolution of complication
Wound necrosis/dehiscence	7	7 day check up	21 day check up
Head tilt	1	7 day check up	21 day check up
Facial nerve paralysis	2	7 day check up	2 month consultation
Para-auricular abscess	2	3- and 9-month consultation	3 weeks after consultation
Total	12		



FIGURE 4 The ear of a lop-eared rabbit 6 months after lateral ear canal resection and bulla osteotomy with marsupialization (LECARBOM).

the opening was closed by 4 weeks. A photograph is shown of a rabbit 6 months after LECARBOM (Figure 4).

3.9 | Bacterial identification and antibiotic susceptibility testing

The bacteria isolated are shown in Table 3. Bacterial cultures were not performed on four ears, due to owner financial concerns. No anaerobic bacteria were isolated. For aerobic culture, only one bacterial species was isolated from 32 (73%) ears, and for five ears, two or more bacterial species were isolated. There was no bacterial growth from seven ears. Too many bacterial species were cultured from too few ears to assess a potential link between bacteria and outcome. The most frequent species

TABLE 3 Results of bacteria isolated from 44 middle ears in rabbits with otitis media.

Bacteria isolated	Number of ears
<i>Pasteurella multocida</i>	7
<i>Bordetella bronchiseptica</i>	6
<i>Staphylococcus aureus</i>	6
<i>Staphylococcus pseudintermedius</i>	3
<i>Corynebacterium</i> spp.	3
<i>Actinomyces</i> spp.	2
<i>Pseudomonas aeruginosa</i>	2
<i>Enterobacter cloacae</i>	1
<i>Serratia marcescens</i>	1
<i>Aeromonas</i> spp.	1
Mixed ^a	5
Negative	7
Total	44

^aThe five mixed cultures consisted of two (3/5) or three (2/5) bacteria. The bacteria identified were *P. multocida* (1/5), *Staphylococcus* spp. (4/5), *Corynebacterium* spp. (4/5) and *Prevotella* spp. (1/5).

isolated were *Pasteurella multocida* in seven ears, *Bordetella bronchiseptica* in six ears, and *Staphylococcus aureus* in six ears. Bacteria isolated were susceptible to marbofloxacin, enrofloxacin, and azithromycin (except *Staphylococcus* spp.) or doxycycline (except *B. bronchiseptica*). Bacteria were resistant to penicillin (except *S. pseudintermedius*). Results of AST for the most common bacteria isolated are presented in Supplement 1.

Of 37 ears with bacteria identified on culture, 31 were sensitive to the first-line antibiotic and received it for 4 weeks. Rabbits without a bacterial culture ($n = 4$) or negative culture ($n = 7$) received a first-line antibiotic for 4 weeks, like other rabbits with positive cultures. Six ears had bacteria resistant to the first-line antibiotic. Two ears had *Pseudomonas aeruginosa*, two had *S. aureus*, one had *Corynebacterium urealyticum*, and one had *Serratia marcescens*. The first-line antibiotic was replaced, and an antibiotic based on the AST was given. The antibiotics were marbofloxacin (for *P. aeruginosa* and *S. marcescens*), enrofloxacin (for *C. urealyticum*), penicillin-G (for one ear with

S. aureus) and trimethoprim-sulfamethoxazole (for the other ear with *S. aureus*).

4 | DISCUSSION

LECARBOM was performed on 48 ears, and all rabbits survived the surgery. This is the largest study of rabbits undergoing surgery for treatment of otitis media reported. Twenty-nine ears were associated with a head tilt supportive of clinical otitis interna. After surgery, 17/29 ears (59%) had resolution or improvement of head tilt. No change was seen in 7/29 ears, and worsening head tilt occurred in 5/29 ears. Otitis externa was diagnosed on initial examination in 38/42 rabbits. After LECARBOM, otitis externa in all 38 rabbits had resolved by 21 days. Three rabbits died in the immediate postoperative period, and one was euthanized at 15 days. There were 12 (25%) postoperative complications, of which 10 were considered minor. These were managed with basic wound care and healed by 21 days. Two major complications were the development in two rabbits of para-auricular abscesses at 3 and 9 months post-surgery. Both were successfully managed using protocols recommended for rabbit abscess management.

Complication rates in dogs and cats after ear surgery are well-described but limited in rabbits.^{8,13} A 2015 conference abstract describes postoperative complications when comparing TECALBO in 13 rabbits and PECALBO in eight rabbits.¹³ The authors found postoperative complications in 4/8 (50%) of the PECALBO group and 8/13 (62%) of the TECALBO group. These complication rates are higher than our 25% rate. Common surgical complications included localized skin necrosis in 12/13 (92%) TECALBO rabbits and 6/8 (75%) PECALBO rabbits, and wound dehiscence in 6/13 (46%) TECALBO rabbits and 1/8 (13%) PECALBO rabbits. Our study had seven (15%) rabbits with partial dehiscence associated with a small margin of incision necrosis. Our complication rate is lower, and after necrotic tissue was debrided, healing by secondary intention was complete by 21 days. The skin over the tragal cartilage is thin and the rostral and caudal auricular arteries and veins are superficial. Gentle pressure and dissection are recommended when making the initial parallel skin incisions and the subcutaneous tissue is separated from the auricular cartilage to avoid compromising the blood supply to the pinna. The authors also reported wound abscesses in 1/13 (8%) TECALBO rabbits and 1/8 (13%) PECALBO rabbits. Two (4%) rabbits in our study developed para-auricular abscesses after surgery.

Compared to other postoperative complications reported for rabbit ear surgery cases,^{8,13} after

48 LECARBOM surgeries, we did not see permanent facial nerve paralysis or recurrence of middle ear infection. Rabbits produce caseous exudate, and it is difficult to eliminate middle ear infections with only ear canal removal and bulla osteotomy, as recurrent middle ear infection is reported after some surgical procedures.¹¹ Leaving antibiotic-impregnated polymethylmethacrylate beads in the tympanic bulla or an active ingress-egress tube have been described in rabbits for managing residual infection that can result in recurrence.⁹ LECARBOM differs from other ear surgeries for otitis media in rabbits as marsupialization of the subcutaneous tissue around the bulla osteotomy to surrounding skin keeps the tympanic cavity open and allows twice daily flushing, which eliminates residual infection. Necrotic tissue, cell debris, fibrin and bacteria were flushed from the wound, and along with systemic antibiotic administration, infection was controlled. In contrast, Eatwell et al.⁸ found that marsupializing the surgical site to the skin at the base of the ear to enable postoperative flushing was not beneficial and instead closed the surgical site.

In this study, of 29 rabbits with head tilt, 17 (59%) rabbits had complete (8 rabbits) or partial resolution (9 rabbits) of vestibular signs. In five (17%) rabbits worsening of their vestibular signs occurred after surgery. After surgery, one rabbit developed a transient new head tilt that resolved by 21 days. New vestibular signs or worsening of preexisting vestibular signs are reported as a complication of tympanic bulla surgery in 10%–20% of cats and dogs.^{17,18} It occurs during curettage of the tympanic bulla's epithelial lining, which must be removed as any tissue left can develop into a fistula. If the surgeon is overly aggressive with curettage in the dorsomedial aspect of the bulla, where the oval window is located, vestibular signs can develop. As the oval window is often hidden from view during bulla osteotomy, it is important to be gentle while performing curettage in this area. While postsurgical vestibular signs are a risk when performing middle ear surgery, unless otitis media is treated to control and stop the infection, it can progress to involve the inner ear resulting in vestibular signs, and further extension to the brain, can result in meningoencephalitis.^{19,20} Successful management of otitis media can be determined by resolution of the increased radiographic opacity within the tympanic bulla on CT.

A lone star retractor is very helpful for performing LECARBOM. The stay hooks are placed in the subcutaneous tissue, and the silastic bands are inserted into the frame's notches to maintain tissue retraction. This allows the annular cartilage to be freed from surrounding tissue and exposes the osseous part of the ear canal. It allows the facial nerve to be identified and avoided during enlargement of the tympanic bulla opening.

The most frequent bacteria isolated in this study were *P. multocida*, *B. bronchiseptica* and *S. aureus* accounting for 43% of singly isolated bacterial species. Interestingly, no anaerobic bacteria were cultured. Although *P. multocida* has been reported from otitis media in rabbits, only a few studies have reported other bacteria, giving the impression that it is the primary cause of otitis media.^{2,21,22} The likely reasons, as reports are 50–100 years old, are the bacteriological culture techniques and the inability to identify isolated bacteria.^{1–3,23} The few studies reporting bacteria cultured from rabbit middle ears have found *P. multocida*, *Staphylococcus* spp. and *B. bronchiseptica* are the most commonly isolated organisms,^{21,22,24} similar to our findings. However, single isolates of other bacteria have been cultured. Generally, bacteria have been isolated as a single pure culture, with mixed cultures being unusual. Fewer reports exist on the antimicrobial susceptibility of bacteria isolated from the middle ears, where it has been found that bacteria are generally susceptible to fluoroquinolones but resistant to penicillin.^{8,21,22} Antimicrobial stewardship guidelines recommend only using fluoroquinolones, a second-line antibiotic, when AST has been performed, and the results show these are the only suitable antibiotics available.²⁵ In this study, the ASTs showed most bacteria isolated were susceptible to azithromycin or doxycycline, suggesting their use as suitable first-line antibiotics, and were sensitive to the second-line antibiotics marbofloxacin or enrofloxacin. Most bacteria were resistant to penicillin-G, a common parental antibiotic in rabbits, and its use as a first-line antibiotic is not recommended unless AST shows the bacterial species are sensitive to it.

In this study, otitis externa was seen in 38/42 (90%) rabbits, of which 32 were lop-eared, and six were erect-eared. In lop-eared rabbits, a 3- to 5-mm gap exists between the tragal cartilage and the ear canal cartilage, letting the ear droop and create a stenotic fold.²⁶ The stenosis prevents drainage of cerumen and in most lop-eared rabbits, results in otitis externa. In rabbits with chronic, refractory otitis externa and no otitis media, a modification of the surgical technique, involving a lateral ear canal ablation without the bulla osteotomy, can be used to treat the otitis externa. When creating the cartilage flap that is to be excised, care should be taken to separate the ear canal epithelial lining from the tragal and ear canal cartilages along the cut edge of the ear canal and to remove any excess cartilage. These two procedures keep the exposed ear canal wide, not semicircular, which helps cure the otitis externa, and allows the exposed ear canal epithelial lining to be reattached to the skin without tension on the wound. Lop-eared rabbits are among the most common rabbit breeds today, representing around 57% of pet rabbits in the UK,²⁷ and around 30% of rabbit patients in

US²⁸ and Finnish²⁹ disease surveys. A higher incidence of otitis media has been reported in lop-eared rabbits.²⁹ The large number of lop-eared rabbits in this study with otitis externa suggests that some middle ear infections may come from otitis externa. Common bacteria isolated from ear canals of rabbits with otitis externa have been reported as *S. aureus* (13%) and *Corynebacterium* spp. (17%)³⁰ two bacterial species found in 20% of our cultures. However, further research is needed to investigate whether otitis media in lop-eared rabbits arises from otitis externa, respiratory infections, or both sources.

Ear surgery in dogs and cats is described as painful, and hydromorphone and morphine are recommended analgesics.³¹ Pain is an important consideration in rabbits as it predisposes them to anorexia due to gastrointestinal stasis, which can be fatal.³² It is critical to provide ongoing analgesia for several days, while reducing narcotic requirements in postoperative care. Morphine temporarily slows gastrointestinal transit in rabbits, but whether buprenorphine does is controversial.^{33–35} Fluid therapy and syringe feeding are essential while the rabbit recovers until it eats and drinks adequately on its own.³⁶

Limitations of this study include the retrospective nature of data analysis, short follow-up length, and not performing CT scans later (3 or 6 months) to assess otitis media. The cause of the head tilt was not investigated to differentiate otitis media from central nervous system lesions. *Encephalitozoon cuniculi* and toxoplasma testing was only performed in a few rabbits and MRI was not used.

5 | CONCLUSION

The study has four principal findings: (1) LECARBOM improved or stabilized clinical signs associated with head tilt in 59% of affected rabbits (2) *Pasteurella multocida*, *Bordetella bronchiseptica*, and *Staphylococcus aureus* accounted for 43% of the bacteria isolated from affected ears, (3) otitis externa was cured in all rabbits undergoing the surgical procedure, and (4) the majority of bacteria cultured from rabbits with otitis media were sensitive to azithromycin, marbofloxacin or enrofloxacin, but resistant to penicillin. Based on these findings, the combination of LECARBOM with postoperative administration of an appropriate antimicrobial, such as azithromycin, should be effective in rabbits with otitis media. Furthermore, clients should be advised that complications, such as wound dehiscence, may develop after about 25% of surgeries.

AUTHOR CONTRIBUTIONS

Monge E, DVM: Conceptualization, methodology, formal analysis, investigation, data curation, writing original draft, final approval of the version to be published,

accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Donnelly TM, BVSc, DipVetPath, DACLAM, DABVP(ECM), D ECZM(SM): Conceptualization, validation, data curation, writing original draft, review and editing, visualization, accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Coutant T, DVM, IPSAV DECZM(Avian): Conceptualization, methodology, review and editing, accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Avery Bennett R, DVM, MS, DACVS: Conceptualization, review and editing, accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Pignon C, DVM, DECZM(SM): Conceptualization, methodology, resources, investigation, writing original draft, supervision, project administration, accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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The authors declare no conflicts of interest related to this report.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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