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Literature Review

Abstracts

RHINOSTOMY AS SURGICAL TREATMENT OF ODONTOGENIC RHINITIS IN THREE PET RABBITS

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Abstract

Disease of the upper airways, specifically chronic rhinitis, is common in pet rabbits and is particularly debilitating in this obligate nasal-breathing species. Cases of chronic rhinitis can be mild to severe (empyema of the nasal cavities). Surgical therapy requires a thorough understanding of upper respiratory anatomy of the rabbit and is an option for chronic rhinitis cases nonresponsive to medical therapy. Diagnostic imaging aids in diagnosing the extent of the disease process and guides the surgical approach. The author reports 3 cases of surgical treatment of rabbit patients diagnosed with chronic rhinitis and empyema of the nasal cavities following advanced or end-stage dental disease. Copyright 2014 Elsevier Inc. All rights reserved.

Key words: computed tomography; maxillary recess; pararhinostomy; rabbit; rhinitis; rhinotomy; rhinostomy

The nasal cavities of rabbits are separated by the longitudinal septum and contain the paired dorsal, middle, and ventral nasal *conchae*, also called nasal turbinates owing to the presence of highly convoluted cartilaginous membranes covered by mucosa, and the third and fourth endoturbinates (Fig. 1A and B).[1-3] Nasal turbinates, in particular the ventral nasal concha, have a very complex arboreal structure (Fig. 1C).[4] With skull bones, the nasal turbinates delineate the dorsal, middle, ventral, and ethmoidal nasal meatuses (Fig. 1A).[3] The nasopharyngeal meatus ventrocaudally extends the nasal cavity.[3] The paranasal cavities of rabbits are represented by the paired dorsal conchal, sphenoidal, and the large, double-chambered maxillary recesses (Fig. 1D-G; Fig. 6).[3,5-8] The nasolacrimal duct passes from the orbital fossa to the nasal cavity.[9] The nasolacrimal duct bends medially, passes through the infratrochlear incisure and the foramen of the lacrimal bone, and enters the bony nasolacrimal canal medial to the maxillary bone adjacent to the maxillary recess (Fig. 1F and G).[3,9] The distal opening of the nasolacrimal duct is located on the dorsomedial side of the nare just caudal to the mucocutaneous junction.[9]

Rabbits are an herbivorous species with elodont (open rooted) teeth.[10] The normal dental formula of rabbits is I2/1 C0/0 P3/2 M3/3 for 28 teeth. Premolars and molars are anatomically indistinguishable and are therefore simply termed cheek teeth. In rabbits, a unique bone structure called the alveolar bulla includes the reserve crown and apices of the 4 caudal cheek teeth (the third premolar and the 3 molar teeth). The dome of the alveolar bulla is caudodorsally adjacent to the orbital fossa and craniomedially adjacent to the lacrimal bone. Cranially, the alveolar bulla is in close proximity to the maxillary recess.[10] The lacrimal bone, located craniolaterally, separates the cranial aspect of the alveolar bulla from the nasolacrimal duct, and craniomedially the maxillary recess (Fig. 1F and G).

Respiratory disease is common in pet rabbits, and as with other animal species, it is caused by a number of primary and secondary disease

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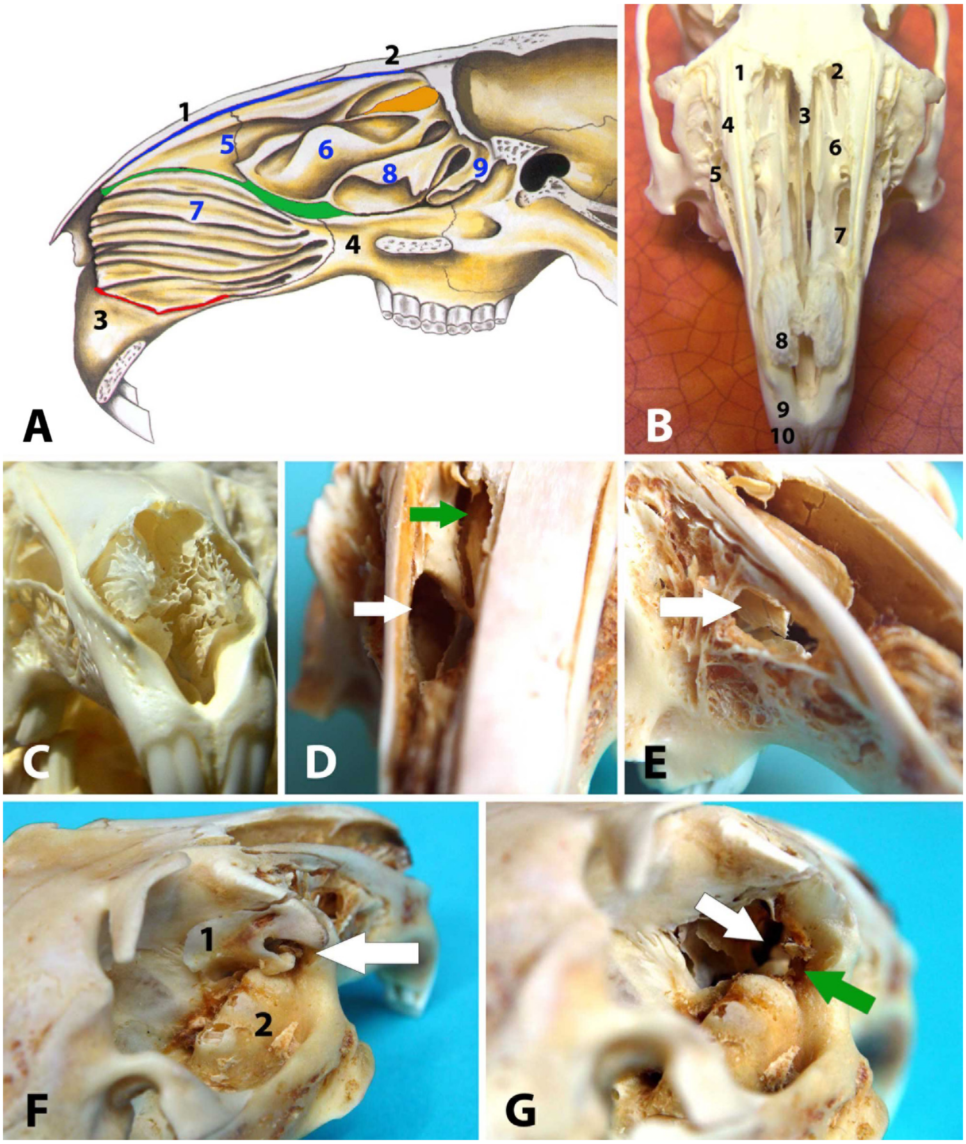

FIGURE 1. Gross anatomy of the nasal cavities of the rabbit. (A) Median section of the nasal cavity showing turbinates and nasal meatuses. View of the right side from the left, after removal of the nasal septum. (1) Nasal bone; (2) frontal bone; (3) incisive bone; (4) maxillary bone; (5) dorsal nasal concha; (6) middle nasal concha; (7) ventral nasal concha; (8) third endoturbinate; (9) fourth endoturbinate. Dorsal nasal meatus (blue line); middle nasal meatus (green line); ventral nasal meatus (red line); and ethmoidal meatus (orange area).[3] (Modified with permission from Popesko et al.[1]) (B) Dorsal view of the nasal cavity, after removal of the nasal bones. Numbers refer to paired and symmetric anatomic structures. (1) Remaining portion of the nasal bone; (2) dorsal recess; (3) nasal septum; (4) nasal process of the incisive bone; (5) perforated surface of the maxillary bone; (6) dorsal nasal concha; (7) maxillary recess; (8) ventral nasal concha; (9) incisive bone; (10) first maxillary incisor tooth. (Used with permission from A. Lennox, DVM.) (C) Close-up of the ventral nasal conchae showing the complex arboreal structure of the turbinates. (Used with permission from A. Lennox, DVM.) (D) After removal of the nasal bone and part of the dorsal nasal concha, the dorsal opening of the right maxillary recess (white arrow) and the dorsal conchal recess (green arrow) are evident. (Used with permission from V. Capello, DVM.) (E) Lateral view of the right maxillary recess (arrow) after removal of a part of the perforated surface of the maxillary bone. (Used with permission from V. Capello, DVM.) (F) Right orbital fossa, caudocranial view. (1) Lacrimal bone. The arrow shows the infrathrochlear incisure and the lacrimal foramen,[2] which represent the proximal opening of the lacrimal duct. (2) Alveolar bulla. In this specimen, the alveolar bulla is not completely normal because the apices of the first 3 molar teeth are penetrating the dorsal surface. (Used with permission from V. Capello, DVM.) (G) Anatomic relationship between the orbital fossa, the alveolar bulla, and the maxillary recess (white arrow) after removal of the lacrimal bone. The green arrow shows the proximal end of the lacrimal duct. (Used with permission from V. Capello, DVM.)

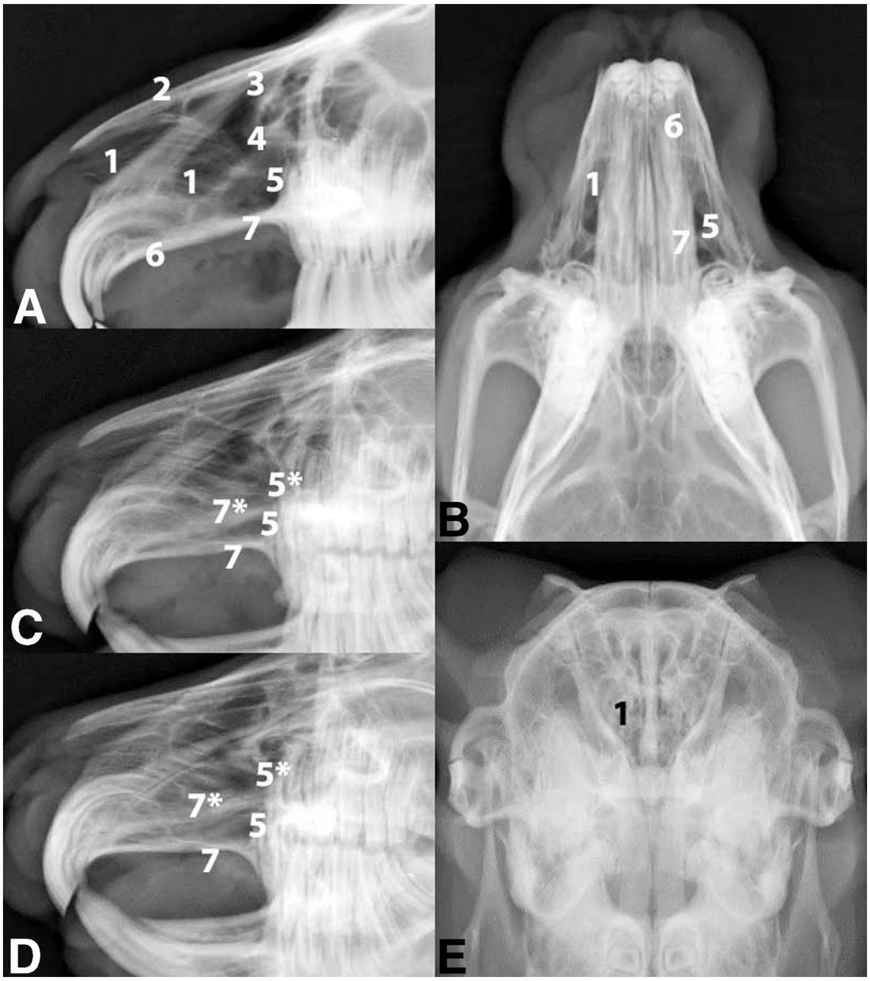

FIGURE 2. Radiographic anatomy of the skull of a 1-kg dwarf rabbit, with special emphasis on the nasal cavities. (A) Laterolateral projection. (1) Ventral nasal concha; (2) nasal bone; (3) dorsal conchal recess; (4) middle nasal concha; (5) maxillary recess; (6) body of the incisive bone; (7) body of the maxillary bone. The 2 parts of the latter bones form the maxillary diastema, which is commonly called the palatine bone. (B) Ventrodorsal projection. (C) Left dorsal to right ventral 20° oblique projection. (5) Right maxillary recess; (5*) left maxillary recess; (7) body of the right maxillary bone; (7*) body of the left maxillary bone. (D) Left dorsal to right ventral 30° oblique projection. Degree of obliquity is not even throughout the length of the skull. Obliquity is more at the *masseteric fossa* of the mandible and less at the nasal cavities. To prevent complete superimposition of maxillary recesses as seen in the laterolateral projection, and superimpostion of the body of the maxillary bone, a higher degree of obliquity (30°) is used than for examination of cheek teeth (15°-20°). (E) Rostrocaudal projection. This projection corresponds with the entire series of axial views of a computed tomography study, and all the anatomic structures are superimposed on a single plane. (Used with permission from V. Capello, DVM.)

conditions. Owing to the close anatomic relationship of dental structures with the nasal and paranasal cavities, severe or end-stage dental disease can indirectly affect nasal structures. Diagnostic imaging modalities used to evaluate rabbit nasal cavities include radiography, computed tomography (CT), rhinoscopy, and magnetic resonance imaging (MRI). Standard radiographic projections of the head, with special emphasis on the nasal cavities, are illustrated in Figure 2. The use of CT as an aid for diagnosis of dental disease and for diseases of the nasal cavities, turbinates, recesses, and tympanic bullae in rabbits has been thoroughly described.[11-14] The normal CT anatomy (axial view and volume rendering in the "airways modality") of nasal cavities in a 1.5-kg pet rabbit is illustrated in Figures 3 and 4. Unlike other diagnostic imaging, endoscopy provides direct visualization of internal anatomic structures.[15] Although the extent of the accessible nasal cavity is limited to the ventral and middle meatuses and adjacent turbinates, diagnostic benefits of rhinoscopy include magnification of visualized structures and the potential for collection of biopsy samples.[15] On entering the ventral meatus through the nares, the ventral and

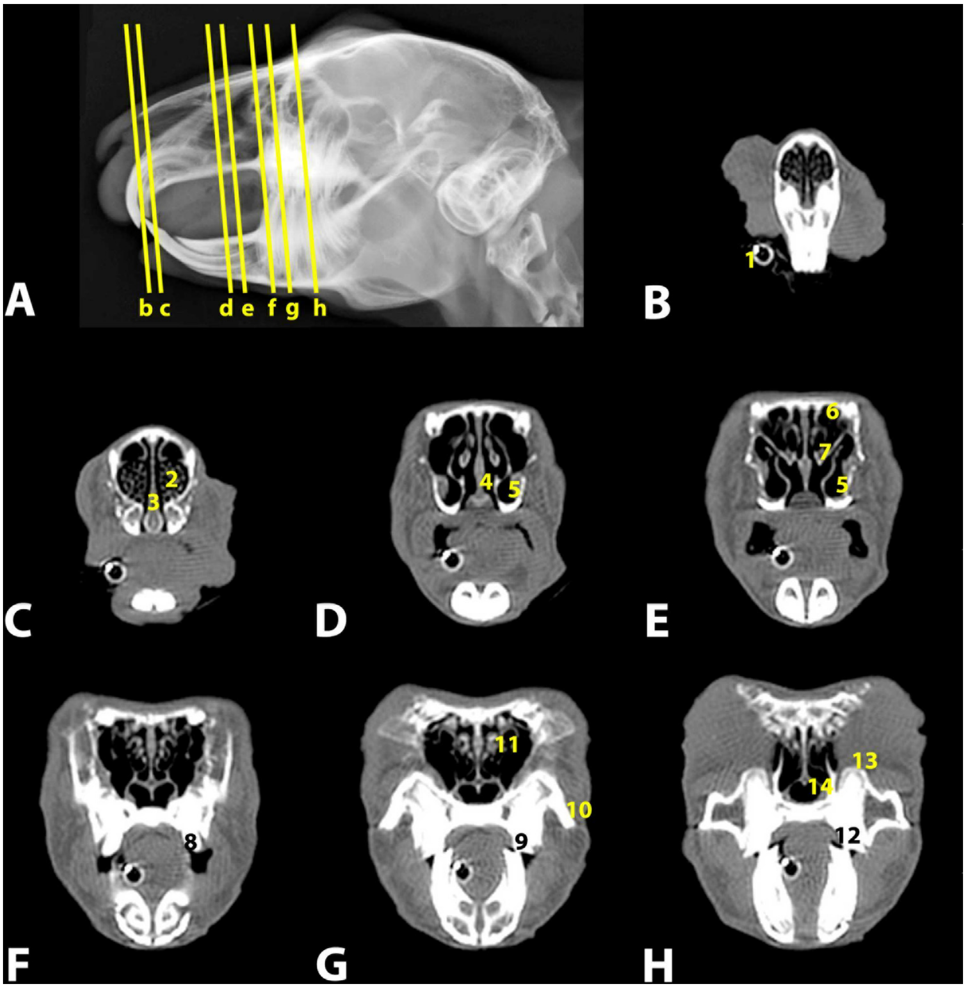

FIGURE 3. Computed tomography of the normal nasal cavity (axial view, bone window). (A) The scout view showing the scanning planes has been adapted from a radiograph of the normal skull for demonstration purposes. Scanning planes are perpendicular to the palatine bone. (B-H) (1) Orotracheal tube; (2) ventral nasal concha; (3) nasal septum; (4) ventral meatus; (5) maxillary recess; (6) dorsal conchal recess; (7) middle nasal concha; (8) first maxillary premolar tooth (CT1); (9) second maxillary premolar tooth (CT2); (10) zygomatic arch; (11) dorsal nasal concha; (12) first maxillary molar tooth (CT3); (13) alveolar bulla; (14) nasopharyngeal meatus. (Used with permission from V. Capello, DVM and A. Lennox, DVM.)

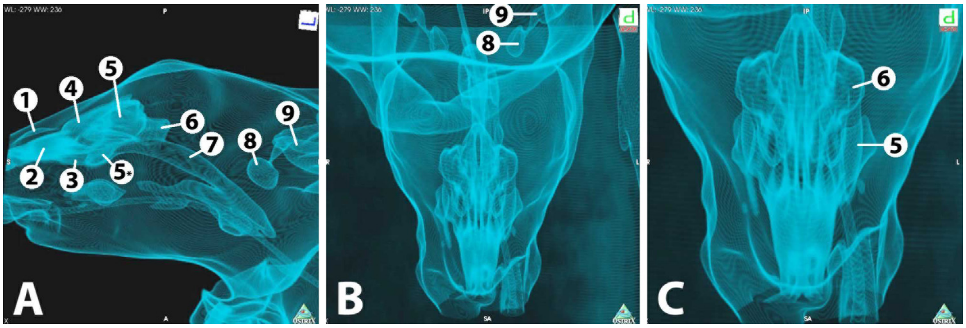

FIGURE 4. Computed tomography of the normal nasal cavity, volume rendering in the "airways" modality. (A) Lateral view of the skull in a normal rabbit. (B) Dorsal view. (C) Dorsal view, close-up. (1) dorsal meatus; (2) middle meatus; (3) ventral meatus; (4) dorsal conchal recess; (5) maxillary recess (dorsal); (5*) maxillary recess (ventral); (6) sphenoidal recess; (7) nasopharyngeal meatus; (8) tympanic bulla; (9) ear canal. (Used with permission from V. Capello, DVM and A. Lennox, DVM.)

middle nasal conchae can be accessed with an appropriately sized endoscope. In larger rabbits, it is possible to visualize the rhinopharynx using a more caudal approach.[16] Rhinoscopy can also be performed from sites other than the natural nasal openings, including through a dorsal or lateral rhinostomy site.[16]

MRI is another useful imaging modality and is ideal for visualization of soft tissues found in the upper respiratory tract of rabbits. The most traditional application of MRI is for the central nervous system, but other soft tissues and pathologic structures with a similar density can be visualized in detail with a quality superior to CT.[17,18]

Rhinotomy techniques for surgical access to the nasal cavities of dogs have been published.[19,20] These surgical techniques include the dorsal approach to access the nasal cavity and paranasal sinuses and the lateral and intraoral approach to access the rostral nasal cavity. Some variations of canine rhinotomy techniques may be adapted for the shorter nasal cavities of cats.[20] With the dorsal approach, the bone flap may or may not be replaced. In the second surgical option, the periosteum and subcutaneous tissue are sutured, leaving a stoma at the caudal aspect of the incision (i.e., performing a temporary rhinostomy).[19-21] Surgical techniques to facilitate drainage of the frontal sinus of dogs and cats have also been reported.[22]

In exotic companion mammals, rhinotomy techniques via a dorsal, lateral, or intraoral transpalatal approach have been reported in the prairie dog for debulking odontomas or extraction of maxillary incisor teeth affected by pseudo-odontomas.[23,24] Dorsal permanent rhinostomy has also been reported for palliative treatment of pseudo-odontomas in prairie dogs.[24,25] In the rabbit, the most common reported rhinotomy technique is dorsal approach. However, in severe cases involving rabbit patients, rhinostomy is used. The surgical procedure can be unilateral or bilateral, depending on the specific case presentation and severity and extent of disease. The dorsal approach is performed along the midline of each nasal bone. The nasal cavity can be accessed by creating a bony flap or through the use of a dental burr to create an opening, which can be enlarged as needed. The size of the opening depends on the surgical goal (rhinoscopy, flushing, or extensive debridement) and outcome desired (rhinotomy vs rhinostomy).

Pararhinotomy is the surgical access to a paranasal cavity (i.e., sinus or a recess). As rabbits do not have sinuses, pararhinostomy is the creation of a temporary or permanent opening into a recess. This surgical approach is actually a rhinostomy procedure with a lateral approach,[12] entering the maxillary recess through the perforated surface (*facies cribrosa*)[1] of the maxillary bone. Surgical approaches and techniques are illustrated in Figure 5.

CASE 1

A 5-year-old, 1.3-kg, neutered male pet rabbit presented with a long history of advanced dental disease, which included 2 years of treatment for multiple sites of concurrent periapical infection, osteomyelitis, and abscessation, located bilaterally at the body of the mandibles and in the left zygomatic area. The mandibular abscesses were initially complicated by bilateral fractures involving the body of the mandibles. The owner reported that the mandibular abscesses occurred after the cheek teeth were treated by another veterinarian. Intraoral inspection showed that a bilateral extraction of clinical crowns of mandibular CT3 and CT4 had been performed. Skull radiographs demonstrated incomplete extraction of those teeth, as fragments of reserve crowns were still visible. The owner declined euthanasia, and a salvage surgical procedure was attempted. Simultaneous debridement of 3 separate abscesses was performed. Extraction of the reserve crowns of the aforementioned teeth was not attempted either intraorally or extraorally because of mandibular instability. Before extraoral debridement of the left maxillary abscess, extraction of the left maxillary CT1 was performed owing to complications associated with periapical infection. Intraoral and extraoral dental procedures were followed with antibiotic treatment using injectable procaine penicillin (40,000 IU subcutaneous, once a day for 21 days, Procacillina; Merial Italia, Milano, Italy). The rabbit was unable to eat owing to bilateral fractures of the mandibles and was fed a commercial hand-feeding formula (Critical Care, Oxbow Animal Health, Murdoch, NE USA) for the same period. The mandibular fractures healed with complications (prognathism of the mandible and malocclusion of incisor teeth), which were extracted 2 months after the first surgery. During the next 2 years, the rabbit underwent frequent dental procedures including coronal reduction of cheek teeth, flushing of nasolacrimal ducts, and surgical correction a lacrimal gland prolapse of the third eyelid. Acquired dental disease of the cheek teeth slowly progressed to end stage including elongation,

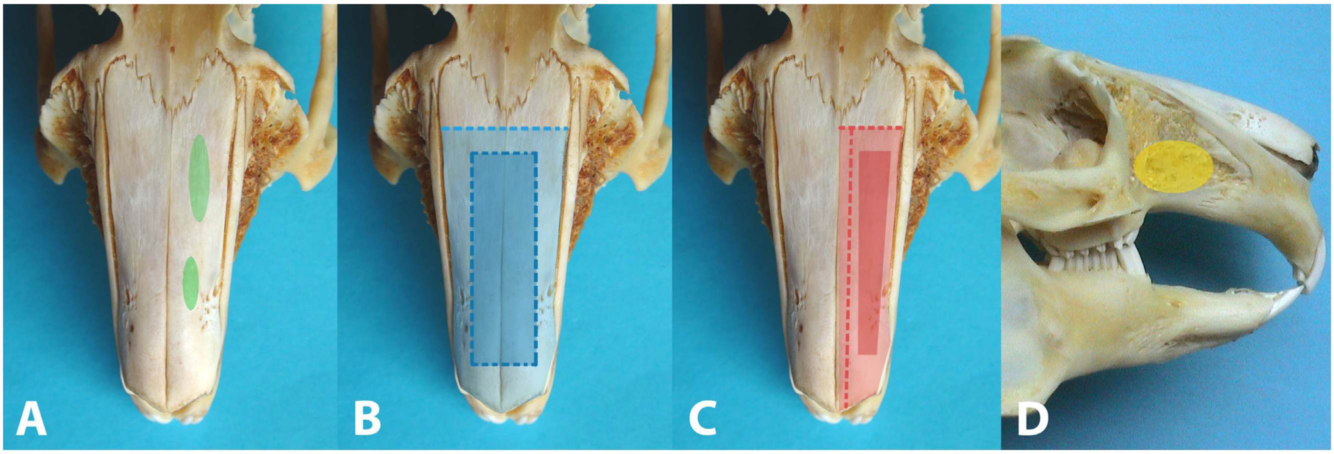

FIGURE 5. The sites and incision lines used by the author for rhinotomy, rhinostomy, and pararhinostomy. Modified approaches may be useful as well. (A) Surgical technique for rhinotomy or for temporary rhinostomy, dorsal approach. The caudal green area shows the site for access with a dental burr to the dorsal nasal concha, the dorsal recess, and the maxillary recess. The cranial green area shows the location to access the ventral nasal concha and the cranial side of the nasal cavity. The exact site is selected based on the target lesion(s) identified using diagnostic imaging. The approach can be unilateral or bilateral. (B) Surgical technique for bilateral rhinostomy, dorsal approach. The light blue area depicts the maximum area of exposure and the bony flap to be removed when separation of the syndesmosis is performed. With this approach, the only osteotomy line is indicated by the light blue dotted line. When narrower exposure is desired (dark blue area), osteotomy is performed along the darker blue dotted lines. (C) Surgical technique for unilateral rhinostomy, dorsal approach. The light red area depicts the maximum area of exposure and the bony flap to be removed when separation of syndesmosis is performed. Avoidance of the syndesmosis between the 2 nasal bones and the insertion of the nasal septum can be performed through a longitudinal paramedian incision. The dark red area depicts narrower exposure. (D) Surgical technique for pararhinotomy or pararhinostomy, lateral approach. The yellow area shows the site for access to the maxillary recess through the perforated surface (*facies cribrosa*) of the maxillary bone. (Used by permission from Vittorio Capello, DVM.)

deformity, abnormal mineralization, and ankylosis of the reserve crowns, specifically the maxillary, resulting in the inability to completely extract the affected teeth. Chronic periapical infection and empyema of the alveolar bullae have been addressed with both intraoral dental treatment, medical therapy and dedicated nutrition (pelleted food by Oxbow; Oxbow Animal Health), allowing for the patient to remain in good overall body condition.

Two years after the first presentation and the first combined surgery, the rabbit demonstrated nasal discharge, partially responsive to systemic and local (nebulization) antibiotic treatment. Episodes of nasal discharge became more frequent and severe and less responsive to treatment. Facial dermatitis was also present, as well as matted fur on the medial surface of the forelimbs and the inguinal area. Mild sneezing progressed to severe dyspnea (Fig. 6). CT of the skull was performed with the goal to provide a detailed diagnosis and pursue exploratory rhinotomy. The following abnormalities were diagnosed: severe obstruction of the nasal meatuses; empyema of the maxillary and dorsal recesses; and deformity, perforation, and empyema of the alveolar bullae. Volume reconstruction demonstrated minimal patency of the nasal passage and the complete obliteration of maxillary recesses. CT also detected empyema of the left tympanic bulla, despite the absence of both clinical signs (otitis externa) and symptoms (head tilt) of otitis (Fig. 7).

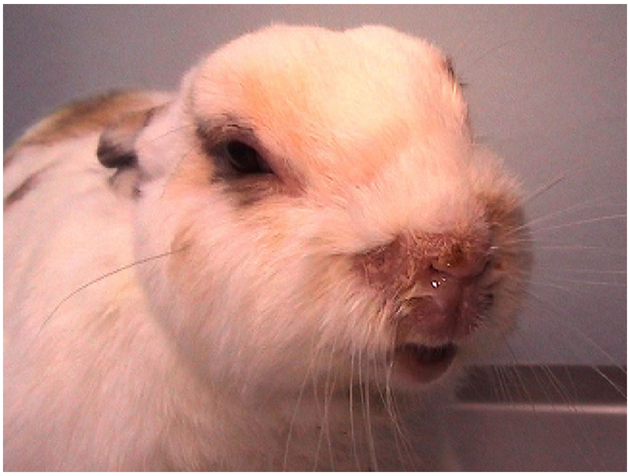

FIGURE 6. Case 1: Severe dyspnea, nasal mucopurulent discharge, and facial dermatitis. (Used with permission from Vittorio Capello, DVM.)

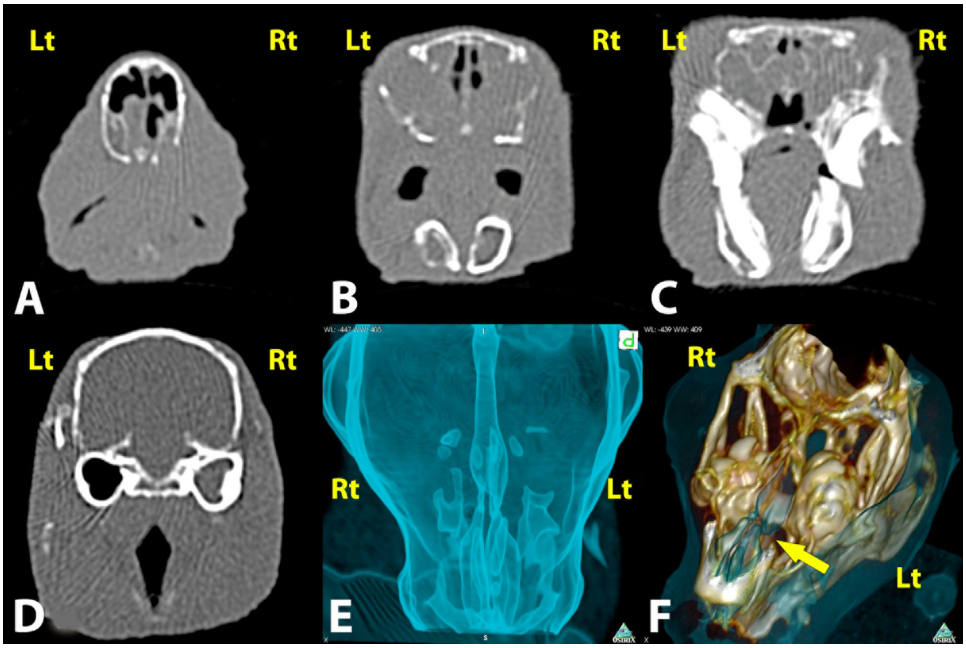

FIGURE 7. Case 1: Computed tomography. (A-C) Severe obstruction of the nasal meatuses and empyema of recesses are visible in 3 slices corresponding to the scanning planes shown in Figure. 3B, F, and H. End-stage dental disease is also present. (D) Empyema of the left tympanic bulla. (E) Volume rendering. The "airways" modality highlights the very limited air passage in this patient. (F) Volume rendering, transverse section after subtraction of the dorsal portion of the skull. The light blue demonstrates the patent airways. The lateral portions not highlighted in blue are filled with pus, e.g., the left maxillary recess (arrow). The severe deformity of both alveolar bullae following advanced dental disease is also evident. (Used with permission from Vittorio Capello, DVM.)

The rabbit was then prepared for a bilateral exploratory rhinotomy procedure (Fig. 8).

Shaving, scrubbing, positioning, draping, skin incision, retraction, and exposure of the nasal bones were performed as described in Figure 8A-C. Detachment of periosteal bone was accomplished through precise and controlled use of a scalpel blade (Fig. 8D). Bleeding was expected during the initial stages of the surgical procedure but was easily controlled with cotton-tipped applicators. In case of bilateral rhinotomy, the bone flap to be cut and elevated involves a large percentage of both nasal bones. The lateral rhinotomy incisions were performed following the anatomic borders of nasal bones (Fig. 8E). A no. 11 scalpel blade was used to pass through the syndesmosis between the nasal bone (medially) and the nasal process of the incisive bone (laterally). Mucopurulent exudate was immediately released during partial rhinotomy (Fig. 8F). The cranial incision of the bone flap was performed between the cranial border of the nasal bones and the cartilage of the nose (Fig. 8G). To lift and tilt the bone flap, incomplete incision of the bone was performed perpendicular to the first 2 lines working with a scalpel blade or a point-tipped burr (Fig. 8H). The bone flap was then gently lifted and tilted caudally using the scalpel handle as a small lever (Fig. 8I). The rhinotomy component of the procedure was then complete, exposing the nasal septum, the conchae, and part of the meatuses. Mucopurulent exudate mixed with clotted blood was filling meatuses and recesses. At this stage, thorough flushing with a sterile saline solution and cleaning of nasal cavities was performed using cotton-tipped applicators. Diseased or necrotic parts of the nasal turbinates were removed and submitted for microbial culture and antimicrobial sensitivity and histopathology. Patency of the cranial potion of the nasal meatuses was assessed by passing a cotton swab through the nares (Fig. 8J). Thorough cleaning, flushing, and suction of maxillary recesses were performed (Fig. 8K-M). As the goal in this patient was to perform temporary rhinostomy, the bone flap was repositioned and 2 small rounded fenestrations were created with a burr to place 2 fenestrated drains for postoperative flushing (Fig. 8N). Suturing of the subcutaneous tissue (Monocryl, 4:0; Ethicon, Johnson & Johnson Medical, Langhorne, PA USA) was sufficient to keep the bone flap in place; 2 small skin incisions of the skin were used to allow egress of the drains. The skin incision was closed in routine fashion with 3-0 monofilament non-absorbable material

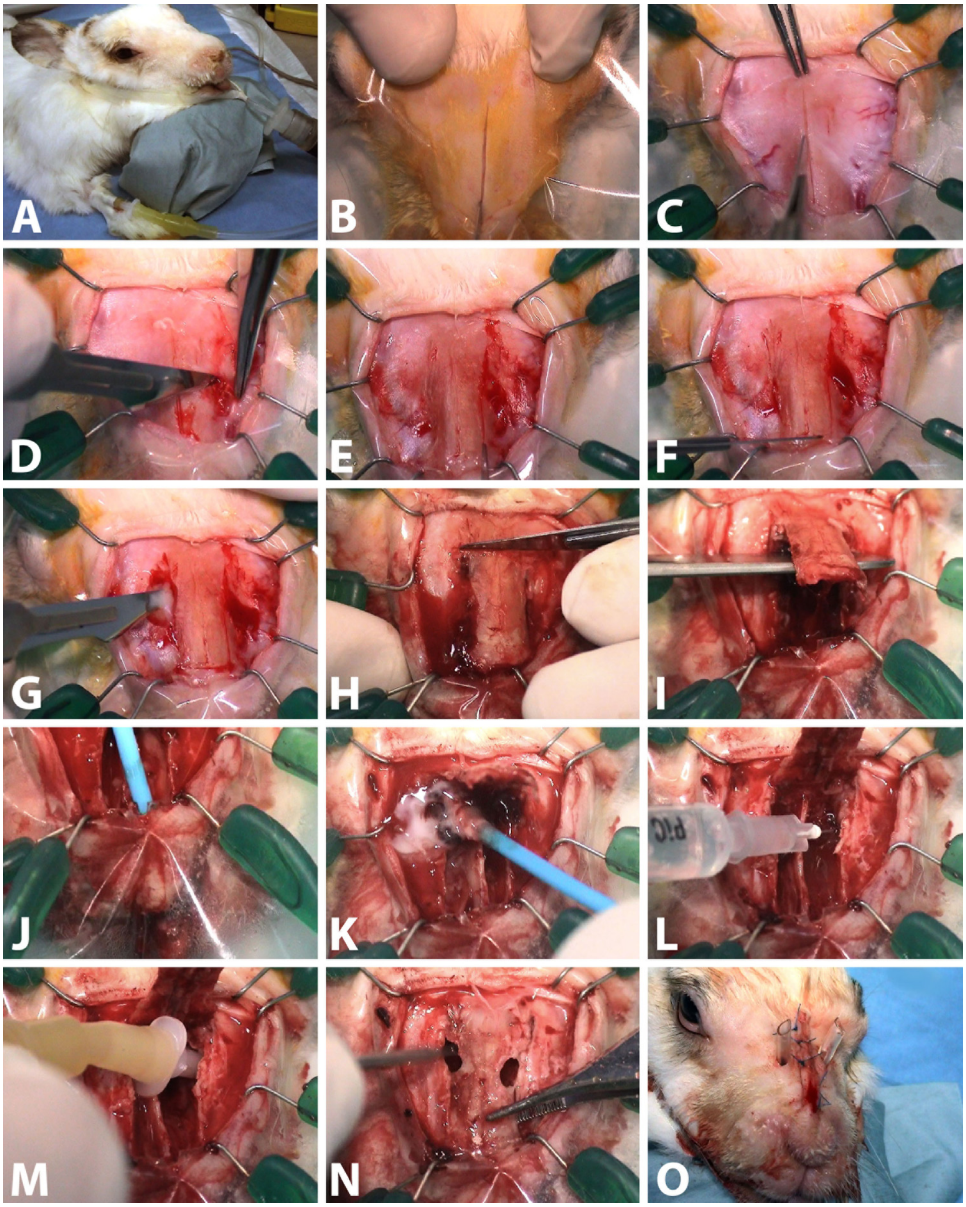

FIGURE 8. Surgical technique for bilateral rhinostomy, shown in case 1. (A) The patient under general anesthesia with an orotracheal tube is placed in sternal recumbency with the head lifted in a steady horizontal position. (B) After shaving and scrubbing, a transparent adhesive surgical drape is placed and contoured. The skin incision is performed on the midline. (C) The Lone Star Retractor (Lone Star Medical Products, Stafford, TX USA) is placed to expose the surface of nasal bones. Incision of the periosteum is performed on the midline. (D) Gentle detachment of the periosteum. (E) Lateral incision of the bone flap, corresponding to the syndesmosis between the nasal bone and the nasal process of the incisive bone. (F) Cranial incision of the bone flap, between the cranial border of the nasal bones and the cartilage of the nose. (G) The same lateral incision as in (E) reveals pus from the nasal cavity. (H) Caudal, incomplete incision of the bony flap. (I) The bone flap is lifted and tilted caudally, allowing exposure of the nasal cavities. (J) Cotton-tipped applicator is passed from the rhinotomy site through the left nare to clean and assess patency of the cranial portion of the nasal meatuses. (K) The right maxillary recess is cleaned of purulent material by using a cotton swab. (L) The left maxillary recess is cleaned by flushing with sterile saline. (M) Accurate suction of the right maxillary recess is performed. (N) The bone flap is repositioned, and 2 small fenestrations are created with a burr for placement of 2 fenestrated drains. (O) Postoperative appearance of skin sutures and bilateral, temporary rhinostomy. (Used with permission from Vittorio Capello, DVM.)

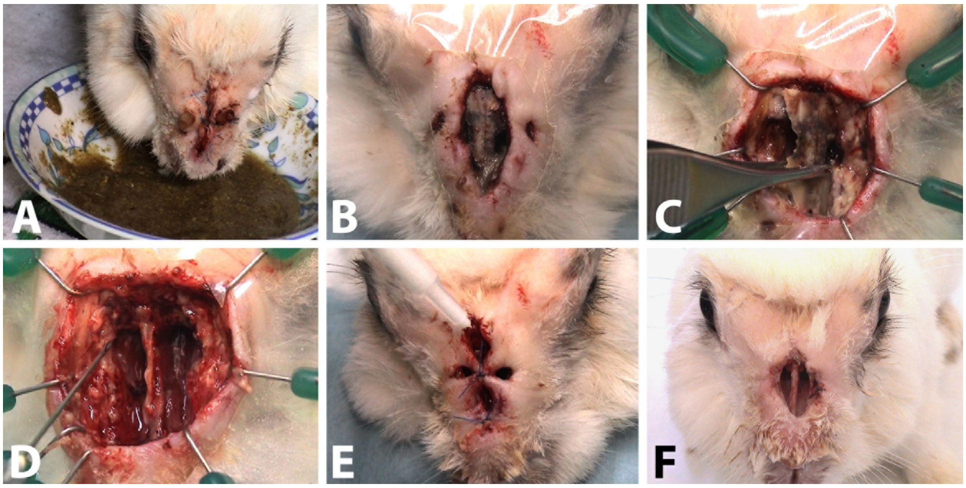

FIGURE 9. Case 1: Follow-up and surgical technique for permanent bilateral rhinostomy. (A) Overall patient condition improved dramatically after surgery, and the patient was able to eat on its own. (B) Avascular necrosis of the bone flap, after removal of skin sutures. (C) Removal of the bony flap during the second surgery. (D) Debridement and flushing of the margins of the stoma. (E) Cosmetic, temporary skin suture and application of HEALx Soother Plus. (F) Remodeling of the initial stoma occurred in the next 4 weeks following healing by second intention. (Used with permission from Vittorio Capello, DVM.)

(Ethilon, Johnson & Johnson Medical), using a simple interrupted pattern (Fig. 8O).

Recovery from surgery and the first 7 days of the postoperative period were uneventful. Dyspnea resolved shortly after surgery, and the overall condition of the patient dramatically improved. The rabbit was able to eat on its own, and flushing of nasal cavities with a sterile saline solution helped remove more exudate and debris (Fig. 9A). Removal of the skin sutures 8 days after surgery revealed avascular necrosis of the bone flap; therefore, the rabbit underwent a second surgical procedure to create a permanent rhinostomy. The necrotic bone was removed and the margins of the stoma were thoroughly flushed with a sterile saline solution and debrided (Fig. 9B-D). A cosmetic, temporary skin suture was performed to partially cover the defect and to allow healing of the subcutaneous tissue to the underlying bone margins (Fig. 9E). A cosmetic skin suture covering temporarily part of the wide stoma was performed with with 3-0 monofilament non absorbable material (Ethilon, Johnson & Johnson Medical), using a simple interrupted pattern. The suture allowed healing of the subcutaneous tissue to the underlying bone margins. An accelerant healing cream containing quaternary ammonium suspended in aloe vera distillate and monoglyceride of fatty acid (HEALx Soother Plus, Lake Worth, FL USA) was applied to the surgical site twice a day to enhance healing. Healing by second intention led to significant remodeling of the initial stoma (Fig. 9F).

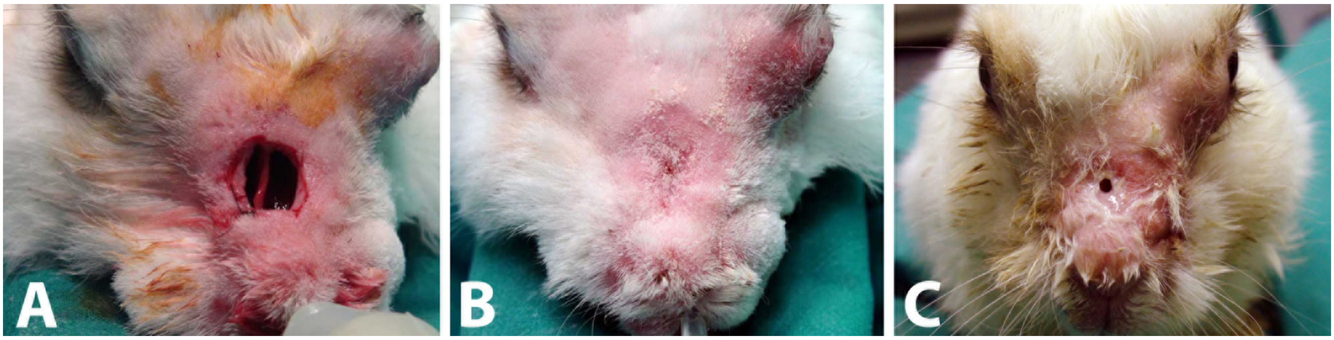

FIGURE 10. Case 1: Permanent bilateral rhinostomy, long-term follow-up. (A) Obliteration of the stoma, 1 year after surgery. (B) Excision of the cutaneous flap to match the stoma of the nasal bones. Note the deviation of the cranial portion of the nasal septum. (C) Patency of a small but efficient stoma is maintained. When the cutaneous stoma reduces its size, signs and symptoms of rhinitis increase. (Used with permission from Vittorio Capello, DVM.)

Approximately 1 year following the permanent rhinostomy procedure, natural healing of the skin resulted in significant reduction of the stoma (Fig. 10A). For this reason, the rabbit underwent a brief surgical procedure to remove portions of the cutaneous flap (Fig. 10B). Four years after the initial surgery, and 2 years following the rhinostomy procedure, the rabbit was still alive with acceptable control of chronic rhinitis, which did not completely resolve. Patency of the small but effective stoma is currently maintained by the owner with daily cleaning using a sterile saline solution, and once every 2 months it is carefully and gently dilated by the author using a cotton swab. Of interest is the observation that when the cutaneous stoma reduces in size, clinical signs associated with rhinitis increase (Fig. 10C).

FIGURE 11. Case 2: Unilateral left purulent nasal discharge. (Used with permission from Vittorio Capello, DVM.)

CASE 2

A 3-year-old intact female lop rabbit was presented with a history of chronic dental disease. Beginning at 2 years of age, the rabbit had been treated for a very large, odontogenic, nonperiapical facial abscess that resulted from trauma associated with a lateral spur of left maxillary premolar. The diseased tooth was extracted and the facial abscess was surgically addressed by complete excision and debridement of the intraoral/extraoral fistula. The rabbit developed severe exophthalmos and keratoconjunctivitis 3 months following the tooth extraction. A retrobulbar abscess resulting from a periapical infection of the first 2 left maxillary molar teeth (CT3 and CT4), perforation of the alveolar bulla, and concurrent empyema of the maxillary recess was diagnosed through CT and MRI evaluation of the patient's skull. Intraoral treatment was aimed to access and debride the alveolar bulla by extraction of the remaining maxillary cheek teeth arcade (from CT2 through CT6), and it was combined with extraoral access into the retrobulbar space via partial lateral maxillotomy. The complex ocular disease resolved in 3 weeks following teeth extraction and partial lateral maxillotomy. Purulent exudate appeared in the left ear canal 2 weeks after recovery, and the rabbit underwent lateral ear canal resection. Involvement of the tympanic bulla was ruled out by CT; therefore, a bullectomy was not performed. Recovery from the lateral ear canal resection was uneventful.

The rabbit began sneezing and developed a unilateral left nasal discharge with mucopurulent exudate 2 weeks after the lateral ear canal resection (Fig. 11). MRI of the rabbit's skull was performed with the goal to evaluate the nasal cavities and contents (Fig. 12). Complete filling of the left nasal cavity with dense material was evident in all 3 scanning planes (transverse, dorsal, and sagittal). The right nasal cavity was normal. Diagnosis was empyema of the left nasal cavity and maxillary recesses. Medical treatment was initiated using 40,000 IU/kg of procaine penicillin administered subcutaneously once a day combined with nebulization of acetylcysteine (Fluimucil, Zambon Group, Milano, Italy). The rabbit's clinical condition slightly improved with treatment, but there was no resolution of the clinical signs; therefore, a rhinostomy was recommended. The images obtained through the MRI suggested a left-side unilateral approach for the rhinostomy procedure (Fig. 13).

An osteotomy of the left nasal bone was performed with the tip of a no. 11 scalpel blade, following the anatomic junctions with the incisive bone on the lateral side and the right nasal bone on the medial side (Fig. 13A). The ostectomy was completed by burring the caudal end and dissecting the cartilaginous rostral end of the left nasal bone. Portions of necrotic turbinates were removed using a small needle holder as a rongeur (Fig. 13B). Mucus, dense purulent material, and blood clots were thoroughly flushed with a sterile saline solution and removed. The left maxillary recess was identified and flushed directly again using a sterile saline solution. Apposition of the skin around the rhinostomy site was done using two 4:0 nonabsorbable sutures (Ethilon, Johnson & Johnson Medical, Langhorne, PA USA), transfixing the periosteal membrane. Recovery of the patient from the surgical procedure was uneventful. The stoma allowed postoperative flushing of the nasal cavity every 8 hours with 5 mL

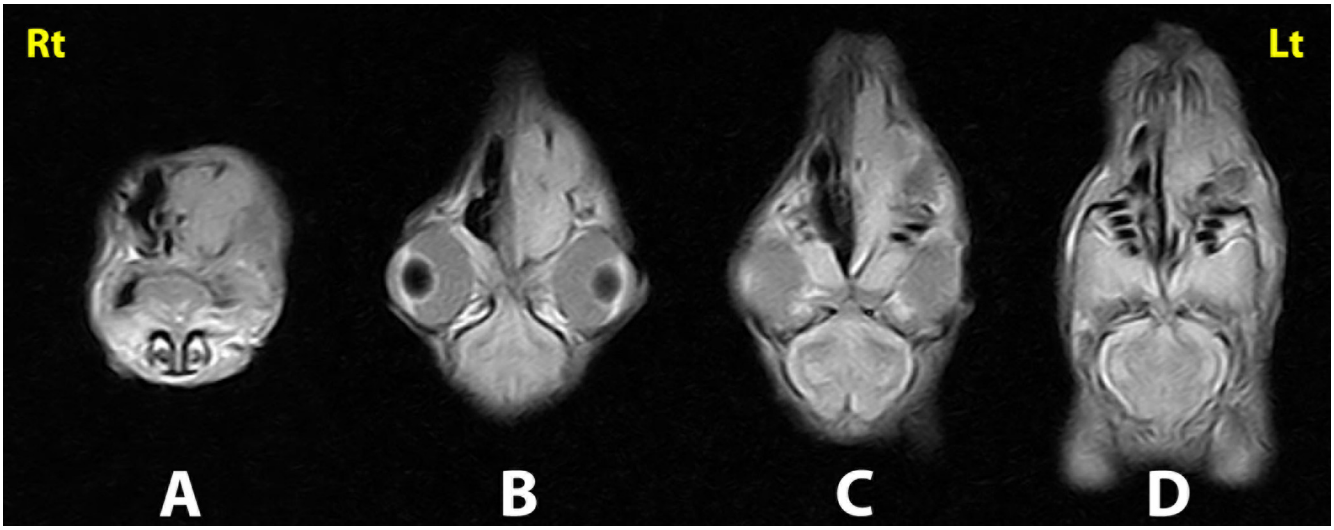

FIGURE 12. Case 2: Magnetic resonance of the skull and the nasal cavities. (A) T2-weighted sequence, transverse view. (B-D) T2-weighted sequence, dorsal view from dorsal to ventral. Complete empyema of the left nasal cavity and the recesses, with deviation of the nasal septum (D). (Used with permission from Vittorio Capello, DVM.)

of a sterile saline solution that led to normal uncomplicated breathing by the patient. Clinical signs associated with the rhinitis disappeared in approximately 2 weeks, and the stoma was progressively reduced by concentric second intention healing of the skin (Fig. 14).

The rabbit had complete resolution of the many facial abscesses, empyema, and exophthalmos 5 months following the first surgical procedure. Unfortunately, the rabbit suddenly died 9 months after the surgical procedure owing to acute rabbit gastrointestinal stasis syndrome of unknown origin.

CASE 3

A 7-year-old, 1.8-kg, neutered female pet rabbit presented for a large facial swelling of the right infraorbital area (Fig. 15A). The overall body condition of the patient was good, and the rabbit had a normal appetite. Inspection of the oral cavity without sedation showed generalized malocclusion of the 4 cheek teeth arcades, in particular the right maxillary arcade. Based on the oral examination, a tentative diagnosis of periapical infection of one or more maxillary cheek teeth and subsequent abscess was made, with possible involvement of the ipsilateral alveolar bulla and the maxillary recess. The rabbit's owners declined CT imaging. Radiographic images obtained under general anesthesia showed deformity of the right alveolar bulla and severe elongation, deformity, and ankylosis of reserve crowns of right maxillary cheek teeth. Involvement of the nasal cavities and the maxillary recess was not apparent (Fig. 15B and C). Stomatoscopy revealed involvement and periapical infection of all right maxillary premolar and molar teeth. The rabbit underwent extraction of the whole maxillary cheek tooth arcade, revealing empyema of the alveolar bulla, which was flushed and cleaned. Several fragments of reserve crowns were removed, but others were not accessible from the oral cavity. Suture of the palatal mucosa was performed with the goal to close the oral opening of the alveolar bulla, especially considering that a concurrent pararhinotomy (e.g., a lateral access to the diseased site) was planned. Following the intraoral dental procedure, the rabbit underwent surgical debridement of the abscess. The affected area was prepared for the surgical procedure. At the base of the abscess, the lateral aspect of the maxillary bone (*facies cribrosa*) was perforated owing to bone lysis (Fig. 15D). The maxillary recess was entered, debrided gently, flushed with sterile saline, and cleaned of purulent debris. It was possible to enter and perform endoscopy for both the maxillary recess and the diseased alveolar bulla (Fig. 15E). More fragments of reserve crowns were removed from the pararhinotomy site. Both the alveolar bulla and the maxillary recess appeared clean at this stage of the surgical procedure. The pararhinostomy was temporarily maintained with marsupialization of the soft tissues, with the goal to enhance healing of the deep portion of the fistula inside the maxillary recess. Postoperative radiographs showed that a fragment of reserve crown was still present, attached to the dome of the

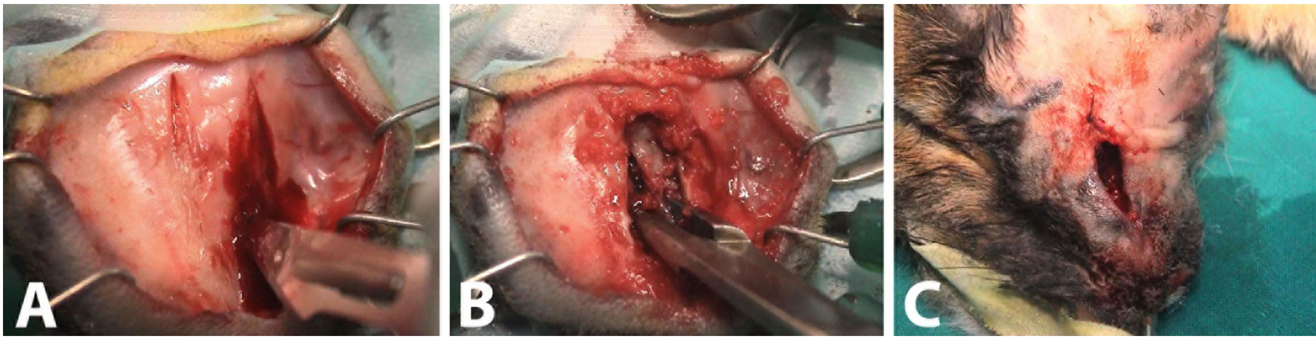

FIGURE 13. Surgical technique for unilateral rhinostomy shown in case 2. (A) Osteotomy of the left nasal bone with a no. 11 scalpel blade along the syndesmosis between the left nasal bone and the nasal process of the incisive bone. (B) Removal of part of necrotic turbinates using a small needle holder as a rongeur. (C) Unilateral rhinostomy site at the end of surgery. (Used with permission from Vittorio Capello, DVM.)

alveolar bulla (Fig. 15F and G). Despite this finding, the rabbit was recovered from anesthesia with no further extraction attempts.

Recovery from anesthesia and surgery was uneventful, requiring minimal postoperative care. Standard postoperative treatment was initiated: 40,000 IU of injectable procaine penicillin once a day for 21 days and meloxicam (0.2 mg/kg orally, twice a day for 7 days, Metacam; Boehringer Ingelheim, St. Joseph, MO USA). Following the surgical procedure, the patient was able to eat on her own. The surgical site, including the maxillary recess, was flushed with sterile saline and debrided twice a day. Application of HEALx Soother Plus was performed both around the stoma and inside the cavity (Fig. 15H). The pararhinostomy site was almost completely healed 18 days after surgery, and complete healing of the skin occurred 24 days following the procedure (Fig. 15I).

The rabbit was rescheduled for anesthesia, repeat radiographic imaging, oral examination, and coronal reduction of the cheek teeth 2 months after the intraoral and the surgical procedure. Dehiscence of the suture of the mucosa had occurred; therefore, the alveolar bulla was open and accessible from the oral cavity. Both repeat radiographic imaging and endoscopic inspection of the alveolar bulla revealed the presence of a retained tooth fragment, although it was not accessible from the oral cavity. The owner declined a second attempt to extract the retained tooth fragment via pararhinotomy of the healed site. The alveolar bulla was covered with granulating tissue, and it was cleaned of debris. The rabbit did not show any clinical disease problems (or reoccurrence of the abscess and empyemas) for the following 1.5 years, after which it was lost to follow-up.

DISCUSSION

A careful understanding of the anatomy of the rabbit nasal cavities is important, especially when considering surgical intervention to resolve upper respiratory disease. The paranasal cavities include the sinuses and the recesses. A skull sinus is a preformed cavity within the thickness of skull bones that communicates with the nasal cavity but is not

FIGURE 14. Case 2: Follow-up after unilateral rhinostomy. (A) Mucopurulent exudate and debris were still produced during the first 2 weeks, but the stoma allowed postoperative flushing of the nasal cavity, and more comfortable breathing. (B and C) The stoma was progressively reduced by concentric healing of the skin. (Used with permission from Vittorio Capello, DVM.)

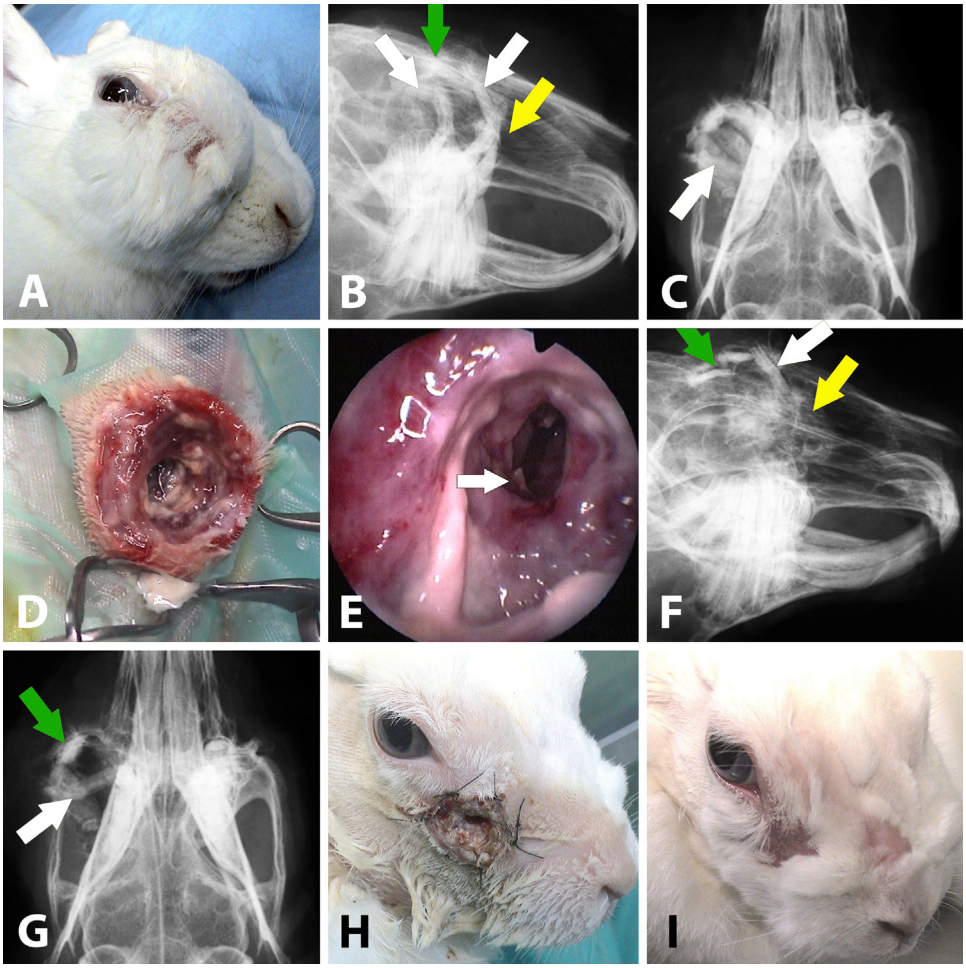

FIGURE 15. Case 3: Pararhinostomy for treatment of a large facial abscess. (A) Facial swelling at presentation. (B) Right 15° ventral-left dorsal preoperative radiographic projection of the skull and (C) ventrodorsal preoperative radiographic projection of the skull. Several elongated, deformed, and ankylotic reserve crowns of right maxillary cheek teeth are visible inside the deformed alveolar bulla (white arrows). Involvement of the maxillary recess was not apparent (yellow arrow). A calcified fragment or density is also visible (green arrows). (D) Intraoperative excision and debridement of the abscess. The maxillary recess was entered through the perforated surface (*facies cribrosa*) of the maxillary bone. (E) Pararhinoscopy (rhinoscopy of the maxillary recess). The cavity in the background is the alveolar bulla. An ankylotic fragment of maxillary cheek tooth is visible (arrow). (F). Right 30° ventral-left dorsal postoperative radiographic projection of the skull and (G) ventrodorsal postoperative radiographic projection of the skull. A fragment of a reserve crown was still present (white arrows). Calcified fragments or densities are visible as well (green arrows). Radiodensity of the maxillary recess is now visible, with this degree of obliquity (yellow arrow). (H) Rhinostomy was temporarily maintained with marsupialization. Follow-up 7 days after surgical debridement. (I) Follow-up 24 days postoperatively. Complete healing of the skin occurred, and fur is regrowing. (Used with permission from Vittorio Capello, DVM.)

actually located within it. A recess is a dead end space within the nasal cavity.[26] Horses, cattle, swine, and dogs have sinuses.[2] Frontal sinuses are divided in multiple compartments.[2,19,20,26] In addition to the frontal and sphenoidal sinuses, paranasal cavities in dogs also include paired maxillary recesses.[19,20,26] The maxillary recess is not called a sinus[26,27] because it is not enclosed in the maxilla.[26]

The paranasal cavities of rabbits are commonly referred to as sinuses in the literature.[3,5-8] Nevertheless, the paranasal cavities of rabbits more closely resemble the maxillary recess of dogs and not a true sinus. The anatomic difference between a sinus and a recess is very important from the pathologic, diagnostic, and surgical standpoint, especially regarding rabbit rhinitis. Although the official anatomic nomenclature[6] does not include specific terminology for the lagomorph species, the maxillary sinus of carnivores is clearly defined as a recess (*recessus*).

Diseases of dental structures can directly or indirectly affect the nasal cavity and the nasolacrimal duct of the rabbit. In cases of rabbit rhinitis, necrosis and lysis of turbinates can frequently occur, which easily results in involvement and disease of the recesses. The anatomic contiguity between the nasolacrimal duct and the maxillary recess[3] can lead to dacryocystitis (often secondary to disease of maxillary incisor teeth), which can progress to infection of the maxillary recess, and subsequently rhinitis. Similarly, the anatomic contiguity between the alveolar bulla and the maxillary recess can result in rhinitis secondary to advanced dental disease. The tympanic bulla is well developed in rabbits. Unlike the alveolar bulla, it is normally a cavitary anatomic structure. The tympanic bulla is connected laterally with the ear canal through the external acoustic meatus and medially with the rhinopharynx through the eustachian tubes.[1,28] The tympanic bulla is therefore indirectly connected to the nasal cavities through the nasopharyngeal meatus and the eustachian tubes.[28] Therefore, disease of the nasal cavity can result in disease of the bullae.

An important physiologic feature of rabbits can increase the severity of upper respiratory disease. Rabbits are obligate nasal breathers, as the epiglottis is normally engaged dorsally over the caudal margin of the soft palate. For this reason, mouth breathing is nonphysiologic and extremely difficult in patients with severe rhinitis. In obligate nasal breathers, severe rhinitis will often result in patients having extreme difficulty in breathing.

Regarding the surgical approach, the opening of a true sinus represents a sinusotomy or a sinusostomy, which only provides indirect access to the nasal cavity. Conversely, the opening of a recess through rhinotomy or rhinostomy (especially in a rabbit with rhinitis and damaged turbinates) results in direct access to the nasal cavity and the potential for effective surgical treatment of chronic rhinitis. It should be noted that the lateral approach to the maxillary recess represents a pararhinotomy. Considering the existing terminology for selected paranasal cavities in other species (e.g., dog) and the specifics of surgical access, the author proposes "recess" instead of "sinus" as the proper terminology for paranasal cavities of rabbits.

Thorough diagnostic imaging is essential to obtain a detailed diagnosis, prognosis, and to help identify those patients that may benefit from a rhinotomy or rhinostomy surgical procedure.[14] Symmetry is an extremely important factor in patient positioning for radiographic imaging of the skull, with the exception of oblique projections.[11] Severe radiographic changes (e.g., mineralized abscesses or masses, and osteolysis) may be apparent, but even optimal radiographic images seldom provide detailed information about the extent and severity of disease of the nasal cavity. In particular, the rostrocaudal view is intrinsically inferior when compared with that obtained by advanced modalities such as CT, as all anatomic structures are superimposed on a single plane. Digital radiology (both direct and computed digital radiology) provides a wider grayscale and allows for easy image adjustment when compared with traditional radiographic films. For this reason, adjustment of the grayscale may allow emphasis of milder radiodense structures such as turbinates. Proper positioning and degree of obliquity is also critical for hiding or showing details of nasal cavities and recesses (Fig. 15B and F).

All the CT images presented in this article have been produced with Osirix (www.osirix-viewer.com), which also provides a useful "airways modality" (Fig. 4). The "airways" modality is particularly advantageous for the evaluation of the empty space within nasal cavities, the related recesses, the tympanic bullae, and, in general, the upper airways.

MRI provides excellent information, and in selected cases, it is even more superior to CT, which is less specific for lower radiodensities. Generally, the thick pus of rabbits has a signal intensity similar to soft tissues, which represents an interesting application for rabbits with severe rhinitis, especially those with multiple empyema syndrome affecting one or more cavities and in cases of retrobulbar and parabulbar abscesses.[14] CT remains superior for diagnosis of bony structures. As CT and MRI each have distinct advantages, ideally both are used as complementary diagnostic tests.[12,14] In most cases both CT and MRI are not feasible for practical and financial reasons; however, clinical evaluation and survey radiographs can guide the clinician to select the most appropriate advanced diagnostic imaging method.

Three paired preformed cavities of the skull (e.g., nasal cavities with related maxillary recesses, and tympanic bullae), and normal structures that are prone to abscessation secondary to dental disease of the cheek teeth (the alveolar bulla), can undergo unilateral or bilateral, partial or complete empyema.[14] Empyema can occur sequentially or as a concurrent event. Many different clinical signs can be present, making this complex disease a syndrome.

Rhinotomy provides access to the nasal cavity through bone incision (osteotomy), with the intention to close immediately after surgery. Rhinostomy is used to describe the same, but with the intent of eventual closure (temporary rhinostomy) or purposely leaving it permanently open (permanent rhinostomy). Both case 1 (ending with permanent, bilateral rhinostomy) and case 2 (unilateral rhinostomy) were examples of panempyema of the skull because of advanced or end-stage dental disease. In case 1, the involvement of the tympanic bulla likely occurred through the eustachian tube. Case 3 is an example of temporary pararhinostomy (lateral rhinostomy through the maxillary recess) unrelated to chronic rhinitis or empyema of the nasal cavities. The temporary pararhinostomy was used as part of the surgical approach to an odontogenic facial abscess arising from the alveolar bulla and creating empyema of the ipsilateral maxillary recess. Excision and debridement of the abscess included exploratory pararhinotomy.

Some distinct features of the surgical techniques should be highlighted. In case of rhinotomy and rhinostomy, temporary occlusion of the carotid arteries is not necessary as reported in dogs and cats.[20] A sharp-tipped no. 11 scalpel blade may be adequate for passage through the syndesmosis, especially in dwarf rabbits, and when bone lysis occurs due to chronic infection. From a technical standpoint, the scalpel blade approach to the rhinotomy employs disarticulation rather than osteotomy and avoids the use of a burr or saw. The goal of incomplete caudal incision of the bone flap in case 1 was to maintain sufficient vascular support. In retrospect, the vascular support was inadequate, and the author now recommends complete removal of the flap. As septic rhinitis was chronic with no hope of resolution, the owner was instructed to ensure patency through daily removal of any accumulating debris. Flushing with a sterile saline solution, cleaning, and suction of maxillary recesses is of particular importance in rabbits with empyema of the nasal cavities. Recesses can be entered with a cotton-tipped applicator, syringe, or small suction device in a dorsoventral, mediolateral, or slightly craniocaudal direction. Cosmetic appearance and owner education for long-term postoperative care are 2 important concerns for these surgeries. An additional concern is the initial snoring sound produced by the patient during the first few days after a rhinostomy procedure is performed. In some cases, the final cosmetic appearance of the stoma must be overlooked when the goal is to keep it open for an extended period. Closure of the stoma might be welcome from the cosmetic standpoint, but in many cases, it may worsen the clinical disease signs. This finding clearly demonstrates that inadequate patency of nasal cavities is a critical adjunct factor for pathogenesis of rhinitis, and additional patency is an important factor for control or resolution of severe chronic rhinitis.

Regarding the retained tooth fragment in case 3, which had been missed during stomatoscopy, this may have occurred because inspection of the alveolar bulla is particularly difficult using a rigid endoscope. In retrospect, the use of a flexible endoscope might have been more useful,[29] even if extraction of an ankylotic tooth fragment is particularly challenging, both from the oral cavity, and through pararhinotomy. In this case, the tooth fragment did not act as a sequestrum with subsequent osteomyelitis.

All the surgical options related to this surgery seem to carry a very good postoperative prognosis. Despite the apparent invasiveness, these procedures were well tolerated and resulted in excellent quality of life and owner satisfaction.

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