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Refereed Peer Review

Bordetella Infections in Dogs and Cats: Treatment and Prevention*

KEY FACTS

- *Bordetella bronchiseptica* has developed resistance to some commonly used antimicrobials.
- Supportive care and rest are often the only treatments necessary.
- Both intranasal and injectable vaccines are available to help protect dogs and cats.
- Research is ongoing to refine current vaccines and develop new ones.

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ABSTRACT: Dogs and cats with respiratory disease caused by *Bordetella bronchiseptica* are often managed with antibiotic therapy and supportive care, although mild infections may not require treatment. Appropriate antibiotics are based on susceptibility data and the ability to reach therapeutic concentrations in respiratory secretions. Other potentially useful medications include antitussives, bronchodilators, and antiinflammatories. Vaccines are available for both dogs and cats to help prevent bordetellosis, and research is ongoing to refine current products and develop new ones.

Bordetellosis in dogs and cats tends to be a mild, self-limiting disease.¹⁻⁴ Clinical signs may last from a few days to a few weeks. Coughing in dogs may be managed by restricting exercise and avoiding excitement.² Cats with mild respiratory signs often improve with supportive care alone.⁵ For dogs and cats with systemic clinical signs, a high risk of transmission to other animals, or preexisting respiratory conditions, recommended medications include antibiotics, antitussives, and antiinflammatories.^{2,3,6,7} Table 1 lists suggested dosages for useful drugs.^{3,6-10}

ANTIBIOTICS

Because *Bordetella bronchiseptica* colonizes the ciliated epithelial cells of the upper respiratory tract, systemic antibiotics may not attain adequate tissue levels at the site of infection. The bronchial–alveolar–blood barrier limits diffusion, and only drugs of low molecular weight and high lipophilicity achieve therapeutic levels.⁸ Aerosol (nebulization) and direct intratracheal delivery of antimicrobials may provide higher concentrations.⁸ When culture and sensitivity results are available, appropriate antibiotics may be chosen after considering susceptibility, ability to reach the respiratory tract, cost, and side effects. Historical sensitivities have been published and may also be used to guide antibiotic choices. Treatment should be administered for approximately 2 weeks or for 1 week beyond resolution of clinical signs.^{3,8,10,11}

Penicillins

Natural penicillin and aminopenicillins (ampicillin and amoxicillin) are commonly used for small animal respiratory tract infections, but *B. bronchiseptica*

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has shown resistance in most studies, except when amoxicillin is combined with clavulanate (Clavamox, Pfizer).¹²⁻¹⁷ Penicillins do not penetrate well into bronchial secretions, which may limit efficacy in tracheobronchitis.⁸ Moderate resistance to amoxicillin-clavulanate was seen in one field study,¹⁸ but this medication may be useful in rhinitis or when other susceptible bacteria are involved in respiratory infections.¹⁰ A report from England showed a significant decrease in coughing associated with tracheobronchitis with the use of either ampicillin or amoxicillin.¹⁹

Cephalosporins

B. bronchiseptica is resistant to cephalosporins in most cases, although these drugs reach higher concentrations in the respiratory tract than penicillins.^{8,14-16,18} Newer-generation cephalosporins have increased efficacy against gram-negative bacteria, but ceftiofur (Naxcel, Pharmacia), an extended-spectrum drug, was shown to be ineffective against swine *B. bronchiseptica* isolates.²⁰ More studies are needed to evaluate the efficacy of newer cephalosporins for bordetellosis.

Macrolides

The use of erythromycin, lincomycin, clindamycin, and azithromycin against *B. bronchiseptica* is not well documented. Several studies report resistance to erythromycin or lincomycin, although high bronchial levels are achieved.^{8,15,21} Macrolides are commonly used in humans with *Bordetella pertussis* (whooping cough) infections.²² Further research is needed, especially with the increasing use of azithromycin (Zithromax, Pfizer) for canine and especially feline bacterial infections.^{2,23}

Trimethoprim-Sulfadiazine

The combination of trimethoprim with a sulfonamide reaches effective concentrations in the respiratory tract and has reportedly been successful in treating bordetellosis in dogs.^{7,8,24-26} One retrospective case study of canine kennel cough indicated trimethoprim-sulfadiazine was effective in reducing the duration of coughing.¹⁹ In another study in which daily injections of

Table 1. Drugs Used in the Treatment of Bordetellosis^{3,6-10}

Drug	Canine Dosage (mg/kg) ^a	Feline Dosage (mg/kg) ^a
Antibiotics		
Amikacin	15–20 q24h IV, IM, SC	15–20 q24h IV, IM, SC
Amoxicillin-clavulanate	12.5–25 q12h	12.5 q12h
Azithromycin	3.3 q24h for 3 days	5–10 q24–48h
Chloramphenicol	25–50 q8h	10–20 q12h
Doxycycline	5–10 q12–24h	5–10 q12–24h
Enrofloxacin	5–20 q24h	2.5–5 q24h
Gentamicin	4–8 q24h IV, IM, SC	4–8 q24h IV, IM, SC
Marbofloxacin	2.75–5.5 q24h	2.75–5.5 q24h
Tetracycline	15–20 q8h	15–20 q8h
Trimethoprim-sulfadiazine	15–30 q12–24h	15–30 q12–24h
Supportive Medications		
Aminophylline	5–11 q8–12h	4–6.6 q8–12h
Butorphanol	0.05 SC or 0.5–1 PO q6–12h	Not used
Codeine	0.1–0.3 q4–6h	Not used
Hydrocodone	0.25 q6–12h	Not used
Prednisone	0.5–1 q24h	1–2 q24h
Theophylline	5–11 q6–8h	4 q8–12h
Theophylline extended release	10 q24h	12 q24h

^aUnless indicated otherwise, route of administration is PO.

trimethoprim-sulfadiazine were given to experimentally infected dogs, coughing was reduced but recurred when the drug was stopped.²⁶ However, in-vitro resistance has been reported, so this combination should be used only when the isolate is cultured and shown to be susceptible.^{13,14,16,17}

Aminoglycosides

Both amikacin and gentamicin are highly effective against *B. bronchiseptica* and generally achieve adequate concentrations in respiratory secretions.^{8,12,14-16,21} Nephrotoxicity is a well-recognized complication of aminoglycoside use, but the risk may be minimized by once-daily dosing and avoiding use in dehydrated or renally compromised patients.⁸ Amikacin, gentamicin, and polymixin B may also be administered by nebulization. This strategy delivers a high concentration directly to the affected tissue (respiratory epithelium) while avoiding systemic side effects. Nebulization techniques and drug dosages are described in the literature.^{2,6,7,27,28}

Chloramphenicol

Although rarely used because of the possibility of human toxicity, chloramphenicol has good penetration into the respiratory tract and in-vitro efficacy against *Bordetella*.^{8,12,14-16} Chloramphenicol is a reasonable alternative antibiotic as long as precautions are taken to avoid human exposure.^{2,8,10}

Fluoroquinolones

Currently, four quinolone antibiotics are labeled for veterinary use in the United States: enrofloxacin (Baytril, Bayer), orbifloxacin (Orbax, Schering-Plough), difloxacin (Dicural, Fort Dodge), and marbofloxacin (Zeniquin, Pfizer). These drugs penetrate into the respiratory tract as well as intracellularly and are good choices for *B. bronchiseptica* infections.^{8,10,13,17,18} In-vitro data generally show excellent susceptibility patterns, with only one report of moderate resistance.¹⁶ One study of feline *B. bronchiseptica* isolates reported both susceptibility and postantibiotic effect properties of the four quinolones; marbofloxacin was the most effective, followed by enrofloxacin, orbifloxacin, and difloxacin.²⁹ Enrofloxacin has been associated with retinal damage, including blindness, in cats when used at high doses or extended durations; thus it is prudent to use any quinolone carefully in cats and to adhere strictly to labeled dosages.³⁰

Tetracyclines

Both tetracycline and doxycycline are effective and are considered by some to be the drug class of choice for treating bordetellosis.^{2,10,11,31,32} In-vitro susceptibility and tissue concentrations are good, but some *Bordetella* strains have shown resistance.^{8,12-18} A feline isolate of *B. bronchiseptica* was found to have plasmid-mediated resistance to tetracycline that was transferrable to *Escherichia coli*.³³ Tetracyclines should be used with caution in pregnant animals as well as in puppies and kittens because of the potential for teeth staining.¹¹

Summary

Antibiotic selection for dogs and cats with *B. bronchiseptica* should be based on bacterial sensitivity results and ability to reach therapeutic concentrations in the respiratory tract. In the absence of culture results, tetracycline, doxycycline, or quinolones (i.e., marbofloxacin, enrofloxacin) are appropriate choices. Amoxicillin-clavulanate may be useful in mixed infections, and severe cases (e.g., pneumonia) may respond to aminoglycosides administered by injection or nebulization. Because many animals affected with bordetellosis have mild clinical signs that resolve in 1 week or less, antibiotic therapy is not always indicated.

SUPPORTIVE MEDICATIONS

Antitussives

A dry, hacking, paroxysmal cough can be a significant irritant to both dogs and owners. As long as the cough is not excessively moist or productive or associated with pneumonia or severe clinical signs, therapy can be directed toward cough suppression.^{2,6,8} Several

authors suggest antitussive medications,^{2,6,8,31} although others caution about antitussive use.^{11,34}

Codeine phosphate or codeine sulfate is the prototypical centrally acting narcotic antitussive.⁸ Hydrocodone (Hycodan, Endo Pharmaceuticals) is commonly recommended because of increased potency and less respiratory depression than codeine.^{2,6,8,31} Butorphanol (Torbutrol, Fort Dodge) is available as an injection and oral tablets and is FDA approved for treating cough in dogs.^{2,6,8,31} Diphenoxylate-atropine (Lomotil, Pharmacia) has been reported to be an effective antitussive for chronic coughing.³⁵ Over-the-counter products containing dextromethorphan have been used but are thought to be less effective.⁶⁻⁸ Dogs receiving any antitussive drugs should be monitored for fever, lethargy, and respiratory distress that may result from accumulation of bronchial secretions.⁷

Bronchodilators

Drugs such as aminophylline, theophylline, terbutaline, and albuterol are peripherally acting antitussives.^{6,8} They may reduce bronchoconstriction secondary to airway inflammation and are occasionally recommended for tracheobronchitis.⁶⁻⁸

Antiinflammatories

B. bronchiseptica infections are associated with inflammation of the upper airway passages. Corticosteroids are useful in suppressing the inflammatory response in uncomplicated cases of infectious tracheobronchitis in dogs.³⁶ An antiinflammatory dose of prednisone for 3 to 5 days helps decrease bronchial secretions and reduce the severity of coughing.^{6,7} Corticosteroids should be avoided if fever or pneumonia is present or if there is a possibility of systemic fungal infection (e.g., blastomycosis).

OTHER SUPPORTIVE CARE

Dogs and cats with bordetellosis should be kept calm and quiet until clinical signs resolve.² Excitement, exercise, pulling on collars, and other stress should be minimized.³⁷ Some patients benefit from humidification or fluid therapy, which helps thin and loosen airway secretions.^{6,24} Because of the contagious nature of the infection, isolation from other animals is recommended. Dog-to-cat transmission has been suggested.^{38,39}

PREVENTION

Animals tend to be exposed to *B. bronchiseptica* in crowded areas, such as boarding kennels, pet stores, training classes, breeding facilities, and shows.³⁷ Managers and caretakers in group situations should be educated on the importance of hygiene and sanitation.³⁷ General recommendations include 10 to 15 air changes

per hour, a relative humidity of 50% to 65%, and an ambient air temperature of 70°F to 75°F.² Thorough cleaning of cages, walls, floors, and bowls with routine disinfectants or household bleach diluted 1:32 with water is essential.² Proper handwashing or disposable gloves are needed for caretakers or others who move from one animal to the next.²

Pet owners should be aware of the risk of contagion and try to minimize contact with dogs and cats that show signs of respiratory disease. Affected animals should be kept at home or in proper isolation facilities until clinical signs resolve.² In addition to these preventive measures, canine *Bordetella* vaccines have been used to control outbreaks of infectious tracheobronchitis and to protect individual dogs. A feline *B. bronchiseptica* vaccine that may help protect cats was recently introduced.

Canine Intranasal Vaccination

The use of a live *B. bronchiseptica* vaccine administered by the intranasal route was reported in swine in 1969.⁴⁰ In 1978, a temperature-sensitive strain was developed that showed 100% protection from challenge in guinea pigs.⁴¹ In 1979, intranasal immunization in dogs was first reported when an experimental attenuated isolate showed 95% of vaccinated dogs had no coughing and reduced numbers of bacteria from nasal swabs after challenge.⁴² One hundred percent of control dogs coughed and had high bacterial counts along with pulmonary lesions consistent with pneumonia. Serum agglutinating antibody titers against *B. bronchiseptica* did not increase in vaccinated dogs, but control dogs had an eightfold increase. The lack of systemic humoral antibody response suggested that local immunity played an important role in protection.⁴²

Similar studies of intranasal vaccination were subsequently reported, and results consistently showed excellent protection against challenge.⁴³⁻⁴⁹ A study measuring *B. bronchiseptica*-specific secretory IgA titers in nasal swabs demonstrated a significant increase 4 days and up to 21 days after vaccination, while humoral antibodies also increased.⁴⁵ In this report, dogs challenged 24 hours after vaccination had no reduction in coughing. However, by 48 hours, 20%; day 4, 56%; day 5, 83%; and day 14, 95% of the dogs had no coughing. This was the first report of rapid onset of immunity after intranasal vaccination along with evidence that secretory IgA was associated with protection.⁴⁵

Live avirulent intranasal vaccines that combine *B. bronchiseptica* with canine parainfluenza virus, along with trivalent products that also add canine adenovirus-2, were reported to have better protection than *B. bronchiseptica* vaccines alone.^{48,49} Maternal antibodies do not block the response to vaccination, and puppies as

young as 3 weeks of age were successfully immunized with one dose in a field study.⁴⁹

A more recent experimental study of the efficacy of an intranasal *B. bronchiseptica* product (NasaGuard-B, Pfizer) found that puppies vaccinated once at 18 weeks of age and challenged 2 weeks later had significantly less coughing than did controls.⁴⁷ Total leukocyte counts were lower, and both serum IgG and salivary IgA and IgG antibody levels were higher than in control puppies. However, puppies vaccinated with both injectable and intranasal products in sequence showed a significant decline in coughing and higher antibody concentrations compared with controls and those vaccinated only intranasally.⁴⁷

There are several theories about how avirulent live *B. bronchiseptica* vaccines work. Intranasal administration stimulates local mucosal immunity (IgA antibodies) in the nasal passages, so antibody-mediated destruction of disease organisms leads to protection.⁴⁵ Another possibility is that avirulent bacteria in the vaccine colonize the respiratory epithelium, which blocks virulent organisms from attaching.^{42,43} Because intranasal vaccines also stimulate systemic immunity (measured by increased serum IgG), protection may also occur by that route.^{46,47,50}

Advantages of intranasal *B. bronchiseptica* vaccines in dogs include rapid onset of immunity, a single-dose requirement for primary and subsequent vaccinations,

Table 2. Currently Available *B. bronchiseptica* Vaccines for Dogs and Cats

Product Name	Manufacturer/ Distributor	Other Antigens Included	Labeled Minimum Age	Labeled Revaccination Interval
Canine Intranasal				
NasaGuard-B	Pfizer	None	3 wk	Annual
Progard-KC	Intervet	Parainfluenza	3 wk	Annual
Intra-Trac II	Schering-Plough	Parainfluenza	3 wk	Annual
Naramune-2	Boehringer Ingelheim Vetmedica	Parainfluenza	3 wk ^a	Annual
Progard-KC Plus	Intervet	Parainfluenza/adenovirus type 2	3 wk	Annual
Bronchi-Shield III	Fort Dodge	Parainfluenza/adenovirus type 2	8 wk	Annual
Canine Injectable				
CoughGuard B	Pfizer	None	Not specified	Annual ^b
CoughGuard CPI/B	Pfizer	Parainfluenza	Not specified	Annual ^b
Vanguard 5/B	Pfizer	Parainfluenza/adenovirus type 2/ distemper/parvovirus	Not specified	Annual ^b
Bronchicine CAe	Biocor	None	8 wk ^c	Annual
Feline Intranasal				
Protex-Bb	Intervet	None	8 wk	Not specified

^aPuppies vaccinated at 3–6 wk of age should be revaccinated at 6 wk of age.

^bHealthy dogs should receive 2 doses administered 2–4 wk apart. If dogs are vaccinated before 4 mo of age, they should be revaccinated with a single dose at 4 mo of age.

^cFor initial vaccination, a second dose is required 2–4 wk later.

approval for use in very young puppies, and avoidance of injection-site reactions.^{2,7} Disadvantages include occasional postvaccination sneezing or coughing, possible reversion to virulence, and difficult administration to fractious dogs.^{2,7} Accidental SC administration of an intranasal product has been associated with hepatic failure.⁵¹

The duration of immunity for canine *B. bronchiseptica* vaccines has not been well studied. Despite label claims that “annual vaccination is recommended,” evidence for exactly how long dogs are protected is lacking. Review articles suggest a duration of immunity of 6 to 12 months,^{2,11,31} but no controlled studies have been found in the literature. Some practitioners recommend vaccinating every 6 months instead of yearly. Others suggest revaccinating at least 5 days before entering a boarding kennel or other high-risk situation.⁷

The concept of boosting immunity in adult dogs by revaccinating with an intranasal product has been studied.⁵⁰ Dogs with preexisting antibody titers against *B. bronchiseptica* were vaccinated, and both serum and saliva samples were collected before and after to monitor changes in titers. The intranasal product used in this study (NasaGuard-B) failed to increase salivary concentrations of IgA or IgG, although serum IgA and IgG titers were higher at day 10 after vaccination.⁵⁰ Although this was a limited study of 10 laboratory beagles, the results question the common belief that intranasal vac-

nation causes a rapid increase in mucosal immunity in previously exposed or vaccinated dogs.⁵⁰

Table 2 lists currently available intranasal *B. bronchiseptica* vaccines for dogs along with labeled minimum ages and revaccination intervals. All but one product contain other antigens. The product label for Progard-KC and Progard-KC Plus claims protection 72 hours after administration, based on prelicensing studies. Although a limited number of reports compare *B. bronchiseptica* vaccines alone versus combination products,^{49,52} it is difficult to determine whether specific vaccines are more effective than others in stimulating immunity or reducing clinical signs of disease. It may not be necessary to include parainfluenza and adenovirus-2 vaccines when choosing *Bordetella* products because these vaccines are commonly given to dogs parenterally in combination with distemper and parvovirus. However, further research is needed.

Canine Injectable Vaccination

B. bronchiseptica bacterins are also available as injectables administered subcutaneously or intramuscularly (Table 2). The earliest report of bacterin use in dogs showed no efficacy unless an adjuvant such as aluminum hydroxide was added.⁵³ Subsequent studies demonstrated good efficacy against experimental *B. bronchiseptica* exposure.^{47,54–57} These vaccines stimulate systemic immu-

nity characterized by high serum antibody (IgG) levels and have recently been shown to also stimulate serum IgA and, to a lesser extent, salivary IgG and IgA.⁴⁷ The mechanism by which parenteral *B. bronchiseptica* vaccines induce protection is not clear but most likely involves both local mucosal and systemic immunity.⁴⁷

Older *B. bronchiseptica* bacterins were occasionally associated with complications, such as injection-site reactions and infections, fever, lethargy, and other signs of postvaccinal illness.^{1,2} Current vaccines have a much lower reaction rate, probably due to purification of the products to remove cell-membrane toxins and extraneous material. One canine vaccine (Bronchicine CAe, Biocor) was reported to immunize laboratory guinea pigs against *B. bronchiseptica*,⁵⁸ and some practitioners have used Bronchicine CAe in cats and ferrets. However, these uses are extralabel, and safety and efficacy have not been reported in species other than dogs.

As with intranasal *Bordetella* vaccines, the exact duration of immunity of parenteral products is unknown and may be more or less than 1 year. One study indicated that an injectable vaccine (CoughGuard B) stimulated higher antibody levels in previously vaccinated dogs than did an intranasal product.⁵⁰ Serum concentrations of IgA and IgG were significantly increased. The authors suggested that parenteral bacterins instead of intranasal vaccines should be used to boost immunity in previously exposed or vaccinated dogs.⁵⁰

Feline Intranasal Vaccination

The prevalence of *B. bronchiseptica* infection or clinical disease in cats is unknown, but studies from various regions have been reported.^{38,59–67} In Louisiana, 19 of 614 (3.1%) shelter cats tested positive on culture, and 148 of 614 (24.1%) were seropositive.⁵⁹ In the United Kingdom, 82 of 740 (11%) cats cultured positive.³⁸ A study from Flanders, Belgium, of 272 cats showed a prevalence of 4% on culture.⁶⁷ Other reports have similar findings, but positive culture or serologic results are not always correlated with clinical signs.^{38,64}

Vaccination using an avirulent live *B. bronchiseptica* intranasal product (Protex-Bb, Intervet) was shown to have an onset of 72 hours and to reduce clinical signs by 92%.⁶⁸ Another study also demonstrated the efficacy of this product.⁶⁹ Safety has been demonstrated in pregnant queens.⁷⁰ The revaccination interval is not specified on the product label (Table 2), but 6-month and 1-year challenge studies demonstrated efficacy of 79% and 90%, respectively.⁶⁸

VACCINATION RECOMMENDATIONS

Canine and feline vaccines have undergone more scrutiny by veterinarians with regard to efficacy, safety,

and clinical relevance of the many products available.⁷¹ The following is a summary of recently published guidelines about *B. bronchiseptica* vaccination from several professional organizations.^{72–74}

The AVMA Council on Biologics and Therapeutics (COBTA) classifies both canine and feline vaccines for *B. bronchiseptica* infection as “noncore” in a recent report.⁷³ Noncore vaccine products are described by COBTA as meeting one or more of the following conditions⁷³:

- Limited potential for exposure to the disease because of lifestyle or geographic region
- Lower virulence representing less severe illness
- Benefit:risk ratios too low to warrant use in all circumstances
- Inadequate scientific information to evaluate clinical need, efficacy, and safety

More specifically, COBTA states that the efficacy of canine intranasal *Bordetella* vaccines is moderate, whereas that of parenteral vaccines is low. Routine vaccination is not indicated, but the use of an intranasal vaccine about 2 weeks before exposure appears to have beneficial results. For cats, COBTA states that vaccine efficacy is low and the duration of immunity is short. Also, very young cats may have adverse events associated with vaccination, and no data exist on the use of the intranasal vaccine in younger cats.⁷³ However, no references are listed to support these statements. Previously cited studies would appear to refute some of COBTA's statements.^{47,50,68,69}

The American Animal Hospital Association (AAHA) Canine Vaccine Task Force also lists *B. bronchiseptica* vaccines as “noncore.”⁷⁴ In this report, noncore vaccines are described as those that should be considered only in special circumstances because their use depends on the exposure risk of the individual animal.⁷⁴ Geographic distribution and lifestyle should be considered, and the diseases involved are generally self-limiting or respond readily to treatment. Canine intranasal *Bordetella* vaccination is “optional” but recommended for dogs housed in kennels or shelters and before boarding in kennels.⁷⁴ For dogs not vaccinated within the previous 6 months, a booster is recommended 1 week before known exposure (e.g., boarding, showing). Duration of immunity is believed to be approximately 10 months. Topically administered vaccines (intranasal) may provide a superior local immune response compared with parenterally administered vaccines. Canine parenteral *Bordetella* vaccines are “optional” but not generally recommended. Duration of immunity of injectables is approximately 9 to 12 months. Revaccination is recommended annually

or more often in very high-risk animals not protected by annual booster.⁷⁴

In 2000, the American Association of Feline Practitioners and Academy of Feline Medicine (AAFP/AFM) Advisory Panel on Feline Vaccines issued a report on vaccine selection and administration.⁷² The only *Bordetella* vaccine currently available for cats was not recommended for routine use. However, vaccination may be considered for cats entering or residing in multiple-cat environments in which *B. bronchiseptica* infections associated with clinical disease have been documented.⁷² The ability of the product to reduce the prevalence of infection or the severity of disease in these environments has not been evaluated.⁷²

Based on the scientific literature reviewed in this article, it is clear that statements issued by COBTA, AAHA, and AAFP/AFM reflect consensus opinion rather than original research or clinical trials. For example, COBTA's assertions that "there are no data on the use of the [*Bordetella*] vaccine in younger cats" and that "some experts expressed concern about the potential for adverse events associated with vaccination of very young cats"⁷³ appear to be refuted by several studies conducted in 4-week-old kittens in which efficacy (reduction in clinical scores) ranged from 76% to 92% and no adverse reactions were reported.^{68,70} Another example is from the AAHA report,⁷⁴ which states that parenteral *Bordetella* vaccines are "not generally recommended," whereas intranasal vaccines are "recommended" despite recent studies demonstrating the efficacy and safety of injectable products (alone or in combination with intranasal vaccines).^{47,50}

Either intranasal or injectable *B. bronchiseptica* vaccinations may be used to protect dogs that may be exposed to infection. Most authors recommend immunization of dogs "at risk," which typically includes dogs that visit boarding or grooming facilities, dog shows or classes, or public areas, such as dog parks. Other dogs that may benefit from vaccination are brachycephalic breeds, dogs with respiratory tract abnormalities (e.g., collapsing trachea), and immunocompromised dogs that may have increased severity of disease if infected with *B. bronchiseptica*.^{2,11}

One recent study evaluated the comparative efficacy of injectable and intranasal vaccines administered either alone or in sequence.⁴⁷ The results clearly showed a significant decrease in clinical signs and the highest antibody levels when both products were used in sequence (i.e., two injectable vaccines followed by one intranasal or one intranasal followed by two injectables, all given 2 weeks apart).⁴⁷ Puppies vaccinated with either product alone had fewer clinical signs (i.e., coughing, fever) than did controls but more clinical signs than did pup-

pies vaccinated with both.⁴⁷ A reasonable conclusion from this report would be that puppies are protected from bordetellosis when vaccinated, but even better efficacy and fewer clinical signs are seen when puppies are vaccinated three times, 2 weeks apart (twice with injectable and once with intranasal).

However, discussions of vaccine efficacy must include recent findings of variations in field and vaccine strains of *B. bronchiseptica*. Keil and Fenwick⁷⁵ have demonstrated variability in the outer membrane protein expression of canine isolates. Nonfimbrial adhesins, such as filamentous hemagglutinin and pertactin, varied depending on the strains. Keil and Fenwick⁷⁶ also reported on the genetic diversity found in field isolates but not in strains used to manufacture vaccines. Their conclusion was that current intranasal *B. bronchiseptica* vaccines do not represent contemporary isolates in either genotype or antigenic expression. Therefore, canine vaccination currently does not control the disease as well as in the past.⁷⁷

Vaccines to protect human infants against *B. pertussis* (whooping cough) were previously whole-cell bacterins. Newer vaccines are acellular, containing inactive *B. pertussis* toxin, filamentous hemagglutinin, and pertactin.²² The efficacy of these new products was 84% in one trial compared with 36% efficacy of a whole-cell vaccine.⁷⁸ Acellular vaccination also resulted in fewer adverse effects, such as fever and injection-site swelling. The same technology used to produce human vaccines with purified proteins, such as filamentous hemagglutinin and pertactin, may prove useful in future development of canine and feline vaccines.³⁷

B. bronchiseptica vaccination for cats may be considered in boarding kennels, catteries, shelters, and multi-cat households and for cats that travel to shows or exhibitions. Cats may also be at risk if they have contact with infected dogs.^{38,39}

Bordetellosis in dogs, cats, and other animals may be a zoonotic disease or opportunistic infection.^{22,79} Several reports have documented human infection associated with immunosuppression,^{22,79,80} so client education is important to minimize transmission of the disease. Frequent handwashing and avoiding contact with respiratory secretions from animals may decrease the risk. Practitioners should consider vaccination of pets living in contact with persons who may be immunocompromised. There is no evidence that *B. pertussis* infects animals.²²

SUMMARY

B. bronchiseptica is one cause of infectious tracheobronchitis in dogs and also has been associated with respiratory disease in cats. Antibiotics are often used to treat bordetellosis, and drug choices should be based on

culture and sensitivity results or on published studies of predicted efficacy. Both intranasal and injectable vaccines are available for dogs, and consideration should be given to using both in sequence for maximal protection. Intranasal vaccination for cats has shown good efficacy in laboratory studies. Further research directed toward acellular vaccines is needed to refine current products and develop new ones.

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4. Antitussive medication should not be used in dogs showing signs of
 - a. paroxysmal cough.
 - b. pneumonia.
 - c. sneezing and nasal discharge.
 - d. retching and gagging.
 5. Which of the following characteristics are found in intranasal *Bordetella* vaccines for dogs?
 - a. onset of immunity in 24 hours; no adverse reactions
 - b. onset of immunity in 3 to 5 days; possible postvaccinal sneezing and coughing
 - c. two doses required for primary immunization; annual boosters recommended
 - d. two doses required in puppies younger than 12 weeks of age; onset of immunity 3 to 5 days after second vaccination
 6. Which of the following characteristics are found in killed *B. bronchiseptica* bacterins for SC or IM use?
 - a. high incidence of vaccine reactions (i.e., local swelling, fever)
 - b. lack of efficacy compared with intranasal vaccines
 - c. stimulation of systemic (IgG), but not mucosal (IgA), immunity
 - d. two doses required for primary immunization
 7. A recent study showed that puppies were best protected from *Bordetella* challenge with
 - a. two injectable vaccines and one intranasal vaccine in 2-week intervals.
 - b. one intranasal vaccine followed in 3 weeks with one injectable vaccine.
 - c. two intranasal vaccines 3 weeks apart.
 - d. two injectable vaccines 3 weeks apart, with a third injectable vaccine at 4 months of age.
 8. The AVMA COBTA classifies *Bordetella* as one of the "noncore" vaccines. Which characteristic does this classification not include?
 - a. limited lifestyle or geographic risk
 - b. a benefit:risk ratio that is too low
 - c. substantial public health importance
 - d. inadequate scientific information available
 9. Why may current canine vaccines against *B. bronchiseptica* not be as effective as in the past?
 - a. widespread preexisting immunity in dog populations
 - b. genetic diversity in field strains
 - c. increased prevalence of other agents, such as parainfluenza virus
 - d. acellular vaccines stimulating weaker immunity
 10. Newer human *B. pertussis* vaccines are
 - a. acellular.
 - b. modified-live.
 - c. killed bacterins.
 - d. recombinant.

ARTICLE #2 CE TEST

The article you have read qualifies for 1.5 contact hours of Continuing Education Credit from the Auburn University College of Veterinary Medicine. Choose the best answer to each of the following questions; then mark your answers on the postage-paid envelope inserted in *Compendium*.

1. An appropriate antibiotic to treat *B. bronchiseptica* based on historical sensitivity data is
 - a. amoxicillin.
 - b. cephalexin.
 - c. trimethoprim-sulfadiazine.
 - d. marbofloxacin.
2. Which class of drugs does not reach therapeutic concentrations in respiratory secretions?
 - a. macrolides
 - b. fluoroquinolones
 - c. penicillins
 - d. tetracyclines
3. The risk of nephrotoxicity associated with aminoglycoside antibiotics may be minimized by administering the drug
 - a. in divided doses three times a day.
 - b. by SC injection.
 - c. by nebulization.
 - d. by IV injection.