

PRACTICAL PHARMACOLOGY

Pharmacologic Approaches to Feline Infectious Peritonitis

Sally Coggins, BVSc (Hons I), MANZCVS (Medicine of Cats), PhD, University of Sydney School of Veterinary Science, Sydney, Australia

Petra Černá, PhD, DACVIM (SAIM), MANZCVS (Medicine of Cats), CertAVP (SAM-F), MRCVS, AFHEA, AdvCertFB, Colorado State University College of Veterinary Medicine and Biomedical Sciences, Fort Collins, Colorado

In the past, a diagnosis of feline infectious peritonitis (FIP) carried a grave prognosis, and most cats died or were euthanized within days to months of diagnosis. However, in recent years, considerable advancements have been made in the treatment of FIP, particularly nucleotide prodrugs such as remdesivir and molnupiravir, which are metabolized to their nucleoside analogues GS-441524 and β -D-*N*⁴-hydroxycytidine (NHC; EIDD-1931), respectively. Also showing promise for adjunctive treatment of refractory FIP are viral protease inhibitors (GC376 and nirmatrelvir).¹⁻¹⁶

In many countries, including the United States, veterinarians can prescribe some or all of the following compounded formulations of remdesivir, GS-441524,

molnupiravir, and NHC. Additionally, off-label prescription of registered human drugs are additional legal avenues open to veterinarians.

Cats may still require initial supportive therapy specific to their FIP presentation and disease severity; however, for most patients with FIP, clinicians can anticipate rapid clinical improvement within days of commencing effective antiviral therapy. It is rare that veterinary medicine has taken a disease from an untreatable death sentence to an 85% long-term survival rate with essentially a monotherapy approach.^{9,11}

This article focuses on the mechanisms of action of these antivirals, the currently understood

Abstract

In recent years, considerable advancements have been made for treatment of feline infectious peritonitis (FIP) involving new antiviral drugs, primarily nucleoside analogues (e.g., remdesivir and its metabolite GS-441524, molnupiravir and its metabolite EIDD-1931). Also promising as adjunctive treatments are viral protease inhibitors GC376 and nirmatrelvir. Although cats may continue to need initial supportive therapy specific to their FIP presentation and disease severity, most patients with FIP experience rapid clinical improvement within days of commencing effective antiviral therapy as well as long-term survival rates. This article focuses on the mechanisms of action of the antivirals, current understanding of their pharmacokinetics in cats, and currently recommended dosing protocols for antiviral medications in the treatment of FIP.



Take-Home Points

- Antiviral drugs, particularly nucleoside analogues such as remdesivir and GS-441524, are highly effective for treating feline infectious peritonitis (FIP).
- Remdesivir and GS-441524 disrupt virus replication via RNA-dependent RNA polymerase, causing chain termination.
- Molnupiravir and EIDD-1931 induce lethal mutations in virus RNA.
- Patients with FIP may need adjunctive therapy based on disease severity but typically show clinical improvement within days of antiviral treatment.
- First-line therapy should prioritize remdesivir or GS-441524 due to their proven efficacy and safety; molnupiravir and EIDD-1931 are good alternative options as second-line antivirals, mainly in cats that fail to respond to therapy with GS-441524, or in situations in which GS-441524 is financially prohibitive.
- Responsible antiviral use is essential for minimizing development of drug resistance.

pharmacokinetics in cats, and the recommended dosing protocols for the treatment of FIP.

NUCLEOTIDE AND NUCLEOSIDE ANALOGUES

Nucleotide and nucleoside analogues are a class of drug with diverse treatment utility, although they are primarily used as antiviral and chemotherapeutic agents.¹⁷ A nucleotide (e.g., remdesivir, molnupiravir) is the prodrug form that incorporates 1 or more phosphate groups into the nucleoside structure, and a nucleoside (e.g., GS-441524, NHC) consists of a nucleobase linked to a sugar moiety.¹⁸ In vivo, nucleotide analogues are typically metabolized to release their core nucleoside, which is subsequently converted into its active form. The active metabolite disrupts virus replication by mimicking native RNA nucleosides and interfering with viral RNA synthesis. How RNA synthesis is ultimately disrupted varies.

REMDESIVIR AND GS-441524

Remdesivir is a nucleotide prodrug that was variably approved around the world for parenteral administration to humans for treatment of SARS-CoV-2 during the COVID-19 pandemic.^{19,20}

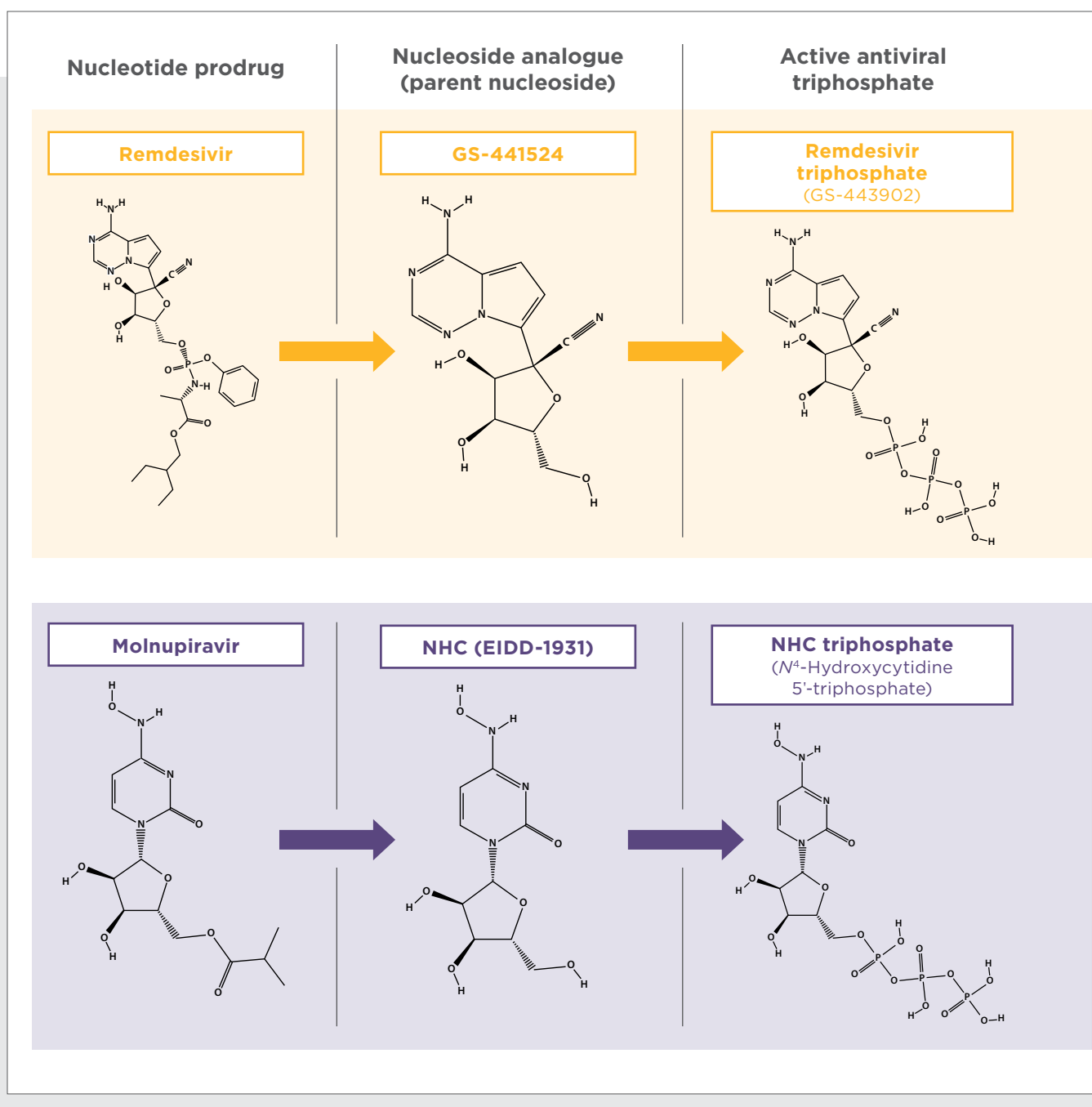
Remdesivir was approved by the U.S. FDA and is available for off-label veterinary use in the United States (although sourcing from a human hospital pharmacy can be challenging); compounded parenteral formulations are also available in Australia, New Zealand, and the United Kingdom.

Remdesivir undergoes several hydrolysis steps to form the primary metabolite GS-441524 and then the

pharmacologically active triphosphate GS-443902.²¹⁻²⁵ GS-443902 acts as an adenosine analogue and disrupts virus replication by incorporating into viral RNA via RNA-dependent RNA polymerase, causing delayed chain termination, inhibiting viral synthesis (FIGURE 1).^{21,22,24,26} In cats, the in vivo conversion from remdesivir to GS-441524 is likely facilitated by blood esterases (rather than hepatic metabolism).²⁷ Regardless of whether a clinician administers remdesivir (the prodrug) or GS-441524 (the core nucleoside), the active triphosphate GS-443902 ultimately disrupts virus replication (FIGURE 1).

The pharmacokinetics of GS-441524 in specific pathogen-free cats after subcutaneous (n = 2) or intravenous (n = 2) administration of 5 mg/kg have been described.⁴ The intracellular concentration of the active triphosphate in peripheral blood mononuclear cells remains 8 to 20 times above the EC₅₀ (half maximal effective concentration) for 72 hours, supporting the effectiveness of once-daily subcutaneous or intravenous dosing of 5 mg/kg GS-441524.⁴ The in vivo pharmacokinetics of GS-441524 after intravenous administration of remdesivir to 3 clinically normal specific pathogen-free cats and cats with FIP have also been described.²⁸ In this study, 10 mg/kg PO molnupiravir, 25 mg/kg PO GS-441524 and remdesivir, and 7 mg/kg IV remdesivir resulted in plasma levels greater than the established corresponding EC₅₀ values, which are sustained over 24 hours for GS-441524 and remdesivir.²⁸

The pharmacokinetics of GS-441524 after intravenous remdesivir administration in 6 cats clinically affected with FIP has also been described; the mean peak plasma concentration (C_{max}) of GS-441524 after a



single 15 mg/kg IV dose of remdesivir was 2632 ng/mL (standard deviation [SD] 862), time to reach C_{max} was 1 hour (SD 0), and elimination half-life was 5.14 hours (SD 0.81).²⁹

Although direct pharmacokinetic studies of GS-441524 administered orally to cats remain limited, the outcome data strongly support the efficacy of current oral dosing protocols. Across the literature, treatment with remdesivir and/or GS-441524 demonstrated remission

and long-term survival rates of 77% to 96% after subcutaneous and oral administration (TABLE 1).^{2,7-12}

MOLNUPIRAVIR AND NHC

Molnupiravir (EIDD-2801), an isopropyl ester prodrug of the nucleoside analogue NHC (EIDD-1931), interferes with replication of various viruses, including SARS-CoV-2.^{30,31} Because of its ability to tautomerize, molnupiravir can substitute for either cytidine or



Mechanism of action

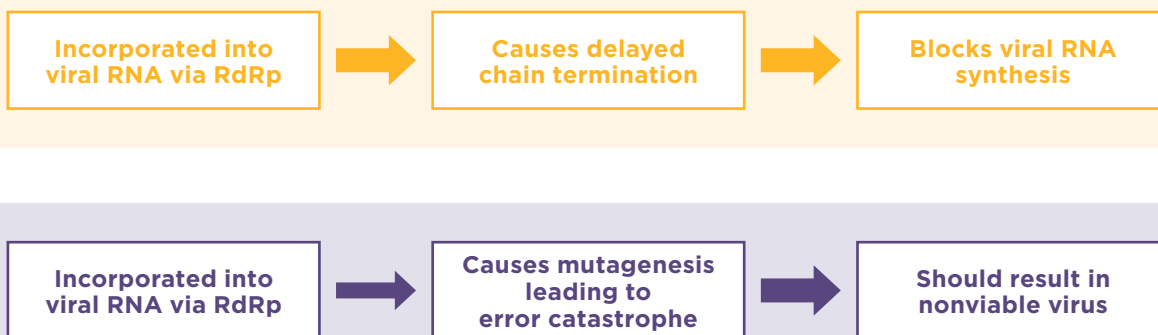


FIGURE 1. Simplified biosynthesis pathway and viral mechanism of action of remdesivir and molnupiravir. Remdesivir and molnupiravir are nucleotide prodrugs that are hydrolyzed after administration to yield their respective parent nucleoside analogues, GS-441524 and β -D-*N*⁴-hydroxycytidine (NHC; EIDD-1931). These nucleosides are then phosphorylated intracellularly to form the active triphosphates (remdesivir triphosphate and NHC triphosphate, respectively), which mediate antiviral activity. The mechanisms of action diverge at this point: Remdesivir triphosphate is incorporated into viral RNA by RNA-dependent RNA polymerase (RdRp) in place of adenosine, halting RNA synthesis after the addition of 3 more nucleotides. This process is known as “delayed chain termination.” In contrast, NHC triphosphate mimics both cytidine and uridine, leading to widespread mutations in the viral genome over successive rounds of replication. This accumulation of errors, referred to as “error catastrophe,” should render the virus nonviable.

uridine and subsequently pair with either guanosine or adenosine in the RNA. In this way, molnupiravir acts as a mutagenizing agent that causes increased mutation frequencies above a tolerable threshold (i.e., a mutation rate that surpasses the level needed to maintain virus viability). This process is called “error catastrophe” and results in production of replication-incompetent genomes in subsequent rounds of RNA synthesis, which ultimately leads to virus death. A study showing pharmacokinetic data for molnupiravir showed promise

for its use and safety in cats.²⁸ After oral administration at 10 mg/kg, molnupiravir was detected in the serum of all 3 study cats at low levels in the first 12 hours after administration, and its NHC metabolite was detected at much higher levels 12 to 24 hours after administration. NHC levels varied markedly between individual cats; molnupiravir and NHC levels peaked at 1.5 to 9 hours, and the level of NHC was 10- to 100-fold greater than that of molnupiravir. NHC was more consistently and quantifiably detected over the

TABLE 1 Recommended Treatment Protocols for GS-441524 and Remdesivir, According to Form of Feline Infectious Peritonitis (FIP)

FORM OF FIP	GS-441524 PO ^a	REMDESIVIR IV OR SC ^b
Effusion(s) and without ocular or neurologic signs	15 mg/kg q24h or divided q12h ^c	10–15 mg/kg q24h
No effusion and without ocular or neurologic signs	15 mg/kg q24h or divided q12h ^c	12–15 mg/kg q24h
Ocular signs (+/- effusion)	15–20 mg/kg q24h or divided q12h ^c	15 mg/kg q24h
Neurologic signs (+/- effusion)	10 mg/kg q12h	20 mg/kg q24h

^aGive to fasted patient with water bolus or tablespoons of wet food, followed by full meal 30 minutes later.

^bWhen giving as IV, give slowly as a constant-rate infusion over 30 minutes to 2 hours; can be diluted in saline.

^cDivided dose may improve plasma concentrations when using oral GS-441524 and is suggested as preferred by some. Once-daily dosing is still highly effective and considered appropriate by the authors, particularly where compliance may be an issue.

TABLE 2 Recommended Doses for Molnupiravir and NHC According to Form of Feline Infectious Peritonitis (FIP)

FORM OF FIP	DOSAGE, PO	
	MOLNUPIRAVIR (EIDD-2801)	NHC (EIDD-1931)*
Effusion(s) and without ocular or neurologic signs	10–15 mg/kg q12h	15 mg/kg q12h
No effusion and without ocular or neurologic signs	15 mg/kg q12h	15 mg/kg q12h
Ocular signs (+/- effusion)	15 mg/kg q12	15 mg/kg q12h
Neurologic signs (+/- effusion)	15–20 mg/kg q12h	20 mg/kg q12h

NHC = β -D-N⁴-hydroxycytidine.

*Dosages listed here are currently recommended for relapses. For first-line therapy, lower doses may be considered. More studies are needed to provide better guidance on dosing of NHC. The molecular weights of molnupiravir and NHC are 329.31 g/mol and 259.22 g/mol, respectively; therefore, if there is complete hydrolysis from molnupiravir into NHC, the dose of molnupiravir administered is expected to be 0.78% (e.g., 10 mg/kg molnupiravir would equal 7.8 mg/kg NHC).

24-hour period, except in 1 cat, for which NHC was no longer detected (based on limit of detection) 12 hours after administration. The study reported no evidence of acute organ toxicity in any of the cats according to pre- and post-treatment CBCs and serum biochemistry panels; however, all 3 molnupiravir-treated cats demonstrated variable signs of nausea, including hypersalivation and/or vomiting.

One study that examined 18 cats with FIP that received molnupiravir showed that molnupiravir might be an effective and safe treatment for domestic cats with FIP at a dosage of 10 to 20 mg/kg q12h.¹⁴ In this study, increased serum alanine aminotransferase (ALT) activity was found in 3 of the 18 cats at days 7 to 9, but all cats recovered without any medications or need to stop the treatment.¹⁴ Uncontrolled data from client surveys suggest effectiveness of molnupiravir as a rescue treatment after failure of GS-441524 therapy as well as a first-line treatment option for cats with FIP.¹³

Among cats with effusive FIP, an open-label longitudinal, noninferiority trial of 10 cats treated with molnupiravir (10 to 15 mg/kg PO q12h) for 84 days showed that molnupiravir is an effective antiviral treatment for effusive FIP.¹⁶ A prospective clinical trial with 62 cats with FIP that received molnupiravir

showed treatment success for 77% of cats and relapse for 11%, but all responded to a higher dose of molnupiravir.³² A study of EIDD-1931 given PO q12h at a median dose of 18.75 mg/kg (range, 12 to 23.8) showed complete response for 9 cats (6 with effusive FIP and 3 with noneffusive FIP); however, this study reported several adverse effects such as neutropenia (3), increased ALT levels (transient in 3, permanent in 1), broken whiskers (1), and hyporexia (6). One cat that experienced relapse responded to an increased dosage (25 mg/kg q12h).³³ A recent study comparing treatment with GS-441524 and molnupiravir showed similar effects and safety for cats with FIP.¹⁵

By targeting mitochondrial RNA, molnupiravir/EIDD-1931 is intrinsically mutagenic for human RNA and DNA.³⁴ Therefore, gloves should be worn when handling the drugs, and the drugs should not be handled by pregnant women. Molnupiravir is not prescribed for humans under 18 years of age, and safety in kittens has yet to be assessed.

Despite preliminary data suggesting that survival outcomes after first-line treatment with molnupiravir and EIDD-1931 may be similar to those after remdesivir and GS-441524 treatment, the increased adverse effects and mutagenic potential of molnupiravir



lead the authors to recommend using remdesivir and GS-441524 as first-line treatment for cats with newly diagnosed FIP when possible (**TABLE 2**).

PROTEASE INHIBITORS

After coronavirus entry into host cells, virus RNA is released and translated, resulting in the production and subsequent processing of 2 key enzymes that are vital for virus replication, 3-chymotrypsin-like protease (3CL^{pro}) and papain-like protease.³⁵⁻³⁸ The enzymes are highly conserved across coronavirus species; therefore, drugs that inhibit them offer promise as broad-spectrum coronavirus antivirals.³⁵ The 2 main protease inhibitors of interest for FIP treatment are GC376 (Anivive Lifesciences, anivive.com) and nirmatrelvir (present in Paxlovid).

GC376

GC376 is a 3CL^{pro} protease inhibitor that stops the cleavage and activation of functional viral proteins required for replication and transcription in host cells. In vitro assessment of GC376 demonstrated potent antiviral effects against FIP virus in various cell cultures.³⁹ Among cats with experimentally induced FIP, 6 of 8 experienced reversal after treatment with GC376,³⁹ but among client-owned cats with naturally acquired FIP, the survival rate was lower (35%) than that achieved with nucleoside analogues.¹ A new study of combination therapy of 46 cats with FIP (36 effusive and 10 non-effusive) that received GC376 and GS-441524 for 4 weeks in different dosage regimens reported that 97.8% of cats responded well to the 4-week therapy although 2 cats required treatment extension of 7 to 12 weeks.⁴⁰ The study demonstrated that GS-441524 combined with GC376 can be safely and effectively used to treat FIP for a shortened treatment period. The absence of a GS-441524 monotherapy control group, however, makes it unclear whether similar outcomes could have been achieved with GS-441524 alone, particularly given the reported success of 6-week GS-441524 monotherapy.⁷ Further studies are needed to evaluate the effectiveness of combination therapy. At the time of this writing, there is no legal access to GC376; however, the drug is undergoing FDA approval for its use in cats with FIP.

Nirmatrelvir

Paxlovid, Pfizer's antiviral combination for SARS-CoV-2, variably approved around the world, is available

to veterinarians via off-label prescription in some countries, including the United States and Australia. Two tablets are contained within Paxlovid: nirmatrelvir (another 3CL^{pro} protease inhibitor but with a very short half-life) and ritonavir (a pharmacokinetic booster, which inhibits cytochrome P450 to delay nirmatrelvir metabolism). Nirmatrelvir inhibits in vitro replication of FIP virus serotypes I and II, and efficacy is increased when used in combination with other antivirals.²⁸

Paxlovid is being actively investigated for FIP treatment, although anecdotally it has been used as a last resort in combination with a nucleoside analogue for a handful of highly refractory cases. The lead author is aware of unpublished and anecdotal data describing 13 cases in which Paxlovid led to subsequent remission. Its use at this time therefore remains preliminary and experimental; however, for nonresponding cats with confirmed FIP, a dose of nirmatrelvir at 75 mg per cat and ritonavir at 25 mg per cat PO q12h could be considered in combination with continued nucleoside analogue treatment. Because ritonavir is a cytochrome P450 inhibitor, it may delay the metabolism of other medications processed by this pathway.

CONCLUSIONS

Judicious use of antivirals by the veterinary community is needed to mitigate risk for development of antiviral resistance (antivirals are antimicrobials too). According to the literature, despite massive use in humans within an 18-month period of the COVID-19 pandemic, very low levels of remdesivir resistance were observed worldwide.⁴¹ In contrast, analysis of SARS-CoV-2 genomes suggests that molnupiravir-associated mutational signatures now exist globally after introduction of molnupiravir for COVID treatment.⁴² In human medicine, introduction of molnupiravir has created new mutations in SARS-CoV-2. Neither of these antivirals should be used in healthy cats to eliminate shedding of feline coronavirus due to the risk for resistance as well as the high likelihood of reinfection among cats in multicat households.

SUMMARY

Treatment for FIP has undergone a revolutionary transformation; antiviral therapies now offer improved survival rates among cats with a condition once considered a death sentence. Continued research and refinement of these therapies promise an even brighter future for affected cats and their caregivers. **TVP**

References

- Pedersen NC, Kim Y, Liu H, et al. Efficacy of a 3C-like protease inhibitor in treating various forms of acquired feline infectious peritonitis. *J Feline Med Surg.* 2018;20(4):378-392. doi:10.1177/1098612X17729626
- Pedersen NC, Perron M, Bannasch M, et al. Efficacy and safety of the nucleoside analog GS-441524 for treatment of cats with naturally occurring feline infectious peritonitis. *J Feline Med Surg.* 2019;21(4):271-281. doi:10.1177/1098612X19825701
- Dickinson PJ, Bannasch M, Thomasy SM, et al. Antiviral treatment using the adenosine nucleoside analogue GS-441524 in cats with clinically diagnosed neurological feline infectious peritonitis. *J Vet Intern Med.* 2020;34(4):1587-1593. doi:10.1111/jvim.15780
- Murphy BG, Perron M, Murakami E, et al. The nucleoside analog GS-441524 strongly inhibits feline infectious peritonitis (FIP) virus in tissue culture and experimental cat infection studies. *Vet Microbiol.* 2018;219:226-233. doi:10.1016/j.vetmic.2018.04.026
- Krentz D, Zenger K, Alberer M, et al. Curing cats with feline infectious peritonitis with an oral multi-component drug containing GS-441524. *Viruses.* 2021;13(11):2228. doi:10.3390/v13112228
- Krentz D, Zwicklbauer K, Felten S, et al. Clinical follow-up and postmortem findings in a cat that was cured of feline infectious peritonitis with an oral antiviral drug containing GS-441524. *Viruses.* 2022;14(9):2040. doi:10.3390/v14092040
- Zuzzi-Kreibitz A-M, Buchta K, Bergmann M, et al. Short treatment of 42 days with oral GS-441524 results in equal efficacy as the recommended 84-day treatment in cats suffering from feline infectious peritonitis with effusion—a prospective randomized controlled study. *Viruses.* 2024;16(17):1144. doi:10.3390/v16071144
- Zwicklbauer K, Krentz D, Bergmann M, et al. Long-term follow-up of cats in complete remission after treatment of feline infectious peritonitis with oral GS-441524. *J Feline Med Surg.* 2023;25(8):1098612X231183250. doi:10.1177/1098612X231183250
- Taylor SS, Coggins S, Barker EN, et al. Retrospective study and outcome of 307 cats with feline infectious peritonitis treated with legally sourced veterinary compounded preparations of remdesivir and GS-441524 (2020-2022). *J Fel Med Surg.* 2023;25(9):1098612X231194460. doi:10.1177/1098612X231194460
- Green J, Syme H, Tayler S. Thirty-two cats with effusive or non-effusive feline infectious peritonitis treated with a combination of remdesivir and GS-441524. *J Vet Intern Med.* 2023;37(5):1784-1793. doi:10.1111/jvim.16804
- Coggins SJ, Norris JM, Malik R, et al. Outcomes of treatment of cats with feline infectious peritonitis using parenterally administered remdesivir, with or without transition to orally administered GS-441524. *J Vet Intern Med.* 2023;37(5):1772-1783. doi:10.1111/jvim.16803
- Jones S, Novicoff W, Nadeau J, Evans S. Unlicensed GS-441524-like antiviral therapy can be effective for at-home treatment of feline infectious peritonitis. *Animals (Basel).* 2021;11(8):2257. doi:10.3390/ani11082257
- Roy M, Jacque N, Novicoff W, Li E, Negash R, Evans SJM. Unlicensed molnupiravir is an effective rescue treatment following failure of unlicensed GS-441524-like therapy for cats with suspected feline infectious peritonitis. *Pathogens.* 2022;11(10):1209. doi:10.3390/pathogens11101209
- Sase O. Molnupiravir treatment of 18 cats with feline infectious peritonitis: a case series. *J Vet Intern Med.* 2023;37(5):1876-1880. doi:10.1111/jvim.16832
- Sase O, Iwami T, Sasaki T, Sano T. GS-441524 and molnupiravir are similarly effective for the treatment of cats with feline infectious peritonitis. *Front Vet Sci.* 2024;11:1422408. doi:10.3389/fvets.2024.1422408
- Reagan KL, Brostoff T, Pires J, Rose A, Castillo D, Murphy BG. Open label clinical trial of orally administered molnupiravir as a first-line treatment for naturally occurring effusive feline infectious peritonitis. *J Vet Intern Med.* 2024;38(6):3087-3094. doi:10.1111/jvim.17187
- De Clercq E. Antivirals and antiviral strategies. *Nat Rev Microbiol.* 2004;2(9):704-720. doi:10.1038/nrmicro975
- Seley-Radtke LK, Yates MK. The evolution of nucleoside analogue antivirals: a review for chemists and non-chemists. Part 1: early structural modifications to the nucleoside scaffold. *Antiviral Res.* 2018;154:66-86. doi:10.1016/j.antiviral.2018.04.004
- Bravo JPK, Dangerfield TL, Taylor DW, Johnson KA. Remdesivir is a delayed translocation inhibitor of SARS-CoV-2 replication. *Mol Cell.* 2021;81(7):1548-1552.e4. doi:10.1016/j.molcel.2021.01.035
- Agostini ML, Andres EL, Sims AC, et al. Coronavirus susceptibility to the antiviral remdesivir (GS-5734) is mediated by the viral polymerase and the proofreading exoribonuclease. *mBio.* 2018;9(2):e00221-18. doi:10.1128/mBio.00221-18
- Warren TK, Jordan R, Lo MK, et al. Therapeutic efficacy of the small molecule GS-5734 against Ebola virus in rhesus monkeys. *Nature.* 2016;531(7594):381-385. doi:10.1038/nature17180
- Avataneo V, de Nicolò A, Cusato J, et al. Development and validation of a UHPLC-MS/MS method for quantification of the prodrug remdesivir and its metabolite GS-441524: a tool for clinical pharmacokinetics of SARS-CoV-2/COVID-19 and Ebola virus disease. *J Antimicrob Chemother.* 2020;75(7):1772-1777. doi:10.1093/jac/dkaa152
- Sheahan TP, Sims AC, Graham RL, et al. Broad-spectrum antiviral GS-5734 inhibits both epidemic and zoonotic coronaviruses. *Sci Transl Med.* 2017;9(396):eaal3653. doi:10.1126/scitranslmed.aal3653
- Humeniuk R, Mathias A, Cao H, et al. Safety, tolerability, and pharmacokinetics of remdesivir, an antiviral for treatment of COVID-19, in healthy subjects. *Clin Transl Sci.* 2020;13(5):896-906. doi:10.1111/cts.12840
- Williamson BN, Feldmann F, Schwarz B, et al. Clinical benefit of remdesivir in rhesus macaques infected with SARS-CoV-2. *bioRxiv.* 2020;585:273-276. doi:10.1101/2020.04.15.043166
- Li Y, Cao L, Li G, et al. Remdesivir metabolite GS-441524 effectively inhibits SARS-CoV-2 infection in mouse models. *J Med Chem.* 2022;65(4):2785-2793. doi:10.1021/acs.jmedchem.0c01929
- Coggins S, Kimble B, Malik R, Thompson MF, Norris JM, Govendir M. Assessing in vitro stability of remdesivir (GS-5734) and conversion to GS-441524 in feline plasma and whole blood. *Vet Q.* 2024;44(1):1-9. doi:10.1080/01652176.2024.2305731
- Cook S, Wittenburg L, Yan VC, et al. An optimized bioassay for screening combined anticoronaviral compounds for efficacy against feline infectious peritonitis virus with pharmacokinetic analyses of GS-441524, remdesivir, and molnupiravir in cats. *Viruses.* 2022;14(11):2429. doi:10.3390/v14112429
- Coggins SJ, Govendir M, Norris JM, et al. Pharmacokinetics of GS-441524 following intravenous remdesivir in six cats and preliminary results of therapeutic drug monitoring (22 cats) during treatment of feline infectious peritonitis: 22 cases (2021-2024). *J Small Anim Pract.* Published online March 17 2025. doi:10.1111/jsap.13849.
- Teli D, Balar P, Patel K, Sharma A, Chavda V, Vora L. Molnupiravir: a versatile prodrug against SARS-CoV-2 variants. *Metabolites.* 2023;13(2):309. doi:10.3390/metabo13020309
- Tian L, Pang Z, Li M, et al. Molnupiravir and its antiviral activity against COVID-19. *Front Immunol.* 2022;13:855496. doi:10.3389/fimmu.2022.855496
- Cerna P, Dow S, Willis M, Shaw K, Hawley J, Lappin M. ABSTRACT ID01: Evaluation of new immunotherapy in cats with feline infectious peritonitis being treated with EIDD-2801 antiviral. *J Vet Intern Med.* 2024;38(5):2922. https://doi.org/10.1111/jvim.17182
- Kennedy A, White J. ABSTRACT ID02: Nucleoside analogue EIDD-1931 in the treatment of naturally occurring feline infectious peritonitis. *J Vet Intern Med.* 2024;38(5):2840-2970. https://doi.org/10.1111/jvim.17182
- Zhou S, Hill CS, Sarkar S, et al. β-D-N4-hydroxycytidine inhibits SARS-CoV-2 through lethal mutagenesis but is also mutagenic to mammalian cells. *J Infect Dis.* 2021;224(3):415-419. doi:10.1093/infdis/jiab247.
- Liu Y, Liang C, Xin L, et al. The development of coronavirus 3C-like protease (3CLpro) inhibitors from 2010 to 2020. *Eur J Med Chem.* 2020;206:112711. doi:10.1016/j.ejmech.2020.112711
- Thiel V, Ivanov KA, Putics Á, et al. Mechanisms and enzymes involved in SARS coronavirus genome expression. *J Gen Virol.* 2003;84(Pt 9):2305-2315. doi:10.1099/vir.0.19424-0
- Chen Y, Liu Q, Guo D. Emerging coronaviruses: genome structure, replication, and pathogenesis. *J Med Virol.* 2020;92(10):418-423. doi:10.1002/jmv.26234
- Kim Y, Shivanna V, Narayanan S, et al. Broad-spectrum inhibitors against 3C-like proteases of feline coronaviruses and feline caliciviruses. *J Virol.* 2015;89(9):4942-4950. doi:10.1128/JVI.03688-14

Sally Coggins

Dr. Coggins graduated from the University of Sydney, Australia, in 2007 and has been a felid-only clinician since 2010. She attained membership in feline medicine with the Australian and New Zealand College of Veterinary Scientists (ANZCVS) in 2012. Dr. Coggins was previously a director at The Cat Clinic, Melbourne; an examiner with the ANZCVS; and a tutor for the University of Sydney Centre for Veterinary Education. Since 2020, she has turned her focus to research, completing a PhD investigating antiviral therapies for feline infectious peritonitis. Dr. Coggins is continuing her research full time as a postdoctoral research fellow, focused on diseases of cats and treatment, at the University of Sydney.



Petra Černá

Dr. Černá is an ACVIM diplomate in small animal internal medicine. She graduated from the University of Veterinary Sciences Brno in the Czech Republic in 2018, where she also obtained her PhD in 2023. After completing 2 internships in the United Kingdom, she completed a small animal internal medicine residency at Colorado State University in 2023. Dr. Černá was awarded the RCVS Certificate in Advanced Veterinary Practice in feline medicine and also gained membership in the ANZCVS in the medicine of cats qualification. She has been awarded the ISFM Advanced Certificate in Feline Behaviour with distinction. Dr. Černá is particularly interested in feline medicine and is currently a PhD candidate at Colorado State University, focused on feline infectious peritonitis.



39. Kim Y, Liu H, Galasiti Kankanamalage AC, et al. Reversal of the progression of fatal coronavirus infection in cats by a broad-spectrum coronavirus protease inhibitor. *PLoS Pathog.* 2016;12(3):e1005531. doi:10.1371/journal.ppat.1005531
40. Lv J, Bai Y, Wang Y, Yang L, Jin Y, Dong J. Effect of GS-441524 in combination with the 3C-like protease inhibitor GC376 on the treatment of naturally transmitted feline infectious peritonitis. *Front Vet Sci.* 2022;9:1002488. doi:10.3389/fvets.2022.1002488
41. Focosi D, Maggi F, McConnell S, Casadevall A. Very low levels of remdesivir resistance in SARS-CoV-2 genomes after 18 months of massive usage during the COVID19 pandemic: a GISAID exploratory analysis. *Antiviral Res.* 2022;198:105247. doi:10.1016/j.antiviral.2022.105247
42. Sanderson T, Hisner R, Donovan-Banfield I, et al. A molnupiravir-associated mutational signature in global SARS-CoV-2 genomes. *Nature.* 2023;623(7987):594-600. doi:10.1038/s41586-023-06649-6

Rise above the rest



**Certified
Veterinary
Business
Leader**

Investing in your leadership skills is more than just advancing your career—it's about driving success for yourself, your team and your practice.

Let the NAVC Certified Veterinary Business Leader program unlock your potential as a leader. This one-of-a-kind certification provides you with a solid business foundation to lead, develop and implement a plan for long-term success.



**Get
certified
today!**

NAVCC
YOUR VETERINARY CERTIFICATIONS