

PATHWAYS TO INNOVATION

Learning and leadership in clinical veterinary research

FEATURING

Artificial intelligence in
veterinary practice

The importance of ethics

Industry and charitable
support for research

Career progression
with a PhD

The latest research
studies

LINNAEUS

FORWARD

**Nefertiti Greene,
President, Science
& Diagnostics,
Mars Petcare**



Change is the only certainty we have in clinical research. The ways we develop and implement new studies are constantly improving, paving the way to scientific discoveries that will help to deliver better care for our patients and their owners.

This innovation is underpinned by an evolution of knowledge and skills development. We cannot deliver our best work without ensuring we have the best possible expertise. Learning from others is vital – but so is the ability and confidence to step forward and pioneer new ways of working.

This latest report, *Pathways to Innovation: Learning and Leadership in Clinical Veterinary Research*, focuses on the opportunities that lie ahead for the veterinary profession. Ciaran O'Flynn explores the development of artificial intelligence to support veterinary care provision, while Professor David Morton CBE highlights the importance of ethics in clinical veterinary research. Chris Jenkins discusses a unique collaboration supporting his research into canine epilepsy, while Dr Hannah Sargent considers the opportunities available to vets and nurses with a PhD.

The report also features the latest research into retention within the veterinary nursing profession, plus three new studies by clinicians in primary care and referral practice. Many of these papers have been published in open access scientific journals with funding from Linnaeus and Mars, to support the expertise and skills of the wider profession, promoting inclusivity in the sharing of knowledge.

Thank you to all the contributors who have shared their insight – I hope you find it both useful and enjoyable.



CONTENTS

The impact of artificial intelligence on veterinary practice

Ciaran O'Flynn, Research Manager – Data Science at Waltham Petcare Science Institute

PAGE 4

Ethics in clinical veterinary research

Professor David Morton CBE, Chair, Ethics Review Panel at the Royal College of Veterinary Surgeons

PAGE 7

Undertaking research with industry and charitable support

Chris Jenkins, Research Assistant, The Kennel Club Genetics Centre and the University of Cambridge, PhD student, University of Manchester

PAGE 10

Beyond the thesis: career opportunities following your doctorate

Dr Hannah Sargent, Clinical Research Associate at Linnaeus

PAGE 13

Clinical research at Linnaeus

1034 studies
Associates were underway, published or presented at veterinary conferences

In 2022, our clinical research team:

Answered 175 support requests on

PAGE 16

ADVISED ON TOPICS INCLUDING ethical and regulatory requirements; data protection; study design; and statistical support for interns and residents
DEVELOPED AND LAUNCHED a clinical research skills course for interns and residents
LAUNCHED THE LINNAEUS CLINICAL STUDIES FUND for clinical veterinary research, awarding four grants in its first three months
AWARDED £50,000 of Open Access Publication Charge (OAPC) funding to support 31 PAPERS
The OAPC covers the fees to publish in peer-reviewed veterinary journals and share knowledge more widely across the profession

Identifying the factors that influence retention within the veterinary nursing profession

Dr Andrea Jeffery, Chief Nursing Officer at Linnaeus

PAGE 17

In vitro susceptibility of canine corneal bacterial pathogens to three cross-linking protocols

Thomas Large, Post ECVO Residency Clinician in Veterinary Ophthalmology at DWR Veterinary Specialists in Cambridgeshire

PAGE 19

Incomplete histological margins following planned narrow excision of canine appendicular soft tissue sarcomas and mast cell tumours

David Haine, Orthopaedic and Soft Tissue Surgeon at Cave Veterinary Specialists in Somerset

PAGE 22

Efficacy of autologous mesenchymal stromal cell treatment for chronic degenerative musculoskeletal conditions in dogs: a retrospective study

Andrew Armitage, Clinical Director at Greenside Veterinary Practice in Roxburghshire

PAGE 25

Learning at Linnaeus

PAGE 28

References

PAGE 31

The impact of artificial intelligence on veterinary practice



By Ciaran O'Flynn,
Research Manager – Data Science at Waltham Petcare Science Institute

Artificial intelligence (AI) is poised to have a huge impact on the veterinary profession in the coming years, but what is it? Where does it exist? And what do we need to know and do about it?



How can we use AI?

In healthcare, AI is being used in a variety of ways to improve diagnosis and treatment, reduce costs, and enhance the patient experience.

One way AI is being used in healthcare is through the development of diagnostic tools that use machine-learning algorithms to analyse medical images and identify signs of disease. For example, AI-powered diagnostic tools are being used to analyse X-rays, CT scans, and MRI images to detect signs of cancer and other diseases. Additionally, AI-powered diagnostic tools can be used to analyse large amounts of patient data, such as lab results and electronic health records, to help physicians make more accurate diagnoses.

Another way AI is being used in healthcare is through the development of personalised treatment plans. AI-powered treatment planning systems can analyse a patient's medical history, lab results, and imaging studies to determine the most effective treatment options. These systems can also be used to monitor a patient's condition over time and adjust treatment as needed.

AI is also being used in healthcare to improve the efficiency of clinical operations. For example, AI-powered chatbots can be used to answer patients' questions and schedule appointments, while AI-powered tools can be used to analyse data from electronic health records to identify patterns and improve care coordination.

Source: ChatGPT

Where does AI exist?

Does AI exist in real applications? Depending on your definition the answer could be yes; in fact this article's summary of AI in healthcare is written entirely by the OpenAI model ChatGPT.¹ Whilst not without controversy, ChatGPT is set to be a major disruptor in this space.

AI is also appearing in several areas related to veterinary health. Within medical imaging, AI-backed systems can be applied to automate and streamline interpretation. In the intelligent assistant space, voice recognition can automate practice management activities, while automated search tools have the ability to query veterinary texts.

AI can also transform information from a doctor's notes into medical codes. For telemedicine, using owner-supplied information can deliver accessible and potentially more cost-effective and individually tailored care.

In the predictive and preventive care space, AI is being used for early detection of kidney disease, Cushing's and Addison's.²⁻⁵ Beyond the veterinary clinic, smart devices can alert owners about their pet's behaviours and health, such as notifying for osteoarthritis signs from accelerometer data.⁶

Why might AI not exist yet? While the examples above might support various aspects of veterinary care provision, they are far off the futuristic *Ex Machina* portrait of AI with very discrete limitations. None exhibit true human-like intelligence, but instead solve problems using the assets of a computer; pattern recognition, repetition and processing. As a result, they lack the anthropic ability to generalise; any changes to the context or setting would likely lead to a rapid decline in performance and therefore utility.

So, while intelligence exists, it has limitations and may not emerge quite as we expect.

What barriers exist?

While still nascent, AI technology is here. So what are the barriers for its further adoption? There are considerations for any innovation – ethics, governance, proper use cases – however, the two that are most impactful to AI are data and trust.

The intelligence of an AI tool is derived from the data from which it is trained: 'rubbish in, rubbish out'. If a training data set is incomplete or holds bias, the same limitations are found within the output AI. If we want good AI tools, we need good data and a rigorous quality control process.

“*“Will AI replace radiologists?” is the wrong question. The right answer is: radiologists who use AI will replace radiologists who don’t.*”

Curtis Langlotz, 2019

However, protocols, process and practice management software are often optimised without prioritisation for data quality. It may be expedient to select Affenpinscher from the breed drop down, 1 January as a date of birth, or use your own personal abbreviations within notes, but this diminishes the quality of data. A guide to data quality is found within the FAIR data principles.⁷

There is also a misconception that the answer to most limitations is to provide more data. Yet the largest and highest quality data sets will still lack crucial information about key causal or explanatory variables.

“*The question of whether machines can think is about as relevant as the question of whether submarines can swim.*”

Edsger Dijkstra, 1984

If our databases were populated only with data from sick pets, we would struggle to make inference about health. If we do not capture why certain tests were ordered or not, we may misinterpret their meaning. These types of bias are often nuanced and difficult to detect with a data-centric lens as they represent 'unknown unknowns'. They require veterinary subject matter expertise to find and, critically, would never be solved by the addition of data alone.

The second barrier to adoption is trust, underpinned by credible communication and education. The hype that exists for AI poses a barrier to trust, for which those of us working in the field must shoulder some responsibility. Most AI is not AI, often simple models are the most effective, and performance metrics on test data mean very little. It is very easy to overreach on the effectiveness of our models, so we must balance their merits equally with their limitations.

A future with AI

While AI is becoming ubiquitous in many parts of our lives, trusting AI with healthcare remains a point of no return for some. Photos of friends being automatically tagged on our

phones is widely accepted yet trust for AI to do more complex tasks requires healthy scepticism. Trust in this context can be obtained through knowledge and understanding of AI, as well as transparency on how an AI tool has been developed, including robust data coding and quality control.

This means that those working in the space will need to level up, including developing a fundamental understanding of statistics and data science.

Forthcoming innovations within AI will not appear overnight, while it still struggles to tick 'I'm not a robot'. AI will neither be a new panacea nor replace the expertise of the veterinary profession, but it will pose challenges to the status quo, bringing both change and opportunity. Some opportunities will require innovative individuals to adopt and realise them, while others will require careful consideration as to whether they create real value.

If successful, good AI should enable us to do more as well as optimise productivity, allowing us to dedicate more time to the human aspects of the profession, leading to improved treatment and care for animals.



ABOUT THE AUTHOR
Ciaran O'Flynn is Research Manager – Data Science at the Waltham Petcare Science Institute. He is also part of the Machine Intelligence and Decision Systems (MInDS) research group at the School of Electronic Engineering and Computer Science, Queen Mary University of London.

Ethics in clinical veterinary research



By Professor David Morton CBE,
Chair, Ethics Review Panel at the Royal College of Veterinary Surgeons (RCVS)



Why should I do clinical research?

New veterinary treatments such as novel medicines, surgical techniques and diagnostic procedures are constantly being developed through a variety of routes, from pharmaceutical research to device manufacturers. It is unsurprising that there are still many questions that need to be answered in animal treatment – and it is our profession who can see the limitations and the potential for improvement through clinical veterinary research (CVR).

How do we define CVR?

There are clear definitions for veterinary research.⁸ CVR involves investigations using clinical patients, whereas experimental research (ER) uses naïve healthy animals, often inducing a disease in them, to study effective veterinary treatments, diagnoses and care.

Critical to this is the balance between our day-to-day work and the treatment we undertake to benefit science. Routine veterinary practice (RVP) covers the daily procedures we perform to ensure the health and welfare of animals. When this aims to generate new knowledge that benefits animals – such as developing new procedures or improving a diagnosis – we are now undertaking CVR. Animal subjects range from domesticated species such as dogs, cats, horses and farmed animals, to feral and wild animals, and the more exotic species in zoos, all vertebrates and also invertebrates such as pet spiders, stick insects, crabs, snails and leeches.

To establish whether a procedure is RVP or CVR, intention and context are key. An RVP intervention in one circumstance may be considered CVR in a different setting, by a different clinician or on a different occasion.

Experimental veterinary research in the UK is covered by the Animals (Scientific Procedures) Act 1986 (ASPA).⁹ CVR is usually carried out by veterinary surgeons in practice or academic institutions, while ER takes place in ASPA-licensed premises, under the authority of an ASPA project licence and by ASPA licensed persons.

The Royal College of Veterinary Surgeons (RCVS) decides whether a project is CVR/RVP or not, whereas the Home Office decide on non-clinical applications and controls all ER licensing. Home Office authorisation is required for procedures that are veterinary treatment but have a scientific or educational purpose, and may cause more pain or suffering than inserting a hypodermic needle.

In the Republic of Ireland, we must follow the Directive 2010/63/EU legislation for the protection of animals used for scientific purposes.¹⁰

What are the critical ethical issues involved in CVR?

Areas concerning animals

It is important that any pain and suffering caused to animals as part of RVP is the minimum necessary to achieve the therapeutic objective and that no avoidable pain and distress is caused.

Areas concerning owners

It is vital to gain informed consent from the owner with objective information and without bias. This includes the retrospective use of pet data in clinical records and the use of

archived materials, including audio-visual records or surplus samples (e.g. tissue biopsies remaining after histopathology, body fluids). An information sheet specific for the research project, as well as a separate consent form, should also be used in any prospective studies. The consent form should preferably be designed as a Q&A tick box with yes/no options for each element of consent, to promote accessibility and uptake by owners.

“It is vital to gain informed consent from the owner with objective information.”

Research design

I am often asked why experimental design involves ethics as it seems to be simply a matter of science. Even science, however, is not always objective and fact based, and often depends on subjective judgements. For CVR, one particular concern is when poor experimental design might lead to incorrect or biased conclusions that could seriously jeopardise the welfare of treated animals if adopted by others, for example after publication. Put it another way, would you expect research that is poorly designed to be accepted for publication by a peer-reviewed journal? It is better for any work to be robustly designed before it is carried out, so it is also more likely to be accepted when submitted for publication; evidence of ethics approval is often needed before the paper can be submitted for peer review. Note that a robust scientific design will equally apply to retrospective studies.

Professional conduct

The public expects a high standard of animal care and integrity from vets, nurses and support staff. This includes respecting values such as honesty, objectivity, training and competence, disclosure of any vested or conflict of interest, and delivering the best standard of care. These personal attributes are essential for trust and for CVR to be acceptable to the animal-owning public, particularly if their pet is being asked to contribute in some way.

Other relevant legislation

This must not be forgotten, such as the protection and use of personal data under the Data Protection Act, Health and Safety Act, and awareness of social media influences. The Animal Welfare Act (2006) and the Animal Welfare (Sentience) Act 2022 will also apply.

When is an ethics review of CVR required?

Since September 2022, the RCVS stipulates ethics reviews should be sought for all studies where owner permission is required before an animal is enrolled, or when informed consent is needed for the use in research of previously collected samples or data from an animal. This includes: prospective clinical trials; studies that use personal data; clinical audits with information collected with the intention to publish; and studies involving the use of samples taken from an animal.

Formal ethics review is not obligatory for studies that do not require contact with the owner or another practice for follow-up, using exclusively archived pet clinical data (not personal data) from the patient management system. However, the RCVS still strongly encourages ethics reviews for such studies.

Where can I apply for an ethics review of CVR?

Veterinary surgeons who are members of the RCVS, Registered Veterinary Nurses and veterinary or nursing students conducting CVR can seek ethics review from the RCVS Ethics Review Panel¹¹ or other appropriate bodies such as university ethical review committees.

Ethics approval must be obtained before a study begins and the investigators should adhere to the approved study protocol.

Any changes to the protocol, including any unexpected outcomes, should be communicated to, and authorised by, the relevant ethics review panel before implementation.

After completion of a CVR study

It would be a courtesy to thank all those involved and if possible, offer to send them a copy of any publications that have resulted from their work.

ABOUT THE AUTHOR

Professor David Morton is a veterinary surgeon experienced in reviewing human as well as animal clinical research and is the Foundation Chair of the RCVS's Ethics Review Panel. The Panel was formed in 2016 and applications have increased from five in its first year to 156 in 2022.



Undertaking research with industry and charitable support



By Chris Jenkins, Research Assistant,
The Kennel Club Genetics Centre and the University of Cambridge,
PhD student, University of Manchester

Coming from a family of Border Collie owners, I understand how this breed is renowned for its hardy reputation. However, it is one of the most severely affected by idiopathic epilepsy (IE) – a chronic and life-limiting neurological disorder characterised by recurrent epileptic seizures.¹²⁻¹⁵



Pictured (left to right): Chris Jenkins and Dr Sally Ricketts (The Kennel Club Genetics Centre), Professor Luisa De Risio (Linnaeus) and Jim Johnson (The Kennel Club Genetics Centre)

IE is one of the most common chronic neurological diseases in dogs, with an estimated prevalence of 0.60-0.75%.^{13,16} It also has a high impact on welfare, with the frequency and length of seizures causing significant distress for the dogs and their owners.^{15,17,18}

The genetic factors underlying IE are being investigated by Sally Ricketts and my colleagues at The Kennel Club Genetics Centre (KCGC) in the Department of Veterinary Medicine at the University of Cambridge. This large-scale study aims to develop tools that identify dogs at greater risk of developing the disease, lower the incidence of the condition in future generations, and help with prevention and treatment.

Study support

I am in the final stages of a part-time PhD focusing on the genetics of epilepsy and other neurological diseases, working at the KCGC. The aim of our research is to find DNA variants that contribute to the risk of a dog developing IE or movement disorders. These neurological conditions are distinct but can have similarities and, in some cases, can be difficult to tell apart without a thorough clinical investigation. There are also many similarities between these canine diseases and those seen in humans, so our findings could support scientific advances in human medicine.

I am registered for my PhD at the University of Manchester and had carried out four years of research at the Animal Health Trust, which sadly closed in 2020. Following this, our group relocated to the University of Cambridge. Our work is funded by a combination of private sector and charitable organisations such as breed clubs and health groups, The Kennel Club Charitable Trust, Petplan Charitable Trust, and Dogs Trust.

We also liaise with the clinical research team and neurologists at referral hospitals across Linnaeus, who provide us with DNA samples and case definitions; work closely with Professor Hannes Lohi's group at the University of Helsinki; and collaborate with others in our international canine genetic research community. The KCGC has also worked closely with Wisdom Panel, which specialises in pet DNA tests.

As a result, Wisdom Panel offered to sponsor my fees for the last two years of my PhD, for which I am very grateful. My PhD will end in a different place to where it began, but with the wide-ranging support we were able to access, we have been able to discover and share new findings.

DNA discoveries

As well as IE in Border Collies, my PhD has investigated IE in Italian Spinones, paroxysmal dyskinesia in Norwich Terriers, and cerebellar ataxia in Norwegian Buhunds. The Norwegian Buhund study successfully identified the DNA variant that causes cerebellar ataxia in this breed, which enabled us to develop a DNA test for dog breeders to help reduce the number of dogs affected by this disease.¹⁹ The DNA variant was in a neurological gene that had never been associated with cerebellar ataxia, but human genetic research has since found evidence that this gene may also be involved in similar human diseases.²⁰

The paroxysmal dyskinesia and IE studies have found regions of DNA that may be associated with these two diseases and represent a solid foundation on which to build future

research. The studies have also increased our knowledge of how these diseases may be inherited and the types of DNA variants that can affect a dog's risk of developing these conditions.

“With the wide-ranging support we were able to access, we have been able to discover and share new findings.”

During my PhD I also implemented a new method into our laboratory – a computational technique called genotype imputation – which had been very successfully used in human complex disease genetics and was starting to be tested in dogs. Our proof-of-principle study applying this technique in the Border Collie and Italian Spinone has since been published in the open-access scientific journal *Animal Genetics*²¹ and has become one of the most frequently downloaded papers during its first 12 months of publication in the journal.

The progress of my PhD has happened with the support of private and charitable organisations. I hope that these results will in time make a significant difference to the future of these wonderful breeds and pave the way for further studies into both canine and human neurological diseases.

Dr Becca Chodroff Foran, Head of R&D at Wisdom Panel:

“The only way we can truly improve the lives of pets is by combining our strengths. The robust diagnoses of veterinary surgeons, combined with the identification skills of geneticists, enables us to find DNA variants that can improve or impact on our pets' health. We have been proud to sponsor Chris's PhD and support his achievements in canine genetics.”

Dr Sally Ricketts, Senior Research Associate, The Kennel Club Genetics Centre, Department of Veterinary Medicine, University of Cambridge:

“It is critical that we undertake genetic studies of these complex neurological diseases to both understand their biology and try to develop tools that breeders can use to reduce the incidence of these debilitating conditions in future generations. IE can be managed but it does not have a cure, so prevention through genetic identification of those at highest genetic risk will be the key to the future health and welfare of breeds such as Border Collies.

“As the supervisor for Chris's research, the support of so many organisations – particularly Wisdom Panel, The Kennel Club Charitable Trust, the Animal Health Trust, University of Cambridge and Petplan Charitable Trust – has enabled us to continue focusing on our studies of IE and the important benefits our research can bring to so many pets.”



ABOUT THE AUTHOR

Chris Jenkins graduated from the University of East Anglia in 2010 with a BSc in Biological Sciences, before studying for an MSc in Molecular Medicine at Cranfield University. He has worked within The Kennel Club Genetics Centre as a Research Assistant since 2014 and has worked on research projects investigating the genetics of a range of canine inherited diseases.

Chris started to work towards his PhD part-time, registered at the University of Manchester, in 2016. Chris's research interests have a focus on the genetics of canine neurological diseases, and he is particularly interested in how computational methods using large collections of whole-genome sequence data can facilitate the study of these diseases.

Beyond the thesis: career opportunities following your doctorate



By Dr Hannah Sargent,
Clinical Research Associate at Linnaeus

The demand for PhDs remains strong – with more than 104,000 students starting a doctorate research course in the UK during 2021/22.²² While known as an intensive and demanding learning period that can last for three to four years²³ when studying full-time, a PhD can also bring clear career benefits.



Armed with a PhD, vets and nurses can explore career opportunities across veterinary medicine; in scientific research outside the veterinary profession; and careers that are not in the field of science at all.

Skills and expertise

Undertaking a PhD enables vets and nurses to grow their expertise in specific areas of interest within veterinary medicine and beyond. This can lead to the development of novel research that has a positive, clinically applicable impact on the lives of pets, their owners and the wider veterinary profession. New effective treatments may be identified through randomised controlled clinical trials, for example, while patterns of health and disease can be identified and explored through epidemiological studies.

There are a range of support networks and opportunities to pursue this work. My PhD in feline chronic kidney disease was a collaboration between the Royal Veterinary College and Royal Canin, enabling me to access funding support, facilities and expertise from both academia and the private sector. This assistance extended to the practical application of my research, involving regular liaison with Royal Canin and a visit to the company in France.

Having an industry partner provides mutual benefit to the company and student with the sharing of resources, cross-functional training and networking opportunities. This helped me to develop my skills in communication and research dissemination, while learning about processes within both academic and commercial environments.

“Having an industry partner provides mutual benefit to the company and student with the sharing of resources, cross-functional training and networking.”

Having previously worked in primary care for eight years – many of these at Village Vet, which is part of Linnaeus – I have since returned to Linnaeus following my PhD and now work as its Clinical Research Associate. This role supports research activity across Linnaeus, enabling me to build on my own experience by promoting research within primary care.

There can be an assumption that a PhD will only be pursued by vets with a specialism or intending to train as a specialist, or for vets and nurses who want to pursue a career in leadership or academia. However, as my experience demonstrates, a PhD can offer access to the wide ecosystem of scientific and clinical innovation taking place within the veterinary profession.

As part of Mars Petcare, Linnaeus also has a global network of expertise to tap into – which offers a range of career development opportunities across science and innovation.

An array of options

Beyond the doctorate, potential career pathways are many and varied. Developing a combination of skills that are clinical, client-facing and commercial is of great interest to interdisciplinary teams. A scientific mindset that challenges assumptions, experiments and follows evidence is recognised as incredibly valuable for senior management and leadership roles.²⁴ PhDs are highly valued in government;²⁵ sectors ranging from consultancy to finance; and other areas of science. They can also provide a route into academia, such as teaching roles.

There are also many options for career progression in primary care or referral medicine. For vets and nurses interested in a career within primary care, a PhD can be incredibly useful. Experience of running clinical trials can aid with handling and caring for patients, as well as communicating with owners. Assimilating evidence-based knowledge, time management and the development of practical scientific skills are frequently used and highly prized in this area of veterinary medicine.

Throughout my PhD I spent several days every month working in a feline clinic, giving me the opportunity to learn advanced cat handling skills and feline behaviour from an experienced clinical veterinary nurse. I utilised these skills daily in primary care practice, a huge benefit of the PhD that I hadn't expected at the outset.

For those attracted to referral medicine, continuing to train in a veterinary specialism remains a favoured option by many vets. A PhD supports this by promoting expertise in clinical research and publishing, as well as developing in-depth knowledge on certain conditions and with the potential to enhance practical competencies. It also develops the ability to assimilate and disperse information widely to a variety of stakeholders, though the dissemination of research in the national and international arena.

Do your homework

There are many factors to contemplate before doing a PhD. Those wishing to pursue a PhD may have a research question and project in mind, or choose to apply for a PhD studentship where the specific research question and project has already been determined by the academic institution.

The practicalities of studying also require careful consideration. As well as deciding on your time commitment and location, funding is a critical factor. There is government student support available, as well as Research Council grants, industry sponsorship, university bursaries and charities that are willing to finance research in their field of interest.²⁶

Looking beyond the work involved in a PhD, its personal advantages may depend on the career choices made after the course. But the wider benefits are clear. Careers are rarely linear and obtaining a PhD offers a wide range of opportunities for progression and development.

The findings of a doctorate can also have a direct and long-lasting impact on the health and welfare of pets and their owners. It can help to grow the knowledge and expertise of the profession – meaning that even those without a PhD can benefit from its opportunities.

Career journeys following a PhD

Dr Nora Schwitzer leads the dentistry referral service at MyVet in Dublin.

"I have always enjoyed exploring new ideas and concepts, and my PhD in Madagascar was a logical next step to satisfy this curiosity. I enjoyed reaching the point where I knew more about Blue-eyed back lemurs than anyone, while contributing to the lemurs' conservation.

"On returning to primary care, I wanted to develop my expertise in a similar way to my PhD. I focus on evidence-based improvements to dental care; working in primary care means this knowledge has a direct application and impact on our patients.

"I continue to read scientific papers and occasionally publish or speak about my findings. Recently, I began to offer wildlife dentistry, which builds on my experiences in primary care and Madagascar."

Dr Esther Bijsmans is Science Communication Lead at Mars Pet Nutrition.

"After working in general practice and caring for individual pets, I wanted to have a broader impact by working on solutions that could benefit many animals at the same time.

"My PhD was sponsored by Zoetis and I worked with students whose PhDs were sponsored by other industry partners, such as Boehringer Ingelheim and Royal Canin. From those interactions I knew there were various roles in industry that would satisfy my academic mind while combining the ultimate aim of working on ways to help pets globally.

"Despite a PhD being perceived as highly specialised, it actually sets you up with the transversal skills of critical and analytical thinking. I also learned how to appropriately design clinical trials and communicate effectively on the results. This has greatly benefited my career in Mars, where I first started in my comfort zone of research, and gradually moved towards my current role, which provides the link between R&D and the business."



ABOUT THE AUTHOR

Dr Hannah Sargent graduated as a veterinary surgeon from the Royal Veterinary College (RVC) in 2013. She then completed a postgraduate certificate in veterinary medicine and surgery and a rotating internship with the University of Nottingham, which was sponsored by the Waltham Petcare Science Institute. Hannah subsequently worked as a veterinary surgeon in primary care practice for eight years, including Linnaeus-owned Village Vet.

In 2021 Hannah completed a PhD in feline nephrology at the RVC, in partnership with Royal Canin, and then joined Linnaeus as its Clinical Research Associate, where she supports the research activity of Linnaeus Associates.

Clinical research at Linnaeus

Research activity between 2019 and 2022:

1,054

studies by Linnaeus Associates were underway, published or presented at veterinary conferences

495 have been published in a peer-reviewed journal or presented at a global conference

A specialist clinician is principal investigator for **61%**

35% led by residents and interns

4% led by nurses and primary care clinicians

18% are prospective studies, nearly half (**44%**) are retrospective studies and **27%** are case series or reports

POPULAR DISCIPLINES: surgery (**25%**); internal medicine (**22%**); neurology (**13%**); diagnostic imaging (**10%**); and anaesthesiology (**10%**)

In 2022, our clinical research team:

Answered

175

support requests on

142

projects

ADVISED ON TOPICS INCLUDING ethical and regulatory requirements; data protection; study design; and statistical support

DEVELOPED AND LAUNCHED a clinical research skills course for interns and residents

LAUNCHED THE LINNAEUS CLINICAL STUDIES FUND for clinical veterinary research, awarding four grants in its first three months

AWARDED £60,000 of Open Access Publication Charge (OAPC) funding to support **33 PAPERS**

The OAPC covers the fees to publish in peer-reviewed veterinary journals and share knowledge more widely across the profession

A wide clinical support network:

Linnaeus and Mars offer

global

access to experts and knowledge

Linnaeus is part of **MARS VETERINARY HEALTH** and **MARS PETCARE**, which offer a global network of scientists, subject matter experts and specialists

The **LINNAEUS CLINICAL BOARD** implements evidence-based best practice. It comprises experienced vets, nurses, patient care assistants and veterinary support staff from primary care and referral centres, representing over **25 DISCIPLINES**

The online **MARS VETERINARY HEALTH MEDICAL LIBRARY** offers free access for Linnaeus Associates to 2,500+ digital books and journals, biomedical databases, and just-in-time veterinary resources

Identifying the factors that influence retention within the veterinary nursing profession



By Dr Andrea Jeffery,
Chief Nursing Officer at Linnaeus



Contribution to the field

There is evidence that the number of Registered Veterinary Nurses (RVNs) in the United Kingdom has declined in recent years. It is important that the number of RVNs grows in line with the number of veterinary surgeons to ensure there are sufficient registered professionals to deliver the care needed for patients.

Introduction

The UK regulatory body for RVNs, the Royal College of Veterinary Surgeons (RCVS), maintains the professional register of RVNs. Every year, a proportion choose not to continue to practice. This research aimed to determine the factors that predict retention rates within the veterinary nursing profession and to set out recommendations that could improve retention.

Objectives

The research critically analysed the views of the veterinary nursing profession to determine factors that influence retention, through analysis of the RCVS 2014 and 2019 large-scale surveys of UK RVNs, each called the RCVS Survey of the Veterinary Nursing (VN) Profession. It is important to note that both surveys focus on the intention to leave and do not include feedback from those who have already left the profession.

Methods

A review of relevant literature was conducted, highlighting factors identified as affecting retention in the UK and internationally, to position the review within the context of what is already known about the subject globally. These studies covered the veterinary profession, human-centred nursing and dental nursing.

The primary data set from the RCVS Survey of the VN Profession comprised 4,586 respondents in 2014 and 6,369 respondents in 2019. An analysis of the quantitative data was undertaken using multivariable logistic regression analysis to identify predictors of intention to leave the profession.

Results

Quantitative analysis of both the 2014 and 2019 surveys identified statistically significant correlations with the intention to leave. Four variables were found to be significant predictors of retention or intention to leave in both years, with the ranges shown reporting the results of the two different surveys:

- Respondents with a second job were approximately 1.6 to 1.8 times more likely to leave the profession
- 70% were less likely to leave if they believed their career could progress
- 75-85% were motivated to stay if they experienced job satisfaction
- 50-60% indicated that employer support was a determinant for not wanting to leave the profession

Although there were other significant predictors to staying within the profession, they did not emerge from both studies. In 2019, those who were satisfied with salary were 53% less likely to intend to leave. The challenge of client expectations was another statistically significant predictor of leaving the profession in 2019.

The following factors were statistically significant predictors of remaining within the profession in 2014 but not in 2019: undertaking nurse clinics; feeling valued; and being respected.

There was also a clear statistical relationship between job satisfaction, career progression and retention. In 2019, those who agreed that veterinary nursing work gives them job satisfaction were 76% less likely to leave the profession. Similarly, those believing that veterinary nursing offers good opportunities for career progression were 70% less likely to intend to leave. In 2019, nurses who were satisfied with the support from their employer were 57% less likely to intend to leave the profession, compared with those who were not satisfied.

The education route into the profession was not significant in terms of retention. However, there are some topics within higher education curriculum, such as problem-solving and clinical decision-making, which could be added to the further education curriculum to help build professional resilience.

Conclusions

The factors that influence the retention of nurses within the profession are multifactorial and individual. Nurses are responsible for ensuring that colleagues are aware of their skillset and they themselves are accountable for utilisation of those skills.

When veterinary nurses are supported by their employers, they are more likely to stay in the profession. A sense of job satisfaction was another important factor. This was supported by human-centred studies, which identified that the ability to use initiative, being empowered within the workplace and having autonomy are key to job satisfaction.

Having a clearly defined career structure with mapped progression routes, similar to those within the National Health Service, would support veterinary nurses, their colleagues and employers. Understanding of the different levels of achievement and required skills at each level of a nurse's career would facilitate collaboration and effectiveness.

ABOUT THE AUTHORS OF THE STUDY

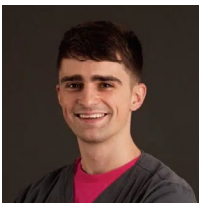
Dr Andrea Jeffery, Bristol Veterinary School, University of Bristol and Linnaeus; Eleanor Taylor, RCVS.

The study has been published in the open access peer-reviewed scientific journal *Frontiers in Veterinary Science*: www.frontiersin.org/articles/10.3389/fvets.2022.927499/full. All references are available to view in full via the online paper.

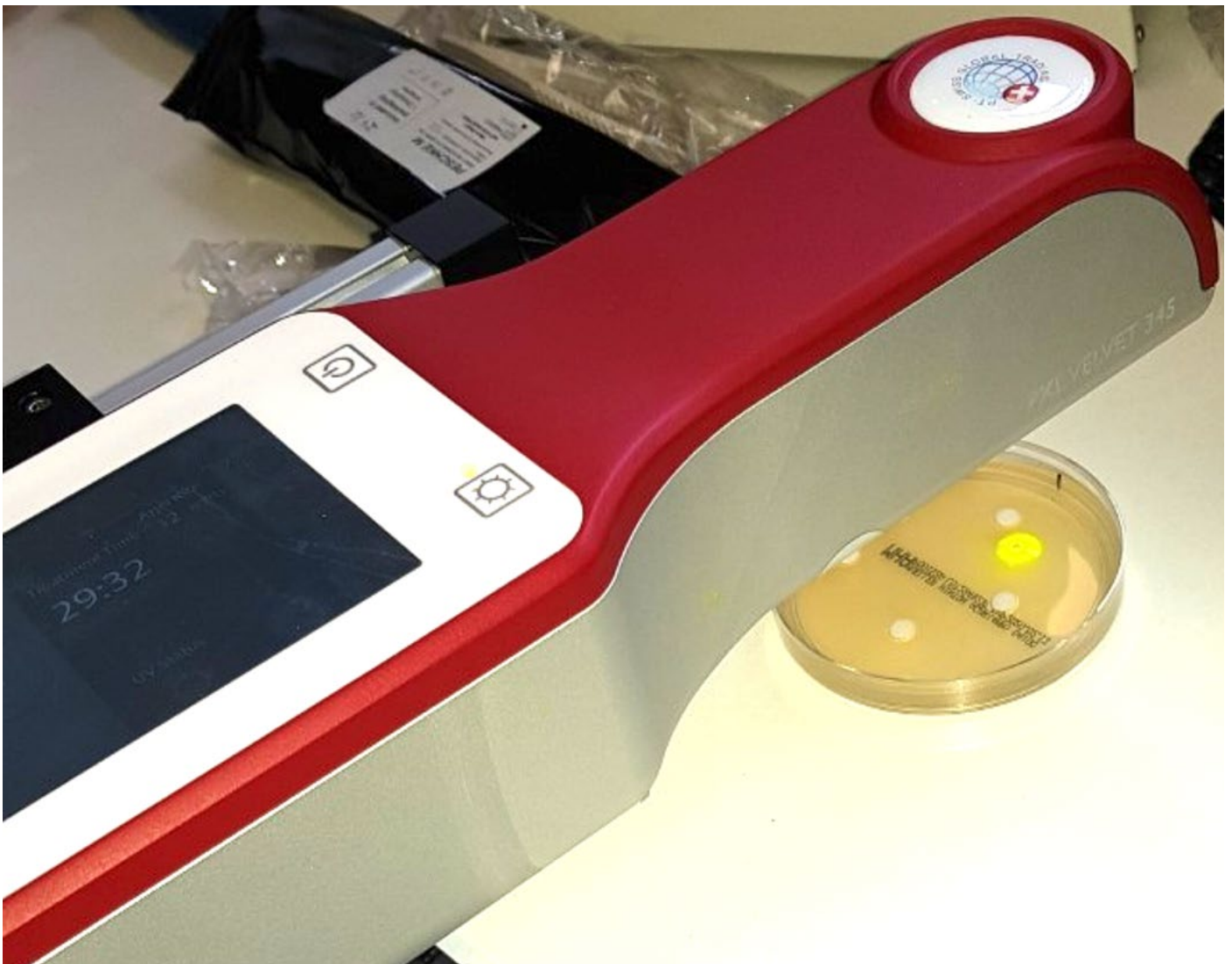
ACKNOWLEDGEMENTS

We would like to thank the RCVS for the data provided in the 2014 and 2019 surveys of the veterinary nursing profession. We would also like to thank Catherine Coates for her editing support. Linnaeus supported the costs of publishing the paper through its Open Access Publication Charge initiative.

In vitro susceptibility of canine corneal bacterial pathogens to three cross-linking protocols



By Thomas Large, Post ECVO Residency Clinician in Veterinary Ophthalmology at DWR Veterinary Specialists in Cambridgeshire



Contribution to the field

Ulcerative keratitis is an ocular condition in which a break in the surface corneal epithelium exposes the underlying corneal stroma and may have serious vision-threatening consequences.^{27,28} The potential for bacterial infection concurrent with ulcerative keratitis is well documented in dogs.^{29,30} Standard medical treatment includes antimicrobials, so treatments are subject to bacterial sensitivity and resistance. In an age of emerging antimicrobial resistance, finding new approaches to treat bacterial infections is increasingly important.

Corneal cross-linking (XL) is a non-surgical, photodynamic therapy that can be used as an adjunctive to antimicrobial treatment in corneal ulceration and melting keratitis.³¹⁻³⁶ Optimising its use in dogs, through the determination of efficacious protocols for treating common corneal bacterial pathogens in ulcerative keratitis, could improve treatment outcomes – particularly as the results of this study highlight that antimicrobial efficacy *in vivo* could differ between bacterial species.

Introduction

A variety of bacterial species have been reported to be associated with ulcerative keratitis in canine patients, including beta-haemolytic *Streptococcus*, *Staphylococcus spp.* and *Pseudomonas spp.*^{40,41} The frequency of positive corneal bacterial cultures in canine and feline patients with ulcerative keratitis indicates the need to address potential bacterial infection as part of treatment.³¹⁻³³

Medical and surgical treatment options are considered for ulcerative keratitis.²⁷ Corneal grafting procedures may result in significant scarring, highlighting the importance of medical treatment to try to reduce the likelihood of surgery⁴² and avoid general anaesthesia where possible.

XL involves a focused ultraviolet A (UVA) light emitted by an XL system focused onto the cornea following saturation with riboflavin (vitamin B2).⁴³ It has demonstrated beneficial effects including an increase in the biomechanical stability of the corneal stromal tissue and increased resistance to degradation by bacterial collagenases.^{37,44} Human *in vitro* studies have shown XL to have an antimicrobial effect within the treatment area.^{38,39}

Existing studies in veterinary patients have reported XL protocols using a UVA irradiance of 3 mW/cm² for 30 minutes and a higher UVA irradiance of 30 mW/cm² for three minutes.³¹⁻³⁶ Studies focusing on UVA irradiance of 3 mW/cm² for 60 minutes have not been reported for clinical use in veterinary patients.

Objectives

The objective of this study was to assess and compare the *in vitro* antibacterial efficacy of three cross-linking (XL) protocols on bacterial isolates obtained directly from cases of canine ulcerative keratitis.

Methods

Three XL protocols comprised UVA 3 mW/cm² for 60 minutes, UVA 3 mW/cm² for 30 minutes, and UVA 30 mW/cm² for three minutes with and without application of riboflavin and a riboflavin-only (RO) protocol. They were performed *in vitro* on the four most common bacterial species isolated from cases of canine ulcerative keratitis. The area of the zone of bacterial growth inhibition (growth inhibition zone; GIZ) associated with each protocol was measured by ImageJ image analysis and compared between protocols.

A review of bacteriology culture records collected from cases of canine ulcerative keratitis examined at DWR Veterinary Specialists was performed between April 2017 and September 2020. Data were assessed to identify cases with a positive bacterial culture and to identify the frequency of different bacterial species isolated.

A single isolate representing each of the four most commonly isolated bacterial species – *Pseudomonas aeruginosa*, *Escherichia coli*, *Streptococcus canis* and *Staphylococcus pseudintermedius* – was used for *in vitro* testing. All protocols were performed on each species in triplicate.

Results

E. coli and *S. canis* demonstrated growth inhibition following all UVA/riboflavin protocols, while *P. aeruginosa* and *S. pseudintermedius* only displayed growth inhibition following the 60-minute UVA/riboflavin protocol.

On average, across bacterial species, GIZ areas for 60-minute UVA/riboflavin protocols were significantly greater than in the 30- and 3-minute UVA/riboflavin protocols ($P < 0.01$). There was no significant difference between 30- and 3-minute UVA/riboflavin protocols. Across bacterial species, mean GIZ areas observed for the RO protocol were significantly lower than in the 60-minute UVA/riboflavin protocol ($P < 0.01$) but not significantly lower when compared to the 30- and 3-minute UVA/riboflavin protocols ($P = 0.1$, $P = 0.99$). *E. coli* was the only bacterial species that showed clear areas of GIZ following application of the XL protocols without riboflavin.

Conclusions

The 60-minute UVA/riboflavin protocol demonstrated an *in vitro* antibacterial effect against all bacterial isolates tested. However, it is important to consider that the clinical use of this protocol is not reported in the existing literature and its safety is unclear.

There was variation in UVA/riboflavin XL protocol efficacy, demonstrated by the GIZ area, across bacterial species. *P. aeruginosa* and *S. pseudintermedius* did not show clear growth inhibition *in vitro* following exposure to XL protocol settings of UVA 3 mW/cm² for 30 minutes and UVA 30 mW/cm² for three minutes.

Future research needs to focus on the *in vivo* antimicrobial effects of XL. While the results of this study indicated antimicrobial efficacy against bacterial pathogens obtained from canine corneas, the variation observed for different bacterial organisms suggests efficacy *in vivo* could differ between bacterial species.

ABOUT THE AUTHORS OF THE STUDY

Thomas Large, Sarah Mack, Elizabeth Villiers and James Oliver, all employed at DWR Veterinary Specialists.

This study has been published in the peer-reviewed scientific journal *Veterinary Ophthalmology* (2022) 00:1-9. doi: 10.1111/vop.13006: <https://onlinelibrary.wiley.com/doi/10.1111/vop.13006>.

ACKNOWLEDGEMENTS

British Association of Veterinary Ophthalmologists (BrAVO): Providers of the BrAVO research and travel grant 2019. Statistical support and analysis was provided by Dr Tim Sparks, Senior Statistician, Waltham Petcare Science Institute.



Incomplete histological margins following planned narrow excision of canine appendicular soft tissue sarcomas and mast cell tumours



By David Haine, Orthopaedic and Soft Tissue Surgeon
at Cave Veterinary Specialists in Somerset

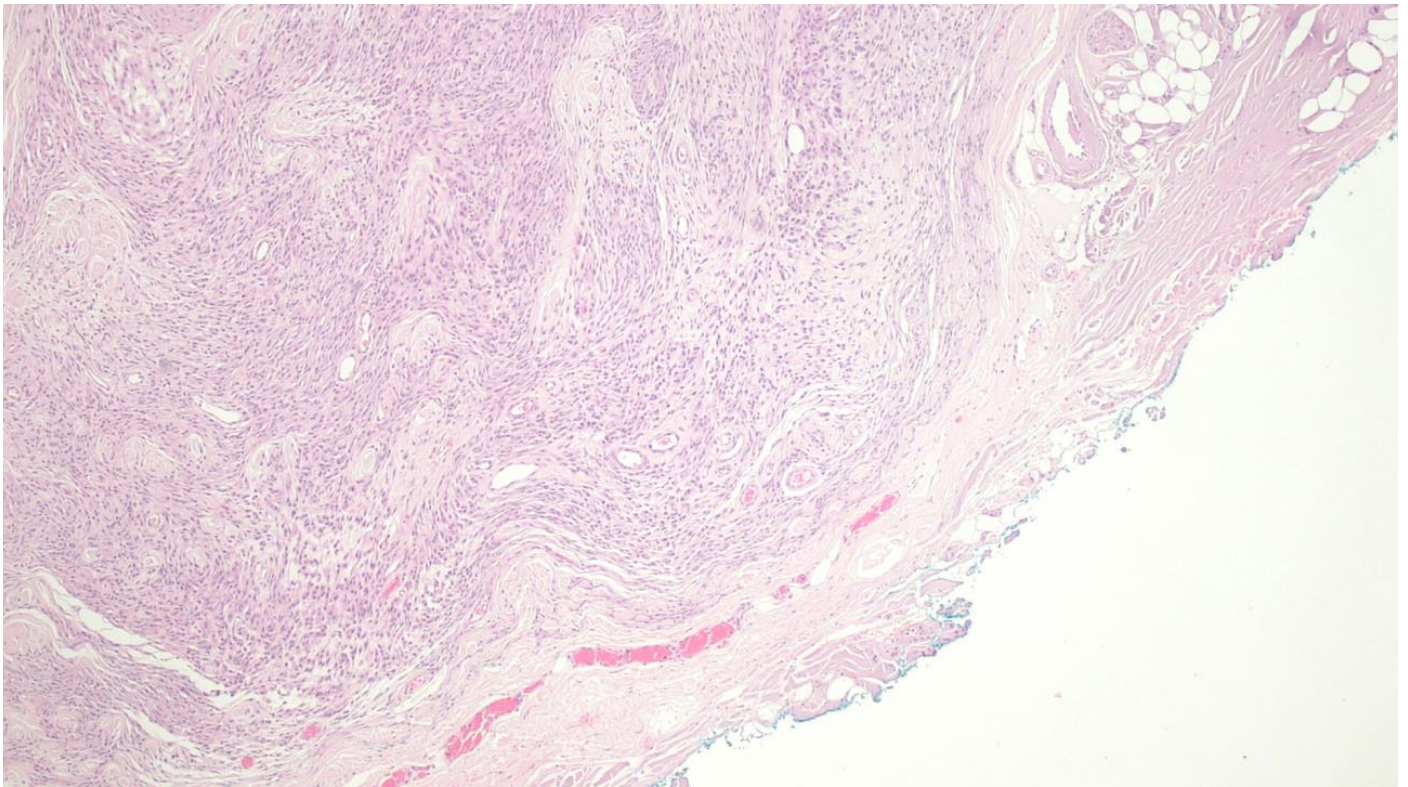


Image credit: Hematoxylin and Eosin stained section of intermediate grade soft tissue sarcoma. Haine, D. L., et al. (2002) Incomplete histological margins following planned narrow excision of canine appendicular soft tissue sarcomas and mast cell tumours, using the residual tumour classification scheme. *Vet Surg.* 51(7):1078-1086. DOI: 10.1111/vsu.13852.

Contribution to the field

Soft tissue sarcomas (STSs) and mast cell tumours (MCTs) are commonly encountered in small animal practice. This study investigated how planned narrow excision (PNE) can be used to manage these tumours and support positive outcomes in canine patients.

The research highlighted how PNE can be used effectively for the diagnosis and management of peripheral STSs and MCTs. It also highlighted the need for further research into the use of PNE for appendicular MCTs and STSs.

Introduction

The clinical presentation and treatment decision-making algorithm for the management of STSs and MCTs is often similar. There is no clear consensus on optimal surgical procedure, although wide or proportional surgical margins and a deep fascial plane are frequently cited as necessary for complete surgical excision. Unfortunately, when the presentation is on the limbs, obtaining these surgical margins is often impossible without considering either radical resection – as partial or complete limb amputation – or techniques potentially associated with additional costs and morbidity.

Marginal excision involves removing macroscopic disease, followed by active surveillance and/or adjunctive therapy based on histopathology. This strategy has been shown to have good long-term clinical outcomes in veterinary patients. In the authors' experience, there is a subset of appendicular tumours where limb salvage is preferred and where a compromise is made to remove as much of the tumour and surrounding tissues as possible, while maintaining a tension-free closure. A PNE removes as much tumour tissue as possible within the constraints of the anatomical location and the need for primary wound closure. This approach may confer better oncologic results than a true marginal or intralesional excision.

Objectives

This retrospective clinical study aimed to describe the frequency of incomplete histological margins following PNE of MCTs and STSs, and to assess the residual tumour classification (R) scheme for reporting histological margins in clinical cases.

The R scheme is an objective measure of histopathological margin reporting. A definition of 'tumour on ink' is used to identify an incomplete histological margin (R1), with all other margin lengths designated as complete (R0). The scheme's simplicity and use in human oncology allows for better comparison of results between studies, while reducing the impact of processing artifacts on interpretation.

We hypothesised that PNEs will result in fewer R1 (histologically incomplete) margins than reported in the literature for marginal excision of these tumours, and the frequency of R1 margins would be associated with the size of lateral surgical margins. We also hypothesised that using the R scheme will improve interobserver agreement in margin reporting.

Methods

The study reviewed the medical records of dogs at a single referral institution, DWR Veterinary Specialists, undergoing PNE of STSs and MCTs between 2016 and 2019.

Cases that received preoperative adjuvant treatment and those in which the intent of the surgery was 'debulking' or 'intralesional', or aimed to excise >10 mm outside the grossly visible tumour (GVT), were excluded.

Data extracted from patient records included breed, weight, age, pre-operative imaging, description of surgery, histopathological tumour characteristics, duration of hospitalisation and short-term hospital follow up. For analysis of surgical margins, lateral measured surgical margins outside the GVT were assigned to one of two groups (0-5 mm or 6-10 mm) based on surgical reports. Radiotherapy reports were also assessed, while histologic specimens were reviewed by a single pathologist to confirm the diagnosis and assign an R scoring.

Veterinary surgeons who referred cases were contacted to obtain follow-up information that would ascertain the patient's clinical status and progression of the disease. This was available for 81% of the dogs. The mean and median duration of follow-up was 844 (standard deviation \pm 245) and 807 (range 411-1,254) days respectively.

Results

The study population consisted of 44 dogs with 47 masses, comprising 23 MCTs and 24 STSs. All tumours underwent sampling before surgery for confirmation of tumour type. We found 26% of MCT PNEs and 42% of STS PNEs resulted in R1 margins. These margins were more likely when performing PNE with 0-5 mm lateral measured surgical margins, compared with 6-10 mm for MCTs (56% versus 7%), but not STSs (41% versus 43%) ($P = 0.049$).

Using the R scheme resulted in higher retrospective percentage agreement in histological reporting compared with defining incomplete histological margin as tumour cells within \leq 1 mm of the margin (83% versus 68% agreement), demonstrating the benefit of objective histological margin reporting. While 26% of surgeries experienced complications, none required additional surgery. Tumours recurred in 17% of STSs and 11% of MCTs with follow-up.

Conclusions

For the cases in this study, PNE appears to be a reasonable surgical approach for limb salvage. When no other options are available, PNE comprising a \leq 10 mm lateral margin and deep fascial plane can be useful for histopathological diagnosis and management of peripheral STSs and MCTs.

This differed slightly for MCTs, as PNE appears to be more effective with a 6-10 mm lateral margin. Indeed, prospective studies will help us to better understand clinical outcomes for appendicular MCTs and STSs using the PNE technique.

Adopting the R scheme led to increased interobserver percentage agreement in histological margin reporting, making the case for further research in this area.

ABOUT THE AUTHORS OF THE STUDY

David Haine, Cave Veterinary Specialists; Rachel Pittaway, DWR Veterinary Specialists; Davide Berlato, AniCura Animal Oncology and Imaging; and Jackie Demetriou, The University of Nottingham.

This study has been published open access in the peer-reviewed scientific journal *Veterinary Surgery*: <https://onlinelibrary.wiley.com/doi/10.1111/vsu.13852>. All references are available to view in full via the online paper.

ACKNOWLEDGEMENTS

The authors would like to thank Tim Sparks, Senior Statistician at Waltham Petcare Science Institute, for his support. Linnaeus covered the costs of the Open Access Publication Charges.



Efficacy of autologous mesenchymal stromal cell treatment for chronic degenerative musculoskeletal conditions in dogs: a retrospective study



By Andrew Armitage, Clinical Director
at Greenside Veterinary Practice in Roxburghshire



Contribution to the field

Chronic degenerative musculoskeletal diseases (MSDs), such as osteoarthritis, are common and cause significant morbidity in dogs. Treatment aims to lessen pain, reduce lameness and improve the patient's quality of life, but traditional therapeutic options often provide symptomatic rather than disease-modifying effects.

This is the first study using 'real-world' data to show that cell-based therapies, injected into multiple areas of MSD pathology in a targeted holistic approach, resulted in rapid and profound positive effects on the patient's pain state and quality of life. This was maintained with repeat treatment for up to two years.

Introduction

Regenerative medicine utilising mesenchymal stromal cells (MSC), which have the capacity to self-renew and differentiate into multiple cell types, has increasingly emerged as an effective clinical treatment for MSDs in human and veterinary patients. They also possess anti-inflammatory and immune modulating properties that can reduce inflammation and pain. Furthermore, several canine regenerative medicine studies have included platelet-rich plasma with MSCs, because the combination is considered to be synergistic in terms of regenerative effects.

Long-term follow up of these treatments, including diagnostic imaging of their disease modifying potential, is lacking in human and veterinary medicine. There is little published evidence linking altered biomechanics to concurrent MSDs, but the prevalence of multiple MSDs in a patient is common and secondary changes frequently complicate the clinical picture.

Objectives

This study aimed to investigate the efficacy of autologous MSCs in 245 dogs deemed unresponsive to conventional treatment by their referring vet, by retrospectively analysing clinical data from a referral regenerative medicine practice.

Methods

The study reviewed medical records of client-owned dogs diagnosed with chronic MSD that were treated with regenerative medicine between September 2017 and May 2021.

The study population comprised 245 dogs with a median age of 6.3 years. They were referred for treatment due to the severity and generalised nature of their MSD, which was unresponsive to traditional treatments. On presentation, the dogs were receiving multiple analgesic medications but still exhibiting pain and lameness. Within the group, 234 had a diagnosis of osteoarthritis while 11 were suffering from tendinopathies and/or lumbosacral disease in the absence of osteoarthritis. Twenty-four had undergone surgery related to cranial cruciate ligament rupture, 24 had had previous surgical arthroscopic intervention for elbow developmental disorders, and two had undergone surgical treatment for osteochondrosis of the shoulder.

On initial presentation all dogs underwent a full orthopaedic and neurological physical examination, with radiography and musculoskeletal ultrasound, to reach a definitive diagnosis.

Confirmation that conventional therapy for the patients' MSD had been unsuccessful was determined by reviewing the clinical history and finding demonstrable persistent pain, lameness and/or disability despite appropriate analgesic medications and previous interventions.

Initial treatment for all dogs consisted of MSCs produced according to current guidelines, administered with platelet rich plasma through one targeted injection to joints and/or tendons. An additional second MSC monotherapy was administered 12 weeks later to dogs with severe pathology and/or previous elbow arthroscopic interventions. Treatment could then be repeated to maintain the positive effect. All dogs were re-assessed clinically at approximately six, 12 and 18 weeks following initial treatment and then every three to six months.

Objective outcome measures and validated subjective outcome measures were used to investigate short-term and long-term efficacy between six and 104 weeks. The time windows were set at the following weeks after initial treatment: 0-6, 7-12, 13-18, 19-24, 25-48, 49-78 and 79-104. Outcome data were collected at predetermined time windows after initial treatment.

The same owner for each dog completed a VetMetrica behaviour-based structured questionnaire prior to treatment; at two, six, 12 and 18 weeks after the first treatment; and every six months thereafter. The VetMetrica quality of life (QOL) assessment covered four domains or metrics: energetic/enthusiastic (E/E), happy/content (H/C), active/comfortable (A/C) and calm/relaxed (C/R).

Where a clinical examination was undertaken, the owners completed the questionnaire before the exam to minimise potential bias. The veterinary assessment was blinded to previous scores because they were entered into the VetMetrica database rather than clinical records.

Results

There were statistically significant improvements in post-treatment compared with pre-treatment measures at all time windows in stance analysis, shoulder and hip range of motion and lumbosacral pressure algometry. This also occurred at 49-78 weeks in carpus and elbow range of motion.

Vet pain and QOL impact scores were recorded 906 times from 223 dogs up to week 104. Improvements in four domains of QOL were statistically significant from 12 weeks, as were scores in vet-assessed pain and QOL impact in all post-treatment measures.

For the A/C QOL domain, the improvement in all post-treatment time windows compared with pre-treatment was significant, with a similar result in E/E after six weeks, and in H/C and C/R after 12 weeks. There were significant time window effects ($P < 0.001$) with all post-treatment means being significantly improved from pre-treatment, but with a deterioration in later time windows.

In those dogs which did not receive an additional injection at 12 weeks after the initial treatment, the mean time before a second treatment was required to maintain improvements in objective measures was 451 days. In cases of tendinopathy, diagnostic imaging demonstrated resolution of abnormal mineralisation and the restoration of normal fibre patterns in the majority of cases.

Conclusions

Appropriate management of MSD requires an accurate diagnosis to fully evaluate the condition and a holistic approach to treatment. We believe the results of this study add considerably to the evidence required to support

the use of MSCs in canine orthopaedic conditions and lays the foundations for further research regarding their regenerative potential and translation into human medicine.

ABOUT THE AUTHORS OF THE STUDY

Andrew Armitage, Greenside Veterinary Practice; Joanna M. Miller, Cell Therapy Sciences; Tim Sparks, Waltham Petcare Science Institute; Alex E. Georgiou, Cell Therapy Sciences and Coventry University; Jacqueline Reid, NewMetrica Research Ltd and University of Glasgow.

This study has been published in the open access peer-reviewed scientific journal *Frontiers in Veterinary Science*: www.frontiersin.org/articles/10.3389/fvets.2022.1014687. All references are available to view in full via the online paper.

ACKNOWLEDGEMENTS

We thank Luisa De Rísio, Linnaeus, and Christine Standen, Cell Therapy Sciences, for their help with preparation of the manuscript. The authors are grateful to all the dog owners who willingly provided data for this work. Linnaeus supported the costs of the Open Access Publication Charges.



Learning at Linnaeus

Linnaeus fosters research collaborations across the UK and globally, as part of the Mars Petcare ecosystem. Its Associates can engage with leading scientists from organisations including the research centre Waltham Petcare Science Institute; health nutrition leader Royal Canin; pet DNA test provider Wisdom Panel; and wearable tech specialist Whistle.

A focus on clinical research has enabled Associates at Linnaeus to complete hundreds of studies. Between 2019 and 2022, 495 studies by Associates were published in a peer-reviewed journal or presented at a global conference. A senior clinician was the principal investigator for 61% of studies, while 35% were led by residents or interns during their training, and 4% were led by veterinary nurses or primary care clinicians.

The clinical board at Linnaeus ensures that important results of new studies inform new internal guidelines and processes when required. Comprised of committed vets, nurses, patient care assistants (PCAs) and support staff, the board is led by Chief Medical Officer, Professor Séverine Tasker.



Internships and residencies

More than 110 residents and nearly 100 rotating and discipline-specific interns are part of Linnaeus. Its centralised training programmes enable participants to develop the skills required for a range of careers in referral and primary care. As part of this, Linnaeus offers support and opportunities in clinical research to ensure this group of ambitious vets can reach their full potential.

Nearly 80% of surveyed rotating interns at Linnaeus have said clinical research remains a high priority during their internship. To help achieve this aim, Linnaeus encourages interns to publish in eminent peer-reviewed journals and present at global veterinary conferences with ring-fenced continuous professional development (CPD) support.

Advice from Linnaeus's clinical research team covers topics including study design, ethical review application, manuscript preparation, clinical studies funding and open access publication fees. In addition, statistical analysis is provided by the Waltham Petcare Science Institute.

This support enables interns to participate in clinical research at Linnaeus. Of the rotating interns surveyed in 2022, who were more than three months into their internships, 73% were involved in a clinical research project.

Linnaeus also offers residencies across 10 disciplines, from anaesthesia to zoological medicine, supported by more than 250 board-certified specialists. To help residents with clinical research, a course on statistics is led by experienced biostatisticians at the Waltham Petcare Science Institute, with all Associates able to access course recordings.

Both interns and residents are offered CPD about clinical research. Unique within the UK veterinary profession, Linnaeus offers a year-long clinical research skills course through online lectures and active learning sessions.

Luisa De Risio, Clinical Research & Excellence Director at Linnaeus, said: *"The research skills course offers consistency, structure and best practice. This not only helps our Associates to reach their full potential – their work can also drive innovation and quality care across the veterinary sector."*

Topics range from ethics to study design, statistical analysis, and peer review, as well as sessions on conducting research during an internship or residency. High-profile internal and external speakers have included representatives from the Royal Veterinary College (RVC), Waltham Petcare Science Institute and Royal Canin.



Nursing

With the guidance and advocacy of Chief Nursing Officer, Dr Andrea Jeffery, veterinary nurses at Linnaeus are also encouraged to develop their research skills. This is supported by the group's unique nursing strategy, which includes a framework for advancement and skills development.

For early career Registered Veterinary Nurses (RVNs) entering referral practice, the unique Post-Registration Programme (PRP) at Linnaeus offers opportunities to explore clinical research. The 12-month programme welcomes two cohorts per year.

The PRP is the UK's first preceptorship programme for multiple referral sites that recruits from a variety of educational institutions around the UK. It comprises five professional development and clinical skills days, plus nurse-led projects to promote evidence-based clinical practice and quality improvement. This includes sessions about clinical research and publishing papers in scientific journals.

Participants rotate around wards, theatre, and diagnostics. They can then choose an optional rotation such as soft tissue surgery, orthopaedics, neurology, internal medicine or dentistry. The nurses are supported by a team that includes PRP managers, skills supervisors, and clinical mentors, and are offered ring-fenced training and study time.

“Nurses at Linnaeus are also encouraged to develop their research skills.”

For more experienced nurses, Linnaeus has launched a pioneering package of support for Veterinary Technician Specialists (VTS) or those who are studying towards this prestigious status. A unique standardised process for all VTS candidates includes an internal mentor and regular contact with Linnaeus's nursing central support team. Linnaeus offers each candidate a training agreement that covers areas such as additional CPD allowances, study time and networking opportunities.

VTS holders can access an enhanced CPD budget and time allowance for attending international specialist conferences, all funded by Linnaeus. They are also invited to interprofessional discipline-specific away days and offered membership to a specialist organisation. To support nurses across its network, Linnaeus runs an internal group for both VTS candidates and holders.

Vicky Ford-Fennah, Professional Development Manager at Linnaeus and a VTS holder in anaesthesia and analgesia, commented:

"Highly skilled nurses are critical to all aspects of veterinary practice, and the expertise of our VTS holders helps to ensure our teams are really efficient, innovative and effective in delivering patient care."

All nursing Associates can access professional development support within their practice, and from Linnaeus's veterinary nursing central support team.

Tools and resources

In addition to its training and CPD programmes, Linnaeus offers Associates a range of valuable resources as a benefit of being part of Mars Veterinary Health. This includes the Mars Center for Veterinary Excellence (MCVE) and the Mars Veterinary Health Medical Library. MCVE is a robust learning hub with access to online courses, procedural videos and webinar events from across the Mars ecosystem.

The Mars Veterinary Health Medical Library is a fully online library of 2,500+ digital books and journals, biomedical databases, and just-in-time veterinary resources. With 24/7 access, Associates can retrieve the information they need anywhere and anytime. A critical evidence-based resource, the library is used by vets, veterinary nurses, PCAs and support staff across primary care and referral practice. It also features leadership and management resources.

"This is a game changer in how we can access knowledge and data from across the global veterinary profession," commented Luisa.

"The library provides simple yet comprehensive access to journals and textbooks that are highly valuable by providing background information for clinical research projects. It also supports everyday evidence-based practice by giving Associates easy access to the veterinary literature that is relevant to their patients' needs."

Linnaeus has also increased its funding for clinical research being published in open access scientific journals, with 33 papers receiving a combined investment of £60,000 in 2022. The Open Access Publication Charge (OAPC) initiative covers the fees for Associates to publish in prominent peer-reviewed veterinary journals. While charges vary, this can cost up to £3,000 per paper.

"This is a game changer in how we can access knowledge and data from across the global veterinary profession."

Luisa adds: *"As well as supporting those who carry out clinical research, we also want to make their findings available to all. This supports the author's profile and career development – and ensures our Associates' work makes the widest possible impact on the health of pets."*

"Clinical research supports all areas of best practice in veterinary care, so it is important that our Associates can undertake studies and share their results as widely as possible."



Page 4: The impact of artificial intelligence on veterinary practice

1. OpenAI. (n.d.) ChatGPT. openai.com/blog/chatgpt/ [Accessed January 2023]
2. Biourge, V., Delmotte, S., Feugier, A. et al. (2020) An artificial neural network-based model to predict chronic kidney disease in aged cats. *J Vet Intern Med.* 34(5), 1920-1931.
3. Bradley, R., Tagkopoulos, I., Kim, M. et al. (2019) Predicting early risk of chronic kidney disease in cats using routine clinical laboratory tests and machine learning. *J Vet Intern Med.* 33(6), 2644-2656.
4. Schofield, I. et al. (2021) Machine-learning based prediction of Cushing's syndrome in dogs attending UK primary-care veterinary practice. *Sci Rep.* 11(1), 9035.
5. Reagan, K. L., Pires, J., Quach, N. et al. (2022) Evaluation of a machine learning tool to screen for hypoadrenocorticism in dogs presenting to a teaching hospital. *J Vet Intern Med.* 36(6), 1942-1946.
6. Chambers, R. D., Yoder, N.C., Carson, A.B. et al. (2021) Deep Learning Classification of Canine Behaviour Using a Single Collar-Mounted Accelerometer. *Animals.* 11(6), 1549.
7. Wilkinson, M. D., Dumontier, M., Aalbersberg, I.J. et al. (2016) The FAIR Guiding Principles for scientific data management and stewardship. *Sci Data.* 3(1), 160018.

Page 7: Ethics in clinical veterinary research

8. Royal College of Veterinary Surgeons. (2023) FAQs – Routine veterinary practice and clinical veterinary research. www.rcvs.org.uk/setting-standards/advice-and-guidance/faqs--routine-veterinary-practice-and-clinical-veterinary/ [Accessed January 2023]
9. UK Research and Innovation. (2022) Regulation and policy. www.ukri.org/about-us/mrc/our-policies-and-standards/research/research-involving-animals/regulation-and-policy/ [Accessed January 2023]
10. Health Products Regulatory Authority. (2014) Scientific animal protection. www.hpra.ie/homepage/veterinary/scientific-animal-protection [Accessed January 2023]
11. Royal College of Veterinary Surgeons. (2023) Ethics Review Panel. www.rcvs.org.uk/who-we-are/committees/standards-committee/ethics-review-panel/ [Accessed January 2023]

Page 10: Undertaking research with industry and charitable support

12. Hülsmeier, V., Zimmermann, R., Brauer, C., et al. (2010) Epilepsy in Border Collies: clinical manifestation, outcome, and mode of inheritance. *J Vet Intern Med.* 24(1), 171-8.
13. Kearsley-Fleet, L., O'Neill, D. G., Volk, H. A., et al. (2013) Prevalence and risk factors for canine epilepsy of unknown origin in the UK. *Vet Rec.* 172(13), 338.
14. Packer, R. M., Shihab, N. K., Torres, B. B., et al. (2016) Risk factors for cluster seizures in canine idiopathic epilepsy. *Res Vet Sci.* 105, 136-8.
15. Santifort, K. M., Bertjin, E., Bhatti, S. F. M. et al. (2022) Phenotypic Characterization of Idiopathic Epilepsy in Border Collies. *Front Vet.* 9, 880318.
16. Heske, L., Nødtvedt, A., Jäderlund, K. H., et al. (2014) A cohort study of epilepsy among 665,000 insured dogs. *Vet J.* 202(3), 471-6
17. Packer, R. M., Volk H. A. (2015) A review of the impact of epilepsy and its comorbidities on health-related quality of life in dogs. *Vet Rec.* 177(12), 306-15.
18. De Riso, L., Freeman, J., Shea, A. (2016) Evaluation of quality of life of carers of Italian spinoni with idiopathic epilepsy. *Vet Rec Open.* 3(1), e000174.
19. Jenkins, C. A., Kalmar, L., Matiasek, K., et al. (2020) Characterisation of canine KCNIP4: A novel gene for cerebellar ataxia identified by whole-genome sequencing two affected Norwegian Buhund dogs. *PLoS Genetics.* 16(1), e1008527.
20. Qaiser, F., Sadoway, T., Yin, Y., et al. (2021) Genome sequencing identifies rare tandem repeat expansions and copy number variants in Lennox-Gastaut syndrome. *Brain Commun.* 14;3(3), fcab207
21. Jenkins, C. A., Dog Biomedical Variant Database Consortium, Schofield, E. C. et al. (2021) Improving the resolution of canine genome-wide association studies using genotype imputation: A study of two breeds. *Animal Genetics.* 52(5), 703-713.

Page 13: Beyond the thesis: career opportunities following your doctorate

22. Higher Education Statistics Agency. (2023) Who's studying in HE? www.hesa.ac.uk/data-and-analysis/students/whos-in-he [Accessed April 2023]
23. Prospects. (2022) What is a PhD. www.prospects.ac.uk/postgraduate-study/phd-study/what-is-a-phd [Accessed April 2023]
24. Harvard Business Review. (2022) Act Like a Scientist. hbr.org/2022/05/act-like-a-scientist [Accessed April 2023]
25. Civil Service. (2015) Why STEM graduates should consider the Civil Service. civilservice.blog.gov.uk/2015/06/19/why-stem-graduates-should-consider-the-civil-service/ [Accessed May 2023]
26. Prospects. (2023) Funding postgraduate study. www.prospects.ac.uk/postgraduate-study/funding-postgraduate-study [Accessed April 2023]

Page 17: Identifying the factors that influence retention within the veterinary nursing profession

Jeffery, A., Taylor, E. (2022) Veterinary nursing in the United Kingdom: Identifying the factors that influence retention within the profession. *Front. Vet. Sci.* 9:927499. All references can be found in the online paper: <https://doi.org/10.3389/fvets.2022.927499>.

Page 20: In vitro susceptibility of canine corneal bacterial pathogens to three cross-linking protocols

27. Gelatt K. N ed. (2021) *Veterinary Ophthalmology*. 6th ed. Hoboken New Jersey, Wiley-Blackwell
28. Kern, T. J. (1990). Ulcerative keratitis. *Vet Clin North Am Small Anim Pract.* 20(3), 643-666
29. Wang, L., Pan, Q., Zhang, L., et al. (2008) Investigation of bacterial microorganisms in the conjunctival sac of clinically normal dogs and dogs with ulcerative keratitis in Beijing, China. *Vet Ophthalmol.* 11(3), 145-149.
30. Prado, M. R., Rocha, M. F. G., Brito, É. H. S., et al. (2005). Survey of bacterial microorganisms in the conjunctival sac of clinically normal dogs and dogs with ulcerative keratitis in Fortaleza, Ceará, Brazil. *Vet Ophthalmol.* 8(1), 33-37
31. Pot, S. A., Gallhöfer, N. S., Matheis, F. L., et al. (2014) Corneal collagen cross-linking as treatment for infectious and noninfectious corneal melting in cats and dogs: results of a prospective, nonrandomized, controlled trial. *Vet Ophthalmol.* 17(4), 250-260.
32. Spiess, B. M., Pot, S.A., Florin, M., et al. (2014). Corneal collagen cross-linking (CXL) for the treatment of melting keratitis in cats and dogs: a pilot study. *Vet Ophthalmol.* 17(1), 1-11.
33. Famose, F. (2014) Evaluation of accelerated collagen cross-linking for the treatment of melting keratitis in eight dogs. *Vet Ophthalmol.* 17(5), 358-367.
34. Hellander-Edman, A., Makdoui, K., Mortensen, J., et al. (2019) Corneal cross-linking in 9 horses with ulcerative keratitis. *BMC Vet Res.* 9, 128.
35. Hellander-Edman, A., Ström, L., Ekestén, B. (2019) Corneal cross-linking (CXL) – a clinical study to evaluate CXL as a treatment in comparison with medical treatment for ulcerative keratitis in horses. *Vet Ophthalmol.* 22(4), 552-562.
36. Famose F. (2015) Evaluation of accelerated collagen cross-linking for the treatment of melting keratitis in ten cats. *Vet Ophthalmol.* 18(2), 95-104.
37. Spoerl, E., Wollensak, G., Seiler, T. (2004) Increased resistance of crosslinked cornea against enzymatic digestion. *Curr Eye Res.* 29(1), 35-40.
38. Martins, S. A. R., Combs, J. C., Noguera, G., et al. (2008). Antimicrobial efficacy of riboflavin/UVA combination (365 nm) in vitro for bacterial and fungal isolates. *Invest Ophthalmol Vis Sci.* 49(8), 3402-3408.
39. Schrier, A., Greebel, G., Attia, H., et al. (2009) In vitro antimicrobial efficacy of riboflavin and ultraviolet light on *Staphylococcus aureus*, methicillin-resistant *Staphylococcus aureus*, and *Pseudomonas aeruginosa*. *J Refract Surg.* 25(9), S799-S802.
40. Hindley, K. E., Growth, A. D., King, M., et al. (2016) Bacterial isolates, antimicrobial susceptibility, and clinical characteristics of bacterial keratitis in dogs presenting to referral practice in Australia. *Vet Ophthalmol.* 19(5), 418-426.
41. Tolar, E. L., Hendrix, D. V. H., Rohrbach, B. W., et al. (2006). Evaluation of clinical characteristics and bacterial isolates in dogs with bacterial keratitis: 97 cases (1993-2003). *J Am Vet Med Assoc.* 228(1), 80-85.
42. Gogova, S., Leiva, M., Ortillés, Á., et al. (2020) Corneconjunctival transposition for the treatment of deep stromal to full-thickness corneal defects in dogs: a multicentric retrospective study of 100 cases (2012-2018). *Vet Ophthalmol.* 23(3), 450-459.
43. Spoerl, E., Huhle, M., Seiler, T. (1998) Induction of cross-links in corneal tissue. *Exp Eye Res.* 66(1), 97-103.
44. Wollensak, G., Spoerl, E., Seiler, T. (2003) Stress-strain measurements of human and porcine corneas after riboflavin-ultraviolet-A-induced cross-linking. *J Cataract Refract Surg.* 29(9), 1780-1785.

Page 23: Incomplete histological margins following planned narrow excision of canine appendicular soft tissue sarcomas and mast cell tumours

Haine, D. L., Pittaway, R., Berlato, D., Demetriou, J. (2002) Incomplete histological margins following planned narrow excision of canine appendicular soft tissue sarcomas and mast cell tumours, using the residual tumour classification scheme. *Vet Surg.* 31(7):1078-1086. All references can be found in the online paper: <https://onlinelibrary.wiley.com/doi/full/10.1111/vsu.13852>.

Page 26: Efficacy of autologous mesenchymal stromal cell treatment for chronic degenerative musculoskeletal conditions in dogs

Armitage, A. J., Miller, J. M., Sparks, T. H., Georgiou, A. E., Reid, J. (2023) Efficacy of autologous mesenchymal stromal cell treatment for chronic degenerative musculoskeletal conditions in dogs: A retrospective study. *Front. Vet. Sci.* 9:1014687. All references can be found in the online paper: <https://www.frontiersin.org/articles/10.3389/fvets.2022.1014687/full>.

ACKNOWLEDGEMENTS

With thanks to everyone who contributed to *Pathways to Innovation: Learning and Leadership in Clinical Veterinary Research*:

- Nefertiti Greene, President, Science & Diagnostics, Mars Petcare
- Ciaran O'Flynn, Research Manager – Data Science at Waltham Petcare Science Institute
- Professor David Morton CBE, Chair, Ethics Review Panel at the Royal College of Veterinary Surgeons
- Chris Jenkins, Research Assistant, The Kennel Club Genetics Centre and the University of Cambridge, PhD student, University of Manchester
- Dr Hannah Sargent, Clinical Research Associate at Linnaeus
- Dr Andrea Jeffery, Chief Nursing Officer at Linnaeus
- Thomas Large, Post ECVO Residency Clinician in Veterinary Ophthalmology at DWR Veterinary Specialists
- David Haine, Orthopaedic and Soft Tissue Surgeon at Cave Veterinary Specialists
- Andrew Armitage, Clinical Director at Greenside Veterinary Practice

The report was compiled by Rebecca Bannister and designed by Ian Hughes.

"Excellence in research is fundamental to the evidence-based clinical care that supports our patients, clients and colleagues. It is therefore important to celebrate the innovation and new findings that will help us to continue delivering the best possible care. I would like to extend my gratitude to the report's authors and everyone at Linnaeus who contributes to, and supports, clinical research."

Professor Séverine Tasker, Chief Medical Officer, Linnaeus

To view Linnaeus's series of reports online, please visit linnaeusgroup.co.uk/about-us/insight-reports.

linnaeusgroup.co.uk/careers

linnaeusgroup.co.uk/medical-and-nursing

The views or opinions expressed in this report are solely those of the authors involved and do not necessarily represent those of Linnaeus Veterinary Limited.

LINNAEUS

Friars Gate, 1011 Stratford Road
Shirley, West Midlands B90 4BN
T 0121 712 7050
E enquiries@linnaeusgroup.co.uk

linnaeusgroup.co.uk

LINNAEUS