BEYOND THE LIMP: A SURGEON'S GUIDE TO PREVENTING THE NIGHTMARE OF EQUINE PARENTS (LAMENESS)

Kaiyad B. B.[1], Patel J. B.[2], Suthar D. N.[3], Sutaria P. T.[3], Vyas A. V.[4], Patel J. P.[1], Gangurde A. A.[1]
[1]M.V.Sc. Scholar, [2]Assistant Professor, [3]Associate Professor, [4]Senior Research Assistant
Department of Veterinary Surgery and Radiology, College of Veterinary Science and Animal Husbandry, Kamdhenu University, Sardarkrushinagar.
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Introduction

"No foot, no horse." This centuries-old adage remains the absolute truth in equine medicine. For a horse owner (or "equine parent") lameness is more than just a medical condition; it is a nightmare that halts performance, drains finances and causes immense distress to the animal. In the world of equine companionship, the horse's ability to move is its very essence. For an "equine parent" whether a competitive rider or a backyard enthusiast the sight of a horse "nodding" or "hitching" its stride is the beginning of a nightmare. Lameness is the single most common reason for veterinary intervention and sadly, a leading cause of premature retirement from work. As a MVSc Scholar of Veterinary Surgery and Radiology, I often see the final stages of this nightmare: the rotated coffin bone (laminitis), the fractured navicular bone or the torn suspensory ligament. Yet, the most profound surgical insight I can offer is this: Most lameness is not a sudden accident; it is the result of long-term mechanical failure that could have been prevented.

The "Root" cause of the lameness

Statistically, nearly 70–80% of equine lameness originates in the foot. Whether it is a high-performance athlete or a sturdy working pony the hoof bears the entire weight and mechanical stress of the body. When the balance of the hoof is disrupted the tendons, ligaments and joints begin to fail.

The Biomechanics of the Equine Foot:

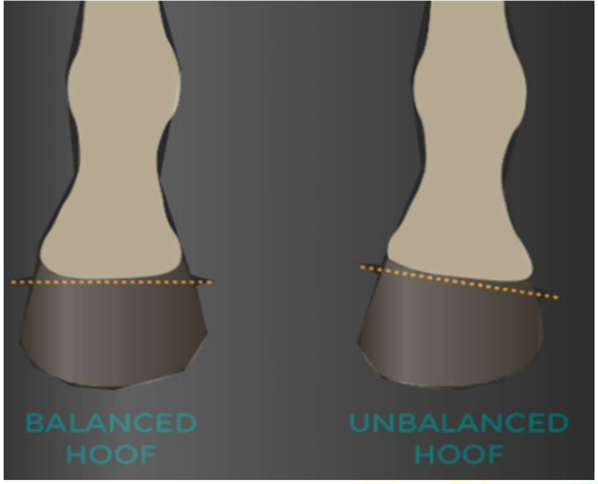
To prevent lameness, one must understand that the horse's hoof is a complex shock-absorption system. When a 500kg horse gallops the force exerted on a single limb can be triple its body weight.

The Digital Cushion: This fatty fibrous tissue at the heel acts as a hydraulic pump, aiding blood circulation.

The Laminar Attachment: This is the "velcro" that holds the coffin bone to the hoof wall. If this fails (Laminitis) the nightmare begins.

Inside the hoof two main structures that need to stay stuck together: The Sensitive Laminae, Living tissue with blood vessels and nerves attached to the Coffin Bone. & The Insensitive Laminae, Hard, horn-like ridges on the inside of the Hoof Wall. These two layers have thousands of tiny, interlocking finger-like projections (laminae). They "zip" together exactly like Velcro. This bond is the only thing holding the heavy skeleton of the horse to the hard outer hoof capsule.

Preventative Insight: If the hoof is left too long at the toe, it creates a "long-lever arm" effect putting immense strain on the Navicular bone and the Deep Digital Flexor Tendon (DDFT). When the toe is too long the DDFT is stretched tight like a guitar string during every single step. Because the DDFT is pulling so hard it presses the Navicular bone against the Coffin bone with massive force. The constant pressure causes the Navicular bone to lose bone density or develop radiolucent zones that seen on X-rays or may developed desmitis.



The Golden Rules of Farriery (Shoeing)

Modern farriery is as much a science as surgery.

The 4-to-6 Week Rule: Even if the shoes look "fine" the hoof wall grows, shifting the weight-bearing axis. Regular trimming is non-negotiable.

Medio-Lateral Balance: The horse should land flat. If one side of the hoof hits the ground before the other, it creates shearing forces that lead to "Sidebone" or "Ringbone" (osteoarthritis).

The Barefoot Debate: While some horses thrive barefoot, high-performance horses or those on hard terrain require shoes to prevent "Bruised Soles" and "White Line Disease."

Nutrition: Building the Hoof from Within

A surgeon can stitch a wound, but we cannot "fix" a brittle hoof wall. That requires internal chemistry.

Biotin & Zinc: Essential for the production of keratin. A deficiency leads to "Shelly Hoof" where shoes won't stay on.

The Sugar Danger: Overfeeding lush green pasture or high-grain diets leads to "Metabolic Laminitis." High sugar causes an enzyme breakdown in the hoof laminae, causing the bone to rotate - a surgical emergency that often has a poor prognosis.

Environmental Management

"Environmental Lameness" is preventable.

Hygiene: Standing in urine-soaked bedding causes ammonia to eat away at the frog, leading to Thrush. A black, foul-smelling discharge is your first warning sign.

The Surface Factor: Avoid "Arena Fatigue." Working a horse exclusively on deep sand causes soft tissue strain, while hard roads cause concussion-related joint disease.

Early Detection:

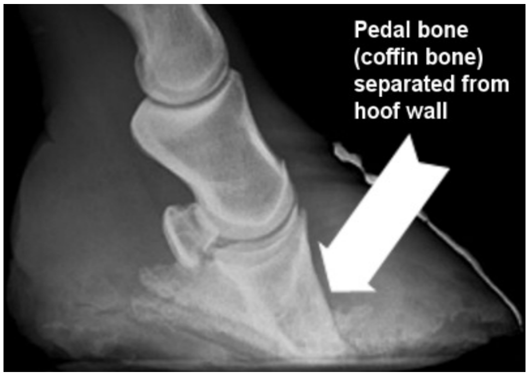
By the time a horse is lame (visible at a walk), the pathology is advanced. Owners must look for **Sub-clinical Signs**:

The Digital Pulse: Learn to palpate the digital arteries at the back of the fetlock. A strong, "throbbing" pulse indicates inflammation inside the hoof (abscess or laminitis).

Heat Sensing: Use the back of your hand to compare the temperature of all four hooves daily.

The "Pointing" Hoof: If your horse stands with one front foot further forward than the other they are "off-weighting" a painful heel.

(Healthy Hoof X-ray)



First Aid for Sudden Lameness

STRICT REST: "Do Not Walk It Off" The biggest mistake owners make is forcing a suddenly lame horse to keep walking to see if they will "warm out of it." If the lameness is due to a hairline fracture or a partial tendon tear every single step pushes the structure closer to a complete rupture. Stop the horse immediately. If you are riding, dismount. Slowly walk them to the nearest deeply bedded stall or a small confined yard and restrict all movement.

COLD THERAPY: Immediately apply cold therapy to the affected leg. Hose the lower limb with cold running water for 15 to 20 minutes or apply an ice pack. This constricts the blood vessels halts the inflammatory cascade and provides excellent natural pain relief. It is particularly crucial if you suspect acute Laminitis or a fresh tendon strike.

CALL THE VET: Call your veterinarian immediately but do not administer any painkillers (like Flunixin) unless explicitly told to do so over the phone. Painkillers mask the symptoms. When the veterinarian arrives to perform a diagnostic Lameness Exam, they need to see exactly where it hurts to perform accurate nerve blocks and target the X-rays. If you hide the pain with medication, you delay the correct diagnosis.

Conclusion

As a scholar of Radiology, I advocate for the "Annual Soundness Exam." A single set of baseline X-rays (Lateromedial and Dorsopalmar views) can tell us if the coffin bone is aligned or if early arthritic changes are starting. This allows for "Corrective Farriery" before the horse ever takes a lame step.

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ASSISTED REPRODUCTIVE TECHNOLOGIES AND BIOSECURITY

Patel P.N.[1], Gurde A.A.[2], Patel S.[3]
[1]Assistant Professor, Department of Veterinary Gynaecology and Obstetrics (LFC), Shourabh College of Veterinary Science, RAJUVAS, Kheda
[2]Assistant Professor, Department of Animal Nutrition (LFC), Shourabh College of Veterinary Science, RAJUVAS, Kheda
[3]Assistant Professor, Department of Veterinary Pathology (VCC), Shourabh College of Veterinary Science, RAJUVAS, Kheda
[1]Corresponding Author email: drpraptipatel.vet@gmail.com

Abstract

Assisted Reproductive Technologies (ART) including artificial insemination, embryo transfer, in vitro fertilization, and semen/embryo cryopreservation have become central to improving genetic gain, efficiency, and resilience in livestock production. However, these technologies also create specific biosecurity risks because gametes, embryos, and associated equipment can carry pathogens between animals, farms, and even countries. This article examines the interface between ART and biosecurity from a practical, field-oriented perspective, summarizing major disease transmission risks linked to semen collection, AI, embryo production, and transport, and outlining evidence based mitigation strategies. It emphasizes standardized operating procedures, strict hygiene and disinfection, traceability, and staff training as core elements of an ART aligned biosecurity framework. The article also discusses how emerging digital tools such as RFID-based sanitation monitoring and electronic recordscan strengthen compliance and auditability. By integrating disease-risk management into ART workflows, veterinary practitioners and production units can sustain both genetic progress and herd health, supporting long-term food security and animal welfare.

Keywords: Assisted Reproductive Technologies (ART), biosecurity, artificial insemination, embryo transfer, disease transmission, cryopreservation

Introduction

Assisted Reproductive Technologies have transformed veterinary practice and animal production, enabling rapid genetic improvement, controlled breeding cycles, and the conservation of rare or high value germplasm. In cattle alone, millions of inseminations and hundreds of thousands of embryo transfers are performed annually, supported by global networks of semen and embryo banks. Yet, each step of these pipelines, from semen collection and processing to embryo flushing, culture, freezing, and transfer represents a potential opportunity for pathogen entry or spread. Biosecurity, in contrast, has historically been framed as a set of farm level measures to prevent disease introduction and limit within herd transmission. When ART is superimposed on traditional biosecurity models, it exposes gaps: a single batch of AI semen or an embryo shipment can introduce a systemic disease into a previously naive herd, making the "farm" boundary less relevant than the integrity of the reproductive pipeline itself. This article therefore argues that ART must no longer be treated as a purely technical exercise, but as a high-risk biosecurity node that demands specialized protocols, culture, and continuous assessment.

Assisted Reproductive Technologies: A practical overview

ART in veterinary medicine encompasses a range of techniques aimed at manipulating gametes and embryos to improve reproductive efficiency and genetic quality. The most widely used tool remains artificial insemination, in which semen is collected from selected males, processed, cryopreserved, and inseminated into females at precisely timed intervals. In addition, embryo transfer, where embryos are collected from genetically superior donors and transferred to recipient animals that enables the multiplication of high value genetics at a much faster rate than natural breeding. In species such as cattle, fixed-time AI protocols and ovarian stimulation further intensify the use of ART, particularly in large scale cow-calf operations and pasture based systems. These protocols partially bypass the need for daily heat detection, but they also increase the number of animals handled, the frequency of procedures, and the volume of biological material moved through centralized facilities. As ART becomes more standardized and commercialized, reproductive units function as "hubs" where animals, personnel, and biological products converge, creating dense networks of contact whose biosecurity implications are often underappreciated.

Biosecurity threats associated with ART

From a biosecurity standpoint, ART can facilitate both horizontal and vertical transmission of pathogens. Semen and embryos may carry bacteria, viruses, and protozoa that are not always detectable at routine screening level, and these can be transmitted to recipients, offspring, and even indirectly to bystander animals via contaminated equipment or personnel. In cattle, for example, pathogens such as *Trichomonas foetus*, bovine viral diarrhoea virus (BVDV), and certain mycoplasmas can be transmitted through infected semen or contaminated AI equipment, leading to reproductive failure, abortion, and immunosuppression. Equally important are non-pathogen specific risks such as cross-contamination between animals during handling, reuse of non-sterile equipment, and inadequate disinfection of AI guns, catheters, and embryo transfer equipment. Even where the originating farm is officially disease-free, lapses in hygiene during collection or processing can introduce a new pathogen into the reproductive pipeline. Furthermore, international trade in semen and embryos multiplies these risks, as a single contaminated shipment can expose multiple herds across different production systems and countries.

Integrating biosecurity into ART workflows

To mitigate these risks, veterinary practitioners and reproductive units must embed biosecurity into every stage of the ART chain. At the collection stage, donor animals should be screened for key reproductive and systemic pathogens, and procedures should follow standardized operating procedures (SOPs) that define acceptable hygiene levels, equipment use, and waste disposal. Semen and embryo processing laboratories require physical containment, controlled airflow, and strict separation of "clean" and "potentially contaminated" areas to minimize cross-contamination. On farm, AI and embryo transfer procedures should be performed under conditions that mimic surgical asepsis as closely as possible. Each AI gun, catheter, embryo transfer device, and inseminating sheath should either be single-use or undergo validated cleaning and sterilization protocols; reusable equipment must be inspected after each use and retired when its integrity is compromised. Personnel should be trained not only in technical skills but also in biosecurity behaviors, including the use of dedicated outerwear, gloves, boots, and hand hygiene, and strict adherence to movement protocols that limit unnecessary contact between animals of different health or genetic status.

Digital tools and monitoring for ART linked biosecurity

Modern biosecurity in ART settings is increasingly supported by digital tools that enhance traceability and compliance monitoring. Electronic records can link each semen dose or embryo to its donor, collection date, pathogen screening results, and destination, enabling rapid traceback in case of disease detection. Radio frequency identification (RFID) tags and access control systems can be used to monitor staff movement, boot and hand sanitization compliance, and equipment use, thereby reducing the risk of cross contamination between buildings or units. Adenosine triphosphate (ATP) luminometry can provide immediate feedback on the cleanliness of equipment surfaces, helping units to verify that cleaning protocols are effective rather than merely followed. When combined with regular biosecurity audits and staff training, these tools create a feedback loop that identifies weak points in ART related workflows and allows continuous improvement.

Practical recommendations for veterinary practitioners

For veterinarians working with ART, three overarching priorities emerge. First, every ART procedure should be accompanied by a written biosecurity-oriented SOP that covers donor screening, equipment handling, hygiene, and waste management, and that is regularly reviewed and updated. Second, staff must receive periodic training in both ART techniques and biosecurity, with clear responsibilities defined for each role and opportunities for supervised practice of sterile procedures. Third, veterinary units should establish formal relationships with external laboratories and diagnostic services to ensure timely and standardized pathogen screening, while also maintaining internal quality control mechanisms for cleaning and equipment performance. At the farm level, veterinarians should advise clients to keep AI and embryo transfer related activities separate from routine herd management whenever possible, and to enforce strict visitor and vehicle protocols around areas where reproductive procedures are performed. This includes limiting the number of people entering collection rooms, using dedicated transport routes for semen and embryo containers, and avoiding shared equipment between different farms or age groups without thorough disinfection.

Conclusion

Assisted Reproductive Technologies are central to modern veterinary practice and animal production, but their benefits can only be sustained if they are firmly anchored in robust biosecurity. Semen, embryos, and the associated equipment and personnel form a dynamic network of contacts that can rapidly spread pathogens if not managed with discipline. By integrating standardized operating procedures, rigorous hygiene, clear responsibilities, and digital traceability and monitoring into ART workflows, veterinary practitioners can ensure that genetic progress goes hand in hand with disease prevention and herd health. In doing so, they not only protect individual animals and farms but also contribute to the broader goals of food security, animal welfare, and public health.

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PRECISION NUTRITION IN LIVESTOCK: A NEW FRONTIER FOR FOOD SAFETY

Gurde A.A.[1], Patel P.N.[2], Patel S.[3]
[1]Assistant Professor, Department of Animal Nutrition (LFC), Shourabh College of Veterinary Science, RAJUVAS, Kheda
[2]Assistant Professor, Department of Veterinary Gynaecology and Obstetrics (LFC), Shourabh College of Veterinary Science, RAJUVAS, Kheda
[3]Assistant Professor, Department of Veterinary Pathology (VCC), Shourabh College of Veterinary Science, RAJUVAS, Kheda
[1]Corresponding Author email: akshaygurde2797@gmail.com

Abstract

Precision nutrition in livestock refers to the targeted adjustment of dietary composition and intake to match the specific requirements of individual animals or groups, based on real time data, growth models, and health monitoring. Beyond enhancing productivity and efficiency, this approach has emerged as a critical lever for improving food safety by influencing the gut microbiota, reducing colonization of food-borne pathogens, and limiting the need for antimicrobial interventions. By optimizing protein, amino acid, carbohydrate, mineral, and additive profiles, precision feeding systems can decrease the shedding of *Salmonella*, *E. coli*, and other zoonotic agents along the production chain. This article examines how precision nutrition interacts with food-safety objectives, reviews current technologies such as automated feeders, sensors, and decision-support systems, and proposes a practical framework for veterinarians and farm managers to integrate precision nutrition strategies into routine health management. The goal is to demonstrate that what goes into the animal's ration is not only a determinant of growth and efficiency but also a direct contributor to the safety and quality of animal source foods reaching the consumer.

Keywords: Precision nutrition, livestock, food safety, precision feeding, zoonotic pathogens, gut microbiome

Introduction

Livestock production is under unprecedented pressure to deliver safe, affordable, and sustainable animal source foods, while simultaneously reducing antimicrobial use and environmental impact. Traditional feeding systems often rely on broad category rations adjusted mainly for age or weight class, with only coarse control over nutrient oversupply or imbalance. This imprecision can lead to excess nitrogen and phosphorus excretion, inefficient energy use, and suboptimal immune function, all of which indirectly influence food safety outcomes at the farm level. Precision nutrition reframes this challenge by treating each animal or at least each production group, as a unique metabolic unit whose nutrient requirements can be modeled and met with high resolution. In broilers, for example, precision feeding systems can adjust diets daily to match predicted growth and nutrient needs, blending protein dense and energy dense components in real time. In ruminants, similar principles are applied through phase feeding, amino acid balancing, and individualized mineral supplementation. From a veterinary perspective, the key insight is that tightly controlled nutrition can act as a "silent" food safety intervention, shaping both animal health and the microbial landscape of the final product.

What is precision nutrition in livestock?

Precision nutrition in livestock is the practice of aligning the supply of nutrients with the animal's actual daily requirements, minimizing both deficiency and excess. This is achieved through a combination of accurate feed analysis, dynamic ration formulation models, and automated delivery systems that can adjust feed composition and quantity in response to real time data on body weight, growth, intake, and sometimes even milk or meat composition. In practice, precision nutrition may involve phase feeding, amino acid balancing, split sex feeding, and tailored mineral packages, all aimed at closing the gap between average requirement curves and individual animal performance. In monogastrics such as broilers and pigs, precision feeding can reduce crude protein intake by up to 20–25 %, while maintaining or even improving growth and feed efficiency. In ruminants, precision strategies such as synchronized nutrient supply and bypass nutrient formulations reduce wasteful nitrogen excretion and improve the retention of carbon, nitrogen, and phosphorus within the animal and its products. From a managerial standpoint, this means that the same genetic potential can be expressed with lower feed costs, reduced environmental load, and, crucially, a more stable and robust health status in the herd.

Linking precision nutrition to food safety

From a food safety perspective, precision nutrition acts at multiple levels: it influences the gut environment, modulates the microbiome, and alters the conditions under which zoonotic pathogens can proliferate. Overly rich, poorly balanced diets particularly those with excess protein or rapidly fermentable carbohydrates can create dysbiosis, favoring the growth of pathogenic *Enterobacteria* and other food-borne agents. By contrast, rations that are precisely tailored to the animal's stage and environment tend to support a more stable and competitive microbial community, which can reduce colonization and shedding of *Salmonella*, *Campylobacter*, and toxigenic *E. coli* strains. In addition, precision-nutrition strategies can reduce the need for routine antimicrobial use by improving overall health and resilience. When animals receive the right balance of energy, protein, vitamins, and trace minerals, their immune system functions more efficiently, and they are less prone to subclinical infections that might otherwise trigger blanket antibiotic application. This in turn lowers the risk of antimicrobial residues in edible tissues and of selecting for multidrug resistant strains, which are major concerns for both food safety and public health. At the post farm level, better nutrient retention and reduced pathogen load translate into lower contamination risk during processing and a safer product for consumers. For example, pigs fed low protein, precision balanced diets have shown lower shedding of *Salmonella* in faeces, which directly reduces the bioburden entering the slaughterhouse environment. In dairy and beef systems, similar strategies can lower faecal contamination of carcasses and improve the hygienic quality of milk and meat.

Technologies and on-farm practices

Implementing precision nutrition systematically requires a combination of hardware, software, and husbandry practices. Automated feeding systems capable of blending different feed components in variable proportions allow for daily or even feeding cycle adjustments based on predicted requirements. Sensors that monitor body weight, feed intake, and, in some systems, milk or body condition indicators provide real time data to decision support models, which then generate ration recommendations or directly control feeders.

On the technical side, this may involve phase feeding protocols, amino acid-based rationing, and the targeted use of feed additives such as organic acids, probiotics, prebiotics, and enzymes that enhance digestibility and support gut health. For example, in broilers, precision feeding systems can reduce protein - crude protein levels while supplementing essential amino acids, thereby maintaining performance while lowering nitrogen excretion and gut ammonia, which in turn suppresses pathogenic bacterial growth. In ruminants, balancing rumen degradable and rumen undegradable protein, and using protected minerals, can improve nutrient utilization and reduce faecal load of excess nitrogen and phosphorus. From a veterinary standpoint, the challenge is to embed these technologies into routine herd health protocols. This includes regular assessment of body condition, feed intake, and production parameters; periodic faecal screening for pathogens; and adjustment of rations in response to disease outbreaks, seasonal stress, or changes in genetic merit. Veterinarians and nutritionists must work closely with farm managers to ensure that precision nutrition tools are not used merely to cut costs, but to create a more resilient, safer, and healthier production system.

Practical recommendations for veterinarians

For veterinarians working with livestock producers, incorporating precision nutrition into practice begins with a shift in mindset: feed rations should be viewed not only as drivers of productivity but also as levers of food safety and disease control. Key recommendations include:

- Collaborate with nutritionists to design phase feeding and amino acid balanced rations that minimize excess protein and nitrogen excretion, particularly in broilers, pigs, and high yielding dairy cows.
- Encourage the use of on-farm monitoring tools body weight scales, automated feeders, milk yield or egg production data - to support dynamic rationing and early detection of nutritional imbalances.
- Promote the targeted use of feed additives, such as organic acids, probiotics, and enzymes that improve gut health and reduce colonization by food-borne pathogens.
- Advise producers to integrate precision nutrition strategies into biosecurity and disease control plans, ensuring that ration changes are coordinated with vaccination, hygiene, and antimicrobial use policies.
- Support training of farm staff in feed handling practices, feed hygiene, and equipment cleaning, so that the benefits of precision nutrition are not undermined by contamination or cross-feeding errors.

By embedding these practices into routine herd health consultations, veterinarians can position precision nutrition as a core component of a modern, food safety-oriented livestock management system.

Conclusion

Precision nutrition in livestock is no longer a niche research concept; it is a practical, scalable frontier for improving food safety alongside productivity and sustainability. By aligning nutrient supply with actual animal requirements through data driven feeding strategies, veterinarians and producers can reduce the presence of zoonotic pathogens in the gut, lower the need for antimicrobials, and minimize the environmental and sanitary risks associated with excess nutrient excretion. As automated feeding systems, sensors, and decision support tools become more accessible, the integration of precision nutrition into everyday veterinary practice will be essential to safeguarding both animal health and the safety of the food chain.

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CANINE DISTEMPER IN WILDLIFE: A SILENT CROSS-SPECIES THREAT

Sakshi Patel[1*], Ajay Mendake[2], Patel Prapti Nikunjkumar[3], Gurde Akshay Anil[4]

[1]Department of Veterinary Pathology (VCC), Shourabh College of Veterinary Science (SCVS), RAJUVAS
[2]Department of Livestock Production and Management, SCVS, RAJUVAS
[3]Department of Veterinary Gynecology & Obstetrics (LFC), SCVS, RAJUVAS
[4]Department of Animal Nutrition (LFC), SCVS, RAJUVAS
Corresponding author email : sakshi.patel.vmk23@aau.ac.in

Abstract

Canine distemper virus (CDV) is a highly contagious morbillivirus belonging to the family *Paramyxoviridae*, infecting a wide range of carnivorous and some non-carnivorous species. Originally recognized in domestic dogs, it has evolved into an important multi-host pathogen with global distribution in wildlife. The virus produces severe systemic disease marked by immunosuppression and involvement of the respiratory, gastrointestinal, and nervous systems, frequently leading to high mortality in immunologically susceptible populations. Its capacity for cross-species transmission and maintenance through domestic dog reservoirs presents a serious threat to wildlife conservation. Diagnosis is based on molecular and immunological methods, while control primarily relies on vaccination and effective surveillance at the wildlife–domestic animal interface.

Keywords: Canine distemper virus, morbillivirus, wildlife disease, cross-species transmission, conservation impact

Introduction

India harbours rich wildlife diversity and has implemented significant conservation efforts to protect endangered species, particularly wild felids. However, infectious diseases increasingly threaten these initiatives, largely due to growing interactions between wildlife and domestic animals. CDV is a highly contagious, pantropic morbillivirus that infects a wide range of carnivores and some non-carnivorous species. Initially identified in domestic dogs (*Canis familiaris*), CDV has emerged as a major multi-host pathogen affecting wildlife globally. Its ability to cross species barriers and cause high mortality in immunologically susceptible populations has resulted in repeated outbreaks and population declines, posing a serious conservation concern.

Etiology and Viral Features

CDV belongs to the genus *Morbillivirus* within the family *Paramyxoviridae*. It is an enveloped, single-stranded negative-sense RNA virus with an approximately 15.7 kb genome. The virus encodes six structural proteins: nucleocapsid (N), phosphoprotein (P), matrix (M), fusion (F), haemagglutinin (H) and RNA-dependent RNA polymerase (L). Among these, the H protein is primarily responsible for host cell attachment and serves as the key determinant of host range and genetic variability. Although CDV is antigenically classified as a single serotype, it exhibits significant genetic diversity with multiple globally distributed genotypes, including America, Europe, Asia, Africa, Arctic and wildlife-associated lineages, largely driven by variation in the H gene. The virus is environmentally fragile and is rapidly inactivated by heat, ultraviolet radiation, desiccation, detergents and lipid solvents, reflecting its enveloped structure and limited environmental stability.

Host Range

CDV has one of the broadest host ranges among morbilliviruses, primarily affecting members of the order Carnivora. Within Canidae, domestic dogs act as the principal reservoir, while infections are also reported in African wild dog (*Lycaon pictus*), grey wolf (*Canis lupus*), coyote (*Canis latrans*), jackals (*Canis aureus, Canis mesomelas*), foxes including red, Arctic and bat-eared fox and dingo (*Canis dingo*). In Felidae, CDV has been documented in lion (*Panthera leo*), tiger (*Panthera tigris*, including Amur tiger), leopard (*Panthera pardus*), snow leopard (*Panthera uncia*), clouded leopard (*Neofelis nebulosa*), leopard cat, jungle cat, fishing cat and domestic cat, often with subclinical infection. Other susceptible families include Mustelidae (ferret, mink, otters, weasels, badgers), Procyonidae (raccoon, coati, kinkajou), Ursidae (black bear, brown bear, giant panda), Viverridae (civets, genets, linsangs, palm civet in India), Hyaenidae (spotted and brown hyena) and Ailuridae (red panda). Beyond carnivores, occasional infections or exposure have been reported in non-human primates such as *Macaca mulatta* and *Macaca fascicularis*, seals including Baikal and Caspian seals, porpoises associated with related morbilliviruses and rare cases in peccaries

Transmission and Epidemiology

Domestic dogs act as the principal reservoir of CDV and transmission occurs mainly through aerosolized respiratory droplets and direct contact with ocular, nasal and oral secretions. Viral shedding may also occur via urine, faeces and skin exudates during the acute phase of infection. Shedding can persist for up to 90 days, even in subclinical cases, thereby contributing to silent transmission within susceptible populations. Due to its environmental fragility, CDV survival outside the host is limited and spread depends largely on close contact between infected and susceptible animals

Pathogenesis and Host Specificity

CDV enters the host via the respiratory or oral route, initially replicating in macrophages and tonsillar tissue before spreading to regional lymph nodes within 24 hours. This is followed by a lymphoid phase marked by dissemination to lymphoid organs, causing severe lymphoid depletion, leukopenia and immunosuppression. Subsequent viremia results in systemic spread to the gastrointestinal tract, liver (Kupffer cells) and respiratory epithelium, leading to fever and multisystem involvement. In later stages, epithelial infection via nectin-4 causes respiratory, gastrointestinal, urinary and endocrine involvement, while CNS invasion leads to demyelination, encephalitis, seizures, paralysis and ataxia. Host specificity and tissue tropism are governed by interactions between the viral H protein and cellular receptors, primarily SLAM (CD150) on immune cells during early infection and nectin-4 on epithelial cells during later stages. Variations in key amino acid residues of the H protein, particularly at position 549, influence receptor binding affinity, host adaptation and cross-species transmission.

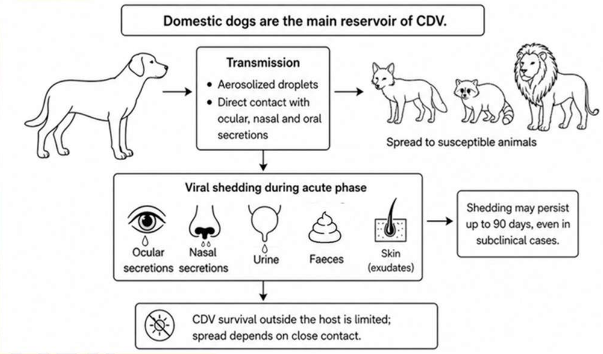

Figure: Transmission and Epidemiology of CDV

Pathology

Gross lesions: Pneumonia, enteritis, lymph node enlargement or depletion and neurological degeneration.

Microscopic lesions: Bronchointerstitial pneumonia, lymphoid depletion, syncytial cells and eosinophilic intracytoplasmic/intranuclear inclusion bodies in lungs, kidney, intestine, urinary bladder and brain. In felids, demyelinating lesions may be less pronounced than in canids.

Clinical Disease in Wildlife

Disease ranges from subclinical infection to acute fatal disease. Common signs include fever, ocular/nasal discharge, respiratory distress, gastrointestinal signs, neurological dysfunction and dermatological changes such as hyperkeratosis and enamel defects. Chronic neurological disease often leads to fatal encephalitis.

Diagnosis

Diagnosis of CDV infection involves a combination of histopathological, immunological, molecular, serological and virological methods. Histopathological examination typically reveals characteristic inclusion bodies along with tissue necrosis in affected organs. Immunohistochemistry enables detection of viral antigens across multiple tissues, including occasional unusual sites such as the pancreas in tigers. Molecular techniques such as RT-PCR targeting N, H and P genes, real-time PCR and nucleotide sequencing followed by phylogenetic analysis are widely used for sensitive and specific detection as well as strain characterization. Serological diagnosis includes virus neutralization tests, considered the gold standard, along with ELISA and indirect fluorescent antibody tests (IFAT). Virus isolation can be performed using Vero-SLAM cell lines for confirmation and further characterization of the virus.

Molecular Epidemiology

CDV has a single serotype but multiple evolving genotypes. The H gene shows highest variability, leading to geographic clustering: Asia-1, Asia-2, Africa, Europe/South America and wildlife-specific strains. Spillover from domestic dogs to wildlife is the dominant transmission pattern.

Conservation Impact

CDV has been associated with major wildlife population declines across multiple regions and species. Notable impacts include a severe outbreak in African lions in the Serengeti, resulting in approximately one-third population loss, repeated pack collapse events in African wild dogs and critical endangerment episodes in Ethiopian wolves. In addition, infections have been documented in Amur tigers, while mortality has been reported in captive giant pandas and black-footed ferrets have experienced near-extinction level impacts during outbreaks. In India, CDV has been confirmed in multiple wild felids, with evidence of ongoing circulation in both captive and free-ranging populations, highlighting its continued threat to wildlife conservation.

Treatment and Control

There is no specific antiviral treatment for CDV and disease management is primarily supportive and symptomatic. Experimental antiviral approaches, including polymerase inhibitors, fucoidan, flavonoids, phenolic acids, mesenchymal stem cells and silver nanoparticles, have demonstrated partial inhibitory effects against viral replication in laboratory studies. Vaccination remains the cornerstone of prevention, with modified live virus vaccines such as Onderstepoort and Rockborn strains being widely used, although their application in wildlife is limited by safety concerns. Recombinant canarypox-vectored vaccines have shown promising protective efficacy in several species. However, overall control of CDV is constrained by logistical challenges in wildlife vaccination, limited accessibility of target populations and continuous spillover from domestic dog reservoirs.

Conclusion

CDV is one of the most important infectious threats to global carnivore conservation. Its wide host range, strong immunosuppressive ability and persistent spillover from domestic dogs make it difficult to control. Effective management requires integrated surveillance, molecular epidemiology, improved vaccination strategies and strict reduction of contact between domestic dogs and wildlife populations.

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THE GOLDEN LANGUR: AN ENDANGERED GEM OF THE EASTERN HIMALAYAS

[1*]Gangotri Phukan, [2]Sakshi Patel
[1*] PG scholar, College of Veterinary Science, AAU, Khanapara, Ghy-22
[2] Assistant Professor, Department of Veterinary Pathology (VCC), Shourabh College of Veterinary Science, RAJUVAS, Kheda, Rajasthan
Corresponding author's email: gangotri.phukan.vmk23@aau.ac.in

Introduction

The golden langur (*Trachypithecus geei*) is among the most unique and visually captivating primates found in South Asia. This endangered primate is native to a small area in north-western Assam, India, and parts of Bhutan. Because its habitat is so limited, it is considered endemic, meaning it is not naturally found anywhere else on Earth. This species is admired for its distinctive golden fur and tree-dwelling lifestyle. However, despite its beauty and ecological value, the golden langur is under serious threat from habitat loss, human expansion, and environmental pressures. As a result, protecting this species has become a major focus for conservationists.

Taxonomy

Phylum: Chordata
Sub-phylum: Vertebrata
Class: Mammalia
Order: Primates
Family: Cercopithecidae
Sub- family: Colobinae
Genus: Trachypithecus
Species: Trachypithecus geei

Two distinct subspecies of this primate have been identified, primarily separated by variations in coat color and their geographic ranges: *Trachypithecus geei bhutanensis* (northernbhutan) and *Trachypithecus geei geei* (southern Bhutan and India). However, *T. g. bhutanensis* has not yet been formally described in accordance with the rules of the International Code of Zoological Nomenclature (ICZN).

Physical Features

This species is medium-sized and easily recognized by its golden to pale cream-colored coat. In adult males, the fur varies from a creamy shade to a rich golden tone, while females and younger individuals generally display paler coloration.

The coat also shifts with the seasons, appearing lighter and cream-colored during summer and becoming darker, with a golden hue, in winter. They have a black hairless face, surrounded by long, flowing hair that enhances its striking appearance and possess a long tail, which plays a crucial role in balance as it moves through treetops. Its slim limbs and lightweight body are well-suited for life in the forest canopy. They show clear sexual dimorphism with males being noticeably larger and stronger than females.

Geographical Range

Golden langurs are found only in a limited area, primarily in western Assam and neighbouring regions of Bhutan. Their habitat is naturally bordered by rivers such as the Brahmaputra, Manas and Sankosh. This narrow distribution makes the species especially vulnerable to environmental disturbances and habitat changes.

Habitat

These primates inhabit tropical and subtropical forests, including semi-evergreen and riverine ecosystems. Being strictly arboreal, they rely heavily on continuous forest cover. When forests become fragmented, their movement is restricted, leading to isolated populations. Bhutan provides relatively stable conditions due to its extensive forest conservation efforts.

Feeding habits

They are herbivores. Mainly consume leaves, making them primarily folivorous. However, their diet also includes fruits, flowers, seeds, and young plant shoots. Occasionally, they feed on crops grown by nearby communities, which can lead to human-wildlife conflicts. Their digestive system is specially adapted to process fibrous plant material.

Behavior and Social Structure

These langurs are active during the day (diurnal) and live-in social groups that usually consist of one adult male, several females, and their young ones. Group sizes typically range from three to fifteen individuals. They spend most of their time feeding, resting, and grooming. Generally shy in nature, they prefer staying high in the forest canopy.

Major Threats

The survival of the golden langur is threatened by several factors. The most serious issue is habitat destruction due to deforestation for agriculture, infrastructure, and settlements. Habitat fragmentation poses a significant threat as it isolates groups and lead to decline in breeding activity. Additional threats include road accidents, electrocution from power lines, attacks by stray dogs, human encroachment and conflicts with humans over crops. In some areas, interbreeding with other langur species also poses a risk to their genetic purity.

Conservation Status

Due to its declining numbers and restricted range, the golden langur is listed as Endangered on the IUCN Red List and is protected under Appendix I of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). In India, it receives the highest legal protection under Schedule I of the Wildlife Protection Act 1972 (amended in 2022).

Conservation Efforts

The golden langur in India requires immediate and focused conservation efforts because it is found in a very restricted range and depends closely on forest habitats. Conservation measures have mainly focused on protecting its habitat through the creation of protected areas such as wildlife sanctuaries and national parks in both India and Bhutan. In India, the Chakrashila Wildlife Sanctuary is especially significant as it serves as the primary protected habitat, supporting a stable population of the species. In Bhutan, important parts of its distribution occur within protected regions like the Royal Manas National Park, Black Mountain National Park, and Phipsoo Wildlife Sanctuary. In addition to habitat protection, legal enforcement has helped reduce hunting pressure on the species. Ongoing scientific studies and monitoring programs are used to understand population status and trends over time. Furthermore, awareness programs in local communities encourage people to support conservation efforts and promote peaceful coexistence with this endangered primate.

Future Strategies

To ensure long-term survival, several actions are necessary. These include stopping deforestation, installing insulation on power lines, controlling stray dog populations, creating forest corridors to reconnect fragmented habitats and monitor gene flow and hybridization among populations. Strengthening conservation policies and increasing local awareness are equally important for sustainable protection. Conservation awareness programs and community participation have been encouraged in villages near forest edges, particularly around Chakrashila Wildlife Sanctuary. Since the species frequently occurs close to human settlements, involving local people is essential, as peaceful coexistence is key to its long-term protection.

Conclusion

The golden langur represents the rich natural heritage of Northeast India and Bhutan. However, its future is uncertain due to ongoing environmental and human-induced challenges. Protecting this species requires a combination of research, conservation planning, and community involvement. Safeguarding the golden langur ultimately contributes to preserving the broader ecosystem it depends on.

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BEHAVIOUR-BASED EARLY DETECTION OF PAIN AND DISEASE IN ANIMALS: ROLE OF PRECISION LIVESTOCK TECHNOLOGIES

Manash Jyoti Barman
Lakhimpur College of Veterinary Science, Assam Veterinary and Fishery University
(781022)
Email: manashjyotibarman2004@gmail.com

ABSTRACT

Early and accurate detection of pain and disease in livestock remains a pivotal challenge in veterinary medicine. Since animals cannot verbally communicate discomfort, behavioural changes including alterations in feeding, activity, posture, and social interaction—serve as the earliest detectable health indicators, often preceding overt clinical signs. Precision Livestock Technologies (PLT) are an emerging paradigm that integrates sensors, thermal imaging, computer vision, and AI to enable continuous, automated, and individualised behaviour monitoring. This review examines the biological basis of behaviour as a health indicator, the architecture and mechanisms of PLT, and their applications in detecting conditions such as lameness, mastitis, metabolic disorders, and reproductive events. We discuss the implications for animal welfare, production efficiency, and precision veterinary medicine. Challenges including data reliability, cost, and contextual adaptability are also addressed. Ongoing advancements in AI and sensor technology will further enhance the accessibility and predictive accuracy of PLT in diverse livestock settings.

Keywords: Precision livestock technology, animal behaviour, pain detection, disease monitoring, artificial intelligence, animal welfare, wearable sensors, computer vision.

1. Introduction

Early detection of pain and disease in animals remains a critical challenge in modern livestock production systems. Unlike humans, animals cannot verbally communicate discomfort, and clinical signs often appear only after significant disease progression has already occurred. This delay in detection frequently results in prolonged animal suffering, reduced productivity, and increased treatment costs, making proactive health surveillance a cornerstone of sustainable livestock management. Behavioural changes are among the earliest indicators of compromised health. Subtle deviations in activity, feeding patterns, posture, or social interactions often precede visible clinical signs by hours to days, providing a critical window for early intervention. Precision Livestock Technologies (PLT) have emerged as powerful tools to capture and analyse these behavioural changes in real time, enabling proactive disease management, improved animal welfare, and enhanced productivity across diverse production systems. Despite the acknowledged importance of monitoring behaviour, current on-farm practices still miss subtle early signs of discomfort or disease. Visual observation by farm personnel is subjective and inconsistent, and traditional diagnostic methods, such as laboratory tests, often confirm pathology only after significant progression has occurred. This critical delay limits the possibility of timely intervention. Precision Livestock Technologies (PLT) offer a solution by providing objective, continuous, and early detection capabilities that can close this gap. Therefore, behaviour-based precision monitoring is becoming essential for early intervention.

This review aims to consolidate current knowledge on the biological basis of behaviour-based disease detection, examine the technological architecture underpinning PLT, and critically evaluate documented applications and limitations. The implications for veterinary practice, animal welfare, and the evolving concept of precision veterinary medicine are also discussed.

2. Behaviour as an Indicator of Pain and Disease

Behaviour reflects the integrated physiological and pathological status of an animal. Pain and disease disrupt normal biological functions, leading to measurable alterations in observable behaviour. These alterations include reduced feed intake, decreased rumination, altered gait, abnormal postural adjustments, increased recumbency, and social withdrawal from conspecifics.

2.1 Biological basis of behavioural change

Pain or disease state activates complex neuroendocrine and inflammatory stress responses. These physiological shifts affect energy balance, leading to changes in appetite, posture, movement, and social behavior. Critically, these behavioural responses manifest before overt clinical signs are observable. Pain and disease alter physiology, and those physiological changes appear first as behaviour changes. For example, lameness in cattle is characterised by reduced locomotion, asymmetric gait, and uneven weight distribution, while mastitis may manifest as decreased feeding activity and marked changes in milking behaviour. Such behavioural changes arise as a consequence of inflammatory cascades, metabolic dysregulation, and neuroendocrine alterations triggered by the underlying pathological process. Critically, these behavioural indicators typically manifest before overt clinical symptoms become apparent, rendering them highly valuable for early detection and timely therapeutic intervention. The capacity to objectively quantify these subtle changes is, therefore, central to the clinical utility of PLT.

3. Concept and Architecture of Precision Livestock Technologies

Precision Livestock Technologies operate through an integrated three-tier system architecture comprising data acquisition, data processing, and decision support components.

The data acquisition layer involves the continuous collection of behavioural and physiological data using sensors and imaging systems deployed within the production environment. These data are transmitted through communication networks underpinned by the Internet of Things (IoT) to centralised storage infrastructure. The processing layer employs advanced computational techniques, including supervised machine learning and deep learning algorithms, to analyse behavioural patterns and detect statistically significant deviations from established baselines. Finally, the decision-support layer translates these analytical outputs into actionable, user-friendly insights for farm managers and attending veterinarians.

This architecture enables continuous, automated, and individualised monitoring of animals at scale, forming the operational foundation for reliable early disease detection in commercial livestock settings.

4. Mechanisms of Behaviour Monitoring Technologies

4.1 Wearable Sensors

Accelerometers and pedometers represent the most widely deployed PLT devices in commercial livestock settings. Attached to the neck, leg, or ear of the animal, these sensors measure acceleration along multiple axes and capture movement signatures. Proprietary and open-source algorithms subsequently convert raw acceleration data into meaningful behavioural metrics, including walking, standing, lying, and rumination. For instance, the repetitive jaw movements associated with rumination produce distinct and reproducible motion signatures that can be reliably detected and quantified.

4.2 Rumination and Feeding Sensors

Dedicated rumination monitoring systems utilise microphones or motion sensors strategically positioned to detect chewing activity. Acoustic and kinematic signals are processed through pattern recognition algorithms to estimate rumination duration and feeding time. A clinically meaningful decline in rumination time is well-established as an early indicator of metabolic and digestive disorders, including ketosis and subacute ruminal acidosis, providing a practical tool for herd health monitoring.

4.3 Thermal Imaging Systems

Infrared thermography captures surface temperature variations by detecting emitted thermal radiation from the animal's body. Regions of active inflammation, such as those associated with mastitis or podal lesions, characteristically exhibit elevated surface temperatures. Thermal imaging systems convert these signals into detailed temperature distribution maps, enabling the early identification of abnormal heat patterns indicative of underlying pathological processes.

4.4 Computer Vision Systems

Computer vision platforms capture continuous video or image data from animals within their production environment. Artificial intelligence models particularly convolutional neural network-based deep learning architectures analyse these visual data streams to automatically detect and quantify posture, gait characteristics, and body condition score. Changes in stride length, dorsal curvature, or asymmetric weight distribution can be identified as early indicators of lameness with an accuracy approaching or exceeding that of trained human observers.

4.5 Sensor Fusion and Intelligent Alerting

Contemporary PLT platforms increasingly integrate multiple data streams through sensor fusion methodologies. Machine learning models trained on extensive historical datasets establish individualised normal behavioural baselines for each animal. When real-time data deviate significantly from these personalised baselines, the system generates automated alerts for veterinary or managerial review. This multimodal approach demonstrably improves detection accuracy and reduces the rate of false-positive alerts compared to single-sensor systems.

5. Applications in Disease Detection

Precision Livestock Technologies have been evaluated and implemented across a range of clinically significant conditions in dairy and beef production systems. Lameness detection represents one of the most advanced and commercially validated PLT applications. Accelerometer-derived gait metrics and computer vision-based locomotion scoring have been shown to identify gait asymmetries and movement abnormalities with high sensitivity, enabling intervention at subclinical stages of the condition before welfare is severely compromised.

For metabolic disorders, continuous rumination monitoring has demonstrated utility in the early detection of ketosis and subacute ruminal acidosis in periparturient dairy cattle, conditions that carry significant implications for both animal welfare and farm profitability. Mastitis surveillance systems that integrate behavioural data, infrared thermographic findings, and automated milking system parameters have similarly shown promise for early quarter-level detection of intramammary infection. Reproductive monitoring platforms that continuously track activity levels have been widely adopted for oestrus detection and calving prediction, enabling timely and effective breeding interventions. Collectively, these applications illustrate the breadth of clinical utility achievable through behaviour-based PLT monitoring.

6. Implications for Animal Welfare

The relationship between early disease detection and animal welfare is direct and clinically significant. Timely therapeutic intervention reduces both the duration and severity of pain experienced by affected animals, improving recovery outcomes and minimising unnecessary suffering. Within the framework of the Five Freedoms and the evolving Five Domains Model, PLT contributes substantively to the freedom from pain, injury, and disease, as well as to the promotion of positive affective states. Continuous automated monitoring ensures that individual animals including those in large-scale intensive production systems where individual observation is logistically challenging are not overlooked. Furthermore, PLT facilitates evidence-based management, enabling targeted treatments and reducing dependence on population-level prophylactic interventions, thereby advancing both animal welfare and antimicrobial stewardship objectives.

7. Challenges and Limitations

Despite their considerable potential, Precision Livestock Technologies face several important operational and translational challenges. Data accuracy and reliability remain critical concerns, as sensor malfunction, displacement, or environmental interference can adversely affect measurement quality and generate erroneous alerts. Optimising the balance between diagnostic sensitivity and specificity is a persistent methodological challenge. Systems must achieve sufficient sensitivity to detect genuine health deviations while maintaining acceptable specificity to avoid alert fatigue among end-users. High initial capital costs and infrastructure requirements including reliable internet connectivity and compatible farm management software can present significant barriers to adoption, particularly in resource-limited production environments. Substantial variability in farm design, animal breeds, management practices, and climatic conditions complicates the generalisation of predictive models across settings. Algorithms developed and validated in one context may require recalibration before achieving equivalent performance in another. Finally, effective clinical utilisation requires that complex multivariate outputs be translated into simple, actionable recommendations that are accessible to farmers and field veterinarians without specialist data science training.

Key technical and practical barriers include: environmental noise, which compromises data accuracy and causes alert fatigue; breed-specific behavioural variations, which render uncalibrated models unreliable; prohibitive costs for small-scale operations, which restricts access to early detection; a lack of user trust in complex alerts, which delays critical interventions; and the necessity for local validation, without which unique environmental baselines degrade predictive performance.

8. Future Perspectives

Advancements in AI, miniaturized sensors, and cloud infrastructure are set to substantially enhance precision livestock monitoring systems. Future efforts will prioritize improving predictive accuracy, reducing costs, and expanding accessibility, particularly to smallholder contexts. By integrating multimodal data with real-time computing, PLT will enable more precise, individualized disease detection, thus augmenting veterinary expertise within the broader One Health framework of animal, human, and environmental sustainability. Importantly, PLT are envisioned as tools that complement and augment rather than replace the clinical expertise and judgement of veterinary professionals. Their greatest value lies in supporting timely, informed decision-making within a broader One Health framework that connects animal health, human health, and environmental sustainability.

9. Conclusion

Behaviour-based monitoring through Precision Livestock Technologies represents a significant and clinically meaningful advancement in the early detection of pain and disease in animals. Behavioural alterations serve as sensitive, objective indicators of compromised health, frequently manifesting before clinical signs become apparent to the observer. By integrating wearable sensors, thermal imaging, computer vision, and artificial intelligence within a cohesive decision-support architecture, PLT enables a proactive, individualised approach to animal health management. Behaviour-based monitoring is shifting veterinary practice from reactive treatment to early, preventive care. The future lies in integrating these data streams to create truly individualized, predictive, and "precision" veterinary medicine. While challenges related to cost, data quality, and contextual adaptability remain, the trajectory of technological development strongly supports the growing role of PLT in veterinary practice. The synthesis of behavioural science and technological innovation offers a compelling and practical pathway towards improved animal welfare, enhanced livestock productivity, and more sustainable food production systems objectives that lie at the heart of the veterinary profession's contribution to global One Health.

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SUCCESSFUL FIELD MANAGEMENT OF ADVANCED TRAUMATIC RETICULOPERICARDITIS IN A DAIRY COW BY RUMENOTOMY AND PARTIAL PERICARDIECTOMY

Sharanabasava Rajapur
BVSc & A.H. Student, Karnataka Veterinary, Animal and Fisheries Sciences University,
Bidar, Karnataka, India
Corresponding Author Email: uniquevet0406@gmail.com

ABSTRACT

Traumatic reticulopericarditis (TRP) is a common problem in cattle and can lead to serious complications if diagnosis is delayed. In this case, a 3-year-old non-descriptive female bovine was presented with an 8-day history of reduced feed intake. On examination, brisket edema, jugular distension, mild pyrexia (102.5°F), and absence of ruminal motility were noted, suggesting advanced disease. Rumen fluid findings indicated poor rumen activity. Ultrasonography revealed fluid accumulation around the pericardial region, while radiography confirmed the presence of a metallic foreign body (wire). Based on these findings, the case was diagnosed as TRP with pericardial involvement. The animal was managed surgically by rumenotomy for removal of the foreign body. Due to the presence of fibrinous pericarditis, partial pericardiectomy was subsequently performed to relieve pericardial involvement. Postoperative treatment with dicrysticine and prednisolone was given, and the animal showed gradual recovery. A notable feature of this case was the successful performance of partial pericardiectomy under field conditions, which is rarely reported under field condition in bovine practice.

Keywords: Traumatic reticulopericarditis. Bovine. Rumenotomy. Foreign body syndrome. Brisket edema. Ultrasonography, Partial percardiectomy.

INTRODUCTION

Traumatic reticulopericarditis is seen in cattle following ingestion of sharp metallic objects such as nails or wires. In most cases, these objects settle in the reticulum, but in some animals, they gradually penetrate the reticular wall, pass through the diaphragm, and reach the pericardial sac. Eventually this process leads to inflammation around the heart along with accumulation of fibrin and fluid, which interferes with normal cardiac function. Although ingestion of foreign material itself is quite common, extension into the pericardial sac indicates a more advanced condition and is generally associated with a poorer prognosis (MSD Veterinary Manual, 2024). The occurrence of this condition is closely related to management practices at the farm level. Cattle do not selectively avoid metallic objects, especially when feed is contaminated or when animals graze in areas where waste materials are present. Under such conditions, ingestion of wire pieces or nails becomes more likely. For this reason, traumatic reticulopericarditis is often considered an indicator of deficiencies in feed hygiene and waste handling.

The clinical course is usually gradual. In the early stage, animals may show reduced appetite and decreased ruminal activity, often accompanied by reluctance to move. As the condition progresses, signs such as tachycardia, muffled heart sounds, jugular vein distension, brisket edema, and weakness become more apparent. These changes reflect the combined effect of cardiac involvement and ongoing systemic disturbance, and at this stage the prognosis is usually guarded. In field situations, diagnosis is largely based on clinical findings, but imaging plays an important supportive role. Radiography is useful for identifying metallic foreign bodies, whereas ultrasonography helps in detecting fluid accumulation and fibrin within the pericardial sac. Using both methods together provides a better understanding of the extent of involvement and aids in planning further management.

Apart from its clinical importance, this condition also points to broader management issues. The presence of metallic debris in feed or grazing areas suggests lapses in waste disposal and feeding practices. From a One Health perspective, such factors highlight how environmental management directly influences animal health outcomes. In the present case, a three-year-old nondescript dairy cow was brought with noticeable brisket swelling and jugular distension. These findings suggested that the condition had progressed beyond uncomplicated reticulopericarditis. The diagnosis was supported by radiographic and ultrasonographic examination and later confirmed during exploratory rumenotomy. The case is noteworthy because the extent of involvement required management beyond routine intervention under field conditions.

CASE HISTORY AND CLINICAL EXAMINATION

A 3-year-old non-descriptive female bovine was brought to the veterinary clinical complex with a history of reduced feed intake and anorexia for about 8 days. According to the owner, the condition developed gradually, with the animal showing dullness, decline in productivity, and noticeable swelling in the brisket region. There was no record of similar illness in the past, and no recent treatment had been given. The animal was reared under a semi-intensive system, where accidental ingestion of metallic foreign material through feed or surroundings could not be ruled out. On examination, the animal appeared dull and slightly febrile, with a rectal temperature of 102.5°F. A soft, fluctuant swelling was present in the brisket area, indicating edema. Jugular veins were visibly distended, suggesting impaired venous return. Ruminal movements were reduced on auscultation, and the animal showed discomfort on deep palpation of the cranial abdomen. It was also reluctant to move and occasionally exhibited mild arching of the back, indicating pain. Considering the history and clinical findings, a provisional diagnosis of traumatic reticulopericarditis with possible extension to the pericardium was made, and further diagnostic procedures were undertaken to confirm the condition.

DIAGNOSTIC INVESTIGATIONS

Figure 1. Thoracic radiograph (lateral view) demonstrating a radiopaque foreign body in the pericardial region with suspected localized tissue reaction

Figure 2. *Brisket edema observed as prominent ventral subcutaneous swelling in a bovine affected with traumatic reticulopericarditis.*

DISCUSSION

In this case, the animal was presented after about eight days of reduced feed intake and gradual dullness, which already suggested that the condition was not in an early stage. On examination, the combination of brisket edema, distended jugular veins, and absence of ruminal motility pointed towards more than a simple reticular problem. While these signs can be seen in traumatic reticulopericarditis, the extent of edema and venous distension made pericardial involvement more likely, especially in a case with this duration.

Differential diagnoses included uncomplicated traumatic reticuloperitonitis, congestive heart failure, and septic peritonitis. In this case, the detection of a metallic foreign body on radiography, along with pericardial fluid on ultrasonography and associated clinical signs such as brisket edema and jugular distension, strongly indicated traumatic reticulopericarditis. The diagnosis was subsequently confirmed during exploratory rumenotomy, and based on intraoperative evidence of fibrinous pericarditis, partial pericardiectomy was performed to relieve pericardial constriction and improve cardiac function.

The rumen findings supported this impression. Reduced motility along with altered rumen fluid characteristics indicated that the reticulorumen was functionally compromised. These changes are commonly seen in prolonged inflammatory conditions, so when taken together with the clinical signs, the case appeared to be in an advanced stage. This assumption was later confirmed during surgery, where fibrinous involvement of the pericardium was evident.

In many field cases, diagnosis is often made based only on clinical signs, and treatment decisions are taken accordingly. In this animal, however, ultrasonography gave additional clarity. The presence of fluid around the pericardial region helped in anticipating the extent of the lesion before surgery. Radiography was useful in identifying the metallic foreign body, but ultrasonography provided better information about soft tissue changes, which made a practical difference in planning the approach. Reports by Prajapati et al. (2024) and Nasr et al. (2024) describe similar clinical findings in advanced cases, particularly brisket edema and jugular distension, often associated with poor outcomes. In many of those cases, treatment was either conservative or limited to rumenotomy. In contrast, Braun (2024) also noted that once pericardial involvement develops, prognosis becomes guarded and response to routine treatment is often unsatisfactory. The present case differed in that surgical management was extended beyond routine intervention based on intraoperative findings.

Rumenotomy through the left flank allowed removal of the wire and confirmation of the primary lesion. In this case, we decided to go beyond routine rumenotomy and perform a partial pericardiectomy. This is not commonly attempted under field conditions because cases with pericardial involvement usually carry a guarded prognosis. However, removal of the fibrinous material appeared to relieve cardiac compression and was followed by gradual clinical improvement. What was different here was the need to go further and manage the pericardial involvement. Partial pericardiectomy is not routinely performed in field conditions, mainly because such cases are often considered to have an unfavorable prognosis. In this instance, removal of fibrinous material appeared to relieve cardiac restriction, which likely contributed to the animal's recovery. Most reported cases of advanced traumatic reticulopericarditis are either managed conservatively or limited to rumenotomy, often with poor outcomes. In contrast, the present case demonstrates that selected cases can benefit from surgical intervention at the level of the pericardium. The response after surgery was gradual but consistent. Improvement in appetite, return of rumen motility, and reduction in brisket edema indicated that the combined approach was working. Along with surgery, antimicrobial and anti-inflammatory therapy supported recovery by controlling infection and limiting further inflammatory changes. This case also reflects a practical issue commonly seen in semi-intensive systems. Animals are more exposed to contaminated feed or surroundings, and preventive practices like the use of magnets are not always followed. As a result, such conditions are often detected only after they have progressed. Similar observations have been mentioned in field-based studies, where delayed presentation was a common factor influencing disease severity. Overall, this case shows that even when traumatic reticuloperitonitis has extended to the pericardium, recovery is still possible if the condition is properly assessed and managed without delay. It also suggests that, in selected cases, going beyond routine rumenotomy and addressing associated complications can make a meaningful difference in outcome. A notable feature of this case was the successful performance of partial pericardiectomy under field conditions, which is rarely reported in bovine practice.

TREATMENT AND SURGICAL MANAGEMENT

The animal was stabilized prior to surgery and prepared for standing rumenotomy under aseptic conditions. Feed was withheld and the left paralumbar fossa was prepared by clipping, shaving, and scrubbing with povidone-iodine solution. Rumenotomy was performed with the animal in a standing position using local anesthesia. An inverted L-block was achieved with 2% lignocaine. A vertical skin incision was made in the middle of the left paralumbar fossa, followed by blunt and sharp dissection through the subcutaneous tissue and abdominal muscle layers (external abdominal oblique, internal abdominal oblique, and transversus abdominis) to enter the peritoneal cavity.The rumen was exteriorized and secured to the skin using a Weingarth's rumenotomy frame and stay sutu res with vulsellum forceps to prevent contamination. A 10–15 cm incision was made on the rumen wall, allowing escape of gases and ingesta. The ruminal contents were partially evacuated, and thorough exploration of the rumen and reticulum was carried out. A metallic foreign body (wire) was identified and removed. The reticulum was carefully palpated to rule out additional foreign bodies. Following removal, the rumen was lavaged and medicated with intra-ruminal preparations. The rumen incision was closed using a double-layer inverting suture pattern (Cushing followed by Lembert) with chromic catgut No. 2. The abdominal wall was closed in layers using simple continuous sutures, and the skin was sutured using horizontal mattress pattern with nylon.

Based on intraoperative findings of fibrinous pericarditis, partial pericardiectomy was performed to relieve pericardial constriction and remove fibrinous exudate, thereby improving cardiac function

Post-operative Management

Postoperative care included:
Inj. Ceftriaxone – 1.5 g IV For 3 days
Inj. Meloxicam – 8 ml IM For 3 days
Fluid therapy based on dehydration level

CONCLUSION

In the present case, traumatic reticulopericarditis had progressed to involve the pericardium, which was reflected by clinical signs such as brisket edema, jugular distension, and reduced ruminal motility. These findings highlight the importance of correlating clinical examination with diagnostic imaging, especially radiography and ultrasonography, to better understand the extent of the condition.bRumenotomy helped in removal of the foreign body and confirmation of the primary lesion. Further extension of treatment to manage pericardial involvement played an important role in the outcome. The animal showed gradual improvement, with better appetite, return of rumen motility, and reduction in edema over time, indicating a positive response to the combined surgical and medical management. This case shows that even advanced cases can be managed successfully when intervention is timely and appropriately planned. The use of partial pericardiectomy under field conditions, though not commonly attempted, proved beneficial in this instance and may be considered in selected cases.

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BIOGAS PRODUCTION: A PATH TO PROSPERITY FOR AGRICULTURE AND ANIMAL HUSBANDRY

Chetankumar D Chavda[1], Parth Jayswal[2]
[1] PhD Scholar, COVS&AH, Kamdhenu University, Sardarkrushinagar
Corresponding Author's Email: chetanchavda1008@gmail.com
[2]MVSc Scholar, COVS&AH, Kamdhenu University, Sardarkrushinagar

Abstract

By processing organic waste into biogas composed primarily of CH_4 (55–65%) and CO_2 (35–45%) farmers can mitigate the impact of volatile LPG markets while producing a high-potency liquid digestate rich in Nitrogen, Phosphorus, and Potassium. Technical analysis confirms that maintaining a 1:1 feedstock-to-water ratio and ensuring anaerobic stability optimizes gas yield (0.037 m^3/kg of dung) and improves thermal efficiency from 11% in traditional combustion to 60%. Ultimately, the integration of biogas systems facilitates a circular bio-economy, enhancing soil health through organic fertigation and providing a scalable model for rural energy self-sufficiency and carbon footprint reduction.

Introduction

India is an agrarian country, and animal husbandry is the lifeline of our farmers. Generally, farmers view animal dung only as traditional manure; however, from a scientific perspective, this 'waste' is truly as valuable as 'gold.' Currently, the prices of Liquefied Petroleum Gas (LPG) are consistently rising. In Gujarat, the price of a domestic gas cylinder has reached approximately ₹920 to ₹940. Due to ongoing conflicts in Iran and West Asia, there have been significant disruptions in the global supply of crude oil and gas. India imports about 65-70% of its LPG requirements, which primarily pass through the 'Strait of Hormuz.' As this route is affected by war, there are fears of severe gas shortages and further price hikes in the coming days. In such a time of 'crisis,' biogas plants provide an 'opportunity' by making farmers self-reliant. India possesses one of the largest livestock populations in the world. According to the 20th Livestock Census, the total livestock population in India is approximately 535.78 million. Every day, millions of tonnes of dung and kitchen food waste are produced. If this waste is utilized for biogas production, a significant portion of India's rural energy needs can be generated locally at home, while also ensuring effective waste management.

What is Biogas?

Biogas is a gas produced through the decomposition of organic waste (such as cattle dung, agricultural residue, kitchen waste, human excreta, pig manure, and poultry droppings) in the absence of oxygen (anaerobic digestion) (Akinola and Olanrewaju, 2025). It primarily consists of Methane (CH_4), about 55-65%, and Carbon Dioxide (CO_2), about 35-45%. Biogas also contains trace amounts of gases like Nitrogen and Hydrogen Sulfide (H_2S). This gas is smoke-free and serves as an excellent fuel for cooking. By removing impurities like CO_2 and H_2S from biogas and compressing it, Bio-CNG (Compressed Biogas) can also be produced.

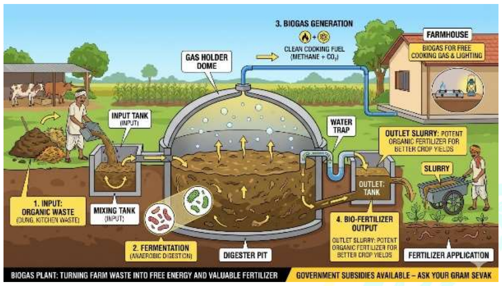
Structure and Working Mechanism of a Biogas Plant

A biogas plant is primarily divided into three main components:

1. **Inlet Tank:** This is where the mixture of dung, organic kitchen waste, and

water (known as slurry) is prepared. Generally, it is mixed in a 1:1 ratio (1 kg of dung per 1 litre of water).

2. **Digester:** This is an airtight underground tank or chamber. Here, anaerobic bacteria decompose the dung and other organic waste through a biological process, which results in the generation of biogas.
3. **Outlet Tank:** Once the gas is produced, the processed liquid residue (digested slurry) flows out through this tank. This leftover slurry serves as a high-quality organic fertilizer.



Multiple Benefits of Biogas

1. Free Cooking Gas and Energy

- **Cost Savings:** Domestic cooking gas can be obtained virtually for free, significantly reducing the monthly expenditure on LPG cylinders.
- **Versatility:** This gas is not limited to cooking; it can also be used for lighting (via biogas lamps) or to power modified internal combustion engines for farm machinery.
- **Environmental Impact:** It reduces the dependency on traditional firewood. By switching to biogas, the labor required to collect wood, the hassle of storing it during the monsoon, and the health hazards associated with smoke are eliminated, thereby reducing indoor air pollution.

2. Superior Organic Fertilizer

- The slurry obtained from the outlet is richer in nitrogen, phosphorus, and potassium compared to raw dung dried in the sun.
- It improves soil structure and promotes sustainable organic farming.

'Slurry' (Liquid Fertilizer): A Nectar for Crops

The slurry discharged from the biogas plant is essentially "liquid gold" for farmers. It is nearly **10 times more potent** than traditional farmyard manure (FYM).

- **Nutrient Rich:** It contains high concentrations of Nitrogen (N), Phosphorus (P), and Potassium (K) in a form that plants can absorb easily (Kumar and Sharma, 2025).
- **Direct Application:** It can be applied directly to the fields along with irrigation water (fertigation).
- **Soil Health:** It significantly enhances soil fertility and encourages the growth of **earthworms**, which naturally aerate the soil and improve its texture.

Operational Guidelines for Daily Maintenance

To ensure the longevity and efficiency of the biogas plant, the following steps should be followed:

a. Quality of Input: Use only **fresh and clean cattle dung** regularly. Avoid using old, dried-out dung as it reduces gas production.

b. Precise Mixing: Maintain a 1:1 ratio of dung to water. Ensure they are mixed thoroughly to create a uniform slurry and feed it into the plant at the same time every day for consistency.

c. Steady Supply: To ensure a constant supply of gas without shortages, the required amount of input must be fed daily. This maintains the bacterial equilibrium inside the digester.

d. Slurry Preparation & Cleaning:

○ **Eliminate Clumps:** While mixing, ensure there are no hard lumps of dung. The mixture should be homogeneous (consistent).

○ **Sedimentation:** After mixing in the inlet tank, let the slurry sit for 10–15 minutes. This allows heavy inorganic particles (like sand or stones) to settle at the bottom, preventing them from entering and clogging the digester.

- **Hygiene:** Once the slurry is fed into the digester, wash the mixing tank thoroughly with water to remove dust and debris.
- **Initial Charging:** When filling the digester for the first time, ensure the slurry is poured evenly from both sides to maintain structural balance.

Protection of Environment and Health

- **Sanitation:** Biogas plants reduce the accumulation of open dung heaps, which in turn decreases filth and the breeding of mosquitoes and flies.
- **Women's Health:** Since biogas is a clean, smokeless fuel, it prevents eye irritation and respiratory (lung) diseases among rural women, which are common when cooking with traditional firewood or dung cakes (Vasco-Correa *et al.*, 2024).

Economic Gains for Farmers: The Mathematics of Prosperity

When dung is processed through a biogas plant, the farmer gets dual benefits: clean fuel and superior manure. Without a plant, dung is typically used as "Dung Cakes" (Chhana), which is inefficient.

- **Efficiency Gap:** The thermal efficiency of dung cakes is only 11%, whereas Biogas has a high efficiency of **60%** (Ahammad and Sreekrishnan, 2024).
- **Daily Dung Production (Average):**
    - **Buffalo:** 15 kg
    - **Cow:** 10 kg
    - **Calf:** 5 kg
- **Gas Yield:**
    - **1 kg Dung:** 0.037 m3 (approx. 1.3 ft^3) of gas.
    - **Human Excreta (per person):** 0.028 m3 (approx. 1 ft^3) of gas.

Consumption Requirements:

Purpose	Requirement (m^3)	Requirement (ft^3)
Cooking	0.227 per person/day	8 ft^3 per person/day
Lighting	0.127 per hour/lamp	4.5 ft^3 per hour (100 candle power)

Hypothetical Example (Farmer with 5 Cattle):

1. **Savings:** Saves approximately ₹1,000 - ₹1,100 per month on LPG cylinders.
2. **Manure Wealth:** Produces 20 to 30 trolleys of high-quality organic fertilizer annually, reducing chemical fertilizer costs by nearly 50%.
3. **Better Yield:** Shifting toward organic farming fetches higher market prices for crops.

Government Assistance and Schemes

Farmers can avail of significant financial help to install these plants:

- **GEDA (Gujarat Energy Development Agency):** Provides substantial subsidies for biogas plants in Gujarat.
- **GOBARdhan Scheme:** The Central Government's "Galvanizing Organic Bio-Agro Resources Dhan" scheme offers incentives to convert waste into wealth (Ministry of Jal Shakti, 2026).
- **Contact:** Farmers can reach out to the District Panchayat Agriculture Department or their local Gram Sevak to apply for these benefits.

Conclusion

❖ Biogas is not just a source of fuel; it is the first step toward a farmer's financial independence. While rising pollution and inflation are "crises," adopting a biogas plant transforms them into an "opportunity." Every livestock-owning farmer should move in this direction today.

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"Cattle dung brings prosperity to the farm—Biogas strengthens the nation's charm."

THE VETERINARIAN: A RESOLUTE GUARDIAN OF FOOD AND HEALTH

Kanjanabh Kumar Das

Intern B.V.Sc. & A.H.
College of Veterinary Science, Khanapara, AVFU
Corresponding author: kumardaskanjanabh@gmail.com

THE ORIGIN

Ever since the genesis of the first veterinary school in Lyon, France and substantially before that, veterinary sciences have played a critical role in safeguarding the health of animals and maintaining a steady source of the global food supply. The earliest iterations of animal husbandry took shape during ancient civilisations, bridging the nutritional gaps as humans transitioned from hunter-gatherers into settlers. Throughout the ages that followed, the interdependence of animals and humans was greatly accentuated, initiating the necessity of a comprehensive scientific discipline in the form of modern veterinary science. Over the years, multiple theories have been proposed justifying the origin of veterinary science, evidence of which extends back to the *Kahun Papyrus* in Egypt (Thrusfield, 2007). Shalihotra, a preeminence in equine medicine of ancient India, is widely regarded as the first veterinarian. The mighty Pandavas, Nakula and Sahadeva, were authorities in equine and bovine medicine, respectively. The revered Mauryan advisor Kautilya addressed the themes of meat science and jurisprudence in his 'Arthashastra'. Notable advancements followed the decades after, with innovations in animal welfare, pathology, medicine and research under eminent personalities such as Rudolf Virchow, Claude Bourgelat and Sir John McFadyean. In modern times, the object of veterinary sciences has extended its spectrum to include companion, exotic and laboratory animals, while seamlessly refining traditional livestock practices. With such deep roots in global history, veterinary science evolved rapidly alongside human medicine, integrating seamlessly into one another under the umbrella of 'One Health'.

THE GUARDIANS OF FOOD

With an exponential surge in global population, the total food demand is expected to increase by 35% to 56% till the year 2050 (Dijk et al., 2021). Animal products, in the form of milk, meat and eggs, constitute a major chunk of this demand. Moreover, in the developing regions of the world, there is a greater prevalence of protein malnutrition, resulting in growth deformities (Smith et al., 2024). Veterinarians act as catalysts in addressing these issues through scientific husbandry practices, genetic improvement, disease surveillance, and prompt interventions. Food spoilage and contamination pose significant challenges in countries like India, compromising both public health and the domestic economy. High ambient temperatures in tropical and sub-tropical climates, coupled with the lack of infrastructural facilities (e.g., cold chain maintenance) and regulatory norms, may be attributed to this problem. Unscrupulous practices in the livestock industry, such as adulteration, fabricated safety claims, and injudicious use of drugs and hormones, often result in serious health hazards. Veterinarians play a key role in regulating and curtailing these practices as livestock product inspectors, public health scientists and animal welfare advocates, working in close association with national bodies as policymakers.

Owing to its vast livestock resources, India ranks topmost among the global milk producers and second among the egg producers (DAHD, 2025). Veterinary services facilitate maintenance of this standard through continuous breed upgradation, Assisted Reproductive Technology (ART), prophylactic protocols and product standardisation, ensuring food security and safety.

THE GUARDIANS OF HEALTH

The escalation in world population has also led to an increased anthropogenic pressure on animal habitats. Human encroachment into forest lands, urbanisation and wildlife exploitation, coupled with climatic stress, have resulted in changes in disease patterns (Esposito et al., 2023). Over 60% of emerging infectious diseases are zoonotic (Jones et al., 2008), and anthropogenic stress stimulates spillover events through vectors or reservoirs. Transmission of several diseases can occur at the human-wildlife interface, and domestic animals reared near forest lands are particularly susceptible, accidentally integrating into the sylvatic cycle. Veterinarians possess the extensive knowledge required to acknowledge these transmission cycles, identify carriers and limit their spread. Malpractices such as illegal wildlife trades introduce novel transboundary diseases into a region, often triggering an ecological collapse. In retaliation, veterinary professionals use complex epidemiological tools such as early warning systems for prompt identification and containment of novel animal diseases. Attributable to their erudition regarding zoonoses, veterinarians often act as a fine link between animal and human health. They undertake vital animal birth control and vaccination programmes in order to curtail disease burdens (e.g., rabies) in society. Advanced knowledge of disease dynamics helps veterinarians predict outbreaks prior to spillovers. This fundamental role of the profession was further solidified during the recent COVID-19 pandemic, in which veterinarians were consulted regarding their proficient knowledge of *Coronaviridae* as animal pathogens.

Historical records establish that it was the collective effort of veterinarians by virtue of which the devastating cattle plague, Rinderpest, was globally eradicated in June 2011 (OIE). The experience gained inevitably paved the way for other eradication programmes, such as the WHO Zero by 30 (dog-mediated rabies) and NADCP (FMD & Brucellosis). Another formidable responsibility of veterinarians is the restoration of endangered animal species to stable numbers through captive breeding programmes. Wildlife veterinarians specialise in resolving human-wildlife conflicts, relocating stranded animals, aiding conservation efforts and maintaining ecological balance. A core aspect of the profession lies in veterinary jurisprudence. Beyond clinical practice, veterinarians are deeply tied to legislative responsibilities- to enact, modify and uphold laws pertaining to animal health and welfare.

THE SACRIFICE

It is self-evident that the veterinary profession presents its own spectrum of occupational hazards. Professionals, especially on-field practitioners, often endure difficult terrain, inclement climate and zoonoses in exercising their duties. In the event of disease outbreaks, veterinarians serve selflessly at the frontline in identifying, mitigating and preventing the crises, frequently at the expense of their own health. Nevertheless, their unwavering contributions throughout the years prove that compassion towards animals fuels the very core of the veterinary discipline.

CONCLUSION

Evidently, veterinary science is truly an all-encompassing and evolving discipline with multifarious obligations, not only towards animals, but also towards One Health. The indispensable nature of this profession effectively positions veterinarians as the resolute guardians of food and health. *"Between animal and human medicine there is no dividing line—nor should there be. The object is different but the experience obtained constitutes the basis of all medicine."* (Rudolf Virchow, 1858)

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Popular Article *ISSN:3048-720X*

PHAGE THERAPY IN COMBATING ANTIMICROBIAL RESISTANCE: A ONE HEALTH APPROACH

Pragya Mishra*, Satvik Narayan Tiwari, Vallabhaneni Srikanth
ICAR-Indian Veterinary Research Institute, Bareilly, Uttar Pradesh
Correspondence: pragyamishra5643@gmail.com

Abstract

Antimicrobial resistance (AMR) has become a major global health concern of the 21st century, threatening the effective treatment of infectious diseases in both humans and animals. The extensive and often indiscriminate use of antibiotics in human medicine, veterinary practice and agriculture has accelerated the emergence of multidrug-resistant (MDR) pathogens, leading to increased morbidity, mortality and economic losses worldwide. The declining efficacy of conventional antibiotics has created an urgent need for alternative antimicrobial strategies that are effective, safe, and sustainable. Among the promising alternatives, bacteriophage therapy has re-emerged as a potential biological approach to combat antibiotic-resistant infections. Bacteriophages or Phages are viruses that specifically infect and lyse bacterial cells, offering advantages such as high host specificity, self-replication at the site of infection and the ability to disrupt bacterial biofilms. Phage therapy has demonstrated potential in managing bacterial infections in human and veterinary medicine including mastitis, respiratory infections, gastrointestinal diseases and wound infections. Additionally, phage therapy has demonstrated potential in controlling bacterial contamination in food processing environments and enhancing biosecurity in animal farming systems. Despite its potential, challenges such as regulatory limitations, limited host range and standardization issues remain. Continued research and policy support are essential to facilitate the safe and effective integration of phage therapy into antimicrobial resistance management strategies.

Keywords: Alternative therapeutics, antimicrobial resistance, bacteriophages, multidrug resistance, one Health, Veterinary medicine

Introduction

Antimicrobials, including antibiotics, antivirals, antifungals and antiparasitics, are medicines used to prevent and treat infectious diseases in humans, animals and plants. Antimicrobial resistance (AMR) occurs when microorganisms no longer respond to these medicines, making infections difficult to treat. AMR is a major global public health threat, responsible for about 1.27 million deaths and associated with 4.95 million deaths worldwide in 2019, with projections of up to 10 million deaths annually by 2050, alongside substantial economic losses, including additional healthcare costs of up to US$ 1 trillion by 2050 and annual global GDP losses of US$ 1 trillion to US$ 3.4 trillion by 2030 (WHO). The rapid rise of AMR is largely driven by human behaviour, particularly the misuse and overuse of antibiotics, which has promoted the emergence of MDR bacteria. Among the most significant contributors are the ESKAPE pathogens viz., *Enterococcus faecium, Staphylococcus aureus* (including MRSA), *Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa* and *Enterobacter* spp., known for evading antibiotic action, forming resilient biofilms and causing severe hospital-acquired infections with high morbidity and mortality.

In response to the growing AMR crisis and the declining development of new antibiotics, alternative antibacterial strategies are urgently needed. The antibiotic pipeline has slowed considerably, with only eight drugs approved by the FDA between 2010 and 2015 compared to numerous approvals during the 1980s (Deak et al., 2016). One promising alternative is phage therapy, which employs bacteriophages, viruses that specifically infect and destroy bacteria. Phages were independently discovered by Frederick Twort in 1915 and Félix d'Herelle in 1917, who coined the term "bacteriophage" and first used it to treat bacterial dysentery in 1919. Phage therapy was widely applied during the 1920s and 1930s but declined after the introduction of penicillin in the 1940s due to the convenience of antibiotics and inconsistent early results. Today, the escalating threat of AMR has renewed global interest in this century-old therapeutic approach (Patel et al., 2025).

What Are Bacteriophages?

Bacteriophages (or phages) are viruses that specifically infect, replicate within and kill bacteria. Discovered over a century ago, they are the oldest and most abundant biological entities on the planet, with an estimated 10^{31} virions distributed throughout the biosphere. Because they are strict parasites of bacteria, phages do not infect human cells (Principi et al., 2019). Bacteriophages have a distinctive tadpole-like structure (Fig.1) with a polyhedral head (capsid) that protects their genome, a tail for attachment and DNA injection, and tail fibers for bacterial recognition. The head is an icosahedral protein shell (20 faces), typically 50-100 nm across, containing the genome; the tail (sometimes contractile sheath + inner tube) connects via a collar to a baseplate with spikes and fibers that bind specific bacterial receptors. Phage genomes are relatively small and tightly packed, most commonly consisting of double-stranded DNA (dsDNA), though RNA genomes also exist.

What's the Mechanism of Action of Phage Therapy?

Phage therapy controls bacterial infections through multiple mechanisms, particularly against multidrug-resistant (MDR) pathogens. Bacteriophages attach to specific receptors on bacterial cells, inject their genetic material (Fig.2) and use the host machinery to replicate. Enzymes such as endolysins then break the bacterial cell wall, causing cell lysis and release of new phages that infect nearby bacteria.

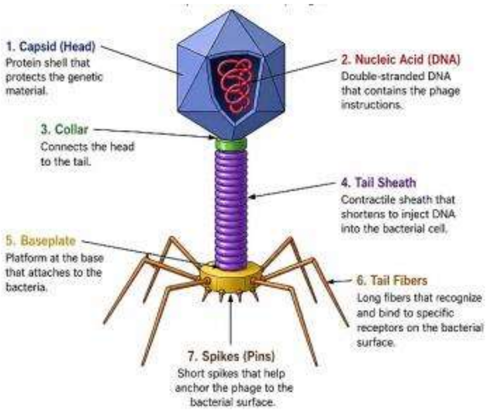

Fig.1. Structure of a bacteriophage

Phages can also disrupt biofilms by producing depolymerase enzymes that degrade the protective matrix surrounding bacterial communities. Their high specificity allows targeted elimination of pathogens while preserving beneficial microbiota. Phages multiply at the infection site as long as susceptible bacteria are present and can enhance antibiotic effectiveness through *phage-antibiotic synergy*. These properties, including targeted killing, self-replication and low toxicity, make phage therapy a promising strategy for managing antimicrobial-resistant infections, particularly in severe hospital-acquired infections where antibiotics are ineffective.

How the Phages can be delivered into the living system ?

Phage therapy can be administered through multiple routes depending on the infection site including oral, topical, intranasal or inhalation, intravenous, intravesical, ocular (eye drops), otic (ear drops), intramuscular, rectal and vaginal routes. Selection of the route is guided by the site of infection, disease severity, and therapeutic objectives. Phages can be prepared in wide variety of delivery systems which are tabulated below:

Phage Delivery System	**Forms**
Liquid suspensions	Saline/ Phosphate-buffered saline (PBS), SM buffer
Lyophilized formulations	Freeze-dried phage preparations
Liposome-based systems	Conventional / Cationic liposomes, Liposome-phage nanoconjugates
Hydrogel-based systems	Carbopol hydrogel, Polymer hydrogels, Ocular gels
Polymer-based encapsulation	Biopolymer and synthetic polymer carriers
Nanofiber-based systems	Electro spun nanofiber mats
Phage-coated biomaterials	Wound dressings, Catheters, Medical implants
Aerosol and inhalation systems	Nebulized phage formulations, Pulmonary sprays
Nano emulsion-based systems	Oil-in-water nano emulsions
Lipid-based nanocarriers	Solid lipid nanoparticles (SLNs), Nanostructured lipid carriers (NLCs)

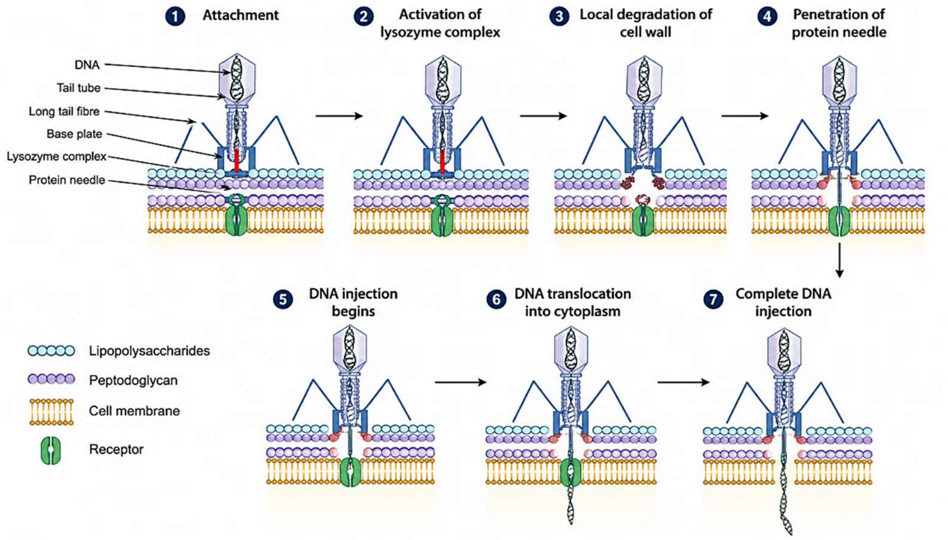

***Fig.2** Mechanism of Bacteriophage Infection: DNA Injection into the Bacterial Host Cell*

What are the Advantages and Limitations of Phage Therapy ?

While phage therapy shows significant potential in combating antimicrobial resistance, it is associated with both benefits and challenges that influence its practical application. The key advantages and limitations of phage therapy are outlined in the table below.

What are the Applications of Phage Therapy ?

Phage therapy has diverse applications in human medicine, veterinary practice and food safety and agriculture due to its ability to specifically target bacterial pathogens, including multidrug-resistant strains. In human medicine, bacteriophages are used in the management of skin infections, respiratory infections, urinary tract infections, wound infections, and sepsis, particularly in cases where antibiotics are ineffective. In veterinary medicine, phage therapy is applied to control diseases such as mastitis, diarrhea, respiratory infections, poultry infections, and aquaculture diseases, helping to improve animal health and reduce antibiotic usage in livestock production systems, which is especially relevant to veterinary and animal science fields. In food safety and agriculture, phages are used for the control of foodborne pathogens, reduction of meat contamination, improvement of dairy safety, and protection of crops, thereby enhancing food quality and supporting sustainable agricultural practices.

Advantages of Phage Therapy

- ✓ High specificity to target bacteria, minimizing damage to beneficial microbiota
- ✓ Effective against MDR bacteria
- ✓ Ability to replicate at the site of infection (self-amplifying)
- ✓ Capable of disrupting bacterial biofilms
- ✓ Reduced side effects compared to antibiotics
- ✓ Minimal impact on normal microbiota
- ✓ Can be used in combination with antibiotics (phage-antibiotic synergy)
- ✓ Environmentally friendly and naturally occurring agents
- ✓ Potential for personalized therapy
- ✓ Low toxicity to humans and animals

Limitations / Challenges of Phage Therapy

- ✓ Narrow host range requiring precise pathogen identification
- ✓ Bacteria may develop resistance to phages over time
- ✓ Potential immune response against phages
- ✓ Regulatory and approval challenges in many countries
- ✓ Lack of standardized dosing and treatment protocols
- ✓ Stability and storage issues under certain environmental conditions
- ✓ Limited large-scale clinical trial data
- ✓ Manufacturing and quality control complexities
- ✓ Need for phage libraries or banks for rapid selection
- ✓ Risk of horizontal gene transfer in some phages

What about Current Research and Evidence ?

1. ***Laboratory Studies:*** In vitro studies demonstrate that bacteriophages effectively kill target bacteria, often outperforming antibiotics against multidrug-resistant strains and biofilms. Lytic phages can reduce bacterial loads by 3–5 log units within 24–48 hours, and phage cocktails help prevent resistance development and enhance biofilm disruption in *S. aureus* and *P. aeruginosa* models (Gliźniewicz *et al., 2024*).
2. ***Animal Studies:*** Preclinical studies in animal models such as mice and rats confirm the effectiveness of phage therapy across different infection sites. Phage treatment achieved 80–100% survival in *Pseudomonas aeruginosa* pneumonia models (Melo *et al., 2020*), improved clearance of MRSA wound infections, and prevented *Escherichia coli* sepsis when administered prophylactically (Wang *et al., 2006*), although immune clearance may limit systemic effects (Melo *et al., 2020*).
3. ***Human Clinical Studies:*** Case reports and small clinical trials report significant clinical improvement and bacterial eradication, particularly in compassionate use for multidrug-resistant infections. Successful outcomes include prosthetic joint salvage and healing of diabetic foot ulcers, with treatments generally well tolerated and no treatment-related adverse events (Aslam *et al., 2018*).
4. ***Gaps in Evidence:*** Despite encouraging findings, current evidence remains limited due to the lack of large randomized controlled trials, variability in dosing ranges (10^8–10^{11} PFU), and insufficient long-term follow-up data. Challenges such as polymicrobial infections, delivery optimization, and cost-effectiveness continue to hinder regulatory approval and routine clinical implementation.

What are the Future Scope and Perspectives of Phage Therapy ?

The future of phage therapy depends on advances in rapid phage selection, combination treatments, genetic engineering and clinical standardization. Automated phagotyping and artificial intelligence-based matching, supported by global phage banks, can enable faster development of personalized therapies (Getz et al., 2025). Combining phages with antibiotics, nanoparticles, or antimicrobial peptides has shown improved effectiveness against pathogens such as *Pseudomonas aeruginosa* and *Staphylococcus aureus* (Bhargava et al., 2021). Genetic engineering approaches, including CRISPR-modified phages and phage-derived lysins, offer enhanced antibacterial activity against resistant infections, including MRSA (Anastassopoulou et al., 2025; Marais, 2021). Wider clinical adoption will require standardized manufacturing, regulatory support, and well-designed clinical trials to integrate phage therapy into routine treatment of multidrug-resistant infections (Bretaudeau et al., 2020).

Adoption within the One Health approach will enable coordinated control of resistant pathogens across human, animal, and environmental sectors. The establishment of well-organized phage banks with genomic characterization will support rapid identification of suitable phages for treatment and outbreak response. Advances in precision medicine are expected to facilitate personalized phage therapy tailored to specific pathogens and patient conditions. Future research should focus on optimizing delivery systems, standardizing dosing protocols, improving large-scale production, and generating robust clinical evidence to support safe and effective use.

Conclusion

Phage therapy is no longer just a scientific curiosity; it is increasingly viewed as a serious response to one of modern medicine's most urgent crises i.e. Antimicrobial resistance. Unlike broad-spectrum antibiotics, phages are highly specific, attacking only their bacterial targets while leaving most of the surrounding microbiome untouched. That precision makes them especially valuable in an era when drug-resistant infections are rising worldwide and treatment options are shrinking. Yet despite its promise, phage therapy is not a simple cure-all. Questions around safety, standardization, regulation, and the evolution of bacterial resistance to phages still need careful attention before the field can fully mature . Even so, the renewed scientific momentum behind phage research reflects a larger truth: some of the most powerful solutions to today's medical challenges may come from revisiting ideas nature has refined for billions of years. As research advances, phage therapy may well become an essential part of the future toolkit against resistant infections.

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ARTIFICIAL INTELLIGENCE IN DRUG DISCOVERY: RESHAPING THE FUTURE OF THERAPEUTICS

Harithalakshmi Jandhyam
Department of Veterinary Pharmacology & Toxicology, Institute of Veterinary Science and Animal Husbandry, Siksha 'O' Anusandhan-Deemed to be University, Bhubaneswar – 751030, Odisha, India.
Corresponding author email: harithalakshmijandhyam@soa.ac.in

Abstract

Traditional drug discovery methods involve target identification, hit to lead optimization, preclinical and clinical trials that are often time consuming, expensive with high failure rates. Artificial intelligence (AI) has emerged as an innovative and transformative force in drug discovery addressing the limitations encountered in drug research. Integration of computations methods such as Machine learning (ML), Deep learning (DL) and Reinforcement learning (RL) enables efficient analysis of vast chemical and biological data sets significantly accelerating the growth of drug development. AI plays a critical role in virtual screening, target identification, drug design, physicochemical assessment, ADMET studies, pharmacodynamics and drug repurposing strategies. In clinical trials, AI enhances patient selection, trial design, outcome prediction and therapeutic intervention. Despite these advancements, challenges such as data set quality, model interpretability, computational demands and ethical concerns remains significant concerns. Nevertheless, ongoing innovations in technology and biopharmaceutics, the hybrid computational and experimental methods are helping to overcome these limitations. Overall, AI is reshaping drug discovery into a faster, more accurate, cost effective process with a potential to revolutionize in the field of therapeutics with a better health care outcome.

Key words: Artificial intelligence, Drug discovery, Therapeutics, Pharmaceutical industry, Clinical trials.

Introduction

Drug discovery is the process of identifying a new drug molecule for the treatment of disease which requires an interdisciplinary collaboration between biology and pharmacology to transform into an effective therapy (Mehran et al., 2026). Traditional approach in drug discovery comprise of identification of the biological targets responsible for disease occurrence, screening of compounds to find the lead molecules, safety evaluations and clinical trials. The conventional drug discovery is a systematic approach involving multiple aspects in drug discovery from finding a target to making it available in the market. With lengthy time lines, late stage failures, poor pharmacokinetic and toxicity predictions costing billions of dollars to bring a single drug in to the market, emphasizing the need for better predictive and computation approaches (Mullard, 2014). In modern era, Artificial intelligence, a data driven process reshaping the drug discovery in a faster and more efficient way, influencing the therapeutics by improving the efficacy, reducing adverse effects, rational optimization, cost effective, multi target drug design strategies and personalized medicine (Chen et al., 2023).

The Role of Artificial Intelligence in Drug Discovery

Artificial intelligence term coined by John McCarthy in 1956 is a revolutionary concept, enables researchers to analyze vast datasets through identifying the molecular patterns, detailing the complex tasks and enhancing the efficacy of drugs (Mak and Pichika, 2018). Large data base available in public domains such as ChEMBL and PubChem act as a fuel in AI models. The core concepts of renowned Pharma companies such as Bayer, Pfizer and Roche integrating these AI based predictive modelling concepts in drug innovation through collaborations with Technology firms (Mak & Pichika 2019). Several AI techniques contribute to address the challenges in drug discovery. Machine learning (ML) algorithms such as supervised, unsupervised, deep learning navigate the complex biological data sets to identify potential drug targets. (Vemula et al., 2023). Supervised learning is used for prediction tasks such as classifying compounds, to train the models for target-drug interactions, analyze bio-chemical properties, while unsupervised learning helps identify patterns and clusters in complex chemical data. These approaches allow efficient exploration of chemical space and improve prediction accuracy. Machine learning typically involves transforming chemical structures into numerical depictions like SMILES strings, enables prediction of biological activity and toxicity. Deep learning (DL) manage large data sets and complex molecular structures, Natural language processing extracts information from scientific literature and Graph neural networks analyse molecular structures with high accuracy. Reinforcement learning further enhances drug discovery by generating novel molecular structures tailored to specific therapeutic targets (Dara et al., 2022; Vemula et al., 2023).

AI-Driven Target Identification and Drug Design

Identifying the correct biological target is a crucial step in drug discovery. AI enhances this process by integrating genomics and biological data. Genomics-based approaches use gene expression data and genome-wide studies to identify disease-related targets. Network-based methods analyze protein interactions to determine key pathways involved in disease progression. AI also enables accurate prediction of protein structures, helping identify binding sites and facilitating structure-based drug design. These advancements significantly improve target validation and drug development success rates. Revolution of AI in drug design enabled to screen millions of compounds in minimal amount of time using AI based molecular docking, Pharmacophore modelling and Deep reinforcement learning techniques successfully designed targeting receptors involved in metabolic and inflammatory diseases (Udegbe, 2024). AI intertwines with the data science, uses algorithms to analyse and visualize complex data sets. Drug-likeness is evaluated using Lipinski's Rule of Five, ensuring optimal pharmacokinetic properties. A major advantage with AI in drug discovery is its ability to predict ADMET with Tools such as DeepTox and Molecule Net helps to reduce the drug failure in the early stages and ensure to proceed with the most promising candidates. AI models also predict potential toxic effects such as hepatotoxicity and cardiotoxicity at early stages (Mayr et al., 2016). This early prediction reduces late-stage failures and helps prioritize the most promising drug candidates for further development.

AI driven drug discovery work flow begins with preparation of chemical structure and optimization using tools like AVOGADRO and Open Babel. Physicochemical properties are analyzed using swissADME and pkCSM platforms. Target prediction tools like SwissTarget Prediction identify potential biological targets by analyzing genomic and proteomic data. Molecular Docking using AutoDock Vina or PyRx evaluates binding interactions, followed by molecular dynamics simulations to study stability using GROMACS. Further Pharmacokinetic and Pharmaco dynamic modeling are performed using tools like PK-Sim, R or Python and integrated using MoBi or nlmixr2, toxicity prediction using **ProTox-II** ensures safety, Clinical trials and followed by drug approval. AI-driven approaches increase early-stage success rates, more efficient decision-making and a higher likelihood of developing effective drugs.

AI in Clinical Trials

Clinical trials rely up on patient selection. AI enhance the trial efficiency by selecting suitable participants through analysing their electronic health records, biomarkers and genetic data. The process is further enhanced through wearable devices, remote monitoring, real-time data acquisition and better patient engagement (Khan et al., 2024). AI also paving way to personalized therapy for chronic hepatitis B condition (Cascini et al., 2022) and within 18 months' development of drug for idiopathic pulmonary fibrosis (Serrano et al., 2024) enhances the therapeutic efficiency, reducing the cost and increasing the success percentage. Ethical concerns are another aspect which requires accountability and transparency. AI contribute to 3R`s especially replacement of animal studies to certain extent in Behavioural research, drug screening and Toxicity testing enabling transparency and enhancing the ethical standards.

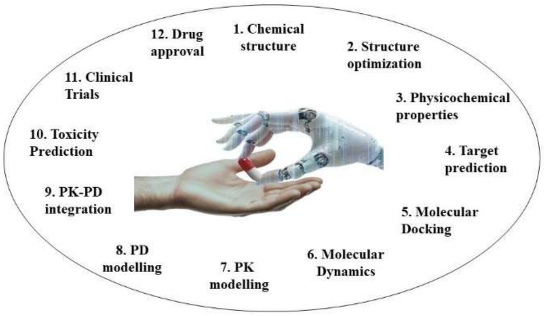

Figure 1. Artificial Intelligence (AI) driven drug discovery work flow

Challenges and Limitations

AI is reshaping the therapeutics and its need is inevitable especially in pharmaceutical and healthcare sector. Nevertheless, it has limitations, for instance AI is based on evaluating data quality but biased data sets lead to unreliable predictions, regulatory concerns, ethical considerations and further need for evaluation in the laboratory using animal models are major concerns. Many AI systems also lack interpretability, making it difficult to understand how decisions are made (Wiens et al., 2019). Additionally, computational methods such as molecular docking may not always accurately reflect real biological interactions, especially when protein flexibility and solvent effects are not fully considered (Pantsar & Poso, 2018). Even advanced tools like AlphaFold may fail to capture dynamic protein conformations, limiting their applicability in certain scenarios (Bowman, 2024).

Future Prospects

The future of drug discovery lies in the integration of AI with emergent technologies such as quantum computing, multi-omics data analysis, and digital biomarkers. These innovations will help formulate more precise and personalized treatments customized to individual patients. AI is also expected to advance drug repurposing and polypharmacology, identifying new therapeutic uses for existing drugs and targeting multiple pathways simultaneously (Han et al., 2023). Continued progress will depend on improved data quality, transparent AI models, and strong collaboration between computational scientists and experimental researchers (Paul et al.,2021). Interdisciplinary collaboration, open data sharing, and methodological advancements will be essential to fully capture the benefits of AI in pharmaceutical research.

Conclusion

Artificial Intelligence is restructuring drug discovery by transforming it into a predictive, well-organized, and data-driven process. From target identification, drug design to clinical trials and safety assessment, AI improves every stage of the workflow while drastically cutting down cost, time, and failure rates. Despite the challenges and limitations, the ongoing developments in AI and initiatives such as interdisciplinary collaborations are anticipated to propel pharmaceutical Research and Development, leading to superior healthcare outcomes globally. Future of AI is promising and expected to grow exponentially creating myriad of opportunities not only in health care but also in manufacturing and other sectors that demand integration of professional and technical skills.

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