Animal Health Research Reviews

cambridge.org/ahr

Review Article

Cite this article: Corbera JA, Melián Henríquez A, Morales Doreste M, Martín Martel S, Tejedor-Junco MT (2025) Implementing evidence-based biosecurity protocols in Veterinary Teaching Hospitals: a critical review and guide for best practices. *Animal Health Research Reviews* **26**, e5, 1–14. https://doi.org/10.1017/S1466252325100030

Received: 1 May 2025
Revised: 12 October 2025
Accepted: 16 October 2025

Keywords:
Antimicrobial stewardship (AMS); biosecurity governance; hospital-associated infections (HAIs); infection prevention and control (IPC); veterinary education and training

Corresponding author:
Juan Alberto Corbera;
Email: juan.corbera@ulpgc.es

Implementing evidence-based biosecurity protocols in Veterinary Teaching Hospitals: a critical review and guide for best practices

Juan Alberto Corbera[1,2], Adrián Melián Henríquez[2], Manuel Morales Doreste[1], Sergio Martín Martel[1] and María Teresa Tejedor-Junco[2]

[1]Hospital Clínico Veterinario, Facultad de Veterinaria, Universidad de Las Palmas de Gran Canaria, Canary Islands, Las Palmas de Gran Canaria, Spain and [2]Instituto Universitario de Investigaciones Biomédicas y Sanitarias (IUIBS), Universidad de Las Palmas de Gran Canaria, Canary Islands, Las Palmas de Gran Canaria, Spain

Abstract

Veterinary Teaching Hospitals (VTHs) represent complex environments that integrate clinical care, education, and research, posing unique biosecurity challenges. In response to increasing scrutiny from accreditation bodies such as the European Association of Establishments for Veterinary Education (EAEVE), there is a growing need for rigorous, evidence-based biosecurity protocols. This review critically analyses internationally recognised protocols – including those of the University of Liège, the American Association of Equine Practitioners (AAEP), and leading small animal institutions – as well as scientific literature addressing best practices in infection control. We identify key components of successful biosecurity programmes, including risk-based patient classification systems, standardised hygiene and disinfection protocols, and the mandatory training for staff and students. Particular emphasis is placed on the difficulties encountered in teaching contexts, where high human–animal interaction increases the risk of zoonoses and nosocomial infections. A comprehensive set of recommendations is presented to support the development of scalable and institutionally adapted biosecurity protocols, with the aim of ensuring the safety of patients, staff, students, and visitors in VTHs while meeting international accreditation standards.

Introduction

Over the past decades, internal regulations governing biosecurity in Veterinary Teaching Hospitals (VTHs) have often lacked the scientific rigour and operational comprehensiveness necessary to address contemporary challenges, including nosocomial infection control, zoonotic disease prevention, and occupational safety. These deficiencies have been repeatedly underscored by accreditation agencies, particularly the European Association of Establishments for Veterinary Education (EAEVE), through its Evaluation System of Veterinary Training (ESEVT). This system mandates the implementation of documented biosecurity protocols, compulsory training for students and staff, and the creation of monitoring and improvement mechanisms, as articulated in Standards 4 and 9.1 of the framework (EAEVE, 2023).

In the context of this review, biosecurity refers to the comprehensive set of preventive strategies designed to minimise the transmission of infectious agents among animals, humans, and the environment within veterinary clinical settings. These strategies encompass hygiene practices, patient isolation, access control measures, the appropriate use of personal protective equipment (PPE), disinfection protocols, education, and continuous surveillance (Stull *et al.*, 2018).

It is essential to differentiate between *biosecurity* and *biosafety*, as the two concepts, while related, address distinct aspects of infectious disease control. Biosecurity is primarily concerned with preventing the spread of pathogens between living organisms and into the surrounding environment. In contrast, biosafety focuses on the safe containment, handling, and management of biological agents within laboratory environments or controlled facilities, aiming to protect laboratory personnel and prevent accidental releases. Thus, while biosecurity addresses external transmission risks, biosafety deals with internal exposure risks (Beeckman and Rüdelsheim, 2020; Renault *et al.*, 2021).

In the context of VTHs, biosecurity documentation can be conceptualised as a hierarchy. A biosecurity programme represents the overarching, institution-wide framework encompassing governance, policies, resources, and continuous improvement mechanisms to manage biosecurity risks. A biosecurity plan is a structured document, developed within the programme, that outlines specific objectives, responsibilities, procedures, and timelines for implementing biosecurity measures in a defined facility or operational area. A biosecurity protocol refers to a standardised set of step-by-step instructions – often presented as standard operating procedures (SOPs) – detailing how individual tasks are to be carried out to meet plan objectives. A biosecurity project is a targeted, time-bound initiative, typically designed to address a specific biosecurity issue or to implement an improvement within the existing plan or programme. This hierarchy ensures alignment between strategic goals, operational planning, and day-to-day practices, while allowing flexibility for continuous refinement (Stull *et al.*, 2018).

Effective governance is the cornerstone of biosecurity in VTHs. At its core, this requires an institutionally approved Biosecurity Manual and the appointment of a designated Biosecurity Officer, which together ensure that written protocols are translated into consistent practice and continuously updated in line with evolving risks (Benedict *et al.*, 2008; Stull *et al.*, 2018).

The consequences of inadequate biosecurity have been substantiated by multicentre studies. In a survey of 38 VTHs, 82% reported at least one outbreak of nosocomial infection over a five-year period, and 45% experienced multiple outbreaks. In addition, a study in two veterinary hospitals found that 30% of clinical areas and 25% of staff uniforms were contaminated with multidrug-resistant staphylococci, highlighting environmental and personnel vectors as critical transmission routes (Worthing *et al.*, 2018). These events led to patient admission restrictions in 58% of institutions and temporary closures of clinical areas in 32% (Benedict *et al.*, 2008). Additionally, 50% of these hospitals reported zoonotic infections affecting personnel or clients within the previous two years (Stull *et al.*, 2018), highlighting the urgent need for harmonised, evidence-based biosecurity strategies.

The global increase in antimicrobial resistance (AMR) has further intensified the risks associated with insufficient biosecurity measures in VTHs. Multidrug-resistant organisms, such as methicillin-resistant *Staphylococcus pseudintermedius* (MRSP), methicillin-resistant *Staphylococcus aureus* (MRSA), and extended-spectrum beta-lactamase (ESBL)-producing Enterobacteriaceae, have been increasingly identified in veterinary clinical environments, posing major challenges to patient safety, infection control, and antimicrobial stewardship (Guardabassi and Prescott, 2015; Worthing *et al.*, 2018).

In addition to controlling the ingress and intra-hospital spread of infectious agents, biosecurity frameworks must also address the risk of 'pathogen escape'. Veterinary healthcare workers may inadvertently act as vectors, carrying multidrug-resistant organisms or zoonotic pathogens from the hospital environment into their households and community settings (Anderson *et al.*, 2020; Sebola *et al.*, 2023; Stull *et al.*, 2018). This outward transmission pathway highlights the importance of rigorous decontamination procedures, occupational health measures, and One Health–oriented protocols that protect both hospital stakeholders and the wider public.

In response to this need and the demands of evaluators, an increasing number of European veterinary institutions have developed formal biosecurity frameworks. A benchmark model is that of the University of Liège (Belgium), whose publicly accessible, SOP-based biosecurity manual has been widely adopted as a reference across Europe, promoting alignment with international safety standards set by organisations such as the World Organization for Animal Health (WOAH) and World Health Organization (WHO; (Biosecurity SOPs applied to the Faculty of Veterinary Medicine, Liège University, 2019). This model integrates infection control measures, PPE guidelines, educational tools, antimicrobial stewardship, and patient risk categorisation.

VTHs, as the clinical and practical arms of Veterinary Establishments (VEs), must comply not only with national legislation concerning occupational health and animal welfare but also with international accreditation requirements. Their dual role as clinical centres and teaching environments imposes an added ethical and pedagogical responsibility: to guarantee the safety of patients and people while embedding biosecurity competencies into veterinary education (Benedict *et al.*, 2008; Marsh and Babcock, 2015; Stull *et al.*, 2018; Williams *et al.*, 2015).

In this regard, biosecurity is not simply a regulatory necessity but a fundamental teaching objective. ESEVT Day-One Competence 1.29 explicitly states that graduates must be able to 'recommend and evaluate biosecurity protocols and correctly apply these principles' (EAEVE, 2023). Therefore, integrating structured, practical biosecurity training into clinical rotations is essential to ensure that students acquire the competencies expected from their very first clinical engagement.

Mandatory and continuous training in biosecurity principles must be extended to all VTH stakeholders, including veterinarians, auxiliary staff, students, administrators, and external collaborators. This aligns with Standard 9.1 of the ESEVT, which demands permanent education programmes in biosecurity to maintain high standards of practice and compliance (EAEVE, 2023).

Given their unique role as academic, clinical, and research institutions, VTHs must model best practices in infection prevention. This review aims to systematically compile, analyse and compare current scientific literature, international standards and institutional biosecurity protocols, with the objective of providing a robust, evidence-based guide to support the implementation and refinement of comprehensive biosecurity frameworks in VTHs.

This work focuses specifically on clinical areas and patient-related biosecurity within VTHs. Although laboratory facilities such as microbiology, parasitology, and pathology laboratories represent important additional biosecurity challenges, they are outside the scope of this article. For detailed guidance on laboratory biosecurity, readers are referred to standards published by the World Health Organisation (WHO) and the World Organisation for Animal Health (WOAH).

Core elements of a biosecurity plan in Veterinary Teaching Hospitals

An effective Biosecurity Plan in a VTH must address the unique operational and educational complexities of an academic veterinary environment. While the fundamental principles of biosecurity mirror those applied in private veterinary clinics or general hospitals, VTHs face additional challenges due to the diversity of stakeholders involved – including undergraduate and postgraduate students, academic staff, clinical veterinarians, technical assistants, and support personnel (e.g., cleaning and administrative staff) – all of whom must be trained in the safe use of clinical facilities and biohazardous environments (Benedict *et al.*, 2008; Weese, 2015; Willemsen *et al.*, 2019).

Governance

A robust biosecurity framework in a VTH must be underpinned by strong institutional governance. Two foundational pillars are essential: (1) a comprehensive, institutionally approved Biosecurity

Manual and (2) the designation of a dedicated Biosecurity Officer or Biosecurity Unit. The need for a written, accessible infection-control plan and a designated lead for infection-control is well established in the veterinary hospital literature (Stull *et al.*, 2018; Stull and Stevenson, 2015).

The Biosecurity Manual should serve as the central, authoritative reference for all infection prevention and control (IPC) measures. It must include SOPs, emergency response protocols, training requirements, and governance structures. Accessibility is key: the manual should be available in both printed and digital formats, disseminated via QR codes, internal networks, and strategically placed signage. Regular review – at least annually and always following significant incidents – is essential to ensure alignment with scientific evidence, lessons learned, and regulatory updates (Benedict *et al.*, 2008; Stull *et al.*, 2018; Weese, 2014, 2015). While the manual provides the institutional framework, effective implementation requires clearly defined responsibility at the individual level.

The Biosecurity Officer (or Biosecurity Unit) is responsible for operationalising the Biosecurity Manual and ensuring consistent application across hospital departments. This role requires a person with a veterinary degree, ideally with postgraduate training in infectious disease control, epidemiology, or public health, as well as formal qualifications in IPC. Key competencies include outbreak investigation, risk assessment, surveillance design, and implementation of infection control protocols. Leadership, communication, and financial planning skills are equally critical to ensure staff engagement and long-term sustainability (Ruple-Czerniak *et al.*, 2013; Smith *et al.*, 2023; Stull and Weese, 2015). Beyond individual leadership, institutional biosecurity also benefits from collective oversight through multidisciplinary governance bodies.

A Multidisciplinary Biosecurity Committee – comprising representatives from clinical staff, biosecurity officers, infection control specialists, educators, administrators, and, where appropriate, students – should oversee compliance, training, surveillance, and incident review. Routine audits, environmental sampling, and constructive feedback mechanisms reinforce adherence and promote shared responsibility (Ruple-Czerniak *et al.*, 2013; Stull and Weese, 2015; Timofte and Jepson, 2024). However, even the most robust governance structures cannot succeed without adequate physical and logistical resources.

Institutional support, enforcement authority, and sufficient resources are indispensable to translate biosecurity strategies from policy into practice. Physical infrastructure should include purpose-built isolation units, decontamination areas, fully equipped PPE stations, and traffic-flow systems designed to minimise cross-contamination. Where feasible, isolation capacity should be species-specific or, at minimum, segregated for small – and large-animal patients, supported by dedicated equipment and independent support flow (Smith et al. 2004; Elchos *et al.*, 2008; Weese, 2014; Williams *et al.*, 2015).

Operational components

The effectiveness of any biosecurity plan ultimately depends on its practical implementation across all areas of the hospital. Fundamental measures such as rigorous hand hygiene, the appropriate use of protective clothing, the minimisation of unnecessary contact with patients, and the safe disposal of biological waste must be consistently applied and closely monitored (Shea and Shaw, 2012). These practices form the cornerstone of infection prevention and are essential for reducing the baseline risk of pathogen transmission within VTHs.

Building upon these foundations, biosecurity protocols must also address the interruption of specific transmission pathways. A clear understanding of infectious disease epidemiology is required to design effective barriers and movement restrictions that minimise cross-contamination and reduce the likelihood of outbreaks (Boerlin *et al.*, 2001; Weese, 2004). These measures, ranging from equipment dedication to restrictions on traffic flow, ensure that both patients and staff are protected from inadvertent exposure.

Operational components must furthermore be dynamic and continuously refined. Surveillance systems, regular audits, and clinical feedback are crucial to identify weaknesses, update procedures, and strengthen compliance. The systematic use of performance indicators and diagnostic audits creates a feedback loop that supports evidence-based revisions of protocols and fosters a culture of accountability (Anderson and Weese, 2016; Burgess and Weese, 2021; Stull and Weese, 2015).

Finally, effective biosecurity requires clear and consistent communication of risks. Information must be conveyed in a manner that is easily understood and readily accessible to all hospital stakeholders, regardless of their background or role. This includes the use of signage, checklists, and visual cues, as well as direct communication strategies that reinforce behavioural expectations. By ensuring that messages are concise, visible, and adapted to different user groups, VTHs can enhance adherence and promote a shared sense of responsibility for infection control (Elchos *et al.*, 2008; Williams *et al.*, 2015).

Risks assessment, transmission pathways, and patient classification

The first step in designing a functional biosecurity plan for a VTH is a comprehensive risk assessment. This evaluation must consider the wide range of hazards that arise from the hospital's dual role as both a clinical centre and a teaching environment, where high volumes of students, staff, and patients converge. Effective risk assessment provides the foundation for all subsequent decisions regarding patient management, staff protection, and environmental controls.

Transmission pathways

A central element of this process is the analysis of pathogen transmission pathways, because understanding how infectious agents spread is essential for defining hospital zones, movement flows, and protective measures. Transmission can occur through direct contact with secretions or lesions, through fomites such as equipment or clothing, via droplets and aerosols generated during respiratory procedures, or by environmental routes including faeco-oral contamination and persistent pathogens. In some contexts, vectors such as ticks and other insects must also be considered. Each of these pathways requires specific containment measures, ranging from the use of barrier nursing and dedicated equipment to ventilation strategies and ectoparasite control (Burgess and Weese, 2021; Stull and Weese, 2015; Weese, 2004; Willemsen *et al.*, 2019).

Physical risks

Physical risks in VTHs primarily arise from the unpredictable behaviour of animal patients, which may result in traumatic injuries such as bites, kicks, or scratches. Additional risks are associated with the routine use of diagnostic imaging equipment (e.g., radiography or Computed Tomography [CT]), which exposes personnel to ionising radiation. Compliance with national radiation safety regulations and the implementation of protection measures defined by institutional Radiological Protection Technical Units (RPTU) are therefore mandatory (Freitas *et al.*, 2021; Mayer *et al.*, 2018).

Chemical risks

VTHs utilise a wide array of chemical substances, including disinfectants, pharmaceuticals, and cytotoxic agents. While many of these pose minimal risk under routine conditions, particular attention is required for inhalational anaesthetics and chemotherapeutic agents, which are associated with significant occupational exposure risks. In teaching hospitals, where the density and turnover of users is higher – including students, residents, and support staff – protocols must explicitly cover the handling, storage and waste management of hazardous compounds to minimise the likelihood of accidental exposure or poisoning (Driscoll *et al.*, 2005; Easty *et al.*, 2015; Fung and Seneviratne, 2016; Kandel-Tschiederer *et al.*, 2010; Shirangi *et al.*, 2014).

Biological risks

Given their referral function, VTHs frequently admit patients from diverse backgrounds, including animals with undiagnosed or emerging infectious diseases. The biological risk is therefore twofold: on the one hand the potential occurrence of nosocomial infections within the hospital environment, and on the other, the zoonotic risk posed to students, staff, and visitors. To mitigate these risks, strict segregation, triage, and isolation procedures are essential, supported by robust hygiene protocols and the systematic use of PPE. As detailed in Section 3.1, the likely transmission pathway(s) should be identified at triage to guide placement, signage, and PPE (Boerlin *et al.*, 2001).

Patient classification (four-tier model)

On admission, patients are classified according to transmission risk and zoonotic significance, which immediately activates proportional precautions (Guptill, 2015; Machado *et al.*, 2023). Importantly, measures must be initiated as soon as suspicion arises, even before laboratory confirmation. For example, patients with suspected parvovirosis, leptospirosis, or dermatophytosis should be categorised as Tier/Class 3 or 4 within the hospital's multilevel infectious-risk system, thus triggering pre-emptive containment procedures (Guptill, 2015; Machado *et al.*, 2023). The use of standardised models enhances consistency, improves training outcomes, and facilitates more efficient resource allocation (Banks, 2020). A practical species-based summary of common infectious agents and their corresponding biosecurity class is provided in Table 1 (see Section 3.7).

Classes and core precautions

Based on current evidence and international best practices, this classification framework provides a structured guide for triage, clinical decision-making, and workflow management within VTHs. The following four-tier system details the patient categories and their corresponding biosecurity precautions:

- ***Class 1 (Green): Low transmission risk, not zoonotic***

Patients in this category present with infectious diseases of minimal transmission potential and no recognised zoonotic risk. Such cases comprise the majority of patients in routine veterinary practice. Standard hospital biosecurity protocols, including basic hygiene measures, are sufficient to manage these patients.

- ***Class 2 (Blue): Low transmission risk, limited zoonotic potential***

Patients may carry pathogens that are zoonotic only sporadically and typically restricted to certain geographic or epidemiological contexts. Effective treatment or prophylaxis is usually available. The same measures applied to Class 1 patients generally suffice, although heightened vigilance, thorough documentation, and client education may be advisable.

- ***Class 3 (Yellow): Moderate transmission risk or suspected zoonotic pathogen; barrier nursing required***

This category includes patients with either suspected or confirmed infectious diseases that pose a moderate risk of animal-to-animal or animal-to-human transmission (e.g., suspected leptospirosis, dermatophytosis). It is critical that precautionary biosecurity protocols are activated as soon as clinical suspicion arises – even prior to laboratory confirmation. Such patients should be housed in designated isolation areas, and staff must employ appropriate barrier nursing techniques (Stull and Weese, 2015; Weese, 2004).

- ***Class 4 (Red): High-risk pathogen or severe zoonotic disease; strict isolation required***

These patients are suspected or confirmed carriers of highly contagious and/or high-consequence pathogens of significant public health concern (e.g., *Brucella,* notifiable zoonoses). Full isolation is mandatory and management often must include coordination with public health authorities as legally mandated. Enhanced PPE, restricted access, and dedicated equipment are essential for the safe management of these patients (Stull *et al.*, 2018; Weese, 2004).

This risk-based classification is directly linked to PPE requirements, which are standardised across hospital zones and tailored to each class level. Specific recommendations for attire, protective equipment, and hygiene practices are outlined in the subsequent section on PPE and Attire, ensuring consistency between patient classification, isolation measures, and staff protection.

Moreover, depending on the VTH's geographic location, the biosecurity plan should incorporate a list of regionally relevant pathogens and assign them to the appropriate biosecurity categories, in alignment with national surveillance systems and international guidance (Chetri *et al.*, 2023; Machado *et al.*, 2023). Patient classification also informs species-specific placement within isolation units; separation of small- and large-animal caseloads is recommended as a baseline, modulated by facility risk assessment.

Definition and scope of barrier nursing

Barrier nursing is the coordinated application of a set of protective measures, including contact, droplet, and airborne precautions; patient segregation (single room or cohorting); dedicated equipment; controlled access; and procedural barriers such as donning and doffing sequences, hand hygiene, environmental cleaning, and

Table 1. Illustrative classification of patients by species, showing the primary transmission pathway together with the recommended precautions. This table is non-exhaustive and is intended to complement Appendix 1

Species	Infectious agent /condition	Primary transmission	Class	Precautions / isolation	Key notes
Dog	Canine parvovirus	Faeco-oral; environmental	**3**	Contact + enhanced environmental disinfection	Non-enveloped virus; high persistence (Dunowska *et al.*, 2005; Weese, 2015)
Dog	*Leptospira* spp.	Urine/water; droplet with aerosols	**3**	Contact + eye/face protection; moisture control	Zoonotic; handle urine with PPE (Guptill, 2015)
Dog	CIRDC (*Bordetella* etc.)	Droplet/contact	**3**	Droplet/contact; cohorting	Restrict movement; signage (Guptill, 2015)
Dog (any)	Rabies suspicion	Bites; saliva	**4**	Strict isolation; public-health coordination	Notifiable; legal protocols apply
Cat	Feline panleukopenia	Faeco-oral; environmental	**3**	Contact + enhanced disinfection	Similar to canine parvovirus
Cat	*Chlamydia felis*	Droplet/ ocular secretions	**3**	Droplet/contact	Eye protection in procedures (Guptill, 2015).
Cat/Calf/Horse	Dermatophytosis (active shedding)	Direct/indirect; fomites	**3**	Contact; dedicated tools; environmental cleaning	If on effective therapy with low spore load → **2** (Willemsen *et al.*, 2019)
Horse	Strangles (*Streptococcus equi*)	Droplet/contact	**3**	Droplet/contact; segregation	Monitor carriers (Weese, 2014)
Horse	Equine influenza	Droplet/short-range aerosols	**3**	Droplet; movement restrictions	Ventilation and cohorting (Weese, 2014)
Horse	EHV − 1 (neurologic)	Droplet/contact; procedures	**3**	Contact/droplet; dedicated staff	High contagion; not zoonotic
Calf/Foal	*Salmonella* spp. (diarrhoeic)	Faeco-oral; environmental	**3**	Contact + enhanced disinfection	Escalate to Class **4** if MDR and an institutional outbreak (Burgess and Morley, 2015; Worthing *et al.*, 2018)
Small ruminants (peripartum)	*Coxiella burnetii* (Q fever)	Airborne from birth products	**4**	Airborne/respirator; restricted access	High risk for pregnant staff (Weese, 2014)
Cattle/goats	*Brucella* spp. (abortion)	Fluids; aerosols	**4**	Strict isolation; respirator; notification	Serious zoonosis; specific legal requirements
Cattle	*Mycobacterium bovis*	Airborne	**4**	Airborne isolation; authority notification	High occupational risk
Sheep/goats	*Chlamydia abortus*	Aerosol/droplet at parturition	**4**	Airborne/droplet; exclude pregnant staff	Zoonotic, severe risk
Ruminants/ equids	*Bacillus anthracis*	Environmental spores	**4**	Strict isolation; authority notification	Notifiable
Birds of prey/poultry	Avian influenza (HPAI)	Droplet/airborne	**4**	Strict isolation; respirators	Notifiable
Psittacines	*Chlamydia psittaci*	Airborne	**4**	Airborne isolation; respirator	Significant zoonosis
Reptiles	*Salmonella* spp. (shedders)	Faeco-oral; fomite	**3**	Contact; gloves; dedicated sinks	Client education essential

waste management. This integrated approach is designed to minimise transmission between patients, staff, and the hospital environment. Within this framework, barrier nursing is mandatory for Class 3 patients and incorporated into the stricter isolation requirements of Class 4 (Stull *et al.*, 2018; Stull and Weese, 2015; Weese, 2004).

- *Minimum elements (Class 3)*: gown and gloves for all contact; procedure masks/eye protection as indicated; patient-dedicated tools; terminal cleaning with agents effective for the pathogen profile.
- *Enhanced elements (Class 4)*: as above plus respiratory protection (FFP2/N95) for airborne-risk procedures, negative-pressure/segregated room where available, entry logs, and public-health liaison for notifiable diseases (Stull *et al.*, 2018; Weese, 2004).

Summary by species and infectious agent (illustrative)

A practical species-based summary of common infectious agents and their corresponding biosecurity class is presented in Table 1, which complements the preceding classification framework.

Triggers, documentation, and EMR integration

Classification is recorded at triage in the Electronic Medical Record (EMR) and subsequently updated as diagnostic information becomes available, thereby ensuring consistent application across all departments. Triggers include compatible clinical syndromes (e.g., acute haemorrhagic diarrhoea, abortion storms, respiratory disease clusters), exposure history, and regional epidemiology (Guptill, 2015; Machado *et al.*, 2023). Once classification is assigned, it automatically determines the required PPE level, room type, signage, and cleaning protocols. Adherence to these measures is reviewed through regular monthly audits (Burgess and Morley, 2015; Ruple-Czerniak *et al.*, 2013; Stull *et al.*, 2018).

Access control, movement management, and personal protective equipment

Area-specific signage by biosecurity level

Effective access control and movement management within VTHs are critical components of biosecurity management. All stakeholders – including students, faculty members, veterinarians, technical staff, external visitors, and clients – must strictly adhere to the established access protocols. These protocols encompass compliance with posted signage, mandatory use of PPE, and adherence to area-specific restrictions, and are implemented through practical measures such as (i) standardised signage templates (e.g., 'Stop – Isolation', 'Contact Precautions', 'Droplet/Airborne Precautions') with clear iconography and colour-coding; (ii) physical barriers and controlled entry points (swing gates, access-controlled doors, anterooms) equipped with donning/doffing stations; (iii) floor demarcation and separation lines (colour-coded pathways; clean, semi-clean, and dirty zones as defined in Section 4.5) using durable tape or paint; (iv) dynamic marking systems – retractable belt barriers, magnetic tape, and portable floor signs – to reconfigure flows during outbreaks or high-risk procedures; (v) one-way traffic for people, animals, equipment, and waste (clean → semi-clean → dirty flow), with no reverse movement except under defined decontamination protocols; and (vi) point-of-use reminders, including laminated checklists at doors, QR codes linking to SOPs) to reinforce correct PPE and movement rules.

Consistent with the hospital's zoning strategy, isolation rooms should be allocated by species where transmission dynamics materially differ; at a minimum, small- and large-animal isolation areas should be distinct, with cross-traffic and shared equipment prohibited unless decontaminated according to SOPs.

Access restrictions for high-risk zones

Client access is permitted only in low-risk areas and strictly prohibited in high-risk zones (e.g., surgical suites and isolation units). These restrictions must be clearly communicated through signage and consistently enforced by the institution. For instance, while client access may be permitted for routine consultations, it must remain strictly prohibited in designated high-risk zones, including surgical suites and infectious-disease units. In VTHs, where the daily volume of students and visitors is particularly high, such restrictions require reinforcement through institutional policies. Lapses in the enforcement of access control have been directly associated with increased biosecurity breaches and exposure risks (Biosecurity SOPs applied to the Faculty of Veterinary Medicine, Liège University, 2019; Stull *et al.*, 2018).

Stakeholder-specific access policy

To enhance clarity, access rules must be specified according to the stakeholder category:

Students: In clinical teaching areas, student access requires mandatory accompaniment by faculty member or designated veterinarians and is strictly conditioned on prior biosecurity training and compliance records. The biosecurity plan must explicitly define the protocols governing student access, including those enrolled in undergraduate and postgraduate veterinary programmes, as well as those participating in academic exchange initiatives. All students must receive training in institutional biosecurity protocols before being allowed into specific areas, and their continued access depends on demonstrated compliance.

Faculty and clinical staff: Access is defined according to zone and role and is enforced through identification badges and access-controlled doors. Strict compliance with movement rules and PPE requirements for each zone is mandatory.

Visitors (general/external observers): Access is by escort only, following a brief induction on local rules. They are strictly excluded from high-risk zones. A unique aspect of VTHs is the presence of visiting professionals, such as external veterinarians undertaking continuing education or specialised clinical training. Unlike master's, doctoral, or exchange students who usually follow formalised university enrolment and access procedures, these professionals may lack institutional onboarding. As such, they must be provided with targeted biosecurity instruction upon arrival and must demonstrate understanding of core biosecurity protocols before being granted access to clinical areas.

Clients and animal owners: Entry to isolation units is not permitted; however, where design allows, indirect visual contact may be provided (e.g., observation windows) under supervision and without compromising containment. The presence of animal owners in isolation areas is a contentious but critical issue in biosecurity planning. In general, owners should not be permitted to enter isolation units. However, where facility design allows, indirect visual contact (e.g., through internal windows or observation corridors)

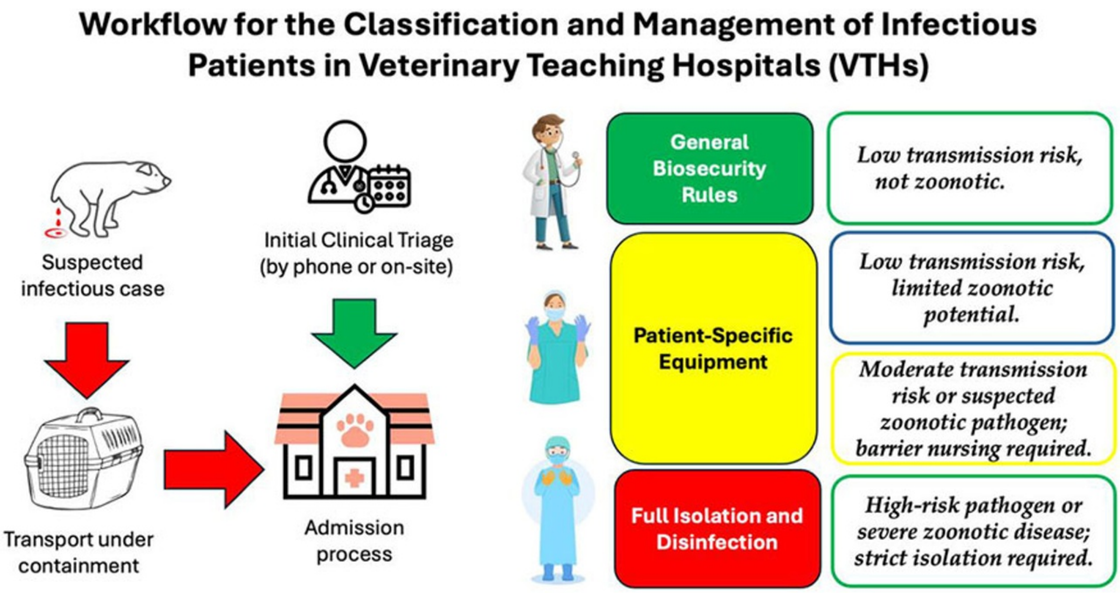

Figure 1. Workflow for the classification and management of infectious patients in Veterinary Teaching Hospitals (VTHs).

may help reduce owners' anxiety without compromising containment measures.

At-risk individuals (e.g., immunocompromised or pregnant): An individual risk assessment is required before assigning tasks involving infectious patients or high-risk materials, and measures must align with occupational health policies and data-protection rules. Particular consideration must be given to at-risk individuals, who may include students, veterinary staff, or animal owners. These cases must be carefully managed within the institutional health and safety policies and in full compliance with data protection regulation, especially regarding the confidentiality of health-related information (Stull and Stevenson, 2015).

Industry representatives and external service providers: Access requires pre-registration, targeted biosecurity instruction on arrival, and escorting, and is restricted to approved zones and time windows. Entry to high-risk areas is prohibited unless expressly authorised by the Biosecurity Officer and in full compliance with SOPs.

While Fig. 1 provides a schematic overview of patient classification and management, detailed, practice-oriented recommendations on the use of PPE – adapted to different user groups such as students, clinical staff, support personnel, and visitors – are provided in Section 4.5. This section specifies colour-coded attire, footwear policies, isolation protocols, and tailored PPE requirements, thereby ensuring that all populations within the VTH receive clear and context-appropriate guidance.

Controlled access to high-risk areas

Surgical suites

Operating theatres represent critical zones where strict biosecurity measures must be enforced to prevent surgical site infections (SSI) and nosocomial transmission of pathogens. All individuals entering surgical areas must wear designated surgical scrubs, caps, masks, and dedicated footwear. Access must be restricted to authorised personnel only, and movement into and out of the theatre during procedures should be kept to an absolute minimum. All surgical instruments and surfaces must undergo validated cleaning and sterilisation protocols in accordance with international veterinary surgical standards (Anderson and Weese, 2016; Verwilghen and Singh, 2015). Preoperative patient preparation, including antiseptic scrubbing and proper draping techniques, remains essential to maintaining an aseptic environment.

Isolation units

The management of suspected or confirmed infectious patients in VTHs must follow established isolation protocols. Core procedures include initial external triage (e.g., keeping the patient in the vehicle until evaluated), the use of dedicated entry points for infectious cases, restricted access for animal owners, patient-specific equipment, and structured cleaning and disinfection routines.

- *Telephone-based pre-screening*: Appointment and arrival calls must include targeted questions to detect signs compatible with infectious disease. This approach is particularly applicable to equine and food-producing animals.
- *In-vehicle screening (large animals, where applicable)*: For equine or other large-animal patients, preliminary evaluation may occur while the animal remains in the trailer or in a designated holding area, reducing exposure in shared spaces. This method is not standard for companion animals.
- *Triage room screening with restricted access*: In small-animal hospitals, screening should take place in a dedicated triage room near reception, with controlled entry and clear zoning to prevent uncontrolled movement between biosecurity levels.

- *Client routing and area access restrictions*: After screening and provisional classification, clients must be routed according to the patient's risk level. Owners of infectious patients must not circulate through clinical areas, where feasible, observation facilities may be provided without compromising containment.

A major limitation in implementing these protocols is often the lack of adequate infrastructure or trained personnel. Therefore, institutions must invest in dedicated isolation facilities and ensure that staff are properly trained to manage infectious disease scenarios. Patients classified as Class 3 or 4 should never enter common areas; instead, they should be kept in carriers or vehicles until evaluated. Admission and reception personnel must be trained in appointment triage procedures, including telephone pre-screening. Clear, standardised signage is essential to prevent inadvertent entry of potentially infectious animals.

Veterinary staff must be familiar with clinical triage protocols and with the safe movement of patients to infectious examination rooms, which should be accessible via separate entrances that prevent contact with uninfected patients or visitors (Machado *et al.*, 2023). All patient transfers must be performed using sealed carriers or wheeled carts, thereby minimising environmental contamination. Owners are not permitted in the isolation area, and unnecessary personal items must be excluded.

Infectious patients requiring hospitalisation must be transferred directly into species-specific isolation rooms. Animals with external parasites, such as fleas or ticks, must be treated before admission. If infectious disease is ruled out after evaluation, the patient may be cleared for regular hospital entry. Animals with symptoms such as acute vomiting, diarrhoea, respiratory distress, or neurological abnormalities of suspected infectious origin must be considered contagious until proven otherwise. Screening diagnostics should be performed before hospital admission when feasible.

Working in the isolation area

In isolation units, animals must be housed individually. Handling must always proceed from lowest to highest risk cases. Between patients, personnel must change PPE and disinfect their hands. Each patient must be clearly labelled, and a dedicated infectious patient logbook, including the pathogen (if known), classification level, and entry/exit staff registry, must be maintained for traceability (Burgess and Morley, 2015; Stull *et al.*, 2018). Access to isolation rooms should be via electronically controlled doors, ensuring that only authorised and trained individuals can enter.

Before entry, personnel must don full PPE in a designated changing area: gown, mask, cap, shoe covers, and gloves (after hand disinfection). Entry into clinical rooms must occur via a disinfectant footbath. Upon exiting, staff must follow correct doffing procedures, discarding PPE into biohazard bins and disinfecting hands and footwear. Glove removal must always be the final step.

In cases where animals require procedures in general hospital areas (e.g., CT scan), transport should be scheduled during low-traffic times. Personnel must change into new PPE before transport and follow strict movement protocols. Transport must be planned and communicated in advance: the patient should be moved in a carrier or covered cart; contact with other patients and staff must be avoided; and all touched surfaces must be disinfected immediately after transfer.

Given the educational nature of VTHs, students must be included in isolation protocols through supervised practice sessions. These should be designed to minimise risks while ensuring skill acquisition. All such training must be formally documented in clinical logbooks.

Behavioural rules in infectious areas

Unlike private veterinary hospitals, VTHs accommodate hundreds of students each year. Therefore, clear behavioural protocols must be established and strictly enforced. Eating and drinking are strictly prohibited in clinical areas. When breaks are taken, individuals must either change clothing or put on clean gowns before returning.

Students must avoid touching their face and ensure that any wounds or lesions are properly covered. Gloves must be worn over hand injuries. All users must receive training in both general and scenario-specific emergency procedures, including notification of VTH administration and external emergency services (e.g., phone 112).

Personal protective equipment guidelines adapted to biosecurity zones

PPE requirements are aligned with biosecurity zoning (see Section 3.1) and patient risk classification (Section 3.5), including barrier nursing for Class 3 and strict isolation for Class 4 (Section 3.6) (Stull *et al.*, 2018; Weese, 2004). The consistent and appropriate use of PPE, together with regulated professional attire, constitutes a cornerstone of effective biosecurity within VTHs. Scientific literature strongly supports that visual differentiation of workwear through colour coding and the routine laundering of clinical clothing significantly reduce the risk of cross-contamination between clinical areas and between hospital and community settings (Weese, 2004). PPE prompts, room type, and signage are automatically generated within the EMR at triage (see Section 3.8).

Students and staff must be explicitly instructed that commuting between home and the Veterinary Establishment must always be done in street clothes. Under no circumstances should clinical work attire – such as scrubs or PPE – be worn on public or private transport. To facilitate compliance, VEs should provide adequate changing rooms and personal lockers, thereby allowing the safe storage of personal belongings and the correct donning and doffing of professional clothing upon arrival and departure (Weese, 2004).

Clean zones

Standard clinical attire (colour-coded scrubs by service) and rigorous hand hygiene are required; gloves should be worn when exposure to body fluids is anticipated or when handling invasive devices. The VTH must implement a colour-coded scrub system for all personnel – particularly students – to prevent cross-use between incompatible areas (e.g., necropsy facility, farm, slaughterhouse, isolation ward) (Boerlin *et al.*, 2001; Singh *et al.*, 2013). Ideally, scrub standardisation should consider both the hospital area and staff role (e.g., surgeons, anaesthetists, students, technical assistants), thereby enhancing visual identification and minimising cross-contamination risks. Several accredited institutions, including the University of Liège (Belgium) and Davies Veterinary Specialists (UK), have successfully implemented such systems as part of their biosecurity frameworks (Biosecurity SOPs applied to the Faculty of Veterinary Medicine, Liège University, 2019). This system facilitates visual identification of staff roles and helps limit microbiological cross-contamination across functional zones. In colder climates, thermal underlayers should always be worn beneath, rather than over, the designated scrubs.

Semi-clean zones

For routine patient contact, staff should wear gloves and a gown; with a mask and eye protection added when required by procedural risk (e.g., risk of splashes or during close respiratory examinations).

Dirty/isolation zones (Classes 3–4)

Barrier nursing must be implemented: gown and gloves for all contact; surgical/procedure mask and eye protection as indicated; FFP2/N95 respirator for aerosol-generating procedures; placement in negative-pressure or otherwise segregated rooms, where available; and the maintenance of entry logs (see Section 3.6).

Footwear and outerwear

All staff and students must wear closed-toe, hospital-only footwear in clinical areas; external shoes are prohibited beyond designated changing zones. Designated changing areas for donning and doffing scrubs must be established. These should be strategically located between clean and contaminated zones, clearly signposted, and equipped with adequate waste disposal facilities to ensure the safe handling of potentially contaminated clothing and PPE. In addition, the wearing of jewellery – including rings, bracelets, and necklaces – is not permitted. Piercings must be removed or covered with adhesive dressings. Hair must be secured and fingernails kept short and unpolished. These measures are intended to minimise fomite-mediated pathogen transmission. Notably, personnel who wear rings have significantly higher microbial loads on their hands, even after washing, than those without rings, supporting strict enforcement of these policies (Anderson, 2015).

Availability and identification

All individuals present in the VTH must wear clearly visible institutional identification badges at all times. In designated isolation units, or during the handling of high-risk patients, disposable PPE – including gowns, gloves, caps, shoe covers, and masks – must be readily available and used in strict accordance with SOPs.

Additional restrictions

The presence of personal companion animals within VTH premises is strictly prohibited. Such animals may carry zoonotic pathogens or act as mechanical vectors of environmental contaminants, thereby compromising the integrity of the hospital's infection-control protocols. Exceptions should be strictly regulated and limited to patients under formal admission and supervision. However, service animals accompanying individuals with disabilities (e.g., guide dogs) must be accommodated in accordance with applicable legal provisions. In these cases, reasonable adjustments should be provided while ensuring that biosecurity risks are adequately controlled, particularly by restricting access to high-risk zones such as infectious disease units or surgical theatres.

Additional attire and hygiene requirements

To further minimise biosecurity risks, the following requirements must be strictly enforced:

- *Internal laundering*: Colour-coded uniforms must be laundered exclusively on hospital premises or via contracted institutional services. Home laundering is not permitted.
- *Mandatory change between incompatible zones*: Uniforms must be completely changed when moving between areas of differing sanitary risk, particularly between clinical blocks, necropsy facilities, outdoor facilities, and isolation units.
- *Footwear specifications*: Footwear must be closed-toe, waterproof, washable, and used exclusively within the hospital. PVC boots or clinical clogs are acceptable options.
- *External garments*: Laboratory coats or jackets used in clinical areas must be washable, sector-specific, and kept on-site for institutional laundering.
- *Body modification protocol*: When piercings cannot be removed, they must be covered with a sterile adhesive dressing, which must be changed daily.

Cleaning, disinfection, and environmental hygiene.

Cleaning staff must receive specific training aligned with biosecurity protocols.

- *Hand hygiene*: Staff must maintain short nails and avoid excessive jewellery. Soap and hand sanitiser dispensers must be available in all isolation areas (Anderson, 2015). To verify cleaning efficacy, some VTHs employ ATP bioluminescence tests or environmental culture sampling, allowing real-time assessment of disinfection effectiveness (Burgess *et al.*, 2004; Traverse and Aceto, 2015).
- *Patient hygiene*: Animal areas must be kept clean. Biological materials (blood, faeces, urine) must be removed, and surfaces cleaned, dried, and disinfected using agents such as Virkon® S (allow 10 minutes contact time) (Geraldes *et al.*, 2021). Waste generated in clinical areas, including potentially infectious materials, must be handled and disposed of in accordance with established veterinary clinical waste management protocols, ensuring segregation, safe storage, and removal by authorised personnel, as recommended by international veterinary guidelines (Weese, 2015; Biosecurity SOPs applied to the Faculty of Veterinary Medicine, Liège University, 2019; Terrestrial Code Online Access – WOAH – World Organisation for Animal Health 2024; AVMA, n.d.).
- *Equipment disinfection*: Cages and feeding accessories must be cleaned daily or as needed. Soapy water followed by Virkon® S for 15 minutes ensures disinfection (Dunowska *et al.*, 2005). External equipment must not be introduced into isolation unless disinfected. Alternatives include 0.5% chlorhexidine solutions (Geraldes *et al.*, 2021). Shared tools must be disinfected between patients.
- *Floor and wall hygiene*: Floors should be swept, washed with detergent (15%), rinsed, and disinfected using 5% bleach, followed by through drying to prevent microbial persistence and surface damage. Quaternary ammonium spray may be applied upon exit from isolation rooms (Traverse and Aceto, 2015). Walls (e.g., tile) should be cleaned using dedicated sponges soaked in 0.5% bleach while wearing gloves and goggles. After use, sponges should be immersed in 10% sodium hypochlorite for 10 minutes, rinsed, and dried (Traverse and Aceto, 2015).

These measures ensure that the hospital's-built environment supports effective biosecurity practices and minimises fomite transmission. Detailed comparative analyses of detergents, sanitisers, and disinfectants by active ingredient and spectrum of antimicrobial activity are available in the specialised literature (e.g., Traverse and Aceto, 2015; Weese, 2015) and guidelines (Stull *et al.*, 2018). Given that the aim of this review is to provide governance-oriented and structural recommendations, product-specific guidance was not included here. Institutions are strongly encouraged to consult those resources when designing or updating their cleaning and disinfection protocols.

To facilitate implementation, we provide Supplementary Table S1 summarising recommended detergents, sanitisers, and disinfectants by hospital area and biosecurity level, organised by active ingredient and indicating spectrum of activity (bactericidal, virucidal, fungicidal, sporicidal).

Monitoring and feedback

Each VTH must implement a formal monitoring and control programme to ensure the effectiveness of its biosecurity system (Benedict *et al.*, 2008). Although the measures can be very extensive – ranging from monitoring surgical-site infections (Verwilghen and Singh, 2015) to studies on antibiotic resistance (Guardabassi and Prescott, 2015) – the minimum components include:

- *Environmental surveillance*: Biannual sampling of surfaces in isolation rooms for pathogens such as *Salmonella* spp. and methicillin-resistant *Staphylococcus* spp. is recommended (Benedict *et al.*, 2008; Burgess and Morley, 2015; Burgess *et al.*, 2004; Stull *et al.*, 2018; Worthing *et al.*, 2018). Environmental surveillance protocols should also include periodic sampling for multidrug-resistant organisms such as MRSP, MRSA, and ESBL-producing bacteria. The detection of these agents serves not only as an indicator of infection-control efficacy but also as a sentinel marker for emerging AMR within clinical environments (Guardabassi and Prescott, 2015; Worthing *et al.*, 2018).
- *Lessons learned sessions*: A biannual review of clinical cases managed in isolation should be carried out, aiming to identify procedural improvements. In addition, onboarding for all new staff must include a dedicated training module on VTH biosecurity protocols.

Antimicrobial stewardship within biosecurity frameworks

Effective antimicrobial stewardship (AMS) is inseparable from biosecurity. Robust infection-prevention practices reduce inappropriate antimicrobial use, while stewardship limits the selection and dissemination of resistant organisms within VTHs (Burgess and Weese, 2021; Guardabassi and Prescott, 2015; Stull *et al.*, 2018; Weese, 2015; Worthing *et al.*, 2018). Recent evidence confirms that nosocomial infections in veterinary hospitals are frequently caused by multidrug-resistant bacteria. According to Sfaciotte *et al.* (2023) pathogens such as MRSA, MRSP, VRE, and ESBL-producing Enterobacteriaceae are recurrently isolated from veterinary clinical environments, often linked to environmental contamination and cross-transmission. Similarly, Sebola *et al.* (2023) identified *Staphylococcus* spp. as the most common agents of hospital-acquired and zoonotic infections, with a high prevalence of multidrug resistance. These findings highlight the need to integrate nosocomial infection surveillance and AMR monitoring within VTH biosecurity programmes. This section outlines the governance, operational, and educational measures required to embed AMS into daily biosecurity practice.

Governance and policy

VTHs must adopt an institutional AMS policy aligned with national regulations and professional guidance, clearly defining the roles of a multidisciplinary AMS team (clinical leads, microbiology/infectious diseases, pharmacy/dispensing, biosecurity officers, nursing/technicians, and education leads). The policy should also specify formulary oversight, escalation pathways for complex cases, and audit/feedback cycles, integrated within biosecurity monitoring systems (Guardabassi and Prescott, 2015; Stull and Weese, 2015).

Prudent prescribing and diagnostics

Clinical decision-making should prioritise diagnosis-driven therapy, including targeted sampling before initiating antimicrobials whenever feasible, the use of local antibiograms, and prompt narrowing or de-escalation once results are available. Empirical protocols must be indication-specific, time-limited, and subject to review within 48–72 hours. Perioperative prophylaxis in surgery should be strictly restricted to evidence-based indications and durations (Anderson and Weese, 2016; Verwilghen and Singh, 2015).

Perioperative antimicrobial prophylaxis should be used selectively and time-limited, in accordance with surgical site infection (SSI) prevention bundles. Prophylaxis is not indicated for most *clean* procedures of short duration; it may be justified for clean procedures with implants or high-consequence failure, and for clean-contaminated procedures, but therapeutic regimens (not prophylaxis) are required for contaminated/dirty surgeries. When indicated, the regimen should consist of a single pre-incisional dose administered within 60 minutes before incision, with intraoperative re-dosing only when the procedure exceeds two drug half-lives or when there is major blood loss. Postoperative continuation beyond wound closure is not recommended, unless there is established infection or strong suspicion requiring culture-guided therapy. Agent selection should reflect the expected flora at the surgical site, local antibiograms, and patient risk factors, and must be integrated with SSI-prevention measures (asepsis, clipping/scrub protocols, theatre discipline) detailed in Section 4.4.1 (Anderson and Weese, 2016; Stull *et al.*, 2018; Verwilghen and Singh, 2015).

Surveillance and metrics

AMS indicators should be incorporated into routine biosecurity audits, including measures of antimicrobial consumption (e.g., DDDvet/DOT) by service or ward, appropriateness audits against local guidelines, and resistance-trend surveillance based on diagnostic submissions and environmental monitoring (e.g., MRSP/MRSA/ESBLs; Burgess and Morley, 2015; Guardabassi and Prescott, 2015; Worthing *et al.*, 2018). The use of dashboards providing regular feedback to clinical services fosters both transparency and continuous improvement (Shea and Shaw, 2012).

Infection-control linkages

AMS must be directly linked to isolation policies, patient risk classification (Classes 1–4), and movement restrictions. Early identification and prompt isolation of animals with suspected resistant infections (e.g., prior MRSP/MRSA colonisation or high-risk syndromes) reduce environmental exposure pressure and subsequent antimicrobial use. Cleaning and disinfection SOPs, together with strict hand-hygiene compliance, are integral AMS enablers, reducing both environmental pathogen load and transmission (Stull *et al.*, 2018; Traverse and Aceto, 2015; Weese, 2004).

Education and culture

Tiered training on AMS principles for students, interns/residents, nursing staff and clinicians should cover key elements such as diagnostic stewardship, empiric-to-targeted transitions, dose optimisation, and discharge prescriptions. Case-based learning, simulation exercises, and structured feedback from audits reinforce behaviours and ensure alignment with Day-One Competences (EAEVE, 2023; Stull and Weese, 2015).

Education and continuous training

Effective biosecurity depends not only on infrastructure and protocols but also on the competence, awareness, and compliance of all individuals operating within the VTH. For this reason, comprehensive education and continuous training in biosecurity must be fully embedded into undergraduate curricula, postgraduate programmes, and staff development initiatives (Core competencies for infection prevention and control professionals, 2020; EAEVE, 2023).

Biosecurity training should be delivered in a tiered and progressive manner, proportionate to the level of responsibility and patient contact. Initial training must be mandatory before students or personnel are granted to access clinical areas, and refresher courses should be scheduled at regular intervals (Kuhar *et al.*, 2024; Morley, 2002).

Training programmes must ensure that all students, veterinary professionals, technical personnel, and support staff demonstrate competence in several core domains. These include the classification of biohazards and patient risk categories; the correct procedures for donning and doffing PPE, with particular attention to sequence and contamination avoidance; and strict adherence to hand hygiene and general hygiene protocols, including clear indications for when soap and water should be used versus alcohol-based solutions. Equally important are the behavioural expectations required in different hospital zones, especially isolation units and operating theatres, as well as emergency biosecurity procedures such as spill response and the management of accidental exposures (Stull and Weese, 2015; Weese, 2015).

Biosecurity training programmes should incorporate education on AMR, emphasising the link between infection-prevention practices and the control of antimicrobial-resistant pathogens (Guardabassi and Prescott, 2015; EFSA 2024). Training must foster an understanding that proper hygiene, patient classification, and isolation protocols are critical elements of antimicrobial stewardship.

Additionally, all VTH personnel should maintain up-to-date immunisation status for relevant zoonoses, such as rabies and tetanus, as part of occupational health protocols (Williams *et al.*, 2015).

To enhance the effectiveness of training, active learning methodologies should be prioritised. Simulation-based sessions for triage, PPE use, and infectious patient handling; video-based instruction modules for asynchronous learning; practical skills assessments integrated into clinical logbooks or Day-One Competency evaluations; and structured internal audits or biosecurity drills used both as training and monitoring strategies have all proven effective. Numerous studies have confirmed that simulation and audiovisual learning, coupled with structured feedback, significantly improve compliance and retention of biosecurity protocols in clinical settings (Stull and Weese, 2015).

Biosecurity must also be regarded as a dynamic and adaptative system. Lessons learned from incidents, outbreaks, or audit results should feed directly into continuous improvement processes. VTHs should foster a safety culture that encourages open communication about breaches or near misses and recognises excellence in adherence (Ruple-Czerniak *et al.*, 2013; Sammer *et al.*, 2010).

Continuing education is a cornerstone of a sustainable biosecurity programme. Training activities should be tailored to the specific needs of different professional groups, considering their roles, baseline knowledge, and level of exposure to infectious risks. For example, clinical staff require advanced training in IPC, outbreak response, and antimicrobial stewardship; students should receive integrated theoretical and practical training modules aligned with their curriculum; and administrative and support personnel should be instructed in procedures relevant to their duties and potential exposure. All continuing education activities must be systematically recorded, including participant attendance, frequency, and – where feasible – evaluations of knowledge acquisition and competency. Maintaining comprehensive training records supports compliance audits, identifies knowledge gaps, and enables targeted retraining, thereby reinforcing the sustainability and long-term effectiveness of the biosecurity programme.

In summary, training must not remain a theoretical exercise but function as a mandatory, auditable programme embedded in institutional governance, ensuring accountability and continuous improvement across all hospital services.

Recommendations and best practices

Based on the comprehensive analysis of current scientific literature, institutional protocols, and international standards, we propose the following evidence-based recommendations for VTHs to strengthen their biosecurity frameworks and align with best practices in veterinary clinical education and infection control.

Develop and disseminate an official biosecurity manual

As detailed in the *Core Elements of a Biosecurity Plan* section, the Biosecurity Manual constitutes the cornerstone of institutional IPC. It should compile all SOPs, emergency measures, and training requirements, and must be accessible in both printed and digital formats (EAEVE, 2023). To ensure its relevance, the manual should undergo regular review and updates, incorporating new scientific evidence, regulatory changes, and institutional experience. Dissemination should be facilitated through QR codes, internal platforms, and clear signage across all clinical areas.

Implement structured classification systems for patients and PPE

A standardised patient classification model based on infectious risk and zoonotic potential (e.g., Classes 1–4) should guide all decisions regarding isolation procedures, PPE requirements, disinfection protocols and movement restrictions (Guptill, 2015; Machado *et al.*, 2023). Standardisation of PPE use across hospital zones – linked to patient classification – ensures both safety and rational use of resources.

Strengthen antimicrobial stewardship within biosecurity frameworks

As detailed in Section 5, biosecurity protocols must be inherently aligned with antimicrobial stewardship principles. This includes promoting responsible antimicrobial prescribing, supporting the early detection and isolation of resistant pathogens, and integrating AMR surveillance into routine audits (Burgess and Weese, 2021; Guardabassi and Prescott, 2015). Effective infection control should be recognised as a cornerstone of combating AMR in veterinary medicine.

Establish a multidisciplinary governance and biosecurity committee

A dedicated Biosecurity Committee should be formed with representation from clinical staff, biosecurity officers, infection control experts, educators, and administrators. Its remits include compliance oversight, training, surveillance, incidents review, and continuous improvement (Stull *et al.*, 2018). Student representation may also be considered to promote engagement and feedback.

The committee should include senior institutional authorities (e.g., dean or VTH director), the Biosecurity Officer, academic representatives, and service heads, along with occupational health and facility managers. Increasingly, VTHs are incorporating the role of a hospital epidemiologist, responsible for monitoring compliance, analysing AMR trends, and investigating outbreaks. This role strengthens institutional capacity to detect emerging threats and embed a culture of continuous quality improvement. Multilevel surveillance studies in VTHs highlight the value of this approach in detecting persistent multidrug-resistant clusters and guiding targeted interventions (Scarpellini *et al.*, 2025).

Monitor compliance and provide constructive feedback

Routine audits, environmental sampling, and behavioural observations are essential to monitor adherence to biosecurity protocols. Sharing results constructively with all stakeholders, including students, foster transparency, and collective responsibility. Publishing internal compliance data, such as hand hygiene adherence or infection trends, has been shown to increase staff motivation (Machado *et al.*, 2023; Shea and Shaw, 2012). Structured feedback mechanisms (e.g., debriefs, anonymous reporting systems) enable benchmarking across departments and early identification of systemic gaps (Burgess and Morley, 2015).

Invest in infrastructure for isolation and hygiene

Robust infrastructure is fundamental for effective infectious disease management. VTHs should prioritise investment in purpose-built isolation units, decontamination areas, PPE stations, and traffic flow systems designed to minimise cross-contamination. Adequate ventilation, signage, and controlled access are key components of functional design (Anderson and Weese, 2016; Verwilghen and Singh, 2015).

Conduct periodic risk assessments and update sops

Comprehensive risk assessments must be performed at least annually, and always following any outbreak or biosecurity incident. These evaluations should consider facility vulnerabilities, behavioural risks, and pathogen circulation data, and must inform SOP revision (Worthing *et al.*, 2018). Lessons learned sessions and feedback loops should be institutionalised to ensure continuous improvement (Ruple-Czerniak *et al.*, 2013).

Conclusions

Biosecurity constitutes a fundamental pillar of patient safety, public health protection, and educational quality in VTHs. The unique integration of clinical, academic, and research activities within these institutions creates both opportunities and challenges for the implementation of infection-prevention strategies.

Although embedding structured biosecurity protocols into daily operations requires organisational effort, infrastructural investment, and cultural change, this review demonstrates that effective, evidence-based models – aligned with international standards such as those of the EAEVE – are already available and scalable across diverse institutional contexts.

Priority areas for intervention include the adoption of standardised risk classification systems, comprehensive staff and student training, systematic PPE management, purpose-built infrastructure for isolation and decontamination, rigorous environmental hygiene, and continuous monitoring mechanisms. In addition, the establishment of interdisciplinary biosecurity committees and routine risk reassessments foster a dynamic and responsive safety culture. Importantly, robust biosecurity frameworks also make a critical contribution to the global fight against AMR, positioning VTHs as key players in both clinical excellence and public health protection.

By embracing these measures, VTHs not only safeguard the health of animals and humans but also model best practices for the future generations of veterinary professionals. In doing so, they fulfil their ethical, pedagogical, and societal responsibilities, consolidating their role as leaders in the advancement of biosecurity in veterinary medicine and as key contributors to the One Health agenda through the training of future professionals.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S1466252325100030.

Data availability statement. Not applicable.

Funding statement. This research received no external funding. The APC was funded by University of Las Palmas de Gran Canaria.

Competing interest. The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Institutional Review Board Statement. Not applicable.

Informed Consent Statement. Not applicable.

References

Anderson M and Weese S (2016) Hospital-Associated Infections. In Griffon D and Hamaide A (eds), *Complications in Small Animal Surgery,* 1st Edn. Ames, Iowa: Wiley Blackwell, pp. 45–53. https://doi.org/10.1002/9781119421344.ch8

Anderson MEC (2015) Contact precautions and hand hygiene in veterinary clinics. *Veterinary Clinics of North America - Small Animal Practice [Internet]* **45**(2), 343–360. https://doi.org/10.1016/j.cvsm.2014.11.003

Anderson MEC, Wimmers M and Weese JS (2020) Infection prevention and control best practices for small animal veterinary clinics. 2nd Edn. Guelf; https://www.amrvetcollective.com/assets/your-practice/resources/OAHN-IPC-Guide-SB-Final-Jan0820_All_tagged-SUR.pdf?utm_source=chatgpt.com (accessed 10 August 2025).

AVMA (n.d.) AVMA policies relevant to waste disposal. https://www.avma.org/resources-tools/one-health/waste-disposal-veterinary-practices/avma-policies-relevant-waste-disposal (accessed 20 April 2025).

Banks D (2020) Biosecurity Policy [Internet]. [place unknown]; https://knowledge.rcvs.org.uk/document-library/dvs-infection-control-and-biosecurity/dvs-infection-control-and-biosecurity.pdf (accessed 22 March 2025).

Beeckman DSA and Rüdelsheim P (2020) Biosafety and biosecurity in containment: A regulatory overview. *Front Bioeng Biotechnol* **8**, 547059. https://doi.org/10.3389/FBIOE.2020.00650/BIBTEX

Benedict KM, Morley PS and Van MDC (2008) Characteristics of biosecurity and infection control programs at veterinary teaching hospitals. *Journal of the American Veterinary Medical Association* **233**(5), 767–773. https://doi.org/10.2460/javma.233.5.767

Biosecurity SOPs applied to the Faculty of Veterinary Medicine, Liège University (2019) Liege; https://www.fmv-biosecurite.ulg.ac.be/generale/?langue=en (accessed 20 April 2025).

Boerlin P, Eugster S, Gaschen F, Straub R and Schawalder P (2001) Transmission of opportunistic pathogens in a veterinary teaching hospital. *Veterinary Microbiology* **82**(4), 347–359. https://doi.org/10.1016/S0378-1135(01)00396-0

Burgess BA and Morley PS (2015) Veterinary hospital surveillance systems. *Veterinary Clinics of North America: Small Animal Practice* **45**(2), 235–242. https://doi.org/10.1016/j.cvsm.2014.11.002

Burgess BA, Morley PS and Hyatt DR (2004) Public veterinary medicine: Public health environmental surveillance for salmonella enterica in a veterinary teaching hospital. *Veterinarni Medicina* **225**(9), 1344–1348.

Burgess BA and Weese JS (2021) Prevention of infectious diseases in hospital environments. In Sykes JE and Greene CE (eds), *Greene's Infectious Diseases of the Dog and Cat*, 5th Edn. St. Louis, Missouri: Elsevier, pp. 171–186. https://doi.org/10.1016/B978-0-323-50934-3.00015-X

Chetri S, Bano N and Rekha MM (2023) Supporting triage of infected dog patients in a veterinary disease control unit: Epidemiological Analysis and Recommendations. *Revista Electronica de Veterinaria* **24**(2), 305–316.

Core competencies for infection prevention and control professionals (2020) *Geneva*. http://apps.who.int/bookorders. (accessed 20 August 2025).

Driscoll T, Nelson DI, Steenland K, Leigh J, Concha-Barrientos M, Fingerhut M and Prüss-Üstün A (2005) The global burden of disease due to occupational carcinogens. *American Journal of Industrial Medicine* **48**(6), 419–431. https://doi.org/10.1002/AJIM.20209

Dunowska M, Morley PS and Hyatt DR (2005) The effect of Virkon®S fogging on survival of Salmonella enterica and Staphylococcus aureus on surfaces in a veterinary teaching hospital. *Veterinary Microbiology* **105**(3), 281–289. https://doi.org/10.1016/j.vetmic.2004.11.011

EAEVE. (2023) Standard Operating Procedure 2023 European System of Evaluation of Veterinary Training (ESEVT) [Internet]. Leipzig; https://www.eaeve.org/fileadmin/downloads/SOP/SOP_2023/ESEVT_SOP_2023_adopted_by_the_36th_GA_in_Leipzig_on_8_June_2023__Annex6_mod._ExCom_07.04.2025_.pdf (accessed 20 April 2025).

Easty AC, Coakley N, Cheng R, Cividino M, Savage P, Tozer R and White RE (2015) Safe handling of cytotoxics: Guideline recommendations. *Current Oncology* **22**(1), e27–e37. https://doi.org/10.3747/CO.21.2151

ECDC EFSA and EMA (2024) Antimicrobial consumption and resistance in bacteria from humans and food-producing animals: Fourth joint interagency report on integrated analysis of antimicrobial agent consumption and occurrence of antimicrobial resistance in bacteria from humans and food-producing animals in the EU/EEA (JIACRA IV – 2019–2021). *EFSA Journal* **22**(2), 8589. https://doi.org/10.2903/j.efsa.2024.8589

Elchos BL, Scheftel JM, Cherry B, Debess EE, Hopkins SG, Levine JF and Williams CJ (2008) Compendium of veterinary standard precautions for zoonotic disease prevention in veterinary personnel. *Journal of the American Veterinary Medical Association* **233**(3), 415–432. https://doi.org/10.2460/javma.233.3.415

Freitas FP, Koehncke NK, Waldner CL, Belotta A, Lanovaz J and Mayer MN (2021) A 7-min video training intervention improves worker short-term radiation safety behavior during small animal diagnostic radiography. *Veterinary Radiology and Ultrasound* **62**(1), 27–36. https://doi.org/10.1111/vru.12927

Fung V and Seneviratne M (2016) Regulatory verification on safe use of cytotoxic drugs in veterinary clinics and animal hospitals. *Australian Veterinary Journal* **94**(11), 400–404. https://doi.org/10.1111/avj.12515

Geraldes C, Verdial C, Cunha E, Almeida V, Tavares L, Oliveira M and Gil S (2021) Evaluation of a biocide used in the biological isolation and containment unit of a veterinary teaching hospital. *Antibiotics* **10**(6), 639. https://doi.org/10.3390/antibiotics10060639

Guardabassi L and Prescott JF (2015) Antimicrobial stewardship in small animal veterinary practice: From theory to practice. *Veterinary Clinics of North America: Small Animal Practice* **45**(2), 361–376. https://doi.org/10.1016/j.cvsm.2014.11.005

Guptill L (2015) Patient management. *Veterinary Clinics of North America: Small Animal Practice* **45**(2), 277–298. https://doi.org/10.1016/j.cvsm.2014.11.010

Kandel-Tschiederer B, Kessler M, Schwietzer A and Michel A (2010) Reduction of workplace contamination with platinum-containing cytostatic drugs in a veterinary hospital by introduction of a closed system. *Veterinary Record* **166**(26), 822–825. https://doi.org/10.1136/VR.B4871

Kuhar DT, Babcock H, Mays Brown V, Carrico R, Conner M, Myers Cox K, Daniels N, Dekker E, de Perio MA, Anne Preas M et al. (2024). Infection control in healthcare personnel: Epidemiology and control of selected infections transmitted among healthcare personnel and patients centers for disease control and prevention national center for emerging and zoonotic infectious diseases division of healthcare quality promotion. [place unknown].

Machado IC, Nunes T, Maximino M, Malato J, Tavares L, Almeida V, Sepúlveda N and Gil S (2023) Epidemiologic factors supporting triage of infected dog patients admitted to a veterinary hospital biological isolation and containment unit. *Veterinary Sciences* **10**(3). https://doi.org/10.3390/vetsci10030186

Marsh AE and Babcock S (2015) Legal implications of zoonotic disease transmission for veterinary practices. *Veterinary Clinics of North America: Small Animal Practice* **45**(2), 393–408. https://doi.org/10.1016/j.cvsm.2014.11.008

Mayer MN, Koehncke NK, Belotta AF, Cheveldae IT and Waldner CL (2018) Use of personal protective equipment in a radiology room at a veterinary teaching hospital. *Veterinary Radiology and Ultrasound* **59**(2), 137–146. https://doi.org/10.1111/VRU.12583

Morley PS (2002) Biosecurity of veterinary practices. *Veterinary Clinics of North America: Food Animal Practice* **18**(1), 133–155. https://doi.org/10.1016/S0749-0720(02)00009-9

Renault V, Humblet MF and Saegerman C (2021) Biosecurity Concept: Origins, Evolution and Perspectives. *Animals* **12**(1), 63. [accessed 2025 Apr 26]. https://doi.org/10.3390/ANI12010063

Ruple-Czerniak A, Aceto HW, Bender JB, Paradis MR, Shaw SP, Van Metre DC, Weese JS, DA W, Jh W and Morley PS (2013) Using syndromic surveillance to estimate baseline rates for healthcare-associated infections in critical care units of small animal referral hospitals. *Journal of Veterinary Internal Medicine* **27**(6), 1392–1399. https://doi.org/10.1111/JVIM.12190

Sammer CE, Lykens K, Singh KP, Mains DA and Lackan NA (2010) What is patient safety culture? A review of the literature. *Journal of Nursing Scholarship* **42**(2), 156–165. https://doi.org/10.1111/J.1547-5069.2009.01330.X

Scarpellini R, Cordovana M, Ambretti S, Esposito E, Mondo E, Giunti M and Piva S (2025) Epidemiological Multilevel Surveillance of Methicillin-Resistant Staphylococci in a Veterinary Teaching Hospital and First Characterization of Staphylococcus Pseudintermedius Isolates Using IR Biotyper® [Internet]. [accessed 2025 Aug 10]. https://doi.org/10.2139/SSRN.5336868

Sebola DC, Oguttu JW, Kock MM and Qekwana DN (2023) Hospital-acquired and zoonotic bacteria from a veterinary hospital and their associated antimicrobial-susceptibility profiles: A systematic review. *Frontiers in Veterinary Science* **9**, 1087052. https://doi.org/10.3389/FVETS.2022.1087052/FULL

Sfaciotte RAP (2023) Nosocomial infection in veterinary medicine: A rare event or neglected by veterinarians? *International Journal of Zoology and Animal Biology* **6**(1), 1–15. https://doi.org/10.23880/izab-16000432

Shea A and Shaw S (2012) Evaluation of an educational campaign to increase hand hygiene at a small animal veterinary teaching hospital. *Journal of the American Veterinary Medical Association* **240**(1), 61–64. https://doi.org/10.2460/javma.240.1.61

Shirangi A, Bower C, Cdaj H, Preen DB and Bruce N (2014) A study of handling cytotoxic drugs and risk of birth defects in offspring of female veterinarians. *International Journal of Environmental Research & Public Health* **11**(6), 6216–6230. https://doi.org/10.3390/IJERPH110606216

Singh A, Walker M, Rousseau J, Monteith GJ and Weese JS (2013) Methicillin-resistant staphylococcal contamination of clothing worn by personnel in a veterinary teaching hospital. *Veterinary Surgery* **42**(6), 643–648. https://doi.org/10.1111/j.1532-950X.2013.12024.x

Smith BP, House JK, Magdesian KG, Jang SS, Cabral RL, Madigan JE and Herthel WF (2004) Principles of an infectious disease control program for preventing nosocomial gastrointestinal and respiratory tract diseases in large animal veterinary hospitals. *Journal of the American Veterinary Medical Association* **225**(8), 1186–1195. https://doi.org/10.2460/javma.2004.225.1186

Smith JM, Saegerman C and Vaillancourt JP (2023) Editorial: Promoting compliance with biosecurity in animal production. *Frontiers in Veterinary Science* **10**, 1215433. https://doi.org/10.3389/FVETS.2023.1215433/BIBTEX

Stull JW, Bjorvik E, Bub J, Dvorak G, Petersen C and Troyer HL (2018) 2018 AAHA Infection Control, Prevention, and Biosecurity Guidelines. *Journal of the American Animal Hospital Association* **54**(6), 297–326. https://doi.org/10.5326/JAAHA-MS-6903

Stull JW and Stevenson KB (2015) Zoonotic disease risks for immunocompromised and other high-risk clients and staff: Promoting safe pet ownership and contact. *Veterinary Clinics of North America - Small Animal Practice*. **45**(2), 377–392. https://doi.org/10.1016/j.cvsm.2014.11.007

Stull JW and Weese JS (2015) Hospital-associated infections in small animal practice. *Veterinary Clinics of North America: Small Animal Practice* **45**(2), 217–233. https://doi.org/10.1016/j.cvsm.2014.11.009

Terrestrial Code Online Access - WOAH - World Organisation for Animal Health. 2024. https://www.woah.org/en/what-we-do/standards/codes-and-manuals/terrestrial-code-online-access/ (accessed 20 April 2025).

Timofte D and Jepson RE (2024) PRO: Environmental microbiological surveillance does support infection control in veterinary hospitals. *JAC-Antimicrobial Resistance* **6**(4). https://doi.org/10.1093/JACAMR/DLAE113

Traverse M and Aceto H (2015) Environmental cleaning and disinfection. *Veterinary Clinics of North America: Small Animal Practice* **45**(2), 299–330. https://doi.org/10.1016/j.cvsm.2014.11.011

Verwilghen D and Singh A (2015) Fighting surgical site infections in small animals. are we getting anywhere? *Veterinary Clinics of North America: Small Animal Practice* **45**(2), 243–276. https://doi.org/10.1016/j.cvsm.2014.11.001

Weese JS (2004) Barrier precautions, isolation protocols, and personal hygiene in veterinary hospitals. *Veterinary Clinics of North America: Equine Practice* **20**(3), 543–559. https://doi.org/10.1016/j.cveq.2004.07.006

Weese JS (2014) Infection control and biosecurity in equine disease control. *Equine Veterinary Journal* **46**(6), 654–660. https://doi.org/10.1111/EVJ.12295

Weese JS (2015) Cleaning and disinfection of patient care items, in relation to small animals. *Veterinary Clinics of North America: Small Animal Practice* **45**(2), 331–342. https://doi.org/10.1016/j.cvsm.2014.11.004

Willemsen A, Cobbold R, Gibson J, Wilks K, Lawler S and Reid S (2019) Infection control practices employed within small animal veterinary practices – A systematic review. *Zoonoses and Public Health* **66**(5), 439–457. https://doi.org/10.1111/ZPH.12589

Williams CJ, Scheftel JM, Elchos BL, Hopkins SG and Levine JF (2015) Compendium of veterinary standard precautions for zoonotic disease prevention in veterinary personnel: National Association of State Public Health Veterinarians: Veterinary Infection Control Committee 2015. *Journal of the American Veterinary Medical Association* **247**(11), 1252–1277. https://doi.org/10.2460/JAVMA.247.11.1252

Worthing KA, Brown J, Gerber L, Trott DJ, Abraham S and Norris JM (2018) Methicillin-resistant staphylococci amongst veterinary personnel, personnel-owned pets, patients and the hospital environment of two small animal veterinary hospitals. *Veterinary Microbiology* **223**, 79–85. https://doi.org/10.1016/J.VETMIC.2018.07.021

Appendix 1. Illustrative examples of diagnoses/conditions for each category of infectious-risk classification in Veterinary Teaching Hospitals

(This list is non-exhaustive and intended for training and protocol development purposes)

Category	Risk description	Example diagnoses/ conditions
Category 1	Low transmission risk, not zoonotic	Non-infectious dermatopathies (e.g., allergic dermatitis in dogs and cats), endocrine disorders (e.g., hypothyroidism, hyperadrenocorticism, diabetes mellitus without concurrent infection), degenerative joint disease, idiopathic epilepsy, and intervertebral disc disease without infectious aetiology.
Category 2	Low transmission risk, limited zoonotic potential	Mild gastrointestinal parasitism (e.g., *Giardia* spp. in asymptomatic, non-shedding dogs), dermatophytosis under effective treatment with low spore load, bacterial conjunctivitis resolved with treatment, and *Corynebacterium bovis* mastitis in dairy cattle with appropriate control measures in place
Category 3	Moderate transmission risk or suspected zoonotic pathogen; barrier nursing required	Canine parvovirosis (suspected or confirmed), leptospirosis (acute stage, pending confirmation), dermatophytosis in actively shedding animals (cats, calves, horses), MRSP/MRSA wound infections, *Bordetella bronchiseptica* in dogs, *Chlamydia felis* in cats, and *Salmonella* spp. in foals or calves without systemic signs.
Category 4	High-risk pathogen or severe zoonotic disease; strict isolation required	Rabies suspicion, highly pathogenic avian influenza (HPAI) in poultry or birds of prey, confirmed *Salmonella* spp. with multidrug resistance and active shedding in large animals, *Bacillus anthracis* in ruminants, active *Mycobacterium bovis* infection in cattle or goats, African horse sickness in equids, highly virulent FMDV outbreaks in cloven-hoofed species.