Hospital biosecurity – a risk assessment approach or: how many isolation rooms do you really need?

Fiona Park, M.A.C.V.Sc (Avian Health)
Canley Heights Veterinary Surgery, cnr Harden St.and Avoca Rd., Canley Heights. NSW 2166.

What is the Problem?

Disease control within a veterinary hospital to reduce spread of disease between patients is a concern for any veterinary practice, and clinics seeing any avian caseload are no different. Avian practice does differ from small animal practice in that for dogs and cats there is a fairly well known range of contagious diseases such as parvovirus or cat flu, which are often suspected or risk of their presence recognised at clinical consultation (though a few diseases have carrier states eg FeLV, FIV, cat flu). Rapid in clinic tests for detection eg for parvo are available, and the need to isolate can often be an easy decision to make. Short incubation periods, having vaccines available to control spread, and often a full recovery after treatment of such small animal viral disease, also contrasts to the situation in avian practice.

The avian clinic has a lot more complex situation to deal with. Contagious diseases to consider include a multitude of avian viruses, with differing susceptibility or range for different taxonomic orders or families of birds, some with long incubations or carrier states, and with various or non-specific clinical effects and eventual or rapid death in cases despite treatment (see Tables 1-4). Rapid in house diagnostic tests for contagious disease are mainly limited to *Chlamydophila* testing, faecal parasite testing or gram stains. The patients are varied also, being individual pets, aviary birds or wild rehabilitation birds, all with differing disease risk concerns. At times the individual or associated flock has high economic value (or genetic value, in the case of endangered species). One of the contagious diseases likely to be seen, i.e. chlamydophilosis, is of zoonotic concern. The recognition of likely contagious avian cases to isolate is not as obvious, especially considering the presence of hard to detect carrier states. And veterinary clinics seeing bird patients range for example from small animal clinics seeing the very occasional bird, clinics with a high or all bird caseload, clinics with see other species such as reptiles, to zoo veterinary hospitals, captive breeding programs and rehabilitation centres. Some clinics will have a reasonable avicultural paediatric caseload, with the nestling patients very at risk of acquiring infections and taking them back to the nursery risking many other chicks. Cross species transfer (such as Salmonella between reptiles and birds) may be a further concern.

Can We Totally Eliminate Risk of Disease Transfer?

Many factors such as those above make biosecurity and disease control in an avian hospital a difficult subject to address. A recent article describes an avian hospital which boarded birds as well, having individual isolation rooms for each bird or group of birds from the same household. Emphasis was on prevention of potential aerosol transfer of disease, use of disinfectants, and some barrier nursing. Measures to reduce disease transfer included individual room ultraviolet air filtration and room air exiting to central HEPA air filtration, disposable aprons per room for staff, handwashing and foot bath protocols on entry and exit each room, use of chlorine disinfectants for cages and cage furniture between birds, cage equipment confined to each room, chlorine disinfection of equipment such as scales transferred between rooms, and some traffic control in that birds for admission were scheduled at times when other birds weren't being admitted (1). Without going to negative pressure rooms and full airlocks there is still potential for aerosols to spread. If

traffic flow is considered the examination rooms and admission or general common hospital areas could still potentially be a site of disease cross transfer, despite the obvious expense for the rest of the hospital setup. A lot of money could be spent to bring facilities up to strict human hospital isolation for each individual bird , but total elimination of any potential pathogen transfer is unlikely to be feasible, especially on a costs basis or for a clinic only seeing a few birds. Another approach could be through risk assessment and management to minimise potential transfer as much as possible, including assessment for specific cases to be isolated.

Human hospitals have detailed protocols for disease control, with input from epidemiologists for evidence based procedures based on patient classifications (2). For example, standard precautions are outlined for general hospital cases; with additional isolation precautions based on suspicion or diagnosis for certain disease categories (respiratory infectious disease, patients with resistant organisms, patients with all other known or suspected infectious disease, and immunocompromised patients) (3). Patients are recommended kept in negative pressure rooms for a few infectious diseases of concern such as pulmonary tuberculosis, smallpox, and SARS (3). Decisions to isolate can be based for example on history, clinical examination/assessment, and prior test results, which can allow suspicion (until otherwise ruled out) or diagnosis of contagious disease. For human hospitals, despite the protocols, approximately 5-10% of patients can acquire a surgical wound infection or transmissible infection after admission (3). In human hospitals, contagious disease transmission is rare except among immunocompromised patients (2).

Three categories of patients used within a university veterinary hospital are (a) animals with known highly contagious disease or suspected rabies, (b) animals suspected of contagious disease or at increased risk for acquiring infectious disease, and (c) animals with no historical, laboratory or physical examination evidence of infectious disease (4). Macaque monkeys were to be not hospitalised and were treated as outpatients only, except under extreme cases, because of disease transfer concerns (4). Other protocols included isolation of selected cases, traffic flow restrictions within the hospital (including car park triage of potential contagious cases, direct transfer from isolation to radiology or surgery areas for isolation cases, scheduling radiology or surgery of potential contagious cases for last or later in the day if possible), and some general restrictions including allocation of separate staff for contagious cases if possible. (4).

Hand washing is emphasised as extremely important in prevention of disease transfer in human and veterinary hospitals (3,4). Other procedures outlined for human hospitals include levels of barrier nursing (gowns, gloves, masks) and traffic/movement protocols for patients in the isolation categories (3). The pharmacy, radiology, postmortem, surgery and supplies storage areas are specifically mentioned for disease control protocols by a university veterinary hospital (4). Appropriate use of disinfectants and cleaners is one of several environment control strategies aimed to reduce incidence of hospital infections (2). Note that various disinfectants are not effective against all disease agents, e.g. psittacine beak and feather virus is quite resistant to many, and that disinfectants are less effective or ineffective in the presence of organic matter (5,6).

1. Factors to Consider in Disease Transfer Between Birds in Hospital

To consider the risk of disease transfer between avian patients in a simple manner, disease could be regarded as the result of interaction of the disease agent itself (the amount of the agent plus the nature of the agent), the bird's immunity, and the environment. (paraphrasing ref. 7).

Disease agents

Infectious disease agents which may be involved include viruses, bacteria, fungi, and parasites. For each, ideally evaluate the epidemiology. To control or eliminate a disease you need to be able to well define the disease, and for it be easily recognised or detected by a cheap and rapid test (8). Problems arise in that the epidemiology is not fully known for some agents, for some disease syndromes the infectious agent hasn't been identified yet (e.g. proventricular dilatation disease syndrome), and that new infectious diseases may always occur. It is only possible to work based on the current state of knowledge and be aware there may be unknowns. Also one needs to know what diseases are likely to be exotic to Australia, and what are likely to be common in Australian practice.

Disease risk assessment for import of psittacine birds into Australia has been evaluated by the Australian quarantine service, AQIS (9,10,11). Principles outlined in these assessments to evaluate chances of a bird having a disease prior to import, acquiring it during import, or consequences after import, might be useful when considering chances of infectious disease entry and spread in hospital. Evaluating risk for any disease, e.g. for endangered species programs, can involve assessment of how serious the disease is, how widespread, where it came from, whether it will persist, and it's implications (12).

Following from and extrapolating from these principles, it may help to consider:

(a) **Ability to Recognise the Bird Has the Disease Agent** – consider limitations of tests (13,14), including time to get a test result e.g. get a result days or weeks after the bird enters hospital. Few pathognomonic clinical presentations, often non-specific general signs of illness. Can develop index of suspicion at times e.g. parrot species with nasal discharge, respiratory signs, green diarrhoea beware chlamydophilosis (note that no test or test combination will reliably prove a bird is free of chlamydophila, and carriers are hardest to identify -17). Young galah with feather problems beware circovirus. Need knowledge of species susceptibilities plus clinical assessment more than just reliance on diagnostics – some diagnoses are only possible postmortem. Some rapidly fatal diseases may only be presented as dead birds for postmortem, or birds that die acutely after admission.

(b) **Carrier States Or Persistence of Shedding** e.g. especially Herpes viruses (12), also psittacine beak and feather disease/polyoma virus (15), others.

(c) **Methods of Acquisition Or Spread** – in particular: horizontal transmission via faecal/ingested, aerosols/inhaled, vectors (mechanical or transport only, or intermediate hosts), direct contact or environmental contamination by tissues (12). Some diseases are vertically transmitted e.g. retroviruses such as leucosis/REV in poultry, Mycoplasma, Salmonella, and some adenoviruses (12); but this transfer is not likely within hospital (though may have implications for breeding birds after hospitalisation).

Consider – pest control in the hospital, mosquito vectors hopefully excluded in

hospital. Spread as fomites on staff hands, clothes, instruments and equipment. Spread on cage furniture such as perches and dishes. Persistence in the environment or in the cage. Control of spread in aerosols or via inhalation is obviously harder than spread via direct contact or acquisition via faeces/ingestion.

Enveloped viruses are more fragile in the environment often needing close contact and involving carriers for their spread, in comparison to non-enveloped viruses (12).

(d) **Effects of the Disease** – treatable, controllable, low infectivity, not likely to cause high morbidity or mortality, not persist as a problem or as a carrier state, any zoonotic concerns; versus untreatable, likely to cause significant illness or even death, highly contagious. For example:

(i) chlamydophilosis can be treated with antibiotics but carriers and recurrence are a feature, plus there is zoonotic concerns and aerosol spread.
(ii) virulent avian influenza is exotic to Australia with huge potential impact if it occurs in the poultry industry, potential zoonosis, rapidly spreading with fatalities.
(iii) psittacine beak and feather disease virus (circovirus) can be fatal and result in long-term carriers, with no treatment to eliminate the infection once acquired, and is very persistent and robust in the environment.
(iv) ascarid infections – faecal spread, antiparasitics often effective though heavy burdens can cause debility and possible death, can persist in dirt floors of aviaries but far less so when concrete flooring is used.

The bird itself

May want to consider:

Species Susceptibilities	to infection, or to being a carrier or shedding the disease agent. Avirulently infected (hard to recognise if infected) or severely infected**.**
Age	young birds and especially nestlings often more seriously affected by or likely to acquire a particular disease.
Value	cherished household pet, high monetary or genetic value.

The environment

May want to consider (apart from in house procedures such as disinfection, airflow, barrier nursing, traffic flow etc) -

The Origin of the Bird and Where it Will Be Discharged to, such as –

(a) sole household pet – won't have contact with other pet birds, maybe limited but not close contact with wild birds if kept outdoors
(b) household pet in contact with particularly at risk humans (eg cancer or transplant patients), or if the bird is confirmed or suspected to have a zoonosis
(c) multibird households – other birds which may be exposed or pass on disease

(d) aviary birds – small aviary collections, high monetary value avicultural collections, large avicultural collections, avicultural collection with a nursery or nestlings, high genetic value aviary collection such as endangered species captive breeding programs

(d) wild or free ranging birds – casualty birds which come in from the wild state and may be released back into the wild. Concerns of what disease they may carry into captive bird populations, plus what disease they may acquire in captivity and take back into wild populations. Differing epidemiologies of diseases of captivity versus wild population disease, concerns about exposing wild populations of endangered species. Wild rehabilitation birds often are trauma victims with orthopaedic problems rather than disease but not always. In Australia wild birds include parrot species which are susceptible to diseases captive parrots may have, contrasting to countries in the Northern hemisphere which which don't have indigenous wild parrots populations.

(e) imported birds – legal or illegal, exotic disease concerns

Reducing Exposure to the Hospital Environment –

(a) Does the bird need admitting at all, considering there will be no way to feasibly assure absolutely no risk of disease transfer? Or to just admit briefly or consider outpatient treatment for a bird from an expensive collection, considering the need of the collection greater than the need for the individual bird to have full hospital treatment. In comparison, a highly cherished family pet it may be better to admit where the risks of not hospitalising are greater than the risk of disease transfer to the patient while in the hospital. Need to decide whether to board birds or not – i.e. admitting birds optionally to be exposed to the hospital environment. Screening of boarding birds – testing limitations again. Consider treatment of nestling birds as outpatients e.g. for crop surgery, as nestlings often highly susceptible to infectious disease effects.

(b) Triage cases before they get to the clinic, or when making house calls. Do house calls first in the day before entering the clinic so to reduce chances of bringing disease from the clinic to an aviary. Receptionists could schedule infectious cases (such as likely psittacine circovirus/PBFD cases) to be seen toward the end of the day if possible, e.g. clients which ring with a galah losing feathers and having beak problems. Similarly, try to work within the hospital from least at risk to most risk cases, or even have a different staff member to handle cases at risk of disease transfer.

Separation of Birds Or Bird Populations Inside the Hospital

Without isolating each individual bird on a room by room basis, the avian patients could at least be separated into several groups in separate rooms or areas. A decision should be considered on how many and which groups for each individual hospital's caseload.

e.g. Wild birds – different disease patterns and risks compared to captive birds.
Captive birds – high risks if acquired or of acquiring a disease (disease susceptibility on species or if very young, or high economic or genetic value), high risks of shedding a disease (possible import, clinical suspicion, carrier species for a particular high concern disease), a general hospital population.
Further categories?

Avian contagious diseases of concern warranting special precautions or isolation at Colorado State University veterinary hospital were avian paramyxoviruses, psittacine beak and feather disease, tuberculosis, proventricular dilatation syndrome, avian pox, influenza, Newcastle Disease, paramyxovirus –1 infection in pigeons, various herpesviruses, and chlamydophilosis (4).

2. Hospital Contagious Disease Considerations for Australian Avian Practice – Emphasis on Psittacine/parrot Species. (Refs used – 13,15,16,22, plus as cited).

Diseases

Viral

a. Psittacine Beak and Feather Disease/circovirus – commonly seen, carrier wild and captive parrots. Old World Parrots (African and Australasian parrots)/cockatoos mainly, rare in New World Parrots (African parrots). Acute disease/deaths in young if exposed and develop disease, acute liver disease in young, immunosuppression, chronic feather progressive changes in older birds which survive infection, or can become long-term carriers. Only a few species can clear infection once acquired, hence lifelong infection in most parrots once acquired. Very resistant to disinfection, persistent in environment. Of great concern, especially if young birds/nestlings exposed. Young cockatoos and African Grey parrots very prone to acute/peracute illness.

b. Polyomavirus – highly infectious disease of psittacine species mainly, highly fatal in young if develop disease, unapparent in adults. Can cause nonprogressive feather dystrophy. If disease in adults, often has underlying PBFD e.g. eclectus parrots. Very resistant to disinfection. Of great concern especially if young exposed.

c. Exotic diseases – psittacine pox (pox skin lesions, or diphtheritic form especially recently imported Amazon parrots overseas), insect or contact spread as per other pox viruses. Host specific to psittacine birds. Recovered birds not likely to be carriers.

d. Pacheco's Disease/Internal Papillomatosis Disease – ingestion/inhalation spread, probably all psittacine/parrot species susceptible but actual disease is species-specific. Some conures fairly resistant (eg Patagonian, nanday) and often implicated in outbreaks as a carrier source. Incubation 5-14 days (16), causes outbreaks of often birds dying very suddenly with liver necrosis. South American species (Amazon parrots, other conures, macaws), African Grey parrots, budgerigars and cockatiels fairly highly susceptible with high death rates overseas in outbreaks. Recovered birds likely to become lifelong carriers. Internal Papillomatosis Disease – mucosal papillomas of the gastrointestinal system of psittacine birds, especially of the cloaca. Mainly New World parrots (macaws, amazon parrots, conures), some cases will later develop bile duct carcinomas (16). Some cases in Australia recently, previously exotic.

e. Proventricular Dilatation Disease Syndrome (suspected viral) – inevitably die if develop clinical signs such as gastrointestinal stasis, vomiting, passage undigested seed, weight loss, can have CNS clinical signs. Sporadic or slow outbreaks in aviaries Especially African grey parrots, South America species (such as macaws, Amazons and conures), cockatoos overseas, but probably affects all parrots. Cause suspected viral, method of spread unsure (16).

f. Amazon Tracheitis – amazon parrots, severe dyspnoea and tracheitis.

g. Reovirus – severe hepatitis, especially in recently imported wild African Grey parrots overseas.

h. Notifiable exotic diseases – Newcastle Disease and Avian Influenza are highly contagious often fatal respiratory diseases, with wild bird carriers and devastating effects especially if they enter the poultry industry. Respiratory, gastrointestinal and neurologic signs can be involved, with up to high mortalities in poultry. Can infect probably all bird species. Parrots are moderately susceptible to Newcastle disease (mainly gastrointestinal signs, occasional respiratory or neurologic signs), but rarely get clinical Avian Influenza during outbreaks (16).

Bacterial, Fungal and Parasitic

a. Chlamydophilosis is the main bacterial disease of concern in parrot species. Plus commonly problems in pigeons. Most parrots have high background chlamydophila antibody levels, indicating prior exposure (14), and many parrot species are susceptible (17). Aerosol spread occurs after shed in droppings, eye/nasal/respiratory exudates; infection acquired by ingestion/inhalation; all birds sharing the same airspace should be considered exposed, though not all will develop infection. Susceptible to many disinfectants, unstable when exposed to heat or sunlight, except can be infectious for months when protected in dry faeces. Asymptomatic carriers are common, can get varying clinical disease with non-specific illness or respiratory and intestinal signs. Latent infection can become active if the bird is stressed or has other concurrent disease. Treatment with antibiotics for clinical effects, but won't eliminate all carrier states. (17).

b. Other bacterial diseases – large scale bacterial epidemics are uncommon in pet bird medicine, and are restricted to a few species, e.g. *Chlamydophila*, *Mycobacterium*, *Pasteurella*, some salmonella species, and *Yersinia pseudotuberculosis* (18). Bacterial and fungal infections of birds involve some primary infections, with others being opportunists of debilitated or immunocompromised hosts (19), e.g. *Aspergillus* sp and *Candida* sp. infections. Poor aviary management and hygiene is often a factor.

c. Parasitic diseases – endoparasites mainly faecal or blood-borne/biting insect spread, ectoparasite control.

Some local observations at Canley Heights Veterinary Clinic:

Black cockatoos	yellow-tailed seem very prone to severe chlamydophilosis, glossy black all ages prone to develop acute illness with PBFD.
Gang gang cockatoos	prone acute feather and beak dystrophy with PBFD, also sporadic mycobacterial infections.
Neophema sp	very prone to chlamydophilosis
Polyomavirus	in adult eclectus always have underlying PBFD. Many species of parrot nestlings dying acutely.

Some case examples to consider:

1. Relatively low value hand raised nestling (e.g. sun conure) from high value collection and high value nursery (macaws, other less common conures, amazons), with crop burn for crop surgery – do as outpatient/ admit for immediate surgery and discharge shortly after for home nursing rather than hospitalise for injectable fluids and aftercare? Risk exposure to disease which will be taken back to the nursery. Treat most nestlings as outpatients, with some exceptions?
2. Red tailed black cockatoo (high value aviary bird) not in critical state with heavy metal poisoning, some vomiting – outpatient treatment revisits for treatment vs stress/not feed well in hospital plus risk of contagious disease in hospital? A species that doesn't cope well with hospitalisation.
3. Seriously ill African Grey (high value and cherished pet), needs intensive and supportive care – hospitalisation in isolation, in area away from contagious disease isolation ward and away from general hospital ward.
4. Much loved galah with PBFD and ill with secondary infections – high risk contagion to other birds, but needing more than outpatient care. Hospitalisation in contagious disease isolation (but note concurrent immunosuppression, risk of other infections in hospital)?

Hospitalisation away from wild bird area (as wild rehabilitation cockatoos seen). Another isolation area?

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Table 1: Major Avian Viruses Affecting Certain Species

(Summary from Cross, ref 15, plus as cited. Not fully comprehensive)

Species	Systems Involved	Viruses/disease	Survival In Env
Gallinaceous Birds Mainly	Skin/nervous system	Marek's Disease	-
	Respiratory	Infectious bronchitis Infectious Laryngotracheitis (ILT) Turkey Rhinotracheitis Quail Bronchitis	Fragile (5) - - -
	Gastrointestinal	Rotavirus Coronavirus enteritis of turkeys Haemorrhagic viral enteritis of turkeys	Unsure (5) Fragile (5) -
	Liver	Inclusion Body Hepatitis (adenovirus)	Varies (5)
	Lymphoprolifer-ative viruses	Retroviruses, Marek's Disease (mainly poultry losses)	Unstable (5)
	Immunodeficiency viruses	Marek's Disease Infectious Bursal Disease of chickens Chicken Anemia Virus	- - -
	Nervous system	Avian Encephalomyelitis Turkey Meningoencephalitis	- -
Waterfowl Only (Anseriforms)	Skin	Papillomas of the webbing of feet (ducks)	-
	Gastrointestinal	Duck viral enteritis (ducks, swans, geese)	-
	Liver	Duck viral hepatitis (ducks only)	-
Pigeons Mainly	Respiratory	Pigeon Herpesvirus 1 (same herpes virus group as Owl herpesvirus, Falcon herpes)	-
	CNS/other	Pigeon paramyxovirus 1	-
Parrots Mainly, Only (Psittacine Sp.)	Skin	Psittacine Beak and Feather Disease (circovirus) – probably all parrots. Also pigeon and finch circoviruses occur. Psittacine polyomavirus – probably all parrots. Psittacine poxviruses (amazon pox, lovebird pox, budgerigar pox): EXOTIC	Robust (5) Stable (5) Stable in soil (5)
	Respiratory	Amazon tracheitis (herpes virus): EXOTIC A Bourke parrot herpesvirus seen here.	- -
	Gastrointestinal	Galah enterovirus (0ften associated with PBFD infection) Proventricular Dilatation Disease Syndrome (suspected viral): EXOTIC Internal Papillomatosis Disease/IPD (Psittacine Herpesvirus 1 associated –20): EXOTIC, but some cases here. IPD especially in macaws, amazons (21).	Robust (5) Unknown -
	Liver	Pacecho's Disease (Psittacine Herpes virus 1): EXOTIC – probably all parrots susceptible, especially South American and Australian parrots. Also PBFD virus, polyoma can cause hepatitis; IPD can result in bile duct carcinomas. PBFD also immunosuppresses	Fragile (5) -

Table 2: Major Avian Viruses Affecting Multiple Species
(Summary from Cross,ref 5. Plus other refs as cited)

SYSTEM AFFECTED	VIRUS	SURVIVAL IN ENV?
Skin	PBFD/circovirus in psittacines (also circovirus in finches, pigeons). Pox viruses – many bird species, different strains affect different spp. Named after main species affected. Papillomas on feet/legs – chaffinch, greenfinch, cockatoos, ducks. 1 case papillomas African grey parrot's head.	Robust (5) Stable in soil (5), robust (12) -
Respiratory (And Other Systems)	Newcastle Disease – probably all bird species, conjunctivitis in humans. Waterfowl carriers. Other paramyxoviruses. Avian Influenza A – probably all bird species, pigs, horses, seals, whales, mink, primates, humans. Waterfowl carriers.	Stable (5) - Unstable (5), fragile (12)
Gastrointest- Inal	Reovirus – chickens (tenosynovitis, hydropericardium), other birds enteritis and liver/spleen involvement, Amazon parrots chronic respiratory signs.	Stable (5)
Liver	Herpes viruses causing hepatic necrosis – many groups of herpes viruses, each group with certain bird host ranges.	-
Lymphoprol- Iferative Viruses		Can be unstable (5)
Neurologic	Newcastle Disease Avian Influenza A Eastern and Western Equine Encephalitis – all birds susceptible, espec poultry, passerine birds, waterfowl. Other arboviruses	

Table 3: Diseases Commonly Seen Or of Exotic Disease Concern in Australian Avian Practice (22,23)

Commonly seen:	
VIRAL:	PBFD, polyoma virus in psittacine spp.
BACTERIA:	Salmonella, E. coli, Chlamydophila, Pseudomonas
FUNGAL:	Aspergillus, Megabacteria, Candida
PROTOZOA:	Trichomonas, Giardia, Cochlosoma
PARASITES:	Ascarids, Capillaria, Cestodes, Cnemidocoptes mites, Airsac mites
Exotic diseases:	Newcastle Disease, Avian Influenza Psittacine birds – psittacine pox, Pacecho's disease-Internal Papillomatosis, reovirus, Proventricular Dilatation Disease,, Amazon Tracheitis waterfowl – Duck Viral Hepatitis, Duck Viral Enteritis, Goose parvovirus

Table 4: Viruses, System Affected, Transmission, Carriers

(Summarised and adapted from Cross, ref 15. Other refs listed)

Organ system, **Viruses**	Transmission/acquired by, some clinical features	Spp susceptible to clinical disease	Carriers?
	SKIN		
PBFD/ circovirus	Unknown how acquired, but postulated by inhalation, oral (16). Shed in feather dust, faeces. Minimum incubation 21 days. Acute and chronic forms. In many cases can diagnose or suspect by clinical exam as has such distinct pathologic features involving feather dystrophy and beak changes. Can have chronic progressive feather changes. Acute usually in nestlings, which can die. Mainly Old world parrots, rare reports in New World Parrots (13,16).	61+ psittacine spp. Some may recover from acute infection and seroconvert (love birds, rainbow lorikeets, eclectus, king parrots, budgerigars). Most don't recover. Pigeons, finches. Canary nestlings suspected (16)	Yes
Poxvirus	Via vectors: mosquitoes, mites, biting flies Via traumatised skin from contaminated food and water. Direct by ingestion scabs or inhalation aerosols. Numerous poxviruses, differing host ranges for each strain. Skin form: proliferative lesions unfeathered skin (face,legs). Diptheritic: oral cavity, trachea (13). Less common – systemic (16).	Many spp., named for main host spp. Including canaries, fowl, pigeons, psittacine spp. Wild birds, recently imported parrots (16). Psittacine pox – EXOTIC (22).	No – lifelong immunity after infection.
Polyomavirus	Horizontal transmission, also probably vertical. Most birds which survive acute phase make a full recovery but can shed. Shed in faeces, feather dust, possibly oral secretions; acquired likely by inhalation (16). Highly infectious (13). Nestling acute deaths, older birds feather changes or inapparent. Like PBFD virus, probably can cause disease in all parrot spp., but chronic progressive feather abnormalities are NOT a feature.	Psittacine spp. Also a polyoma virus like disease in Gouldian finches (16).	Yes. Infection persists in the kidneys of carriers, with intermittent shed in droppings.
Cutaneous papillomas, papilloma viruses	Papillomas of the skin of chaffinches and canaries – papillomavirus found on electron microscopy. Papilloma like growths on cockatoos feet, webbing of duck's feet – herpesvirus found on electron microscopy, but not proven to cause the lesions. Intestinal papillomatosis disease of psittacine spp. – see later. One case in African Grey parrot, head and eye papilloma – papillomavirus found. Other reports papillomalike lesions other parrots various parts of skin, but viruses not identified		

Table 4: Viruses, System Affected, Transmission, Carriers (Continued)

Organ system, **Viruses**	Transmission/acquired by, some clinical features	Spp susceptible to clinical disease	Carriers?
SKIN			
Herpes virus of skin	Marek's disease produces free virus in the feather follicle cells of chickens. See red skin follicles, raised nodules of neoplastic lymphocytes.	Chickens. Not reported in parrot species.	
RESPIRATORY SYSTEM Viruses that can primarily cause respiratory signs, or cause respiratory signs as part of systemic disease. Avipox,PMVs, orthomyxoV, coronaV, herpesV, adenoV			
Newcastle disease (PMV 1)	Acute, mild to severe disease, highly infectious. Virus survives well in sea or fresh water. Affects all ages of birds (5). Velogenic: diarrhoea, resp. signs, CNS signs later in older birds. Morbid/mortality to 100%. Oedema head. Mesogenic: mainly resp/GIT signs. Lentogenic: mild resp signs. DDxs: one ddx point – NO sinusitis; else ddx CNS signs (chlamydophila meningitis, salmonella purulent encephalitis encephalomalacia, lead toxicity, calcium deficiency), resp/GIT diseases. (5) Shedding mainly in faeces, though virus is in respiratory secretions also (5). Acquired by respiratory and gastrointestinal routes, vertical transmission possible (lentogenic and apathogenic strains) but rare with velogenic strains as birds stop laying (5). Mechanical transfer (wind, insects, humans, equipment) (5). Most common carriers wild waterfowl, parrots, some passerines, owls (5).	Probably all bird spp. susceptible, differing susceptibility to different strains, so any spp. can be a source for others. Highly virulent mainly in tropical birds especially tropical parrots. EXOTIC notifiable disease in Australia, of concern to poultry industry. (22).	Avirulent reservoir in waterfowl. Birds which live closely associated with water seem resistant to developing clinical signs. Persistent infections limited to weeks or months (5).

Table 4: Viruses, System Affected, Transmission, Carriers (Continued)

Organ system, **Viruses**	Transmission/acquired by, some clinical features	Spp susceptible to clinical disease	Carriers?
RESPIRATORY SYSTEM (Continued)			
Avian influenza	Excreted by respiratory and faecal routes, ocular secretions. Horizontal spread, including by contact direct or indirect. No vertical transmission as embryos die before hatch. All ages susceptible. Very contagious. Respiratory, GIT signs; neurologic signs only in adults; ascites; cyanosis; oedema head; acute death. Morbid/mortality to 100%. Virulence varies. Can be peracute with haemorrhages seen at postmortem (5). Can get sinusitis/swollen sinuses (5). DDx: resp/GIT pathogens, chlamydophila, paramyxovirus, Mycoplasma. (5).	Large host spectrum, many bird spp. (5) Range peracute disease to inapparent carriers. EXOTIC notifiable disease in Australia of concern to poultry industry (22).	Waterfowl, have inapparent intestinal infections. Carriers can shed for weeks (5). Wild bird carriers – waterfowl, passerines (5).
Infectious bronchitis	Very contagious, acute respiratory signs, few die. No neurologic signs. Inhalation spread. A coronavirus.	Chickens	
Infectious laryngotracheitis (ILT)	Highly contagious, severe respiratory signs,bloody tracheal exudate. All ages, some mortality. Acute onset. Herpesvirus.	Chickens, peafowl, pheasant.	Recovered birds lifelong carriers.
Amazon tracheitis	Thought ILT herpes virus variant. Acute respiratory disease, eye/nose discharge, dyspnoea, some die with tracheal blockage. DDx other respiratory disease (10).	Amazon parrots. EXOTIC to Australia (9).	
Turkey rhinotracheitis, quail bronchitis	Respiratory viruses	Turkey Quail	
Pigeon herpes virus	URT, possible liver involvement and general illness pigeons. High morbidity, low mortality. Same herpesvirus group as falcon and owl herpes virus.	Pigeons	Commonly get carriers.
GIT VIRUSES Few viruses solely affect the gastrointestinal tract, most involve the GIT as part of multi- organ disease.			
Of gallinaceous birds solely:	Rotavirus enteritis, coronavirus enteritis of turkeys, haemorrhagic enteritis(adenovirus) of turkeys.	Gallinaceous birds, turkeys	

Table 4: Viruses, System Affected, Transmission, Carriers (Continued)

Organ system, **Viruses**	Transmission/acquired by, some clinical features	Spp susceptible to clinical disease	Carriers?
GIT(Continued)			
Reovirus	Chickens: arthritis, tenosynovitis, hydro-pericardium. Other birds: enteritis, liver/splenic enlargement. Recently imported parrots acute outbreaks diarrhoea, oedema legs/head, deaths (16). Virus very resistant to disinfectants, not always pathogenic, but can be primary pathogen. (16).	Recently imported parrots, especially Old World parrots, African Greys (16). Other birds, poultry. Parrot form EXOTIC to Australia (22).	Survivors are potential carriers? (16).
Duck virus enteritis (herpes virus)	Acute, highly fatal, highly contagious herpes virus infection. Water main mode transmission. All ages affected, deaths mainly in adult breeders. Usually die quickly before can observe clinical signs. PM – see blood in intestines, petechiae heart and organs, haemorrhagic bands GIT.	Ducks, swans , geese. EXOTIC (22) DDx duck virus hepatitis, avian cholera, necrotic enteritis.	Lifelong carriers (as with other herpes viruses). Shed periodically.
Galah enterovirus	Sudden onset diarrhoea in galahs, many are juveniles and often have PBFD. Some recover if disease is mild.	Galahs	
Proventricular dilatation disease syndrome	Common psittacine disease in the northern hemisphere, virus suspected but not proven. GIT and neurologic signs, some have neurologic signs only. Thought possibly postviral immune mediated disease damaging nerves, classically see passage undigested seed, regurgitation, wasting and dilated proventriculus (16). Can have long incubation, cause not proven but suspect viral involvement,. most birds die. (16).	Psittacine species. Especially macaws, African greys, conures, cockatoos (16). EXOTIC to Australia (22).	Long incubation period possible.
LYMPHOPROLIFERATIVE VIRUSES Mainly losses in poultry. Marek's disease. Retroviruses – leucosis/ sarcoma group, reticuloendothelial virus, LPDT turkeys, leukemia virus Poultry. Other birds.			
IMMUNO-SUPPRESSIVE VIRUSES	PBFD/circovirus, Marek's disease, Infectious Bursal Disease of chickens, Chicken Anemia Virus. Replication in bursa, thymus, bone marrow.		
LIVER VIRUSES	Few viruses affect the liver alone, most affect other tissues as well. Other viruses which replicate in the liver can cause liver problems also e.g. PBFD, polyoma.	Primarily liver - Inclusion Body Hepatitis, Duck Viral Hepatitis, Pacecho's disease	
Inclusion Body Hepatitis	An adenovirus hepatitis	Chickens	

Table 4: Viruses, System Affected, Transmission, Carriers (Continued)

Organ system, **Viruses**	Transmission/acquired by, some clinical features	Spp susceptible to clinical disease	Carriers?
Duck Viral Hepatitis	A picornavirus. High mortality young ducklings up to few weeks old.	Ducks only EXOTIC (22)	Mallards carry but resistant
Herpes viruses associated with liver necrosis	Various antigen groups with particular host ranges, inclusion body hepatitis diseases. Shed in faeces/resp discharge, acquired by inhalation or ingestion- varies (5).	Group 5 viruses: Pigeon-, Owl-, Falcon- herpes. Group 6: Cormorant. Group 7: Quail-, Goose-. Group 8: Storks. Other hosts	Yes, often lifelong
Pacecho's disease of parrots	Psittacid herpesvirus 1 (Group 4 herpes), 3 genotypes. Acute hepatitis and death, high mortality outbreaks but not always fatal. Shed in faeces, eye/resp secretions, think acquired by inhalation/ingestion (16). Illness outbreaks regarded as EXOTIC to Australia, though couple of cases of Internal Papillomatosis Disease in Australia (see IPD). Nb: a psittacid herpesvirus 2 associated with African Grey Parrot skin papillomas cases overseas (20)	Probably all parrot spp, espec South American and Australian parrot species. High susceptible, sudden death – Amazons, cockatoo spp. Macaws – high susceptible, die after few days.	Conures, especially Nanday, Patagonian. Probably any recovered psittacine spp may become long term/ life carrier.
Internal papillomatosis disease (IPD)	Recent studies found consistently associated with psittacid herpesvirus 1 genotype 3, thought a different presentation of psittacid herpesvirus 1 disease (20). Cloacal and intestinal papillomas, with some cases later developing bile duct carcinomas (20). EXOTIC to Australia but recently a few local cases.	Many psittacine species. Highest incidence in neotropical species, especially Amazons and macaws (21).	Likely.
NEUROLOGIC VIRUSES. Many viruses in birds associated with neurologic disease, such as: Newcastle Disease, other paramyxo viruses, avian Influenza, Turkey meningoencephalitis EEE/WEE, other arboviruses, avian encephalomyelitis	Avian encephalomyelitis - poultry Turkey meningoencephalitis - turkeys Eastern and Western Encephaloencephalitis - all birds susceptible espec poultry, waterfowl, passerine birds. North and South America, arthropod vectors, rarely clinical disease in birds, reservoir for mammal infections. EXOTIC to Australia. Pigeon paramyxovirus 1 – Europe. West Nile disease – recent USA outbreak, insect vectors. Others.		