SUPPORTING THE AVIAN SURGICAL PATIENT – THE WHY AND HOW OF METHODS TO KEEP THEM ALIVE

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Anaesthesia and surgery involve exposing an already compromised animal to additional adverse conditions that could be the final factors affecting survival. A risk versus benefit decision has to be made for each surgical candidate.

Supportive care is used to attempt minimise adverse effects associated with anaesthesia and surgery. Analysis in the non-avian medical literature has found has found four major categories of factors for patient risk and complications during the surgical period. These are patient status, patient response to anaesthetic agents, monitoring and support of the patient during anaesthesia, and recovery from anaesthesia (Raffe 1995). Providing support to the surgical patient is not confined to just supportive care procedures during the anaesthetic period, but also involves evaluation of risks prior to anaesthesia and likely level of support needed, pre-anaesthetic supportive care, re-evaluation of care through monitoring intra-operatively, and post-operative monitoring and support.

For surgical patients, supportive care procedures mostly focus on maintaining body temperature (thermal support), circulation and blood volume (fluid therapy, blood transfusions), respiratory function and tissue oxygenation, and energy reserves (nutritional support, blood glucose levels) (Raffe 1995, Sinn 1994, La Bonde 1995, Taylor 2000a). Understanding the relevant physiology involved and how it is affected is important, especially for some of the unique differences between avian and mammalian patients.

Some Key Differences Between Avian and Mammalian Patients From A Supportive Care Aspect

The most notable differences between mammals and birds are the much smaller size of birds, and their higher metabolic rate in relation to any similar sized mammal (Cannon 1996). For birds, these differences mean heat loss under anaesthesia and any blood loss during surgery can be crucial factors for their survival. The smaller patient size and other factors may also restrict application of certain supportive care procedures (for example, limited or very small veins to access, practical difficulties at times may limit blood transfusions as an option, limits to safe amounts of blood to take for pre-operative assessment, stress response of birds to physical restraint limits handling for procedures immediately prior to anaesthesia or for post-operative support, and so on.)

Specific Factors Which Have Been Mentioned Over Many Years As Very Important for Successful Avian Surgery

- Minimise time under anaesthesia and surgery time (prepare everything beforehand, meaning have everything which possibly might be needed ready BEFORE induction)
- Using anaesthetics with rapid induction and recovery times (Cannon 1996, Wood 1994, Altman 1997, Taylor 2000a).
- Do quick surgical skin preparation (Rosskopf et al, 1996).

- Whenever possible use inhalant anaesthetics (isoflourane far better than halothane) (Taylor 2000a), rather than injectable anaesthetics.
- Main factor in amount of heat lost is the duration of anaesthesia and surgery (Wood 1994).
- Chances of survival are traditionally regarded as much reduced once surgery exceeds 20 minutes.
- Provision of warmth is essential (Cannon 1996, Wood 1994), even for short anaesthesia times (Taylor 2000a). Also reduce heat losses - via use of minimal or no alcohol for skin preparation (evaporative chilling), minimal necessary plucking of surgical site (removes insulation)
- Use of warmed rather than room temperature fluids for skin preparation and lavage
- Prevention of direct contact with cold surgical tables eg use of towels, circulating warm water blankets, hot water bottles, under the patient (Cannon 19996, Taylor 2000a, Boedeker etal. 2005)
- Should give fluid therapy (warmed fluids) (Boedeker et al. 2005)
- Gentle technique. It is crucial to have excellent haemostasis to minimise blood loss and shock (Cannon 1996, Taylor 2000c)
- Minimise stress and handling prior to anaesthesia (Taylor 2000a).

The above factors mainly relate to minimising effects of hypothermia and hypovolaemia for avian surgical patients. Greater degrees of hypothermia during anaesthesia are associated with smaller patients, longer surgical procedures, and infusion of cold fluids (Hoskins 1981); but the main factor is length of surgery time (Cannon 1996). In recent years there has been increased attention given to thermal support procedures for avian surgical patients, resulting in dramatic improvements reported for survival associated with very prolonged anaesthesia (Phalen et al. 1996, Rembert et al. 2001). Temperature monitoring during anaesthesia is important as part of achieving these improved outcomes (Taylor 2000c) . More attention has also recently focused on ventilatory support and intermittent positive pressure ventilation (IPPV) (Taylor 2000a, Chermonges-Kasembein 1999). However, meticulous attention to all aspects of pre-, intra-, and post-surgical support is essential for enhanced outcomes.

PRE-OPERATIVE ASSESSMENT AND SUPPORT

A vital aspect of surgical support is knowledge and awareness of potential risk factors associated with the particular patient, its condition, the anaesthetic regime, and effects of the proposed surgery. This allows pre-planning of supportive care for the patient. Thorough pre-operative assessment is important (Altman 1997), as well as knowledge of avian anatomy and physiology. Unfortunately pre-operative assessment is often overlooked (Taylor 2000c), and inadequate pre-operative assessment can be one of the commonest factors involved in the occurrence of problems associated with elective surgeries in birds (Bennett 1994). A problem to be aware of is that birds often hide signs of illness (“ the preservation reflex”). This means that the bird may harbour some underlying problem(s) not readily apparent before anaesthesia is induced. The extra stresses of anaesthesia and surgery on the bird’s body systems, added to the existence of underlying conditions unrecognised prior to induction, may well result in unexpected complications or decompensation.

Is Surgery Necessary, Or Should Surgery Be Delayed While the Bird is Stabilised?

Firstly, consider whether the anticipated procedure is necessary or whether the bird’s condition can be managed another way. Also consider that at times it is better to do a simpler procedure rather than a long technically more involved procedure, when the simpler procedure gives the bird better chance of surviving (Cannon 1996).

If surgery is required, assess how urgently it is needed, or whether it should be delayed to allow stabilisation of the bird. A good example is lipoma cases in cockatoos and galahs. Lipomas are associated with obese

birds that are not good surgical candidates. These birds are likely have fatty livers (i.e. impaired drug detoxification), poor blood clotting associated with reduced production of clotting factors by the liver, intra-abdominal fat compressing their airsacs (i.e .interferes with respiration), and probably artherosclerosis (i.e. cardiovascular system impairment). Lipomas can be treated by dietary means; surgery may not be essential unless the lipoma is becoming necrotic and infected, or ulcerated and bleeding. If necrotic and infected, or there is intermittent mild bleeding, it is often better to hospitalise and stabilise the bird for even a few days before surgery. If there is severe bleeding, you may not have that much time to stabilise beforehand - a judgement call.

Attempt to classify the risk level for the proposed anaesthetic and surgery (La Bonde 1995, Cannon 1996)

Anaesthetic Risk Categories

I. *Minimal risk*. Young, healthy, elective procedure
II. *Some risk*. Young, healthy, non-elective procedure; or healthy not young, elective procedure.
III. Risk present. Has an on-going health problem, elective or non-elective procedure
IV. Significant risk. Has a major health problem, undergoing any procedure
V. Critical. Involves life-saving procedures

Surgical Risk Categories

I. Short procedures such as restraint, sample collection, splint/bandage application. No potential for blood loss, short duration
II. Minor procedures such as minor lacerations, setting and splinting closed fractures, surgical sexing. Minor blood loss, short duration
III. More involved "external" procedures such as removal of cutaneous tumours and severe crop burns, oral or ocular procedures. Moderate potential for blood loss and increased duration
IV. Internal procedures such as abdominal exploratory, organ biopsy, hysterectomy, also orthopaedic. Prolonged anaesthesia, significant potential for blood loss.

These categories are useful in that they focus thought on the length of anaesthesia, potential for blood loss, severity of a procedure, and the patient's status. This helps pre-planning for the type and level of supportive care likely to be needed for the operative period. For example if a transfusion is likely to be needed, blood collection from a donor bird is better done prior to the surgical procedure (rather than during the surgery period when time is critical).

The extent of the pre-operative assessment and expected level of intra-operative supportive care can also be influenced by whether anaesthesia is likely to exceed 10 minutes. For short procedures a physical examination and history may be all that is required as pre-operative examination, but for major surgeries or procedures longer than ten minutes other tests may be indicated (Cannon 1996). Thermal support is needed with even relatively short procedures, as within ten to twenty minutes of induction most birds will suffer a reduction in core body temperature (Taylor 2000a). For procedures longer than 5 to 10 minutes, intubation with a non-cuffed endotracheal tube has been recommended if possible (Coles 2007a, La Bonde 2005), plus insertion of a venous or intra-osseous catheter to allow fluid and drug administration (Coles 2007a). Intubation is also recommended if the anaesthetic or surgical risk level is II or greater, but it may be preferable to use a face mask in small birds (due to the risk that very small sized tubes may block with respiratory secretions) (La Bonde 2005). As the tracheal rings in birds are complete and not able to expand, use of un-cuffed endotracheal tubes is recommended to minimise damage to tracheal mucosa (Taylor 2000a). A need for airsac intubation might be anticipated for cases of tracheal obstruction, or for surgery of the head and neck where access would be limited if a facemask or endotracheal tube was used (Sinn 1994).

Assessing the Patient's Status – the Pre-operative Examination

A thorough pre-operative clinical examination should be done with the aim to detect and correct any abnormalities prior to anaesthesia and surgery (Cannon 1996). A history should be taken, including current nutritional status and diet history (poor diet, any suspicious or possibly pathologic fractures, whether the bird been anorexic for more than 12 hours) (Taylor 2000a). The most common adverse reactions during avian anaesthesia involve cardiovascular and respiratory system function (Jaensch and Raidal 1997), thus evaluation of cardiovascular and respiratory status is essential. During examination of the bird especially note:

- Abnormal respiratory sounds
- Prolonged dyspnoea following handling (breathing should return to normal within 3 to 5 minutes after handling) (Cannon 1996).
- A return to normal respiratory rate within three to five minutes indicates respiratory stability likely adequate for most anaesthetic and surgery procedures (Bennett 1994).
- Signs of blood loss, abnormalities of cardiac function on auscultation and physical examination (Taylor 2000a). Anaemic birds may have pale feet and oral mucous membranes.
- Evidence of dehydration (Taylor 2000a). Note all ill birds should be regarded as having some degree of dehydration (Cannon 1996). Dehydration can be assessed by brachial vein filling or mobility of the skin.
- poor body condition or obesity (Cannon 1996).
- Abnormal droppings (Cannon 1996).
- Always note whether the crop is full on palpation prior to inducing anaesthesia. If the crop is full, either postpone anaesthesia (Sinn 1994), or make sure the bird's head is elevated during induction and surgery and intubate the bird (Taylor 2000a). Aspirating the crop prior to induction is seldom fully effective and can be very stressful for the bird (Taylor 2000a).

Poor risk cases include birds in obvious shock, obese birds, thin birds, birds with ascites or abdominal space occupying lesions, and most of all, birds with obvious dyspnoea or dyspnoea on handling (Coles 2007b). If the bird is dehydrated, has lost blood, had a poor diet, been anorexic, or has evidence of abnormal cardiovascular function, it should be admitted for supportive care prior to surgery (Taylor 2000a). Sometimes days or weeks of supportive care is needed to stabilise the patient before surgery, but this may not always be possible (Sinn 1994), for example, some critical cases. Birds have relatively small liver reserves of glycogen (Bennett 1994, Cannon 1996), and their high metabolic rates mean they rapidly use up their glycogen and fat reserves (Coles 2007c). Thin birds thus will have limited reserves to cope with the energy demands of maintaining their temperature during anaesthesia, surgical shock, and the very energy demanding post-operative shivering. Note that ascites and excessive abdominal fat can interfere with respiration through compressing the airsacs, aggravated when the bird is positioned in dorsal recumbency during anaesthesia (Sinn 1994).

For major surgeries or procedures longer than 10 minutes, laboratory testing should involve at minimum - PCV, total protein, glucose (especially raptors and waterfowl), and uric acid (Taylor 2000c). If there are concerning historic or physical examination findings, additional testing should include a full blood count, biochemistry profile and survey whole body radiographs (Taylor 2000c, Sinn 1994). Faecal parasite examination is also recommended (Cannon 1996), plus extra tests depending on findings (Sinn 1994). Blood clotting (bleeding time) can be tested by plucking a mature feather, which should normally not cause the feather follicle to bleed (Sinn 1994). Note that in some critical cases time constraints may not allow for much testing to be completed pre-operatively.

Surgery should be delayed if possible if uric acid levels are greater than 450 umol/L (30 mg/dL, suspect renal disease or dehydration; PCV and total protein will help differentiate dehydration from renal disease), AST is greater than 200 U/L (650 IU/dL), LDH is greater than 350 IU/L (600 IU/dl), or cholesterol levels are greater

than 700mg/dL. Birds with total serum protein of less than 2mg/dl are severely debilitated, and surgery may be potentially troublesome (Cannon 1996, Bennett 1994).

Pre-operative supportive care

If the PCV is less than 20%, surgery should be postponed or a blood transfusion given; and if the PCV is greater than 60%, suspect dehydration and give fluid therapy (Bennett 1994). Pre-surgical blood transfusions may be also indicated to provide clotting factors if intra-operative bleeding is likely and liver disease (and hence reduced production of clotting factors) is suspected e.g. lipoma surgery. Liver disease can be suspected from physical findings (obesity so likely to have a fatty liver, also sometimes associated with beak overgrowth or feather discolouration), reduced total serum protein, changes in bile acid levels (increased or decreased), liver tissue enzyme changes e.g. AST, and radiographic changes in liver size (Sinn 1994, Cannon 1996). For birds with a history of poor diet, liver disease, or delayed blood clotting Vitamin K can be given pre-operatively at doses of 1-2mg/kg every 24hrs (Taylor 2000a), e.g. again for lipoma surgery cases.

If the blood glucose level is less than 10mmol/L, defer surgery or prepare to give 2.5% glucose or 5% dextrose during surgery (Cannon 1996, Sinn 1994). If the bird has ascites (e.g. egg peritonitis cases), it is better to treat with needle aspiration and antibiotics over several days to a couple of weeks before operating. Ascitic fluid can enter the lungs through any tears in the airsacs during surgery, however removal of the ascites at the time of surgery can cause hypovolaemic shock (Cannon 1996). Reduction of ascites will also reduce compression of the abdominal airsacs, and so aid respiration under anaesthesia.

Blood collection for transfusion is best done pre-operatively if blood loss during surgery is anticipated, as there will not be the luxury of time available to do so midway through surgery. There is controversy, however, over the effectiveness of blood transfusions in birds with acute blood loss; with some thought that there may be equivalent or better response to intravenous crystalloids or colloids (Bos et al. 1990). Donor birds may not always be available, especially donors of the same species – donor birds of different species or taxons have been used at times.

The survival of a first transfusion of fresh red blood cells from same species donors into pigeons has been found to be seven days, in comparison to the normal avian red cell lifespan of 27 days (Finnegan et al. 1997). Transfused red cells from different species or genus donors into pigeons, raptors or parrots have been found to survive as short as 12 hours in the recipient, especially on repeat transfusions (Finnegan et al 1997, Morrisey et al. 1997). This may imply that heterologous transfusions are of minimal benefit except maybe briefly after acute haemorrhage, and homologous blood transfusions are of limited benefit after haemorrhage or for anaemic birds (Finnegan et al. 1997). Note that for healthy pigeons with acute loss of 70% blood volume, intravenous fluids given at an amount equal to the blood volume lost has been found to be an effective treatment, based on PCV levels at 12 hours after blood loss (Finnegan et al. 1997). Colloids such as hetastarch and oxyglobin, at doses of 5ml/kg followed by 10ml/kg of crystalloid fluids intravenously, have also been found an effective alternative treatment for birds suffering acute blood loss (Lichtenberger et al. 2003, Lichtenberger et al. 2007). The intra-osseous route can also be used to administer fluids or colloids when the bird is in shock. Dextrans and hetastarch can be given at 5 to10ml/kg IV every 8 hours to a maximum of four times; and for anaemic birds, hetastarch can be given once pre-operatively at 20ml/kg (Coles 2007b).

Avian blood does not store well over time in standard anticoagulants because of the shorter red cell lifespan, different metabolism, and higher metabolic rate of the nucleated red cells (Morrisey et al. 1997). Avian blood collected in citrate, acid citrate dextrose, and citrate phosphate dextrose adenine (CPDA) is not useable after a maximum of seven days (Morrisey et al. 1997). Blood can be collected into sodium heparin at the rate of 2 units heparin/ml collected blood (Finnegan et al. 1997), or into CPDA 1 part CPDA to 5 parts blood (Bos et al. 1990). Blood can be collected from healthy donors at up to 3% of body weight (30% blood volume) (Bos et al. 1990), although 1% of body weight is regarded as the generally safe amount of blood to take (Jenkins 1993). Instead of being stored, blood can be transfused immediately e.g. using a syringe with a

small amount anticoagulant. Blood groups have not been studied much in birds. Cross matching can be done by mixing recipient serum and donor whole blood on a slide and looking for agglutination (Altman 1997), or by full major and minor crossmatching (Finnegan et al. 1997). If not immediately transfused, blood can be refrigerated and warmed to 37°C prior to transfusion through a blood filter (Finnegan et al. 1997).

Maintenance levels of fluid therapy for birds are given at 5% body weight/kg/day (50ml/kg/day), plus for ill birds an assumed deficit of 10% body weight is replaced by half on the first day and by a quarter on each of the second and third days (Sinn 1994). Fluids, usually Hartmann's solution, are given warmed and subcutaneously or orally; or for very dehydrated birds are best given via intravenous or intraosseous administration (Sinn 1994). Plan for intravenous fluid administration if intra-operative haemorrhage is anticipated (Bennett 1994). Fluid doses are often given as divided doses at least twice daily, or in large birds can be given as continuous intravenous or intra-osseus infusions.

Pre-operative nutritional support may involve gavage feeding via feeding tubes or for parrots, using steel crop needles. Commercial hand rearing mixes, liquidised pelleted foods, small animal A/D semiliquid critical care diet (for carnivorous birds), or avian critical care formulas can be used. Gavage feeding, though at times valuable, can be quite stressful for some birds, and stress and handling prior to anaesthesia should be minimised (Taylor 2000a).

Warmth prior to anaesthesia should be supplied to ill birds struggling to maintain their temperature (Taylor 2000a). Extremely low body temperatures, around 30°C, have been recorded in some ill birds (Verkest and Filippich 1995). Recent trends in trying to reduce hypothermia during anaesthesia of humans and small animals are focussing on active warming of the skin during and prior to anaesthesia, to minimise temperature gradients between the body core and periphery when superficial blood vessels first dilate under anaesthesia. Pre-operative whole body surface warming for 30 minutes in a heated chamber, or by lying still under an active warming system covering the body, has been found helpful to reduce intra-operative hypothermia in humans, but is thought unlikely to be practical for animals except very small ones (Cabell et al. 1997). Based on this principle, though not yet studied in birds, pre-operative active peripheral warming in a heated cage may be worth considering as a way to minimise the initial extent of intra-operative hypothermia.

Note that one study found a drop of body temperature in some very ill birds of up to 4°C during and immediately after clinical examination, which supports the anecdotal recommendation that prolonged clinical examination and handling is contra-indicated in critically ill birds (Verkest and Filippich 1995).

SOME POTENTIAL ADVERSE EFFECTS OF ANAESTHESIA AND SURGERY IN BIRDS

Anaesthesia and surgery can adversely affect many body systems and physiological processes. More detailed work has been done in domestic animals and humans than in birds regarding these effects. Effects may involve the cardiovascular system (as well as involving disorders of coagulation and haemostasis), the respiratory system, thermoregulation and heat balance, fluid balance (and blood volume), acid-base balance, energy balance (including metabolic rate and blood glucose levels), blood gas concentrations, the renal system, the liver (and enzyme metabolism), the nervous system, and the effects of pain (see Tables 1 and 2, adapted from mammalian references). Direct effects on some systems may result in secondary effects on other body systems and processes.

Hypoventilation

Respiratory rates of birds are one third of the rate for same sized mammals, and tidal volumes are four times larger than tidal volumes of same size mammals. As a result, small changes in respiratory rates have greater effect on ventilation in birds than in mammals. Birds also have no diaphragm and depend on active movement of the thoracic wall for respiration. These factors make birds very susceptible to the respiratory depression of anaesthesia (Heard 1997).

Halogenated gas anaesthetics depress the ventilatory response to hypoxia, and isoflourane causes a decrease in respiratory rate and tidal volume in proportion to anaesthetic depth (Jenkins 1993). The potential for hypoventilation is worsened by hindrance of thoracic and keel movement (by drapes, hand pressure on thorax, restricted keel movement when ventrally recumbent), and by certain conditions (eg obesity, presence of ascites, and presence of intra-abdominal masses) which restrict abdominal air-sac expansion (Heard 1997). Some surgical positions (eg with a leg strapped tightly forward to the neck for lateral celiotomy) will greatly restrict thoracic movement, making IPPV essential when such a position is used (Echols pers. comm. in AAVAC surgery practical 2007). The minute volume of chickens in dorsal recumbency is reportedly reduced by 10 to 60% due to pressure of the viscera on the airsacs (Coles 2007a).

Hypovolaemia, Fluid Balance and Blood Loss

Some differences between avian and mammalian blood vessels make blood loss more likely to occur during avian surgery. Avian blood vessels are thin-walled, tend to be more superficial, and are less protected by perivascular tissue. The vessels, being surrounded by less tissue, are prone to move in tissues and retract out of sight. Even with radio-surgical coagulation, the retracted vessels may relax and leak blood making it necessary to frequently re-evaluate vessels for bleeding (Bennett 1994). Excellent haemostasis is essential; and use of magnification helps identification, isolation, and coagulation of the relatively small vessels (Bennett 1994). What appears to be minor bleeding during avian surgery can actually be a critical amount, when considered on a proportional basis. Six drops of blood (0.3ml) lost by a 30g budgerigar is thus 10% of blood volume, and 1ml lost would be 30% of blood volume.

Blood loss by birds is, to an extent, tolerated better than by mammals (Jenkins 1993). The mechanisms birds have to cope with blood loss and shock are different in some ways, but are similar to those of mammals in other ways. The muscles, especially flight muscles, have a disproportionately large blood supply from which little oxygen is taken up when the muscles are at rest. The blood supply to the muscles thus acts as a reservoir of venous blood with spare oxygen, especially in flying birds with more developed flight muscles (Verkest 1994). The LD50 for acute blood loss in mammals is 40-50% of blood volume, for chronic blood loss in flying and diving birds (pigeons and ducks) is 70%, for chronic loss in pheasants and chickens (terrestrial birds) is 40-50%, and for acute loss in ducks is 60% (Lichtenberger et al. 2002). Early or compensatory shock in birds occurs with up to 20% of blood volume lost, and responds well to fluid therapy (Lichtenberger 2004). If the bird suffers blood loss or dehydration, vasoconstriction occurs to redirect muscle blood supply to the vital organs. Changes in muscle capillary bed blood pressure result in decreased blood pressure and capillary hydrostatic pressure, with net result fluid is drawn from interstitial tissues and from within cells. The result is maintenance of plasma volume at the expense of tissue and intracellular dehydration. Birds, unlike mammals maintain their blood volume rather than blood pressure during haemorrhage (Verkest 1994). Due to the rapid movement of fluid from tissues to the bloodstream, the PCV tends not to stabilise for 24 hours after blood loss in birds (Murray 1994). Renal mechanisms, such as renal vasoconstriction, sodium retention, and the increased use of mammalian nephrons (which can concentrate the urine much more than the reptilian nephrons), also come into play to conserve fluid in response to blood loss and shock in birds (Verkest 1994).

The Physiology of Thermoregulation, Heat Balance and Heat Loss During Anaesthesia and Surgery in Birds

Heat Balance in the Non-anaesthetised Bird

Mammals and birds are endothermic, and maintain a nearly constant core body temperature despite widely varying environmental temperatures. Thermoregulatory mechanisms are controlled by the hypothalamus, which initiates vasomotor or metabolic responses to maintain a set body temperature (temperature "set point") Oncken et al. 2001, Cabell et al. 1997). Shivering, panting and behavioural responses to changes in environmental temperature are also regulated by the hypothalamus (Heard 1997). Vasomotor responses (peripheral vasodilation or vasoconstriction) divide the body into a central "core" and peripheral "shell" with regard to temperature, allowing the periphery to function as a "thermal buffer" (Cabell et al. 1997). Thermoregulatory responses are triggered when heat and cold receptors within the body detect raised or lowered body temperature beyond certain "thresholds" (Sessler 1997). In humans the cold and warmth "thresholds" function to maintain core temperature within 0.2°C of a certain hypothalamic "set point" (Sessler 1997). The responses to heat loss in un-anaesthetised animals and humans occur after a core body temperature decrease of 0.25°C; but during anaesthesia, responses such as vasoconstriction are significantly delayed until a drop of about 2.5°C (Cabell et al. 1997).

Body temperature results from the balance between heat production and heat loss (Phalen et al. 1996, Machon et al. 1997). Heat production is mostly a result of cellular metabolism, so body tissues produce heat in proportion to their metabolism (Oncken et al. 2001). Birds have higher metabolic rates and thus higher body temperatures than mammals of comparable size (Maina 1997). Changes in heat production result from changes in metabolic rate (e.g.- diurnal rhythms, physical activity, digestion of food), plus extra heat can be generated mainly via the triggering of shivering (Dawson and Whittow 2000). Shivering increases basal metabolic rate two to five times, and increases glucose and oxygen consumption (Wingfield 2002). With cold exposure and shivering, maximum heat production only lasts a few hours because of fatigue and glycogen depletion (Maina 1997)

Heat transfer and loss occurs via four mechanisms – convection (transfer involving currents of air movement after warming of air around the body), conduction (transfer to in-contact objects e.g. cold operating tables), radiation (direct to the environment independent of currents of intervening air), and evaporation (cooling via moisture evaporating from a surface, e.g. from the respiratory tract especially when panting, or from the skin) (Altman 1997, Oncken et al. 2001, Murison 2001, Rembert et al. 2001). Heat produced deep in the body is transferred to the skin by conduction and the circulation of blood (vascular convection) (Altman 1997). Fat is a good insulator against conductive heat loss (Oncken et al. 2001), but in birds (apart from seabirds, waterfowl and birds undergoing migration) fat is only found deep in the body (Heard 1997, Dawson and Whittow 2000) Though birds lack sweat glands, some evaporative loss of heat from their skin does occur (Dawson and Whittow 2000) Evaporative heat loss from the respiratory system by birds in hot conditions can be greatly increased through panting and gular flutter (Maina 1997).

The feathers reduce radiant heat loss, and reduce convective heat loss via trapping air near the skin especially when fluffed up (Maina 1997). The rate of radiant heat loss is proportional to the temperature difference between the body and the environment (Phalen et al. 1997) – note that birds have a higher body temperature than mammals. Convective losses are highest when there is a high surface area to mass ratio (Phalen et al. 1997), as with the small body size of most birds. Thus birds, by having a higher body temperature and metabolic rate than similar sized mammals, and by having generally smaller body size, may be prone to more radiant and convective heat loss than many mammals. This tendency to heat loss is reduced by the effective thermal insulation given by feathers (Maina 1997).

In humans (with no insulating feathers or fur, but have subcutaneous fat and can sweat), radiation accounts for 55-65% of body heat loss, conduction accounts for 2-3%, and convection for 12-13%; with the remaining heat loss is via evaporation and respiration (Wingfield 2002). For humans, heating of inspired air accounts for 2-9% of heat loss, and 20-27% of heat loss is via evaporation from the skin and lungs (Wingfield 2002).

These proportions of heat loss obviously would vary for birds and under various conditions.

Heat conservation by birds in cool environments

Birds exposed to low temperatures mostly lose heat by convection or radiation (Dawson and Whittow 2000). Initial responses to cold environments by animals and birds involve shivering, raising the hair or feathers to give a "fluffed up" appearance (piloerection) to trap more air near the skin, vasoconstriction to reduce blood flow to extremities (and so reduce heat loss from extremities), and behavioural means (Dawson and Whittow 2000, Murison 2001). Behaviour is the most effective thermoregulatory response to cold environments (Murison 2001), and any impairment of an animal's behavioural responses to cold will result in increased heat loss (Oncken et al. 2001). Cutaneous vasoconstriction is the most energy efficient and commonly used endogenous mechanism to maintain core body temperature (Cabell et al. 1997).

Birds in cool environments will reduce heat loss by behavioural responses involving changes in position (orient to the wind or sun, seek shelter), and changes in posture to reduce surface area and exposure of unfeathered areas (e.g. by hunching or squatting to cover the unfeathered feet, tucking the head under the wing). Conversely, when "sunbathing" on cool days, birds will expose large areas of their wings including the less feathered underside to maximise radiant heat transfer from sunshine (or on hot days hold their wings away from the body to radiate excess body heat). The head, especially in small birds, can lose substantial amounts of heat. Young birds, especially sparsely feathered altricial nestlings, are very prone to chilling as they have poorly developed thermoregulatory mechanisms (Dawson and Whittow 2000).

Effects of anaesthesia and surgical procedures on heat balance

Anaesthesia and positioning for surgery affect all of the responses involved in reducing heat loss:

a. Muscular and postural behavioural responses - Anaesthesia inhibits muscle activity (Pottie et al. 2007, Oncken et al. 2001, Murison 2001, Cabell et al. 1997), and removes the ability to regulate body temperature through behaviour (Sessler 1997, Murison 2001, Machon et al. 1999). The bird thus cannot shiver to produce heat, nor "fluff up" by erecting the feathers to trap more air near the skin, nor voluntarily change posture to conserve heat. When the anaesthetised bird is recumbent, it has much more area in contact with other surfaces than when standing. Conductive heat losses thus can be much greater for the bird, especially when lying directly on cold surfaces (Heard 1997), e.g. cold metal surgery tables. Surgical positioning often involves dorsal recumbency with the head, legs, feet, and less feathered undersides of the wings exposed, rather than tucked into the body and feathers. At room temperature, radiant and convective heat loss will be increased because of this positioning. Heat loss in conscious chickens is reduced up to 20-50% when they squat to cover unfeathered areas of their legs and feet (Dawson and Whittow 2000), and reduced by 15% when they tuck their head under their wing Maina 1997). The removal by anaesthesia of behavioural responses leaves the patient with only autonomic responses to cope with changes in temperature (Sessler 1997)

b. Metabolic and vascular responses – Metabolic responses to heat loss mediated by the hypothalamus are altered by anaesthesia (Murison 2001, Cabell et al. 1997, Machon et al. 1999). The hypothalamic temperature set point is lowered, *metabolic rate and heat production is reduced*, plus anaesthesia results in peripheral vasodilation (Tan et al. 2004). The net effect of this is lowered heat production, increased heat transfer from the body core to the extremities, and subsequent increased heat loss to the environment. In humans eight times more heat can be transferred to the extremities when peripheral vessels are fully dilated rather than fully constricted (Oncken et al. 2001).

Preparation for the surgery, surgical and surgical support procedures can cause cooling: via

- Plucking of feathers – loss of insulation against radiant and convective heat loss (Altman 1997)
- Use of cool fluids for skin preparation – evaporative heat loss (Altman 1997, Hoskins 1981, Cabell et al. 1997, Tan et al. 2004).

- Use of cool fluids for lavage during surgery – use of lavage fluid should be minimised. It is easy to inadvertently use 10ml lavage fluid to flush the abdomen during egg peritonitis surgery in a cockatiel, which would proportionally equal using 1 litre for a 10kg dog.
- Withdrawal of large amounts of warm abdominal fluid at one time, e.g. ascites in egg peritonitis cases. It is better to withdraw ascitic fluid in stages over the days before surgery rather than all at once after induction.
- Administration of cool fluids as fluid therapy. Anecdotally, a core body temperature drop of 2° C in a budgerigar was recorded after administration of room temperature fluids (21° C) at a rate of 3% of the bird's body weight Heard 1997) (i.e. would be 1ml for a 30g bird, equivalent of 1litre for a 30kg dog).
- Opening of body cavities, exposing them to radiant and evaporative heat loss (Altman 1997, Murison 2001). Evaporation from serosal surfaces can account for up to 50% of the heat loss in humans undergoing major abdominal surgery (Cabell et al. 1997).
- Breathing cool, dry anaesthetic gases evaporative heat loss) (Altman 1997, Haskins 1981, Boedeker et al. 2005 Tan et al. 2004) Note that the nasal cavity warms and humidifies inspired air, and extracts heat and humidity from expired air by condensation (Dawson and Whittow 2000). When a bird is intubated, the nasal cavity is bypassed.
- Prolonged surgeries – *longer anaesthesia and surgery time = greater time for heat loss to occur* Wood

Effects of Intra-operative Hypothermia

Anaesthetic induced hypothermia results in progressive adverse changes in cardiovascular, renal, hepatic, immune system and central nervous system function ix. Hypothermia has a general depressant effect, which includes (a) reduced enzyme activity and metabolism (further reducing heat production, and reducing anaesthetic drug metabolism), (b) reduced cardiovascular function: slows heart rate, reduces cardiac output and reduces blood pressure, plus affects conduction predisposing to arrhythmias (arrhythmias are usually not seen till severe hypothermia with core body temperature below 28°C - Hoskins 1981, Murison 2001), (c) respiratory depression, and (d) depressed central nervous system function.(Raffe and Martin 1983, Cabell et al. 1997, Tan et al. 2004, Rembert et al. 2001)

Effects of the reduced circulation include reduced renal blood flow, and metabolic acidosis as a result of poor tissue perfusion and oxygenation (Rembert et al. 2001, Boedeker et al. 2005). The bradycardia of hypothermia does not respond to atropine (Murison 2001). Hypothermia shifts the oxygen dissociation curve of haemoglobin to the left, meaning less oxygen is released from haemoglobin into tissues when there are lower levels of blood oxygenation (Wingfield 2002, Raffe and Martin 1983). Postoperative shivering after hypothermia has further deleterious effects, such as greatly increased use of oxygen (Raffe and Martin 1983).

Stages of Hypothermia During Anaesthesia and Surgery

In conscious animals, hypothermia has several stages. During mild hypothermia (core temperature 32-37°C in dogs and cats), heat is conserved or generated by vasoconstriction, shivering, and non-shivering basal and endocrine thermogenesis. In moderate hypothermia (core temperature 28-32°C), a progressive drop in metabolic rate occurs coupled with a lack of shivering to generate extra heat. In the final severe stage of hypothermia (below 28°C), autonomic and endocrine mechanisms of heat conservation become inactive. After removal from a cold environment, there is often an "afterdrop" decline in core temperature, due to circulatory changes and simple equilibration between core and peripheral tissue temperatures (Wingfield 2002). Vasodilation during "after drop" can increase shock and hypotension (Murison 2001). When the core body temperature in un-anaesthetised patients drops below 34 degrees, shivering stops and peripheral vasoconstriction is replaced by vasodilation (Oncken 2001). Hypoglycemia can occur with severe hypothermia, and thus further decrease metabolic activity (Oncken 2001, Cabell et al. 1997)

Anaesthetic induced hypothermia also occurs in three phases (Sessler 1997):

- a rapid initial decrease in temperature after induction, mainly due to peripheral vasodilation allowing heat redistribution from the warmer core to cooler peripheral tissues (which doesn't change total body heat content, but increases the potential for heat loss from the periphery);
- then heat loss to the environment in an almost linear manner (mostly via radiation and convection from the skin, with heat loss exceeding production); then reaching
- a final steady state of balance between heat loss and heat production.

In humans, the anaesthesia associated lowering of the temperature threshold at which vasoconstriction occurs results in an initial heat redistribution phase lasting about one hour (Sessler 1997). Core temperature stops reducing after 3 to 5 hours in humans effectively insulated or warmed, reaching the steady state third phase where heat loss equals production. In hypothermic patients, the third phase results from eventual intra-operative vasoconstriction and is potentially dangerous as total body heat content continues to decline (Sessler 1997). When intra-operative vasoconstriction eventually occurs (at about 34°C in humans), the hypothermia is difficult to treat by external warming because of limited heat transfer from the periphery to the body core (Cabell et al. 1997). Despite efforts to prevent it, hypothermia is seen post-operatively to some degree in 85% of all human patients (Machon 1999).

In anaesthetised pigeons given no external heat support, core body temperatures sharply dropped >2.5°C within 30 minutes, and continued to drop for 2.5 hours before reaching a plateau about 8 degrees below induction temperature (Phalen et al. 1996). This pattern in pigeons appears to correspond with the above three phases of hypothermia seen in anaesthetised humans. The long held view that survival of avian patients reduces once surgical time exceeds 20 minutes thus corresponds time-wise with the likely onset of the second phase of intra-operative hypothermia (i.e. linear heat loss to the environment) in birds.

INTRA-OPERATIVE SUPPORTIVE CARE

The main concern involving avian surgical technique is achieving excellent haemostasis, via gentle tissue handling coupled with blunt dissection and preferably radio-surgical cautery to minimise haemorrhage and improve visualisation (Taylor 2000b). Thermal support is extremely critical; and longer surgical times mean more time for heat loss to occur, risking severe hypothermia for the bird. Intra-operative fluid therapy is also valuable.

Fluid Therapy

Methods of fluid therapy during anaesthesia and surgery include subcutaneous, intravenous or intra-osseus administration, with intravenous and intra-osseous methods preferred except for the more low risk cases. Fluids can be given as intermittent boluses, or continuously via intravenous or intra-osseous catheters. Intra-osseous catheters can be inserted, usually in the anaesthetised bird, into sites at the proximal tibia or distal ulna (Powers 1997). Intravenous catheters can be used in birds larger than 60g, placed under anaesthesia in peripheral veins in the legs and wing or right jugular vein, fitted with an injection cap, and held in place by sutures placed through encircling adhesive tape (Bond et al. 1993). Fluids should be given warmed – when given at 100ml/kg/hour at 20°C (room temperature) to anaesthetised cockatoos, body temperature dropped 1 degree lower than when fluids warmed to 35 degrees were used (Lau and Filippich 1997).

One technique used, especially in small birds when catheters are difficult to maintain and there are limited adequate size veins for repeat injections, is a bolus intravenous injection of fluids given just after anaesthesia is induced. Single bolus crystalloid fluid injections at 30ml/kg (30% blood volume) and 50ml/kg (50% blood volume) have been studied recently in non-dehydrated birds, and found to temporarily decrease the PCV and total protein levels until 3 and 6 hours post-injection respectively when compared to control birds (Schultz and Wicks 2008). The PCV decreased to 82% of initial level when 30ml/kg was given,

and to 74% of initial level when 50% was given. As the birds studied weren't dehydrated, the PCV changes after bolus fluids may differ in dehydrated birds due to different fluid redistribution. Bolus fluids were concluded safe at these levels, but probably 30ml/kg or less to an anaemic bird would be safer than the 50ml/kg dose (Schultz and Wicks 2008). Another study, using continuous intravenous fluid infusions in healthy birds at 100ml/kg for 1 hour, found PCV dropped in the first hour but had rebounded to normal or mildly above normal one hour after infusion was stopped (Lau and Filippich 1997). The majority of avian patients however are likely to be compromised, and may experience volume overload and not always cope with 90ml/hr maximal dose fluids (Cannon 1996). Doses of 50ml/kg intravenously can rehydrate for a longer period than 30ml/kg doses, and are suggested for birds needing aggressive treatment (Schultz and Wicks 2008). Crystalloid fluids will rapidly spread from the blood stream into interstitial tissues, leaving only 20% still in the circulation after 1 hour, and thus are interstitial rehydrators rather than blood volume expanders (Lichtenberger 2004).

Calculated blood loss can be replaced during surgery with three times the volume of crystalloid fluids, should transfusion not be used (Taylor 2000c). Hartmann's solution is preferred to 5% dextrose (Sinn 1994, Lau and Filippich 1997). 5% dextrose intravenously will cause significant dilution of serum electrolytes, but Hartmann's will maintain electrolyte levels and have a more sustained effect in maintaining blood pressure and blood volume (Lau and Filippich 1997). Maintenance doses for constant infusion of crystalloid fluids are given as 1ml/kg/hr (Coles 2007) to 2-3ml/kg/hr (50-80ml/kg/day) (Taylor 2000c, Lichtenberger 2004). These levels are increased to include resuscitation (urgent correction of blood volume deficits) and rehydration (correction of interstitial dehydration) doses as needed (Lichtenberger 2004). Syringe pumps or infusion pumps can be used to control the rate of constant infusions (Jenkins 1993). A single bolus dose of 50ml/kg will provide the daily maintenance requirement for a bird, and repeated doses at 30ml or 50ml once or twice an hour may assist in correction of hypovolemic shock (similar to the dose levels used as constant infusions in small animal critical patients) (Schultz and Wicks 2008).

Colloids such as Hetastarch or dextrans, and synthetic oxygen carriers (Oxyglobin) are intravascular volume expanders, as they remain in the blood stream due to their high molecular weight preventing diffusion into the tissues. They can be very effective for rapid sustained blood volume expansion and resuscitation after haemorrhage. They can be given at doses of 5ml/kg over 1 minute, followed by 10ml/kg of crystalloid fluids (Lichtenberger 2004). Such doses of Oxyglobin and crystalloids used in ducks with 60% blood volume loss corrected heart rate and blood pressure within 30-120 seconds (Lichtenberger 2004). Hetastarch can be also be dosed as 10-15ml/kg boluses, and all colloids should be given with subsequent doses of crystalloid fluids (Powers 1997). Oxyglobin was found to resuscitate blood volume faster than Hetastarch by a few minutes, and Hetastarch or Oxyglobin were found more efficient when used intravenously rather than intraosseously (Lichtenberger et al. 2007). Two to four times as much crystalloid fluid needs be given to have the same effect as one volume of colloids (Jenkins 1993), hence the small volume resuscitation with colloids can help avoid the risk of over-hydration if just crystalloids are used. Blood transfusions can be given at 10-30ml/kg or at levels to replace volumes lost, however use of colloids and/or crystalloid fluids can be at times as effective as a transfusion (see pre-operative care section in this paper).

Ventilatory Support

Hypoventilation has been considered the greatest risk factor, apart from hypothermia, associated with avian anaesthesia when procedures last longer than one hour (Taylor 2000a). If the bird is not adequately ventilating under anaesthesia, carbon dioxide levels can build up quickly and result in respiratory acidosis. Respiratory acidosis has been found more likely to occur when birds such as galahs are maintained by mask rather than intubated; and more likely with use of halothane rather than isoflourane (Jaensch et al. 1999). Respiratory acidosis depresses the myocardium, resulting in a drop in blood pressure via depressed cardiac output, and can even predispose to cardiac fibrillation (Coles 2007). Note that hypoxia and hypercapnia can occur in anaesthetised birds despite an adequate respiratory rate and tidal volume, hence monitoring only respiratory rate won't indicate if there is adequate ventilation (Jaensch et al 1999). Provision of oxygen is recommended for all birds under anaesthesia, including when injectable anaesthesia is used (Coles 2007a).

Because even healthy birds will hypoventilate when breathing spontaneously under anaesthesia, IPPV has been strongly recommended using 15mm H2O of pressure (Sinn 1994). Apnoea in birds has been reported when IPPV is used at 12 breaths per minute rather than 6 breaths per minute, probably due to depletion of respiratory stimulus associated with carbon dioxide washout (Chemonges-Kasumbein and Filippich 1999). When IPPV is used, the vaporiser concentration of inhalant anaesthetic should be reduced, otherwise the bird may deepen too much (Chemonges-Kasumbein S and Filippich 1999). IPPV at a rate of one to seven breaths per minute has been recommended whenever birds are anaesthetised for any period (Taylor 2000a).

If a bird is too small for endotracheal intubation, a tight seal can be achieved by covering the open end of a face mask with plastic and making a slit to insert the bird's head through (Coles 2007a). This technique, using e.g. cling wrap or latex from examination gloves held in place with tape or rubber bands, can provide enough of a seal to enable expansion of the chest with intermittent pressure on the rebreathing bag. Gentle pressure is needed when using any form of IPPV, as it is easy to damage the bird's lungs with excessive expansion – observe the amount the bird's chest moves when using manual ventilation.

Thermal Support Methods

Development of hypothermia can be a critical factor for survival of anaesthesia for birds. It is essential to use methods to avoid or reduce heat loss to minimise the risk of intra-operative hypothermia. Methods which can be used include :

- minimising loss of insulation - by minimal plucking of feathers;
- minimising evaporative losses - by use of warmed skin disinfectants (and minimal use of alcohol during skin preparation);
- minimising heat loss associated with fluid transfers - by using warmed fluids for fluid therapy and lavage, and withdrawing warm ascitic fluid well before rather after anaesthetic induction;
- minimising anaesthesia and surgery time – minimises time period of heat loss;
- minimising conductive heat loss – covering the surgery table surface, e.g. with towels, circulating warm water heat pads vii, thermostatic controlled heat mats (electric heat pads, reptile heat mats), hot water bottles, microwaveable heat packs;
- using passive and active thermal support to reduce convective and radiant heat loss – convective forced air warmers (can be expensive), radiant heat sources such as heat lamps (e.g. poultry brooder lamps), thermal barriers (drapes, bubblewrap);
- use, in theory, of active warming and humidification of anaesthetic gases to reduce respiratory evaporative losses (can require expensive equipment).

Studies on the efficacy of various types of thermal support have been done in humans, small animals (dogs and cats), and to a more limited extent, in birds. Several themes seem to be apparent from such studies – (a) relative efficacy of different methods can vary between humans, small domestic animals, and birds; (b) no one method is adequate by itself to prevent intra-operative hypothermia, especially in smaller patients; (c) some method to prevent conductive losses to cold surgery tables is always needed; and (d) for birds, some form of active heating is always required, not just passive thermal support using towels or insulating materials. Monitoring of the bird's temperature is important – some birds, especially if aquatic species or heavily feathered, may even become hyperthermic. Cloacal temperature readings have been found to change by amounts corresponding to changes in core body temperature, so are a useful monitoring tool (Phalen et al. 1996).

The Relative Efficiency of Thermal Support Methods

Humidification and warming of inspired anaesthetic gases, though effective in humans, has been found to have very limited effects in reducing intra-operative hypothermia in cats, dogs and rabbits. This is thought maybe due to heat loss by means other than the respiratory tract in animals being more significant than in

humans, associated with the different surface area to weight ratios of animals (Raffe and Martin 1983). Warming and humidification of inspired gases has similarly been found ineffective in preventing changes in body temperature of anaesthetised birds (Boedeker et al. 2005, Phalen et al. 1996).

In cats, oesophageal temperatures have been recorded after 2 hours of anaesthesia to compare control cats placed on newspaper, versus cats placed on circulating warm water blankets plus wrapped with passive insulation, or on circulating warm water blankets and given additional heat. Wrapping the whole cat with circulating warm water blankets actually raised their temperature by 2 hours; next most effective was wrapping with towels covering hot water bottles or using radiant heat from a heat lamp (temperature remained the same by 2 hours). Wrapping in passive insulation (towels or space blankets) wasn't effective, resulting in drops of 1 to 3°C by 2 hours; and placing on newspaper without use of extra heat or insulation resulted in a 5 degrees temperature drop (Hoskins 1981). Conductive heat loss for anaesthetised Amazon parrots placed directly onto a surgery table, rather than on a cotton drape covering the surgery table, has been found to result in a 0.5 degree C greater body temperature drop after one hour (Rembert et al. 2001).

Use of radiant heat from heat lamps, plus active warming of the trunk by hot water bottles, plus the use of heat pads in anaesthetised dogs resulted in 3°C less temperature drop at 3 hours, when compared to control dogs placed on towels with no thermal support. In the same study, use of a forced air warmer ("Bair Hugger" device) resulted in 2.4 degrees less drop in temperature; sole use of heat pads or humidification and warming of inspired air resulted in temperature drops only 1 degree or less than control dogs. Hot water bottles had to be regularly changed, as by 2.5 hours they were cooler than the dogs and acting as "heat sinks". Dogs which underwent laparotomies had greater temperature drops than dogs which didn't have body cavities opened (likely due to increased evaporative heat losses from the internal tissues). (Tan et al. 2004).

The initial heat redistribution phase of peri-operative hypothermia lasts about 20 minutes in dogs and cats (Machom et al.1999); and probably is of similar duration in birds. Hypothermia during this first phase is difficult to prevent, except by pre-operative active skin warming to reduce the core to periphery temperature gradient (Cabell et al. 1997). Active skin warming is more effective when there is peripheral vasodilation, allowing large amounts of heat transfer between the skin and body core. Effective skin warming needs to be continued throughout anaesthesia to reduce the initial redistribution hypothermia, can reduce subsequent direct heat loss to the environment during phase two of hypothermia, and by preventing significant hypothermia may prevent the vasoconstriction of third phase hypothermia (Cabell et al. 1997). Forced air warmers, such as the "Bair Hugger", provide active skin warming and can effectively minimise the first phase of peri-operative hypothermia (Machon et al. 1999). Methods such as pre-operative warming and intraoperative selective warming of AV shunts in limbs have been investigated in dogs and cats but not birds, and have some difficulties impeding their use in practice (Tan et al. 2004). Provision of radiant heat to actively warm the whole body is feasible in small sized patients such as birds, and can be quite effective in reducing hypothermia.

Use of a forced air warmer ("Bair Hugger" device) has been found superior to other warming methods in humans, and reduces convective heat loss from the patient's skin by forcing warm air out of a porous blanket to surround the patient. Similarly, the "Bair Hugger" has been found much more effective than use of circulating water blankets or radiant heat from a 60Watt infrared lamp for reduction of hypothermia in anaesthetised Amazon parrots. Over one hour, body temperature dropped about 2.5°C in the Amazons whether just placed on a cotton drape, or on a drape under the heat lamp (suggesting a heat lamp of such wattage wasn't at all effective); about 1 degree less when on a circulating water blanket; and about 2 degrees less when the forced air warmer was used. (Rembert et al. 2001)

Radiant heat from a 680Watt infrared poultry brooder lamp (stronger than the lamp in the above Amazon study), placed 27cm from the patient, has been found to effectively prevent body temperature drops over 2 hours in anaesthetised doves lying on foam pads. Circulating warm water blankets had minimal effect in preventing hypothermia in the doves, and inspired air warming had no observable effect (Phalen et al 1996).

POST-OPERATIVE SUPPORTIVE CARE

The greatest concerns post-operatively are hypovolemia, hypothermia, toxicity associated with anaesthetic drugs, pain, surgical and non-surgical trauma, and sepsis (Jenkins 1993). Hypothermia can be a consistent finding in birds immediately after anaesthesia despite intra-operative thermal support, and supplemental heat needs be continued post-operatively by using a heated cage or similar (Cannon 1996). Pre-heating of the recovery cage or incubator is recommended (Sinn 1994). An initial temperature of 30 degrees is advised for post-operative caging, depending on species of bird (Cannon 1996). Post-operative shivering is very energetically expensive, and thermal support will be needed till the bird's thermoregulatory mechanisms and core temperature return to normal levels after their suppression by anaesthesia. Monitoring the bird's body temperature post-operatively could be helpful (Jenkins 1993), though the stress of any restraint for this may be better avoided for a bird trying to cope with other post-operative stresses. Some work on post-operative thermal imaging is to be presented at this year's AAV 2008 annual conference (according to the proposed conference program).

Birds are best recovered in a quiet, dim environment (Cannon 1996, Sinn 1994). Wrapping the bird up in a towel while it recovers in a cage may reduce violent wing flapping and self-trauma as the bird wakes (Sinn 1994); or alternately the bird could be gently held, wrapped in a towel and upright, till fully conscious (Coles 2007a). Patients should be recovered where the can be easily observed, and not left unattended till they can perch without difficulty (Sinn 1994). The bird should not be extubated until it is moving the tongue and beak (Taylor 2000a). Monitoring devices should be left in place until the bird absolutely won't tolerate them (Sinn 1994), which usually will be until shortly after the bird starts waking. Check and if needed clean the oral cavity before extubation (Taylor 2000a); and if vomiting, blood, or mucous build up is suspected after extubation (Sinn 1994).

Fluid therapy should be continued post-operatively to correct fluid shifts, fluid losses, electrolyte imbalances, and to provide maintenance levels, until the bird is stabilised. IV and intra-osseus catheters placed under anaesthesia allow repeat dosing of fluids post-operatively to birds that suffer significant blood loss during surgery. Giving repeated intravenous boluses post-operatively is limited by being stressful on the patient, plus eventually limited by the availability of useable veins – it is very useful to place intravenous or intra-osseus catheters, even for routine surgical cases (Jenkins 1993).

Surgery and anaesthesia increase energy and protein demands, but post-operatively the bird may not eat well. Food should be withheld until the bird is perching well. If the bird doesn't start eating well, tube feeding or even oesophageal or duodenal catheter alimentation may be required. If the bird undergoes head or beak surgery it may be prudent to place an oesophageal catheter whilst the bird is still under anaesthesia.

Routine monitoring of the bird's weight during post-operative hospitalisation is a simple and important way to help assess dehydration, the bird's appetite, and the bird's progress. After major surgery the bird should not be discharged till eating well and maintaining weight (except for some birds that won't eat well in hospital). Observe the bird for bleeding, dyspnoea, or picking at wounds after surgery. Simple procedures, e.g. surgical sexing, won't require prolonged monitoring in hospital (Cannon 1996).

Pain management

Post-operative analgesia is important for humane reasons and to aid recovery. Pain in birds can inhibit food and water consumption, prevent normal function of injured parts of the body, and have physiologic effects e.g. via catecholamines (Murray 1994). Birds are often under-treated for pain, and their behaviour responses to pain may be poorly recognised (Paul-Murphy 2007). Assess the likelihood of whether the bird is in pain by deciding (i) whether the lesion would be painful in humans, (ii) if the lesion damaging to tissues and by how much, and (iii) whether bird responds adversely to the lesion (Hawkins and Machin 2004). Orthopaedic surgeries, amputations, beak surgeries, and distal extremity surgeries are likely to be quite painful (Jenkins 1993). Behavioural responses to pain in birds may include guarding behaviour to protect a painful area (reluctance to perch, immobility, lameness, dropped wing), restlessness (due to being uncomfortable), aggression, chewing at a damaged area, or reduced normal behaviour (reduced grooming, reduced social behaviour, passivity) (Jenkins 1993) .

Pain relief can be given using either opioids, non-steroidal anti-inflammatory drugs (NSAIDs), or occasionally use of local anaesthesia. Pain relieving medication can be given pre-operatively, peri-operatively or post-operatively. The effects of opioids in birds are variable between species, and often only last a few hours. Butorphanol at 1-3mg/kg IM is the current recommendation for opioid analgesia in parrots but needs be repeated every 2-3 hours (Paul- Murphy 2007), making it mainly useful for the peri-operative period (e.g butorphanol is often given pre-operatively). Fentanyl, morphine and buprenorphine have been evaluated in birds, but give inconsistent and less satisfactory results in certain bird species (Paul- Murphy 2007). Tramadol at 4mg/kg IV or 11mg/kg PO in raptors has been found to achieve blood levels considered therapeutic in mammals for 10 hours, but it's clinical ability to reduce pain in birds is yet to be evaluated (Souza et al. 2007). Note that opioids can predispose to cardiac arrhythmias during anaesthesia (see Table 1).

NSAIDs should not be used if there is renal impairment, liver dysfunction, severe hypovolemia, or gastric ulceration (Paul-Murphy 2007) – making them less desirable for intra-operative use because renal vasoconstriction, dehydration and shock may well be present. Study of NSAID half lives in bird species of differing body weights suggest allometric scaling to extrapolate NSAID doses may not be useful (Hawkins and Machin 2004). Carprofen (2-4mg/kg IM once daily) or meloxicam (0.2mg/kg once daily) provide good post-operative analgesia (Coles 2007a). Carprofen and meloxicam are the current drugs of choice for long-term pain management in birds, and should they not work another option is piroxicam (low dose 0.1mg/kg daily over several months in arthritic cranes) (Paul-Murphy 2007). Celecoxib at 10mg/kg PO once daily has also been used long term in parrots with PDD (Hawkins and Machin 2004). Flunixin is no longer recommended in birds due to toxic effects and alternatives being available. Don't overlook bandaging and splinting to reduce discomfort for birds with injured limbs.

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Table 1: Some potential complications during anaesthesia and surgery (adapted from Raffe 1995, Nelson and Couto 2003)

System	Effect	Cause	Secondary Effects, Comments	Management
Cardiovascular	**Heart rate and Rhythm**	Anaesthetics have many effects on HR and rhythm, due to the agent and additive effects on pre-existing problems	Heart rate in humans often changes on induction	: Review and confirm adequate ventilation, which will resolve CO2 build up and ensures receives GA drug. Larger patient in unfavourable position – giving ventilatory support will increase O2. Increase fluids rate to counter volume loss if blood loss. The above three steps usually will resolve the fast HR, if not need review the patient.
	Increased Heart Rate	Usually an autonomic response to GA drugs via atropine inhibition sympathetic nervous system or ketamine, light GA, or: hypoxia, CO_2 build up, temp. increase, acute bleeding, adrenergic drugs	In most cases main rule outs in otherwise stable patient are: Depth of GA CO2 build up hypoxia Can also be due to: high sympathetic tone (anxiety, pain), shock, and hypotension NB: also can be due to hypothyroidism, trauma, physiologic in athletic patients, electrolyte disturbances especially of potassium, terminal hypoxia	
	DECREASED HEART RATE	Usually due to : GA agent itself e.g. opioids, xylazine, halothane : surgical stimulat- ion of vagus nerve (eye, larynx, neck, chest surgery) : hypothermia causing reduced metabolic rate : excess GA agent depressing cardio- vascular system	Other causes: cardiac based (high sympathetic tone, sympathomimetic drugs), catecholamines, electrolyte and acid base changes, hypoxia, severe anaemia, hypothermia	Give anticholinergics, hypothermia is treated by warming. Bradycardia of hypothermia is not atropine responsive
	Rhythm disturbances	Can be due to the GA drug, high sympathetic tone (pain, stress, anxiety), other causes, e.g.:	Ventricular arrhythmias noted more often in the ill or debilitated patient, are generally considered more significant due to effects on haemodynamics	In most cases the incidence and type of supraventricular arrhythmia doesn't merit treatment in the healthy patient unless it is prolonged.
	Supraventricul -ar arrhythmias	anticholinergics, opioids, xylazine, inhalant GAs		
	Ventricular arrhythmias	:xylazine, thiobarbiturates, inhalant GAs		Ventricular arrhythmias treated in many cases with lidocaine ½-1mg/kg initial bolus, if necessary repeat bolus or constantly infuse

System	Effect	Cause	Secondary Effects, Comments	Management
Cardiovascular (Cont)	**Blood pressure** USUALLY HYPOTENSION PROBLEMS (rather than hypertension)	All anaesthetics affect blood pressure, usually decreasing it – through 1. reduced myocardial contractility, 2. blood vessel compliance and 3. arterial tone effects Fluid balance shifts during surgery (blood loss)	In most cases compensatory patient response to hypotension is inhibited. Heart rate may influence blood pressure via reduced cardiac output so treatment of heart rate extremes may be considered	Treat one or more of the three variables affected. Decrease GA dose. Fluid administration to increase preload. If decrease GA and fluids not help enough, use specific drugs (dopamine, dobutamine, ephedrine in dogs and cats) Treat with crystalloids, colloids, whole blood
Respiratory System	Respiratory Depression, Apnoea Aspiration of Regurgitus	Pre-existing disease of the resp. tract or chest wall, or abdominal distension may produce hypoventilation. GA drugs can depress respiration or apnoea Surgical positioning Wrong use of anaesthetic equipment Regurgitation - a major concern and complication. can cause inapparent to significant problems.	Sudden change in resp. pattern, bronchospasm, pneumonia, cyanosis, tachycardia, hypoxia	Ventilatory assistance. NB Pulmonary damage from over-inflation can be serious Oxygen, antibiotics, anti-inflammatory drugs
Multisystemic	Hypothermia Shock	Heat loss, reduced heat production as reduced metabolic rate under GA Hypovolaemic (blood loss) or surgical shock	Affects many systems and functions, see text Affects many systems and functions, see text	See text See text

Table 2. Some potential complications after anaesthesia and surgery (adapted from Raffe 1995)

System	Effect	Cause	Secondary Effects, Comments	Management
Cardiovascular			Haemo-dynamic changes in post-op period are due the same causes as for the intra-op period i.e. changes in heart rate, rhythm, and blood pressure.	Similar strategies as for intra-op period
	Heart rate			
	DECREASED HEART RATE	Residual effects anaesthesia, hypothermia (and hence reduced metabolic rate), hypoxia, vagal enhancing drugs (e.g. opioids, alpha 2 agonists), secondary to certain types of surgery		Most cases resolve with anticholinergic drugs (anticholinergics rarely routinely used in bird GAs compared to GAs of dogs and cats). Refractive cases indicate a significant underlying cause needing immediate diagnosis and treatment
	INCREASED HEART RATE	Transient in many cases due to sympathetic activation during GA recovery.	Tachycardia may reflect GA emergence, hypoxia, CO2 buildup, hypovolaemia, or pain	Supplement O2 for cases at risk of hypoxia. Fluid support during anaesthesia will reduce tachycardia and improve tissue perfusion in post-op period. Treat and identify underlying factors.
	Arrhythmias	Factors involved – prolonged surgery periods, extubation, hypoxia, CO2 build up, acidosis, electrolyte imbalance, adrenaline release with recovery, pain, residual GA drugs, certain surgeries	Arrhythmias often noted post-op. Essential to identify and correct the cause, as dysrhythmias may degenerate into life-threatening ventricular arrhythmias. (NB difficult to monitor by auscultation or ECG post-op in birds)	\ Treat underlying cause, and anti-arrhythmic drugs if can't identify or correct cause quickly
Cardiovcular (Cont)	Blood Pressure	Blood pressure regulation is often disturbed by anaesthesia.	Hypovolaemia – due dehydration or blood loss, results in reduced cardiac filling.	Firstly aim to balance vascular capacity and circulating fluid volume. If fluid or fluid product therapy not effective, specific drugs. Almost all cases will respond unless there is continued fluid/blood loss.
	Reduced blood pressure	Classes of specific causes of hypotension - hypovolemia, cardiogenic, vasodilation	Cardiogenic – due GA drugs, heart disease or arrhythmias impair cardiac filling and contraction. Vasodilation – e.g. due to GA drugs or septic shock	

System	Effect	Cause	Secondary Effects, Comments	Management
Multi- **Systemic**	Shock	Hypovolemic or surgical	Effects on many systems, see text	See text
Respiratory	Aspiration Respiratory Depression Or Failure to Re-Establish Spontaneous Breathing	Signs may develop during or in the hours after anaesthesia Residual effects of GA drugs, patient factors (include obesity, pre-existing upper airway or tracheal disease).	Peri-operative procedures eg GA induction, intubation and extubation may produce reflexes which initiate regurgitation Respiratory depression after anaesthesia is common. All GA drugs cause respiratory depression that persists into the recovery period. During GA recovery, there is increased oxygen demand and CO2 production during metabolic processes to re-establish normal body temperature	Oxygen, anti-inflammatory drugs, antibiotics. Treat underlying causes. Support of airway and oxygenation until adequate spontaneous breathing is crucial. Respiratory stimulants such as doxapram if not successful? Can monitor hypoxemia with pulse oximetry (again not very practical for birds during recovery)
Renal	Oliguria/ Anuria in post-op period	ADH release during anaesthesia and surgery in mammals. Poor renal perfusion under anaesthesia	GA drugs have minimal direct effects on kidneys.	Prophylactic fluid therapy during anaesthesia. Fluid therapy post-op
Multisytemic	**Hypothermia**	After having arisen during the anaesthetic period	Affects many systems and functions, see text	See text
CENTRAL NERVOUS SYSTEM	**Delayed emergence** **Seizures** **Pain**	Slow emergence – drugs, patient factors, altered physiology during GA e.g. due to hypothermia DDX HYPOGLY- CEMIA which may be confused with delayed emergence and cause prolonged recovery. Look out for hypo-glycemia in young, mal-nourished, or metabolically abnormal patients	**Hypothermia induces** reduced metabolic rate, reduced drug clearance, CNS depression, reduced blood flow due reduced cardiac output, all of which contribute to a delayed recovery CNS depression may also cause hypoxia, CO2 build up and acidosis due disturbed control of breathing. DDX AZOTEMIA and SHOCK can result in prolonged recovery times.	Stabilise hypo-glycemia, azotemia and shock before anaesthesia. Support and therapy during anaesthesia and in post-op period