CHAPTER

40

Surgical Considerations

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Many avian patients are small and delicate, increasing the risks associated with surgery. Seemingly minor hemorrhage can be life-threatening in patients with such a small blood volume. Their high metabolic rate, small body size, and high ratio of body surface area to body volume predispose them to intraoperative hypoglycemia and hypothermia, the risks of which increase as the duration of anesthesia and surgery increases. These factors make it crucial that the avian surgeon not only have the procedure well thought out, but also have any necessary equipment ready and accessible. Exactness, precision, advanced preparation and minimal anesthesia time are the keys to success in avian surgery.

Avian blood vessels are relatively thin-walled, tend to course in a more superficial manner and are less protected by surrounding tissues than in mammals. Because there is less perivascular tissue in birds, vessels are prone to move within the tissues and retract from the surgeon's view. Even after radiocoagulation, vessels may relax and begin to leak blood after they retract into the tissues. The avian surgeon must frequently re-evaluate vessels for recurrence of hemorrhage and should be meticulous with hemostasis to prevent surgically induced hypovolemia. With the aid of magnification, small blood vessels can be identified, isolated and coagulated, minimizing the risk of recurrent hemorrhage.

Surgery is frequently a life-prolonging procedure when applied correctly to a properly conditioned avian patient; however, birds with severe nutritional and metabolic abnormalities do not have the capacity for long-term recovery from many anesthetic and surgical episodes. The most common cause of problems associated with elective surgeries is inadequate presurgical evaluation of the patient, which prevents proper post-surgical recovery. Although some surgical procedures must be performed on an emergency basis without the benefit of a complete medical evaluation and preconditioning, in many situations there is adequate time to accumulate clinical data. In some cases, surgery should be delayed in the patient's best interest.

Patient Evaluation

When possible, a clinical database acquired prior to surgery should include a complete history, physical examination and laboratory data. A minimum database for any preoperative evaluation should include hematocrit, total serum solids and WBC. If possible, a complete blood chemistry profile, whole body radiographs, electrocardiogram and cultures, if indicated, should be obtained. A blood glucose is useful in Anseriformes and raptors.

Patients with blood glucose of <200 mg/dl should receive 5% dextrose IV intraoperatively. Patients with total serum solids of <2 mg/dl are usually severely debilitated and are poor candidates for surgical recovery. A hematocrit >60% is indicative of dehydration, and fluid therapy should be instituted. If the hematocrit is <20%, surgery should be delayed or a whole blood transfusion should be administered. Blood transfusions are best made from donors of the same species; however, heterologous transfusions appear to be safe and efficacious.[7,26] A serum uric acid of >30 mg/dl indicates dehydration (prerenal) or renal disease. Surgery should always be postponed until a patient is adequately hydrated. The hematocrit and total serum solids can be used to determine whether primary renal disease is a factor.

Serum cholesterol, AST and LDH activities may be helpful in evaluating the preoperative condition of a patient. Of 54 birds used to evaluate various anesthetic agents, three deaths occurred, two of which had preanesthetic serum parameters: AST=>650 IU/l, LDH=>600 IU/L and cholesterol=>700 mg/dl. Many of the birds that survived had high AST and LDH activities but not in combination with a high serum cholesterol level.[17]

Respiratory recovery time is determined by the time it takes a bird to return to a prestressed respiratory rate following two minutes of handling. A return to normal respiratory rate within three to five minutes indicates respiratory stability adequate for most anesthetic and surgical procedures. Periods longer than five minutes indicate severe respiratory compromise.

The bird's nitrogen balance should be addressed, especially in birds that have been anorectic for several days. In a properly hydrated bird, an increase in body weight is a good indicator of a positive nitrogen balance.

Birds have relatively little glycogen stored in the liver. A decrease in blood glucose and insulin combined with an increase in glucagon stimulate hepatic glycogenolysis. Liver glycogen stores may decrease as much as 90% during a 24- to 36-hour fast and potentially quicker in smaller birds.[21] Vomiting and regurgitation may occur if the patient is not fasted, and can result in aspiration pneumonia (see Chapter 39). A short fast of five to eight hours will help decrease the probability of aspiration pneumonia and will have minimal effects on blood glucose.[20] In emergency situations when the digestive tract is full, it should be partially emptied before the bird is placed in dorsal recumbency (see Chapter 39).

When significant hemorrhage is anticipated, intraoperative IV fluid therapy should be provided. A patient may be suspected to have a clotting disorder if perifollicular bleeding occurs during surgical preparation. When a mature feather is removed, there should be virtually no hemorrhage around the follicle.

Nutritional Support

Little is known about the nutritional requirements of the various species of companion and aviary birds. Even less is known about how stress, such as surgery, increases the nutritional and caloric requirements of avian patients. In contrast to starvation, stress may cause an initial hypometabolic state followed by hypermetabolism,[32] which increases the body's need for protein. Protein is necessary for tissue repair, antibody production and blood cell production, all of which are necessary for postsurgical recovery. Carbohydrates (not fats) are nitrogen-sparing energy sources that best correct a stress-related negative nitrogen balance.[32] The postoperative surgical patient must have a positive nitrogen balance to facilitate tissue repair, and a source of nonprotein energy to meet increased caloric requirements.

The basal metabolic rate (BMR) of inactive animals may be determined using the formula BMR kcal/kg/24 hr = $K(BW_{kg}^{0.75})$ (see Chapter 15). Additional energy is required for growth, reproduction, disease and tissue repair and is defined as productive energy (the amount of energy a bird mobilizes above the requirements for existence).[41] Stresses such as severe trauma, head injury and sepsis increase the patient's energy requirements 1.5 to 3.0 times the minimum energy requirement.[13,32] Birds have a higher requirement for protein,[13,32] and their amino acid requirements are different from those of mammals.

Liquid diets that can be used to provide assisted alimentation to pre- or postsurgical patients are commercially available.[13,14,32] Hyperosmolar diets should be diluted (1:1) with water. Only 25% of the calculated requirements should be provided initially in order to prevent diarrhea. Over a period of two to three days, the concentration and volume of formula are gradually increased as the intestines adapt to the hyperosmolar solution.[40]

The patient's water requirements must also be met. When using hyperosmolar diets, water may be pulled into the intestine, which contributes to dehydration. Water requirements vary with species, diet, size, age and environmental temperature (see Chapter 15).[32]

Patient Preparation

Feather Control

In preparing the skin for surgery, feathers surrounding the proposed surgical site should be gently plucked for a distance of two to three centimeters. The contour and covert feathers of the body grow in pterylae or tracts, which are separated by featherless areas (apteria). These feathers may be easily and safely removed individually if plucked in the same direction as their growth. The large flight feathers (remiges and retrices) are attached to the periosteum of the underlying bone and have highly developed feather muscles and ligaments. Removing these feathers is painful and is best accomplished while the patient is anesthetized. When flight feathers must be removed, they should be removed individually by holding the feather at its base and pulling in the direction of feather growth. To avoid injury to the skin, muscles and periosteal attachments, the other hand is used to carefully secure the tissues at the base of the feather while it is being removed (see Figure 15.12).[28]

Small feathers should be pulled in groups of three or four in a direction opposite their growth.[1,18,28] If the skin has been damaged or torn, the feathers in this area can be cut to avoid further damage to the skin.[10] Cut feathers are replaced only during the normal molt cycle.

Excess feather removal will reduce a bird's insulating ability, increase metabolic demand during the recovery period (energy used to regrow the feathers)[28] and, if primary or secondary feathers are removed, the bird will not be able to fly until they regrow. The removal of primary and secondary feathers should be avoided because it is easy to damage the follicle, resulting in the growth of malformed replacement feathers. Flight feathers are molted one at a time and require the structural support of the adjacent feathers for proper growth. Because the skin of birds is very fragile and tears easily, removal of feathers is a delicate procedure, and attempting to remove too many feathers too quickly may result in bruising and tearing of the skin. Feathers in adjacent pterylae can be retracted using a stockinette, masking tape or water-soluble gel.[1,18,28] Water-soluble gels will prevent clear plastic drapes from properly adhering to the skin and should not be used in this situation.

Creating a Sterile Field

Standard aseptic technique[30,39] must be adhered to when performing surgery on avian patients. Poor technique may have devastating consequences. Skin preparation solutions are used to decrease the number of bacteria present on the skin surface to minimize the risk of bacterial contamination of the surgery site. They should accomplish this objective without damaging the skin and predisposing the patient to dermatitis.[27]

Concentrations of chlorhexidine diacetate (0.05%)[a] and povidone iodine (1.0%)[b] are effective for skin preparation. Although studies have shown these concentrations to be cytotoxic *in vitro*, they do not have a significant clinical effect on wound healing. Chlorhexidine gluconate (4%)[c] is equally effective when rinsed with saline or alcohol. A saline rinse has been found to leave sufficient residual chlorhexidine gluconate bound to the skin to be effective. This is beneficial in avian patients where the use of alcohol predisposes to hypothermia. When povidone iodine (1%) was used as a skin preparation, approximately

CLINICAL APPLICATIONS

Clinical pathology parameters for which postponement of surgery may be necessary include:

- PCV: <20% - delay surgery or provide blood transfusion
  >60% = dehydration; give fluid therapy
- Total solids: <2 mg/dl = severe debilitation
- Blood glucose (raptors, Anseriformes): <200 mg/dl - give 2.5-5% dextrose
- Uric acid: >30 mg/dl = dehydration (prerenal) or renal disease
- AST: >650 IU/dl
- LDH: >600 IU/dl
- Cholesterol: >700 mg/dl

50% of the treated dogs developed erythema, edema, papules, wheals and "weeping" of serum from the skin surface.[27] Chlorhexidine is generally preferred over povidone iodine solution as a patient preparation[27] because it has a broader spectrum of antimicrobial activity, longer residual antimicrobial activity, is efficacious in the presence of blood and organic matter and is nontoxic and hypoallergenic. However, in clinical settings, the type of scrub solution used has not been found to affect the rate of wound infections.[34]

It is challenging to create a sterile field of the wing because of the large flight feathers, which should not be removed unless absolutely necessary. The primary and secondary flight feathers can be wrapped together with masking tape. The surgeon can then cover the entire wing with a sterile stockinette or self-adherent bandage material[d] creating a sterile field (Figure 40.1).[28]

Patient drapes are currently available in a variety of sizes, shapes and materials. With avian patients clear drapes are recommended, as they allow the surgeon and anesthetist to visually monitor the patient during the procedure. Clear plastic drapes are commercially available[e] with or without povidone iodine impregnation. These drapes have an adhesive that will stick to dry avian skin and create a sterile field, but must be removed with care to prevent damaging the tissue. These drapes conform closely to the patient's body, are lightweight, disposable and inexpensive, and allow the anesthetist to monitor respiratory movements. As an alternative, a clear plastic drape can be made from plastic kitchen wrap. The border of the plastic should be edged with masking tape, making it easy to find the edges and open the drape. These drapes can be folded with a sheet of plastic but must be gas sterilized and are not adhesive.

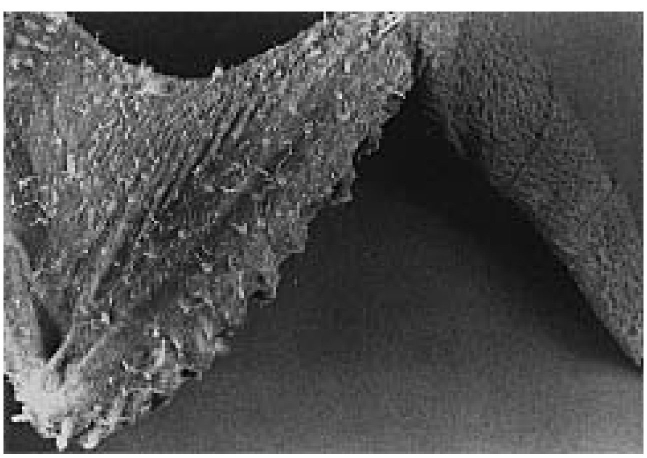

FIG 40.1 Feather removal in preparation for surgery should be sufficient to allow the establishment of a sterile field but not so severe that the bird is predisposed to hypothermia. In this case, the feathers from the mid-diaphysial humerus to the carpus were removed to prepare the bird for the placement of an external fixator to repair a fractured ulna. The primary feathers were clipped and wrapped in a self-adherent bandage material to facilitate the creation of a sterile field without removal of the primary feathers.

In most cases, the plastic drape is small and does not allow the surgeon to create a sterile field incorporating the entire surgery table and instrument stand. In order create such a field, the clear plastic drape is placed over the patient and a large drape sheet with a central fenestration large enough to allow the draped patient to be exposed, is placed over the entire field. This will prevent accidental contamination of the arms and elbows by touching them to an undraped table.

Perioperative antibiotic therapy involves the use of antibiotics such that there are therapeutic tissue levels of the agent present at the time of exposure to bacteria. With most antibiotics, parenteral administration one to two hours preoperatively, and maintaining therapeutic doses for 8 to 16 hours postoperatively, will accomplish this goal. Unless there is infection or significant contamination, use of antibiotics beyond this period is not indicated and has been shown not to decrease the incidence of surgical wound infections.

Wound Healing

Wound healing has been thoroughly studied in mammals, and five phases have been described: the inflammatory stage, the fibroblastic phase, the epithelialization phase, the contraction phase and the remodeling phase.[29,31] The cellular and vascular events of the inflammatory phase have been studied in chickens.[2,8,10,24,25] The inflammatory response in birds is similar to that classically described in mammals with early vasoconstriction to initiate hemostasis, followed by vasodilation within 30 minutes.[25,31] Bradykinin, histamine, 5-hydroxytryptamine and other chemical mediators initiate the acute inflammatory phase of wound healing in birds.[2] During the first two to six hours, large numbers of heterophils, basophils and monocytes migrate into the wound margins.[8,25] Phagocytosis of cellular debris and bacteria begins during this phase. After 12 hours there is a shift in the cellular response from one of primarily polymorphonuclear leukocytes initially to one of primarily mononuclear cells such as lymphocytes, plasma cells, macrophages and monocytes.[25] During the next 36 hours, macrophages and multinucleated giant cells begin to phagocytize those leukocytes that have been involved in the early phagocytosis of tissue debris and bacteria. Fibroblasts begin to appear at the wound margins and proliferate over the next few days.

As soon as necrotic tissue, blood clots and other debris are removed by phagocytic cells, fibroblasts move into the damaged tissue. In the inflammatory phase, the exudate contains fibrinogen, which is converted to fibrin by the release of tissue enzymes. This acts as a hemostatic barrier and a scaffolding for other repair elements such as the incoming fibroblasts. New capillaries enter immediately behind the migrating fibroblasts. They contain plasminogen activator that is necessary for the breakdown of the fibrin. Collagen is synthesized during this fibroblastic phase beginning on the third or fourth day in birds[8] and on the fourth or fifth day in mammals.[31] The collagen bundles are initially small, but gradually enlarge to form dense collagen networks that bind the edges of the wound together. The fibroblastic phase of healing lasts two to four weeks. As the content of collagen increases, the number of fibroblasts decreases, and the capillaries begin to regress. Eventually, the rate of collagen production roughly equals the rate of collagen destruction.[31]

The epithelialization phase is characterized by the migration of epithelial cells from the wound margin. The epidermal basal cells are normally adhered to each other. These adhesions break down, allowing the cells to be mobilized. The cells enlarge and migrate down and across the wound. These cells do not begin to proliferate until the entire wound surface has been covered by a single layer of epithelial cells. Eventually, the normal epithelial thickness is restored.

The contraction phase is described as "the process by which the size of a full-thickness open wound is diminished and is characterized by the centripetal movement of the whole thickness of surrounding skin."[29] Several mechanisms have been theorized to be responsible for this action.[31]

The remodeling phase is described in terms of early wound strength and late wound strength.[31] There is no appreciable gain in wound strength during the first four to six days of healing. However, the fibrin clot, epithelialization and ingrowth of new capillaries occur early and provide some support to the wound. After the early fibroblastic phase, wound strength increases to an early maximum at 14 to 16 days, paralleling the rise in collagen content of the wound.[31] Late wound strength occurs as a result of collagen maturation. The collagen content stabilizes after the third week. Wound strength may continue to increase for a period of years following the stabilization of the collagen content resulting from the intramolecular and intermolecular cross linking of collagen fibers.

Freshly created (within eight hours), uncomplicated wounds should be treated by primary closure with anticipated first intention healing;[5] however, this is not appropriate for the treatment of open, contaminated wounds.

Instrumentation

Instuments for avian surgery should be appropriate to the patient's size. In many cases, ophthalmic instruments are suitable and should be included in the standard avian surgery pack. Iris scissors (curved and straight), forceps with fine teeth, micro Halstead mosquito forceps, jeweler's forceps (curved and straight), iris hooks, eyelid retractors for abdominal retractors, retinal forceps, adventitia scissors, spring handled scissors and Castroviejo needle holders are particularly useful (Figure 40.2). Because avian tissues are delicate, the use of toothed forceps is seldom appropriate. Debakey-type forceps are relatively atraumatic and serve well in avian surgery. Penrose drains or other sterile rubber materials may be used to wrap around structures for elevation or retraction, and eyelid retractors work well as wound retractors (Figure 40.3). A sterile gavage or feeding tube can be used for irrigation or for flushing out hollow viscera (such as the proventriculus during proventriculotomy). Various sizes of bone curettes are useful to retrieve foreign bodies from the ventriculus or proventriculus. A tuberculin syringe with an attached 25 ga needle can be fashioned into a tissue hook by bending the tip of the needle 45 to 90° under the operating microscope.

A mini-Frazier suction tip is well suited for avian surgery because of its small, delicate size. This type of suction tip also has a small hole at the finger rest, which the surgeon may use to adjust the amount of suction created at the tip. Red rubber urinary catheters and infant feeding tubes are available in varying sizes and may be cut off and adapted for use as a

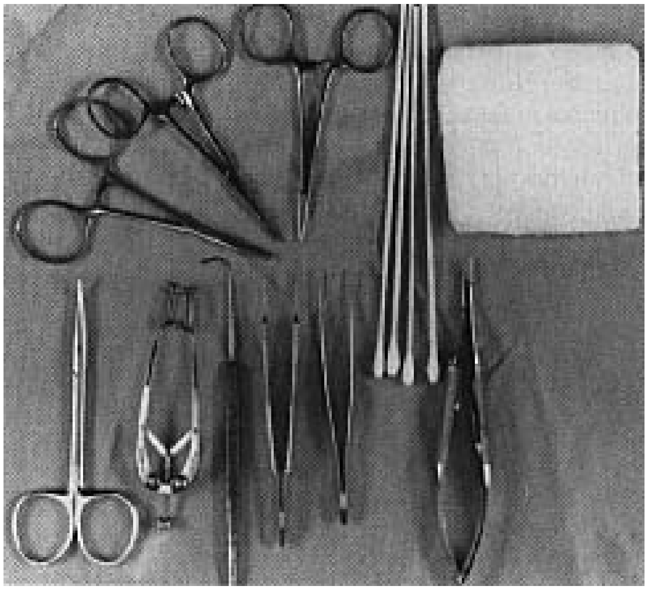

FIG 40.2 Ophthalmic instrumentation is best suited for use in birds.

suction tip. Care must be taken with this type of tip and a powerful suction unit in order not to damage viscera inadvertently suctioned against the tip. The strength of suction can be controlled on most suction units and should be adjusted so that fluids can be evacuated without damaging tissues. A Poole-type suction tip can be fashioned from a catheter by cutting multiple fenestrations along the terminal two to three centimeters of the catheter. By having many fenestrations, the suction force is distributed among the inlets, decreasing the force at any one hole. Additionally, if some of the holes are occluded by tissue, the remaining inlets continue to evacuate the celomic cavity.

A one- to three-millimeter rigid endoscope is helpful for visualizing areas that the surgeon may not be able to access with the operating microscope (eg, lumen of hollow viscera). Abdominal retractors appropriate for small avian patients should maintain retraction but not have blades that extend deep into the body cavity. Mini-Balfour retractors are useful in large patients such as macaws and cockatoos, Alm retractors are appropriate for medium-sized patients like Amazons and conures, and Heiss retractors work well in small avian patients including cockatiels and budgerigars.

In many situations, the placement of ligatures in deep surgical sites is unachievable or results in unacceptable tissue damage due to the relative inaccessibility and delicate nature of avian tissues. Hemostatic clips[h,i] are best for controlling bleeding in these

FIG 40.3 Various types of lid retractors are ideal for use in maintaining access to the abdomen of birds. In this photograph, a lid retractor is being used to maintain an opening in the left abdominal wall. The seventh rib (r) has been isolated and cut ventrally to facilitate its removal for better access to the proventriculus. Several rents can be seen in the relatively clear caudal abdominal air sac (arrow) just to the left of the rib. The proventriculus (p) and ventriculus (v) can be seen deep to the surgical site.

cases. Multiple-sized clips should be available to address varied-sized patients and different surgical needs. The major expense is encountered in purchasing the applier, as the clips themselves are relatively inexpensive. The appliers are available either straight or with a 45° bend. The bent-tipped applier is useful for deep clip placement; however, the bent-tipped instruments are about twice the size of the equivalent straight-tipped applier, making them more cumbersome to use. Generally, the small and medium clips are used most frequently.

Number 15 and No. 11 scalpel blades are most appropriate for avian surgery. Small gauze pads (2 x 2) and sterile cotton-tipped applicators should also be available (see Figure 40.2). Surgical spears[j] are small, wedge-shaped, highly absorbent, synthetic sponges attached to a stick. The point of the spear provides critical control when working under magnification.

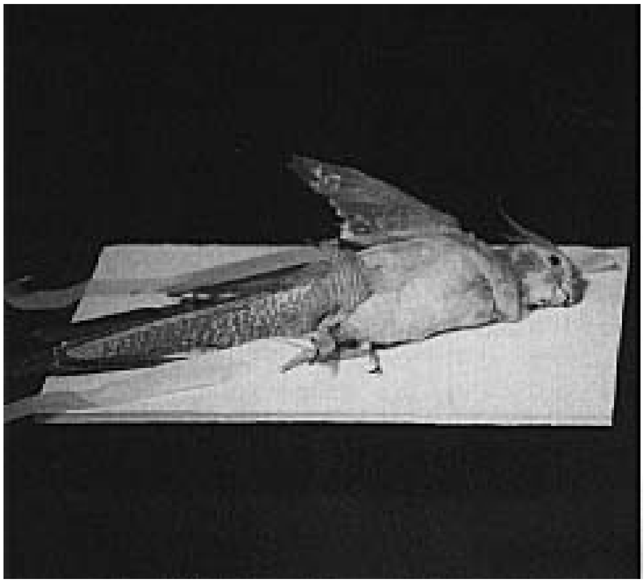

FIG 40.4 Surgical boards made of sterilizable materials are helpful to facilitate the movement of patients undergoing microsurgical procedures. An anesthetized cockatiel hen has been taped to a surgical board in preparation for a hysterectomy.

Absorbable gelatin sponges[k] are valuable for controlling hemorrhage, as is oxidized regenerated cellulose.[l]

With avian patients it is best to place the patient on a restraint board, which is then placed on the operating table. This allows the surgical assistant to move the patient intraoperatively to acheive proper visualization of structures. This is especially important when using the operating microscope as it is much easier to move the patient than to move and refocus the microscope (Figure 40.4). Such boards are commercially available[m] or can be easily constructed from a plastic container lid, a piece of styrofoam or a section of cardboard. Any material that is used should be disposable or sterilizable. Tape restraints are preferred over velcro restraints because they are disposable and minimize the risk of disease transmission.

An ideal monitor for the surgical patient would be easy to apply, unaffected by the surgical environment, economically priced and provide data on the patient's heart rate, respiration, body temperature and hemoglobin oxygen saturation. The high heart rate and small tidal volume of small avian patients are not easily detected by traditional monitors. Pulse oximeters have become standard in human anesthesia but may be unable to detect the high pulse rate of some smaller patients. Sensitive respiratory monitors that have a thermistor that extends to the end of an endotracheal tube[n] are effective in intubated patients but do not function properly if the patient is maintained using a face mask (see Chapter 39). Remote thermometers are available at a reasonable price.[o] The best monitor for surgical anesthesia is still a well trained and experienced surgical technician.

Radiosurgery (Electrosurgery)

Radiosurgery employs high frequency (two to four mHz), alternating current to generate energy waves, which create vibration and molecular heat inside individual cells, causing water to vaporize and the cells to rupture while the active electrode remains cool (Figure 40.5).[15,16,19,33,38] Most electrosurgical units generate wave forms in the frequency range of radio waves, making the term *radiosurgery* applicable. The frequency can be varied to achieve either cutting of tissues or coagulation of vessels. Coagulation occurs when the current density is sufficient to dehydrate cells and coagulate their organic contents.[16,19,33,38]

When set for monopolar operation, a radiosurgery unit employs two electrodes (an active electrode and an indifferent electrode or ground plate), which concentrate the current density at the tip of the smaller (active) electrode. Monopolar radiosurgical techniques are acceptable for gross tissue manipulations in avian patients weighing more than two kilograms. These are analogous to a broadcast antenna (active electrode) and a receiving antenna (indifferent electrode) for radio transmission. The ground (indifferent electrode) should be large and placed as close as possible to the surgical area, and the contact with the patient should be improved using an electrode paste. It is important to keep the active electrode clean and free of char and debris. A dirty electrode will drag

FIG 40.5 Radiosurgery units are indispensable in avian practice. Versatile units are available that also have numerous applications in mammalian surgery (courtesy of Ellman Intl. Mfg. Inc.).

through the tissue, inhibiting the cutting action and increasing tissue coagulation, which can delay healing and predispose the wound to dehiscence.[15,16,19] Many types of active electrode tips are commercially available. Ball-type electrodes create a lot of tissue destruction and are used for fulguration and coagulation of large vessels. Loop electrodes are used to contour tissues, obtain organ biopsies and remove large masses in a piecemeal fashion. Skin incisions and incisions into other fine tissues are best accomplished with fine wire electrodes.

Bipolar Forceps

Bipolar radiosurgical forceps are superior to monopolar forceps in patients weighing less than two kilograms and when manipulating tissues in the realm of microsurgery. With bipolar forceps a ground plate is not needed as one of the tips serves as the active electrode and the other as the indifferent electrode (Figure 40.6). Compared with the fine-needle or wire monopolar electrodes, the tips of the bipolar forceps are broader, allowing the current to be dispersed just enough to accomplish the tissue welding that is critical for hemostasis. The current passes from one tip (active electrode), through the contacted tissue and to the other electrode (indifferent) without passing through the entire patient. In avian patients, bipolar forceps induce less reflex hemorrhage and provide improved tissue control. With the two electrodes in such close proximity, the transmitted wave currents are different from those generated with the monopolar system, resulting in precise control of energy application.

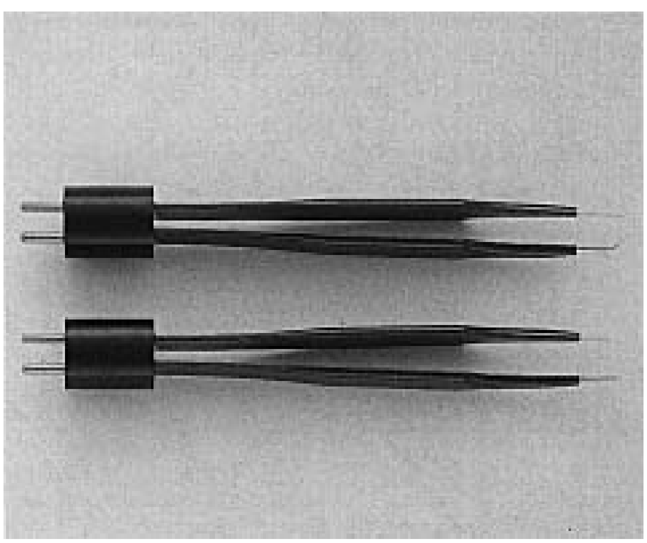

FIG 40.6 Several styles of bipolar forceps are available. The top one has been specifically designed for avian microsurgical application. These tips are thinner than normal bipolar tips and the active electrode has a 45° bend to facilitate cutting of avian tissues (courtesy of Ellman Intl. Mfg. Inc.).

Some commercially available bipolar ophthalmic forceps are slightly wider than is ideal for avian surgery. These forceps can be made more appropriate for avian surgery by using a fine sharpening stone to reduce the width of the tips. It is best to make the active electrode tip slightly narrower than the indifferent tip. Forceps with the active electrode slightly bent are commercially available and are best for avian surgery.[p] The energy passes through the tissue between these tips in a manner not attainable with unmodified, straight-tipped bipolar forceps. A lower energy setting can be used with these forceps. With the Surgitron,[q] the fully filtered wave pattern of the *cutting* settings are used most commonly. The unit is set at 1 for vessel coagulation, 2 for muscle transection, and 3 for incision of dry skin. For vessels that are difficult to coagulate, the *cutting/coagulation* settings may occasionally be indicated. The *coagulation* setting is used primarily for tissue fulguration (such as the destruction of cloacal papillomas).

Incision Techniques

The Harrison modified bipolar forceps[p] may be used to make primary skin incisions, coagulate cutaneous vessels prior to blade incision and coagulate individual vessels. These forceps may also be used with or without current for tissue dissection. Skin incisions should be planned in a manner to minimize the effect on feathers and feather tracts and to avoid the major blood supply to feathers. The skin is tented with thumb forceps and grasped with the bipolar forceps at the location of the proposed incision (Figure 40.7).

The current is activated (using a foot switch) precisely as the grasp on the tissue is relaxed slightly, and with a smooth, rapid motion, the forceps are pulled off the tissue.[15,16] When correctly applied, a fine, white blanching of the tissues occurs with a barely discernible separation of the skin that can be seen under magnification. This will create a small incision in the tissue that may then be parted to allow introduction of the indifferent electrode of the bipolar forceps (non-bent tip). The electrode is inserted subcutaneously to the extent of the proposed incision. The electrodes of the bipolar forceps are lightly apposed, the current is activated and the forceps withdrawn. This creates a skin incision with minimal damage. If properly performed, the skin should remain a normal color except immediately adjacent to the incision (which should be white), and there should be no hemorrhage.[15]

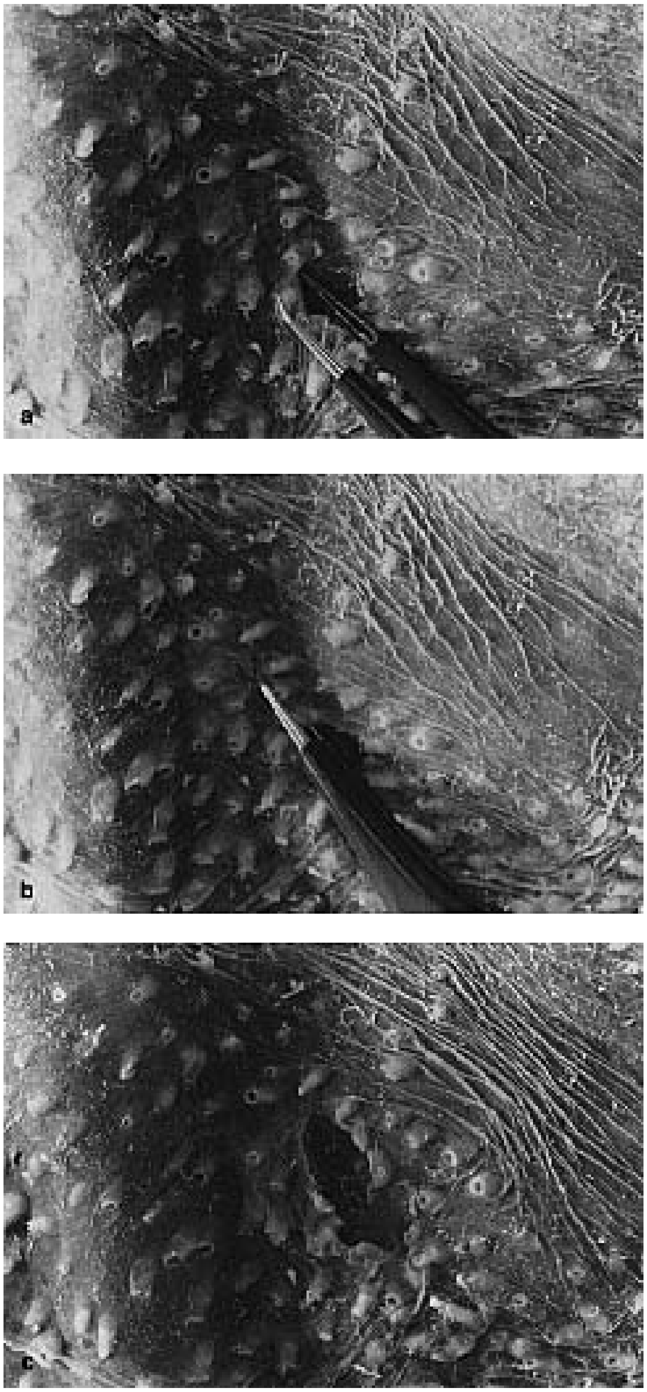

FIG 40.7 **a)** When possible, the site for a skin incision is chosen by selecting an area that does not pass directly through a feather follicle. A small nick incision is made with a scalpel or by raising the skin slightly with a pair of forceps and grasping the tissue with the bipolar forceps. **b)** The indifferent electrode of the bipolar forceps is then inserted under the skin, the tips are gently apposed and the forceps are pulled out of the nick incision in a straight line. **c)** The length of the bloodless incision line can be increased as needed. Note that the skin is incised between, not through, the feather follicles.

When thicker tissue is to be transected, small bites of tissue are grasped with the bipolar forceps, the current is activated and the forceps are withdrawn through the tissue, creating a small nick. This process is repeated until the tissue is completely transected, stroke by stroke.

Coagulation Techniques

If hemorrhage is encountered, a sterile cotton-tipped applicator is used to dry the area for radiocoagulation, which cannot be achieved in a wet field. The swab is rolled toward the source of blood flow with gentle pressure to serve as a tourniquet (Figure 40.8). The pressure is relaxed slightly to identify the source of hemorrhage. Once the vessel is identified, the slightly broader, flat indifferent electrode is placed under the vessel, and the bent-tipped, active electrode is loosely apposed to occlude the vessel. The current is activated as the forceps are relaxed, sealing the vessel. At high current or coagulation settings, the vessel frequently retracts within the tissue due to vasospasm. This results in temporary hemostasis only. As the vessel relaxes, the hemorrhage recurs.

When using monopolar radiosurgery, the power settings vary with the type and size of the electrode, the area of electrode surface in contact with tissue, the nature of the tissue, the operation performed (cut or coagulation) and the depth of the incision desired. Higher settings are necessary with tough tissues, deep incisions and large electrodes. Healing after radioincision is by first intention. When used correctly for creating an incision, the current should be activated *before* touching tissue, and the electrode should glide effortlessly, producing only a slight color

FIG 40.8 A cotton swab is used to roll toward a bleeding vessel and, with gentle pressure, to occlude the vessel, stop the bleeding and allow the identification and coagulation of the severed vessel.

change in the tissue. When used for coagulation, the electrode should be activated *after* contacting the tissue and should produce a white spot at the site of energy transfer. Current applied repeatedly to the same area will cause excessive heating and damage to underlying tissues.

A radio current may pass through any portion of the exposed metal portion of the electrode. When the current is activated, it is important to be certain that only the tissue to be cut or coagulated is in contact with the metal portion of the electrode tip. This is especially important when attempting to coagulate vessels in the abdominal cavity through a small incision in a small bird. If the electrode inadvertently touches other structures (abdominal wall, parenchymous organs), the current will pass from the electrode through the first tissue it touches and exit at the ground plate, potentially without even contacting the intended tissue. Most bipolar forceps are insulated such that only the tips are exposed. This reduces the likelihood of errors causing unwanted damage to adjacent structures.

The fine-tipped monopolar electrode requires a higher setting when used on avian tissues than when used on thicker mammalian skin. When a vessel is encountered at these high settings, the electrode has a tendency to cut rather than coagulate the vessel, resulting in hemorrhage. A second effort must then be made to locate the vessel and coagulate it separately, creating the potential to induce more damage to the vessel and surrounding tissues. In mammals, the tissues surrounding vessels will heat slightly with the application of radiocurrent, which helps seal any transected vessels.

The application of a bipolar radiosurgical unit to avian practice and to veterinary practice in general is limited only by the time that the clinician spends in practicing with this equipment. Each radiosurgical unit requires precise adjustments that must be performed by the surgeon who will be using the instrument. Time invested in practicing with a radiosurgical unit will be well worth the improvement in clinical results.

Magnification

The hands and fingers are able to accomplish tasks of intricate detail, and vision is generally the limiting factor in surgical procedures. Therefore, some form of magnification is recommended for avian surgery[33] and is an integral part of an avian specialty practice.

Operating Microscope

In patients weighing less than a kilogram, an operating microscope and microsurgical instrumentation are mandatory and would be considered advantageous in larger birds. Using microsurgical techniques, severed nerves and vessels, which if left unrepaired would result in a dysfunctional post-fracture limb, can be anastomosed. Binocular magnification loupes of 2.5x to 8x are adequate for many procedures. Head sets with higher magnification usually create disorientation because of the constant micromovements of the head. Attaching a fiberoptic lamp to the loupe facilitates vision. With the use of magnification, individual vessels are more easily identified for coagulation, minimizing the degree of hemorrhage associated with a procedure.[1,19,33] Because minor hand tremors are magnified, it is recommended that microsurgeons abstain from the use of alcohol, caffeine, other stimulants and heavy exercise prior to surgery.[16] The major disadvantage of performing surgery under an operating microscope is that it generally requires more time to complete a procedure than when a magnification loupe is used.

The operating microscope should have a lens objective of approximately 150 mm with 12.5 mm ocular lenses.[12] An electronic zoom is advantageous. A fiberoptic ring light can be attached to the lens for improved illumination of the surgical field. This type of ring light can be connected to most standard endoscope light sources. Bright white light is critical for visualization during microsurgery. Microscopes are expensive, but used and reconditioned models are becoming more readily available.

Microsurgical Instruments

There are four requirements for microsurgical instruments: they should be long, be counterbalanced, have round handles and have miniaturized tips (Figure 40.9).[16] It is important that only the tips of microsurgical instruments are miniaturized. The handles should be of normal length to help provide stability to the tips and diminish the effect of hand tremors. The handles should be long enough to rest comfortably in the hand between the thumb and index finger. The instrument should be held like a fine writing instrument and be manipulated with minimal pressure. Gripping the instrument will fatigue the hand and fingers, causing motion at the tips. Microsurgical instruments have a counterbalance and are contoured to rest in the groove between the thumb and index finger. They should lie in the hand and not fall out when the grip is released (Figure 40.10). The handles should be round (except for scissors) to facili-

FIG 40.9 A microsurgical needle holder with long, rounded, counter-balanced handles and miniaturized tips is compared to a standard needle holder.

tate a rolling action that results in smooth, precise, flowing movements at the tip. This rolling motion is especially important for delicate cutting, suturing and knot-tying. It is important to note that totally miniaturized instruments (older generation of ophthalmic instruments) are not appropriate for microsurgery. These instruments have short shanks and handles, and their use under the operating microscope results in loss of balance and control leading to fast, jerky movements.

The microsurgical pack should include micro-scissors, micro-needle holders and a variety of micro-forceps. Needle holders should not have a clasp or box lock, as the motion that occurs when the lock is set and released is enough to cause the needle to tear tissues. Inexpensive forceps can be fashioned by placing vulcanized silicone on the handles of jewelry forceps. Layers of liquid plastic (dispensed from a hot glue gun) may be applied to the handles to achieve the necessary round shape. An ophthalmic Castroviejo needle holder can be modified for microsurgery by grinding the tip narrower, removing the box lock and making the handle round.[12,16]

For microvascular work, specialized clips are used to maintain the severed ends of the vessel in approximation. A colored background is placed under the vessel to improve contrast and make identification of the vessel easier. These backgrounds are commercially available[r] or can be made from pieces of balloon appropriately sterilized. Vessel dilators are also necessary. A vascular irrigation system can be made using a 27 or 30 ga needle, the tip of which has been cut off and polished smooth so it will not damage the vascular intima. A motorized rotary tool and the operating microscope are used to modify the needle. Heparinized irrigation solution in a hand syringe with the modified needle attached is used to clear the vessel of clots and debris.[12,16] Suture material for small avian patients usually is of 6-0 to 10-0 size, while for microvascular work, 10-0 nylon suture on a 75 micron needle is routinely used.[12]

Developing Microsurgical Skills

The avian surgeon should take advantage of every opportunity to gain experience. Human plastic surgeons and microvascular surgeons are valuable resources. Continuing education courses and opportu-

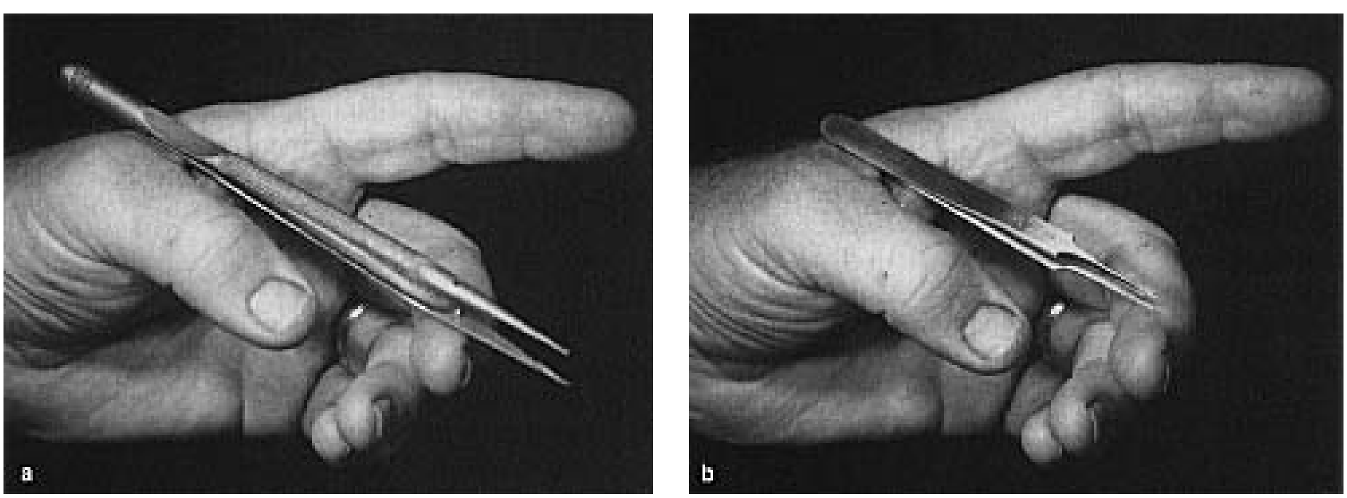

FIG 40.10 **a)** The handles of microsurgical instruments should be of sufficient length to allow them to rest comfortably in the groove between the thumb and index finger. **b)** Miniaturized instruments are difficult to manipulate and cause increased fatigue of the hands during use.

nities to practice on cadaver specimens are also valuable. Prior to practicing on tissues, it is helpful to gain experience manipulating objects under magnification by picking up and moving small objects (eg, canary seeds) with the microsurgical instruments. A slit can be placed in a latex glove to practice suture placement and knot tying. Initially, the clinician must develop new eye-hand coordination, and it is important to develop dexterity with both hands under the operating microscope. Microsurgery is tedious, time-consuming work, and it is imperative that the surgeon be comfortable. Prior to the onset of the procedure, the height of the table and chair should be adjusted for the surgeon's maximum comfort. Motion from the shoulders and arms should be minimized by resting the mid-antebrachium along the edge of the table to serve as a fulcrum. The fourth and fifth fingers should also rest on the table to provide a second fulcrum and additional stability. The hands should be relaxed, and any motion should originate from the wrists and fingers, resulting in smooth, accurate paint brush-type movements. Breathing patterns should be natural. Breath-holding results in tremors at the instrument tips.[16]

Suture Materials

The goals of incision repair are to limit the adverse effects of the repair technique and to restrict the loss of tissue function. In routine avian surgery, suture sizes of 3-0 to 6-0 are most commonly used.[18] For small patients and microsurgery, sutures of 10-0 may be necessary. Companion birds may have a rather formidable beak that could easily remove the toughest materials; however, they generally do not traumatize suture lines.[1] This characteristic allows the use of continuous patterns in the skin of many avian patients. Topical medications, splints and bandages are not well tolerated by companion birds.

Many factors should be considered when selecting an appropriate suture material for a given procedure. The tissue characteristics, the presence of contamination or infection and the characteristics of the suture material influence the selection. The ability of suture material to potentiate infection is roughly proportionate to the inflammatory reaction caused by the suture.[36] The inflammatory response and reaction to various suture materials differ between birds and mammals. A number of factors influence the amount of inflammation a suture material induces including the surface area of material exposed to the tissue, the tissue in which the material is used (ie, fascia does not react to silk while intestines and skin react strongly), the method of placement (tight sutures strangulate tissue), the length of time the material has been present (some sutures stimulate a reaction shortly after placement but become inactive within a few months) and the chemical properties of the material.[36,37]

Suture is a foreign material in a surgical wound and may potentiate infection. Bacteria may be protected from the body's defenses within the suture material. By reducing the amount of material implanted (the fewest number of sutures and the smallest diameter possible to accomplish the task) and minimizing surgical tissue trauma, the risk of suture-related infection may be diminished.[36,37] Braided sutures should not be used in contaminated or infected wounds as they delay the clearance of bacteria, prolonging and promoting inflammation.[36] Bacteria are better able to bind to braided materials than monofilament suture made of the same material. Where there is contamination or infection, a monofilament, nonreactive material such as nylon is indicated, as it will not allow bacterial wicking and will retain its tensile strength long enough for resolution of the infection and completion of tissue healing. In a study of the ability of bacteria to adhere to suture material it was found that monofilament, nonabsorbable materials have the least capacity for adherence while polyglycolic acid and polyglactin 910 have the most.[36]

Sutures that act as a wick to allow transport of serum and bacteria are called capillary sutures.[37] They may potentiate the spread of infection from a contaminated or infected tissue into a sterile area.[36] Multifilament sutures are also more likely to cause the formation of suture sinus tracts and granulomas than monofilament materials. The advantage of braided sutures is that they generally have better handling characteristics.

The extent of tissue damage during suture placement also influences the reaction and the risk of infection. Sutures should be placed with a minimum amount of both intrinsic (tension on tissue within the loop of suture material) and extrinsic (tension on surrounding tissues) tension. Knots must be securely tied, yet the surgeon must attempt to use the least amount of suture material to decrease the foreign body reaction. It is important to use the fewest throws to create a secure knot, which will fail by suture breakage and not by knot failure. For chromic catgut, polyglactin 910, polyglycolic acid and polypropylene, three throws are required and four are required for polydioxanone and nylon.[35] When starting and finishing a continuous pattern, a different number of throws is required to create a secure knot. To start a continuous pattern with polygycolic acid, polyglactin 910 and polypropylene three throws are required. Four are required for chromic catgut and five for polydioxanone. When ending a continuous pattern, it takes five throws for polypropylene, chromic catgut and polyglycolic acid, six for nylon and polyglactin 910, and seven for polydioxanone to create a secure knot.

After considering suture characteristics, tissue interaction and the processes of wound healing, the final factor in suture selection is personal preference. The technique of suture placement and tissue handling remains more important for uncomplicated wound healing than the selection of suture material.[37] The placement of sutures in a manner that allows accurate tissue apposition appears to be more critical in avian patients than in mammals. Tension and the resultant tearing of tissue in birds dictates the use of more sutures per centimeter, less intrinsic tension (within the suture loop) and atraumatic insertion. Most avian tissues have low tensile strength. It is important to use the smallest swaged-on atraumatic needle that is available for a particular suture. Many visceral organs are very delicate and require that the surgeon develop specialized handling techniques.

Evaluation of Suture Materials in Birds

The tissue reaction to five suture materials (polyglactin 910, polydioxanone suture, monofilament nylon, medium chromic catgut and monofilament stainless steel) in pigeons was evaluated at 3, 7, 15, 30, 60, 90 and 120 days following implantation in the body wall.[4] In mammals, it is known that chromic catgut is absorbed by the action of proteolytic enzymes released from monocytes. The pigeons in this study developed a marked granulocytic inflammatory response the the catgut that diminished during the period of evaluation; however, the material was still present at the end of the study indicating prolonged absorption of the material. Polyglactin 910 is considered nonreactive in mammals. It is absorbed by the process of hydrolysis and does not require enzyme degradation. In this study, polyglactin 910 caused the most intense inflammatory reaction but it was absorbed the most quickly (completely gone by day 60). Polydioxanone is a monofilament material, which, like polyglactin 910, is absorbed by hydrolysis. It is considered nonreactive in mammals and is usually completely absorbed by 180 days after implantation. This material behaved similarly in the pigeons studied. It caused minimal tissue reaction and absorption was underway at the close of the study.

Nylon and stainless steel cause minimal tissue reaction but are nonabsorbable. In the pigeons, they caused minimal tissue reaction but, because they are stiff and potentially more mechanically irritating to surrounding tissues, they were more often associated with hematoma, seroma and caseogranuloma formation. Based on the findings reported in this study, chromic catgut should be avoided in avian surgery. Slowly absorbed monofilament, synthetic materials absorbed by hydrolysis rather than proteolysis are most appropriate when wound healing is expected to be prolonged. Rapidly absorbed, braided, synthetic materials absorbed by hydrolysis are best used when the benefit of rapid absorption outweighs the disadvantage of a pronounced inflammatory reaction.

(The editors have experienced some adverse reactions with Polyglactin 910 in psittacine birds; therefore they personally use nylon for subcutaneous sutures and stainless steel wire for skin.)

Tissue Adhesives

Tissue adhesives of cyanoacrylate have many applications in avian medicine and surgery. The cyanoacrylate monomer is a liquid that polymerizes in the presence of the small amount of water present in tissues. The time required for the liquid to become solid and bond tissues depends on the amount of water (more water present will delay curing) and the thickness of the acrylic applied (thicker will delay curing). Medical grade adhesives[s] are biologically inert and cause minimal tissue reaction. Some prefer to use the less expensive commercial grade of glue (eg, SuperGlue); however, these contain substances that are toxic to tissues[6,19] and are not recommended for medical use.

These materials hold tissues in approximation to allow healing to progress; however, cells cannot penetrate the adhesive. It is important not to allow the adhesive to run between the tissues to be apposed as the presence of the acrylic will delay healing by creating a physical barrier. In some cases, especially with water birds, the acrylic may be applied in a thin layer over the apposed incision to create a seal yet allow epithelial cells to migrate under the acrylic during the healing process. These adhesives may also be used to secure IV catheters in place, to attach the limbs or digits of tiny patients to splints for orthopedic problems and various other purposes. Caution should be exercised when using these materials in the presence of anesthetic gases with which they are synergistic and may cause ocular irritation and vomiting in avian patients.[19]

Postoperative Care

The patient should be placed in an incubator at 85°F with supplemental oxygen during recovery from surgery. It is best to continue maintaining the postsurgical patient in a small, controlled environment during the convalescent period (see Chapter 39). The patient's activity level should be kept to a minimum to allow proper tissue healing. A square, box-type enclosure is preferred and in most circumstances perches should be removed or lowered to decrease the likelihood of falling. Food and water should be placed where they are easily accessed by the patient. Toys and extraneous objects within the enclosure should be removed.

Postoperative antibiotic therapy should be instituted when there is a specific indication, such as with open, contaminated wounds or where there has been intraoperative contamination of the surgical field. IM perioperative antibiotic therapy is recommended for general prophylaxis in these cases.

In general, avian patients do not traumatize their surgical incisions, and they poorly tolerate bandages and other devices. Elizabethan collars or neck braces should be reserved for the most desperate cases. If an Elizabethan collar is considered necessary, the patient's neck should first be wrapped so the collar will be held in position against the mandible. Using this technique, a smaller, looser collar may be utilized.[22] In some patients, the center core of cardboard from a roll of bathroom tissue may be padded and used as a neck brace alone or in conjunction with an Elizabethan collar. The first day, the Elizabethan collar should open rostrally in the traditional manner. This will allow the patient time to become accustomed to the collar, and it will not damage the wings while the patient is struggling to escape the device. The second day, the collar should be reversed such that the cone opens caudally. This will allow the patient more ready access to food and water. The patient should be kept in a plain box with nothing to trap and hold the collar. Food and water should be placed on a pedestal for easy access. The patient's weight should be closely monitored to assure that an adequate amount of food and water is being consumed. The collar should be regularly evaluated for evidence of pressure or esophageal obstruction.

Analgesics

Historically, it has been considered that birds have a remarkable capacity to deal with pain, although the assessment of what animals perceive as pain is difficult. Research in the area of avian pain perception has been minimal. Companion birds have a well developed sense of touch and react by loud vocalization and withdrawal when potentially painful stimuli are applied. Clients expect that analgesia will be provided for their pet, and it is the responsibility of the entire staff to relieve a patient's postoperative pain and suffering.

Some research has been conducted with respect to pain in pigeons and poultry. One study was conducted in budgerigars[3] to evaluate the effect of high doses of butorphanol tartrate[t] and flunixin meglumine[u] on heart rate, motor control and respiratory rate.

Butorphanol is an opioid analgesic with both agonist and antagonist properties, resulting in a "ceiling effect" such that above a maximum effective dose, neither beneficial nor deleterious effects are noted. The action and potency of opiates and opioids is related to the specific receptor sites to which a given agent binds.[3]

There are three major types of opiate receptors. Mu receptors mediate analgesia and euphoria. They are also responsible for physical dependency, sedation and respiratory suppression. Kappa receptors also are involved in analgesia and, to a lesser degree, with sedation and respiratory depression. Sigma receptor stimulation results in cardiac and respiratory stimulation, anxiety and hallucinations.

Butorphanol exerts its effects at mu and kappa receptors. Doses of 3 to 4 mg/kg of butorphanol given to budgerigars had no statistically significant effect on heart rate or respiratory rate;[3] however, some treated birds lost motor control. This effect was considered minor and all birds remained alert. Return to normal motor coordination occurred within two to four hours post-administration. No gastrointestinal effects were observed with this agent. This study did not evaluate the minimum and maximum effective doses. It would be advisable to start with a standard dose of 0.2 to 0.4 mg/kg of butorphanol, recognizing that doses up to ten times this dose are safe in birds.

Buprenorphine hydrochloride[v] is another opioid with agonist/antagonist activity that appears to be effective in controlling pain in avian patients. A dose of

0.01 to 0.05 mg/kg IM appears to provide adequate postoperative analgesia.[23]

Flunixin meglumine is a nonsteroidal anti-inflammatory agent that is a potent analgesic for certain types of pain; however, surgical pain is rarely responsive to this class of analgesic, and it is more appropriate for use in the treatment of inflammatory conditions. It has been recommended for use as an analgesic in companion birds at 1 to 10 mg/kg SID IM or IV.[9,23] Flunixin at 10 mg/kg had no effect on respiratory or heart rates in budgerigars.[3] Additionally, motor function remained normal following IM administration of flunixin. Regurgitation or vomiting occurred within two to five miniutes after administration in five of six patients. Tenesmus was also observed several minutes after administration of flunixin. Aspirin has been recommended at a dose of one 5 gr tablet dissolved in 250 ml drinking water. These nonsteroidal agents have the potential to cause serious gastrointestinal side effects and may prolong clotting time. They should be used with caution until their benefits and limitations are better understood.

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a. Nolvasan Solution, Fort Dodge Laboratories, Inc, Fort Dodge, IA
b. Betadine Solution, The Purdue Frederick Co, Norwalk, CT
c. Hibiclens, Stuart Pharmaceuticals Division of ICI America, Inc, Wilmington, DE
d. Vetrap, 3M Company, St. Paul, MN
e. Incise, Johnson & Johnson Co, Inc., New Brunswick, NJ
f. Safe & Warm, Safe & Warm, Inc., Boulder City, NV
g. Heiss blunt retractors, small Alm retractors - Fine Science Tools, Foster City, CA
h. Ligaclip, Pitman Moore, Mundeleing, IL
i. Hemoclip, Weck, Solvay Animal Health, Inc, Mendota Heights, MN
j. Weck-Cell Surgical Spears, Solvay Animal Health, Inc., Mendota Heights, MN
k. Gelfoam, Upjohn Co., Kalamazoo, MI
l. Surgicel, Johnson & Johnson Co, Inc., New Brunswick, NJ
m. Miami Vise, Henry Schein, NY
n. The Beeper, Spencer Instrumentation, Irvine, CA
o. Model Bat-12, Sensortek, Santa Clara, CA
p. Harrison Modified Bipolar Forceps, Ellman Intl. Mfg, Hewlett, NY
q. Surgitron, Ellman Intl. Manufacturing, Hewlett, NY
r. Visual Background, Ethicon, Somerville, NJ
s. TissuGlu, Ellman Intl. Mfg, Hewlett, NY
t. Torbugesic, Fort Dodge Laboratories, Fort Dodge, IA
u. Banamine, Schering Corp, Kenilworth, NJ
v. Buprenex, Rickitt & Colman, Hull, England

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