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Laser Surgery in Aquatic Animals (Sea Turtles)

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Introduction

Flexible-fiber hollow waveguide carbon dioxide (CO_2) lasers have been used for a variety of procedures in many exotic species throughout veterinary fields, including small mammals, reptiles, fish, dolphins, sea turtles, and other aquatic species. Procedures most commonly performed in aquatic animals include dermal mass excisions or ablations, abscess debridement, laser-assisted amputations, and other dermal incisions. In sea turtles, the CO_2 laser is used to assist in flipper amputations, enucleations, and esophagostomies, and is most commonly used for fibropapilloma (FP) tumor excisions.

Sea Turtle Fibropapilloma Surgical Excision Procedure

Overview

Fibropapillomatosis (FP) is a debilitating infectious neoplastic disease that affects sea turtles of all species, but most commonly juvenile green sea turtles (*Chelonia mydas*). Originally isolated to equatorial regions and warmer climates, the disease is spreading and is now considered a global threat. The exact etiology of the disease is multifactorial, and not yet completely understood. It is known to be associated with chelonid fibropapilloma-associated herpesvirus (CRPHV or ChHV5). However, the disease expression and tumor formation are variable and are suspected to be influenced by environmental stressors and overall immune status (Aguirre and Lutz 2004; Herbst et al. 2008; Page-Karjian et al. 2012; Alfaro-Nunez et al. 2014). The disease is often self-limiting and has been documented to spontaneously regress (Hirama and Ehrhart 2007; Page-Karjian et al. 2014). However, although the tumors are locally aggressive and benign, the disease is often fatal due to physical debilitations created by their presence. The tumors block vision, prevent appropriate feeding and foraging behaviors, limit swimming and diving abilities and predator evasion, cause increased entanglement risk, and cause overall immunosuppression leading to other secondary illnesses (Herbst 1994).

FP is usually easy to recognize on physical exam, characterized by the presence of external cutaneous proliferative masses (papillomas) that vary greatly in number, size, and physical characteristics (Figure 21.1).

Earlier stages can be more plaque-like, resembling other diseases. Diagnosis can be confirmed histologically. Turtles diagnosed with FP are given a tumor score of 1–3 based on the size and number of tumors (Table 21.1) (Work and Balazs 1999).

External tumors most commonly occur on the skin (the inguinal and axillary regions being the most prevalent) and ocular conjunctiva, but can also be found on the flippers, other cutaneous regions, cornea, face, carapace, plastron, and cloaca. Internal tumors are most commonly associated not only with lungs and kidneys but also have been reported throughout the gastrointestinal (GI) tract, liver, heart, bone, and other organs (Herbst 1994). Overall, case management and treatment options cannot be based exclusively on external tumor scores (Page-Karjian et al. 2014). Each turtle must be assessed individually based on FP tumor score, size, location, characteristics, turtle's body condition, other injuries, secondary illnesses, overall health, and facility/staff resources available. Currently, there are no effective treatments for internal tumors and animals thus afflicted have a poor prognosis. Humane euthanasia is recommended for these cases.

Many FP tumors, particularly larger tumors, are highly vascular. Intraoperative hemostasis is essential for patient safety, decreased postoperative morbidity, and surgeon visualization. The bloodless surgical field provided by the use of a CO_2 laser enables the surgeon to more accurately follow clean surgical margins around the tumor and navigate tissue planes more precisely. Another benefit of CO_2 laser surgery over conventional scalpel is the prevention of surgical site contamination and infection through vaporization of infectious agents and neoplastic cells at the surgical site. Furthermore, since FP surgeries typically involve multiple excisions, the noncontact incision of the laser prevents accidental bacterial and neoplastic contamination of consecutive surgical sites. The local thermal effects combined with decreased tissue manipulation have been shown to decrease the chances of tumor seeding and recurrence (Lanzafame et al. 1988a,b).

There are some disadvantages of using the CO_2 laser that must be considered during FP excision. Since many tumors grow on or near boney tissue of the carapace, plastron, skull, or digits, the surgeon must adjust for these locations to prevent complications. The power necessary to penetrate the epithelium and dense soft tissue closely associated with the bone to effectively ablate neoplastic cells, can also cause collateral thermal damage to underlying bone, leading to abscess formation. Also, hemostasis with the laser is only effective for vessels less than 0.5 mm in diameter. As many FP tumors have vessels larger in size, additional means of hemostasis are often required, such as ligatures or radio-cautery. Another limitation of surgical lasers in sea turtles results from the highly viscous tear film produced by the salt glands. The thick tear film makes laser usage and visualization more challenging for ocular and periocular procedures.

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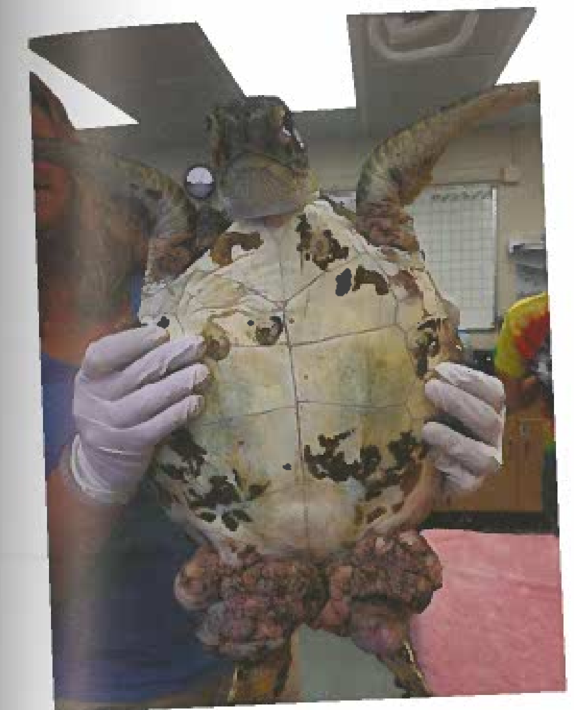

Figure 21.1 Juvenile green sea turtle (*Chelonia mydas*) with fibropapillomatosis.

Table 21.1 Sea turtle fibropapilloma tumor scoring system: green sea turtles afflicted with fibropapillomatosis are assigned tumor scores based on the size and number of external tumors (Work and Balazs 1999).

Tumor size (cm)	0	1	2	3
<1	0	1–5	>5	>5
1–4	0	1–5	>5	>5
4–10	0	0	1–3	>4
>10	0	0	0	>1

Preoperative

Prior to surgery, sea turtles with FP should undergo a thorough diagnostic work up to assess their overall health and screen for the presence of internal visceral tumors. The ideal database prior to surgery includes a complete physical exam, complete blood cell count (CBC) with differential, plasma chemistry panel, radiographs, computed tomography (CT), GI endoscopic exam, and laparoscopic exam of the coelomic cavity. While none of these diagnostics are definitive, they are the most comprehensive tools available at this time. Radiography and ultrasonography have very limited sensitivity for internal tumor identification. Larger tumors, especially pulmonary, are often visible on radiographs (Figure 21.2).

CT studies are more sensitive for smaller pulmonary lesions, but tumors can still be overlooked (Figure 21.3).

Renal tumors and other coelomic visceral tumors are rarely visualized on CT. These tumors are sometimes identified with endoscopic and laparoscopic exams (Figure 21.4).

However, tumors on the dorsal aspect of lungs or kidneys, and within organ parenchyma, will not be visible (Mader 2006). Magnetic resonance imaging (MRI) can be more sensitive for smaller visceral tumors. However, MRI requires heavy sedation and is often not readily available or is cost-prohibitive (Croft et al. 2004). Turtles affected with FP are commonly found to be emaciated, anemic, and have pneumonia or other infections and injuries. These conditions often require stabilization and treatment prior to surgery. For anesthetic safety and decreased postoperative morbidity, a general rule of thumb is that the animal should be determined to be healthy enough overall for general anesthesia and have an albumin >1.0 g/dl and a PCV (packed cell volume) >20%, depending on the size and number of tumors being excised. Periocular tumors typically have less bleeding and less exposed surface area, and therefore can be done with lower values. Turtles with small tumor burdens often do not require general anesthesia and have less risk of hemorrhage, and surgery can be performed during more debilitated conditions using local anesthesia.

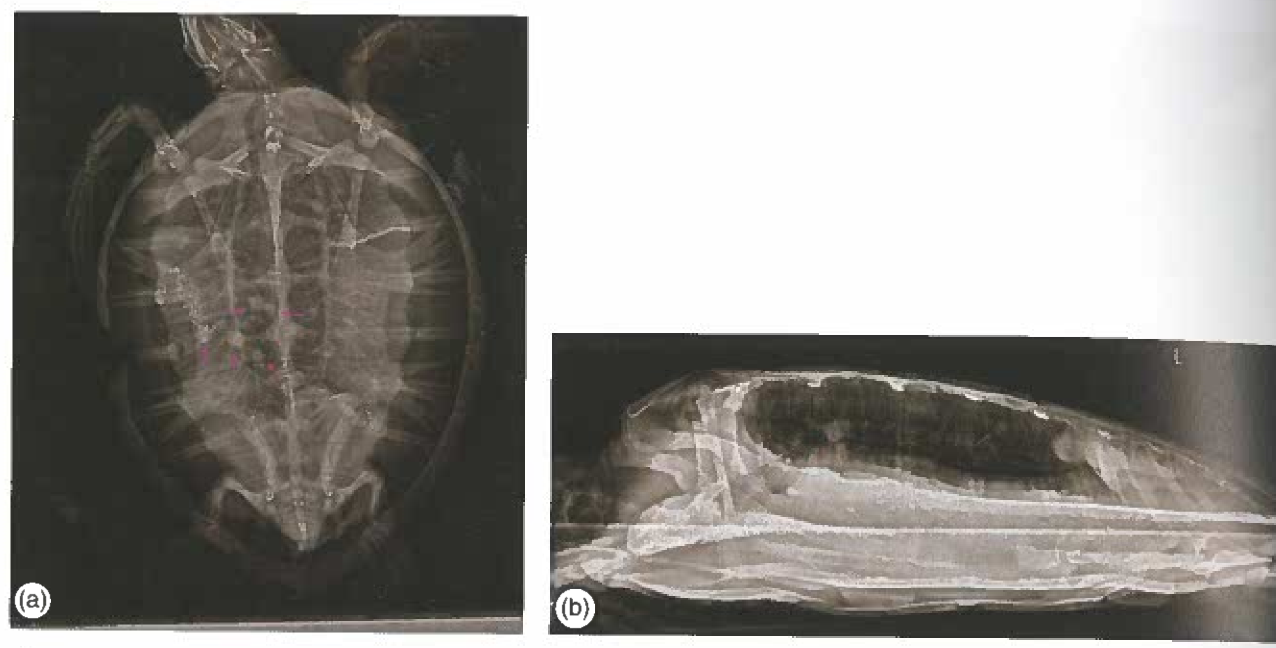

Figure 21.2 (a–b) Radiographs of juvenile green sea turtle (*Chelonia mydas*) with pulmonary fibropapillomatosis. (a) Dorsoventral view showing numerous soft tissue nodules of various size throughout the pulmonary fields (several are highlighted with arrows). (b) Left lateral view showing multiple soft tissue nodules of various size within the pulmonary parenchyma (some lesions are highlighted with arrows).

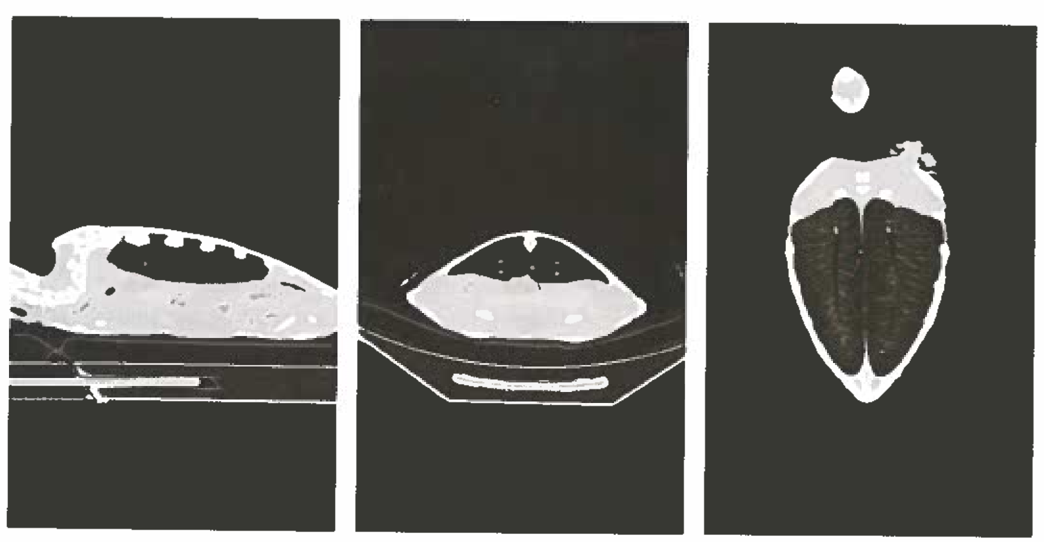

Figure 21.3 Images of three-view computed tomography (CT) scan of a juvenile green sea turtle (*Chelonia mydas*) with a visible pulmonary mass (highlighted with arrows) consistent with fibropapillomatosis.

Turtles undergoing surgery for excision of FP tumors often require general anesthesia for the procedure. A variety of sedation protocols are acceptable (Norton et al. 2017). At our rehabilitation facilities, a common sedation protocol includes a combination of intravenous dexmedetomidine 50 µg/kg, ketamine 1.0–1.5 mg/kg, and butorphanol 0.4 mg/kg. Isoflurane or sevoflurane are recommended for anesthetic induction and maintenance. Local anesthesia is also used in conjunction with general anesthesia for additional intraoperative and post-operative analgesia, which lowers necessary gas concentrations (Figure 21.5). Lidocaine 2% or lidocaine 1% + epinephrine is administered up to 6 mg/kg total dose as local subcutaneous (SC) ring blocks or SC splash blocks around the tumors. The lidocaine can be diluted with sodium bicarbonate or saline to increase volume for larger tumor burdens. Lidocaine 2% (preservative free) can also be administered intrathecally for regional

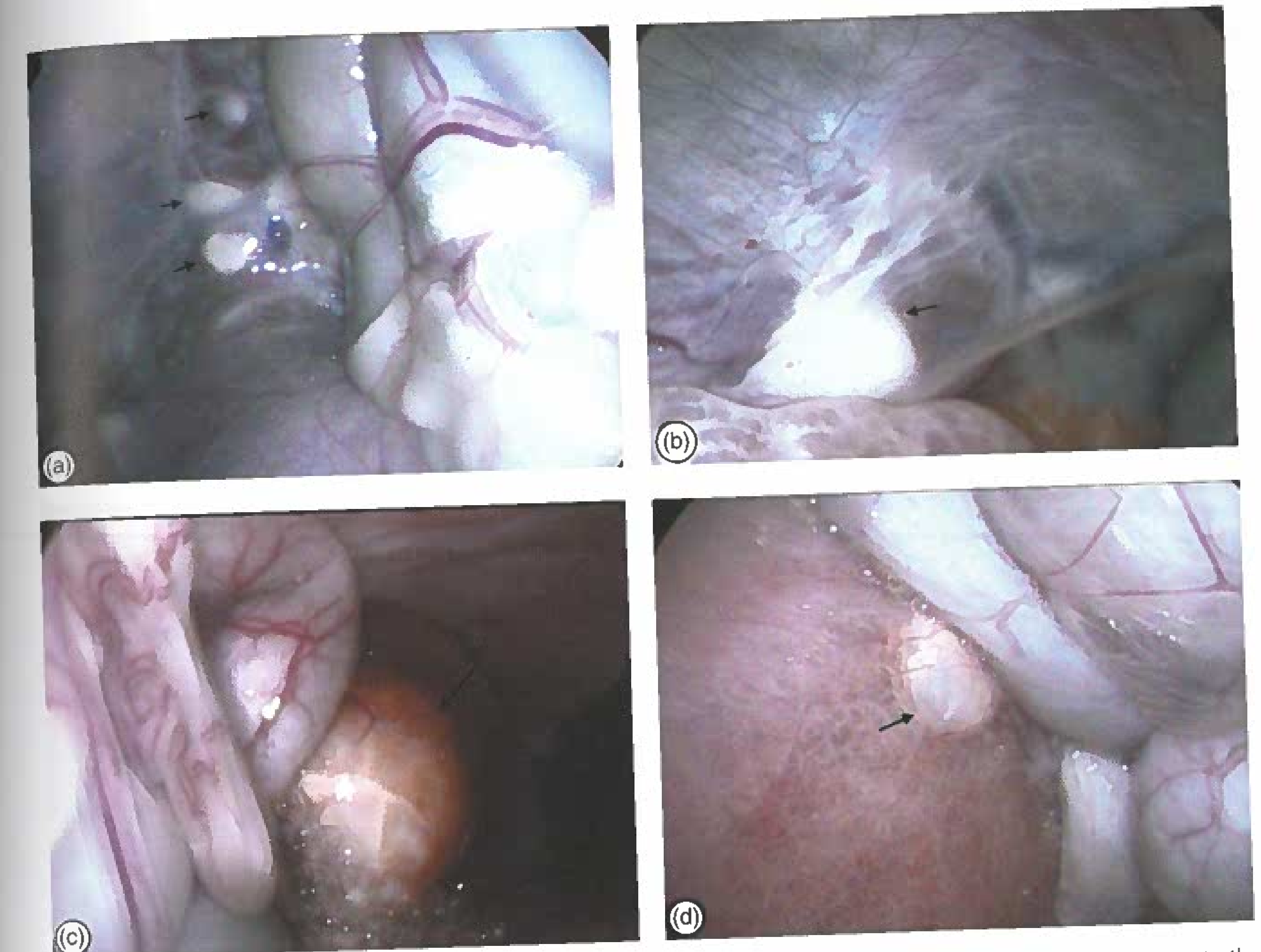

Figure 21.4 (a–d) Images of fibropapilloma tumors identified on laparoscopic exam of the coelomic cavity of a juvenile green sea turtle (*Chelonia mydas*). (a, b) Renal tumors. (c) Hepatic tumor. (d) Pulmonary tumors.

anesthesia for inguinal procedures (Mans 2014). Often times, local anesthesia (with or without sedation) is adequate for animals with a small number of minor tumors or posterior quadrant procedures.

FP tumor burdens are quite variable, and frequently very extensive. To formulate surgical planning, all factors of intraoperative and postoperative patient morbidity must be considered, including hemorrhage, protein loss, anesthesia time, pain, and infection. In an effort to minimize anesthetic complications, a general rule of thumb is to limit anesthesia time to one hour. Tumors are prioritized based on size, location, and detriment to the patient. Periocular tumors that block vision, large tumors limiting swimming or resting behaviors, and necrotic and infected tumors are removed first. For extensive tumor burdens, surgical procedures are often divided into anatomical regions or quadrants (for example, all tumors from right inguinal region) (Figure 21.6).

The turtle should be prepped for surgery using standard aseptic surgical prep techniques, using either chlorhexidine or betadine scrub and alcohol. Povidone-iodine 5% and saline are recommended for periocular procedures. Alcohol is highly flammable, and therefore a thorough final rinse is performed with saline to prevent ignition with the surgical laser. Efforts should be taken throughout surgery to maintain sterility and prevent cross-contamination of surgery sites.

Procedure

To begin, a circumferential incision is made through the dermis surrounding the tumor with an additional 1–2 cm margin of clean skin where anatomically possible (Figure 21.7a). Hand movements should be slow and steady using the maximum wattage with which the surgeon is comfortable (Table 21.2). The wattage must be powerful enough to cut full thickness in a single sweep

Figure 21.5 Lidocaine is administered intrathecally for regional anesthesia. Using sterile technique, Lidocaine 2% (preservative-free) up to 4 mg/kg is administered into the subdural space between coccygeal vertebrae using a 25 or 27 g needle at a 45° angle (Mans 2014). Frequently, 2 mg/kg is effective, leaving additional lidocaine dosing for other SC local blocks.

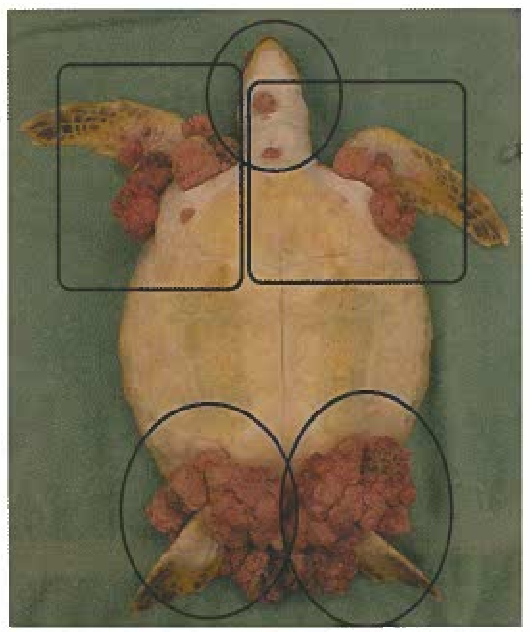

Figure 21.6 Turtles with stage 2–3 FP tumor burdens will undergo multiple procedures for surgical excision to minimize complications and post-operative morbidity. Surgeries are commonly divided into quadrants based on anatomic regions as shown.

(Video 21.1). If the wattage is too low, charring and repetitive cutting motions will cause increased collateral thermal tissue damage. If the wattage is too high, the laser will penetrate unintended deeper tissue layers. The thickness and toughness of sea turtle skin varies based on species, size, and anatomic location. The skin over the flippers is toughest, but extreme care must still be taken to protect underlying muscle, tendons, nerves, vasculature, and bone, as there is minimal SC tissue (Video 21.2). Irrigating the incision with sterile saline while cutting and allowing brief periods of tissue rest between incisions can help decrease thermal damage. SuperPulse mode can also be used for this purpose. In the inguinal region, care must be taken to avoid carapace or plastron marginal bone and coelomic lining that is fairly superficial in certain areas, especially in thin turtles. For dermal incisions, 0.4 mm spot size at 14–18 W continuous wave non-SuperPulse is commonly recommended. After the dermal incision is completed, the power setting is often decreased to 12–16 W continuous wave non-SuperPulse for SC dissection underneath the tumor. The tumor and dermal margin are retracted upward, and the laser used to cut through SC tissue to dissect and peel away neoplastic tissue, maintaining perpendicular orientation to the cutting surface throughout (Figure 21.7b–c and Video 21.3). As the end of excision is approached, saline-soaked gauze is placed behind the cutting surface as a backstop to prevent trauma of underlying tissue or drapes (Figure 21.7d). Most dermal FP tumors are superficial and do not extend beyond the dermis (Video 21.4). However, some tumors (especially inguinal and shoulder tumors) can invade deeper tissues, requiring more extensive dissection. Most hemostasis is achieved with the laser, though larger more vascular tumors may require additional measures. Supplemental hemostasis can be achieved with radiocautery and ligatures. Studies have shown that poliglycaprone 25 (monocryl) and polyglyconate (maxon) sutures cause the least tissue reaction in sea turtle skin (Govett et al. 2004). Hemostasis with the CO_2 laser is effective for vessels less than 0.5 mm diameter and in parallel orientation. Since some vessels originate from deeper tissues, they may initially be perpendicular and require tissue manipulation to reorient for effective hemostasis. Increasing the distance of the hand piece to 1–3 cm from tissue helps defocus the beam and increase coagulation. Once the tumor has been completely excised, the power is decreased to 10–12 W continuous wave, non-SuperPulse mode and a 1.4 mm spot size used with a defocused beam (1–3 cm from tissue surface) for tissue contraction and additional hemostasis. The use of an adjustable handpiece simplifies the adjustment of spot size enormously, further reducing anesthesia time. The defocused beam is used in a spiral or painting motion, beginning centrally and working outward toward margins (Figure 21.7e). This helps to shrink the size of incision to facilitate healing, reduce infection, and seal off nerve endings, lymphatics and blood vessels. Incisions are left open to heal via second intention. Previous methods of suturing and grafting proved unsuccessful. Incisions are covered with a topical

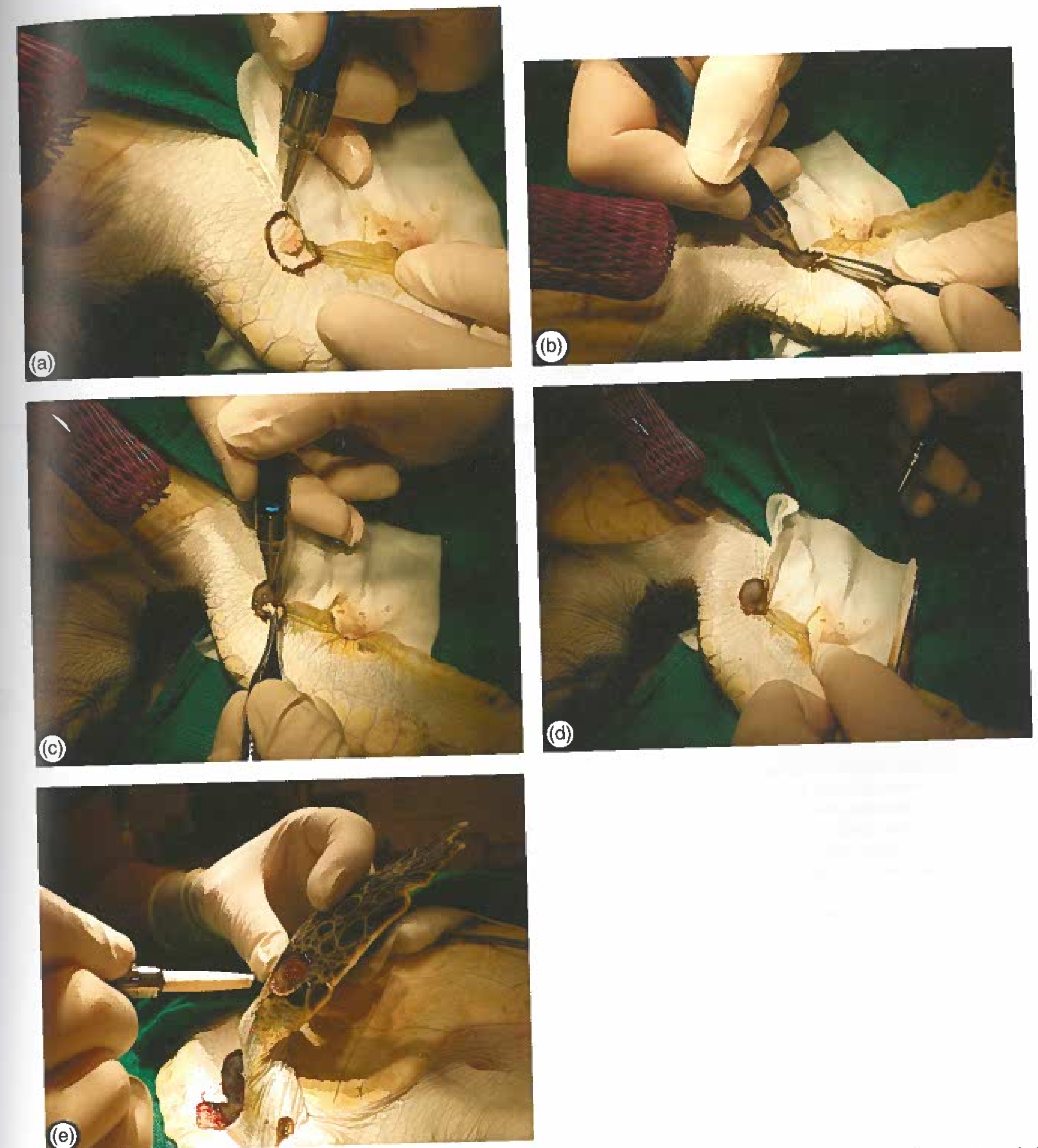

Figure 21.7 (a–e) Surgical excision of fibropapilloma tumor from the ventral front flipper of a juvenile green sea turtle (*Chelonia mydas*). (a) Circumferential incision through the dermis including tumor and additional 1–2 cm margin of normal skin. (b, c) The laser beam is oriented perpendicular to the cutting surface while the tissue margin is retracted upward for SC dissection underneath the tumor. (d) Saline-soaked gauze is placed behind the tumor to protect underlying tissue and drapes during excision. This is particularly necessary for tumors along flipper margins, and during the final stages of any excision. (e) After excision, a defocused beam with Wide Ablation tip is used in a spiral motion for hemostasis and contraction of the incision.

Table 21.2 General laser settings for fibropapillomatosis tumors.

Procedure	General FP surgery		
Laser type and wavelength (nm)	CO_2 (10600)	CO_2 (10600)	CO_2 (10600)
Spot size (mm)	0.4	0.25–0.4	1.4
Power (W)	14–18	12–16	10–12
Exposure	Continuous wave	Continuous wave	Continuous wave (defocused)
Mode	Non-Superpulse	Non-Superpulse	Non-Superpulse
Duty cycle (%)	100	100	100

hydrogel or collagen product for moistening and protection during recovery. The incisions are either bandaged or left open, depending on size, location, and hemorrhage (Figure 21.8). Incisions with continued concerns for hemorrhage are bandaged with a hemostatic agent for 12–48 hours as needed to control bleeding. Pressure bandages are placed using Vetwrap, Elasticon, or action-bandages (Figure 21.9).

Video 21.1 Dermal incision using CO_2 laser for fibropapilloma tumor excision from juvenile green sea turtle (*Chelonia mydas*) (*This video does not include audio commentary.*). A dermal incision is made using a 0.4 mm focal spot size at 16 W continuous wave exposure in non-SuperPulse mode. The power is set such that a full thickness incision is made through the dermis in a single sweep, using slow and steady linear hand movements while maintaining traction along the incision.

Video 21.2 CO_2 laser excision of fibropapilloma tumor from the dorsal aspect of a front flipper of a juvenile green sea turtle (*Chelonia mydas*). (*This video does not include audio commentary.*) Prior to the start of this video, a circumferential full thickness dermal incision was made around the FP tumor and the adjacent 1 cm of normal skin using a 0.4 mm focal spot size and 12 W continuous wave exposure in SuperPulse mode. The video begins at the start of SC dissection. The laser is used to dissect through the tissue planes underneath the tumor and associated dermis. The focal spot is redirected to maintain a perpendicular orientation to the cutting surface. Traction is maintained on excised tissue to facilitate visualization and depth of tissue plane, and maintain control of the depth of the incision. There is minimal SC tissue in this location, so extreme care must be taken to avoid cutting underlying musculature, nerves, tendons, and bones unless associated with the tumor.

Video 21.3 CO_2 laser SC dissection during excision of a large cluster of fibropapilloma tumors in the inguinal fossa and from a proximal rear flipper of a juvenile green sea turtle (*Chelonia mydas*) (*This video does not include audio commentary.*). Prior to the start of the video, a circumferential full thickness dermal incision was made around the region of FP tumors to be excised (depicted in Video 21.1). SC dissection is performed using a 0.4 mm focal spot size at 14 W continuous wave exposure in non-SuperPulse mode. The laser orientation is adjusted throughout surgery to maintain perpendicular orientation to the cutting surface. Traction is maintained on tissue to allow visualization and accurate control of tissue depth. The surgery is performed from superficial areas to deeper regions, constantly moving around the tumor pedicle to ensure maintenance of the desired tissue plane. If the surgeon continues in same region without equalizing the depth in other regions, they will inadvertently remove viable deeper layers of tissue. There is some hemorrhage noted from the transection of a deeper vessel in the SC adipose tissue. Not shown in the video is hemostasis provided with hemostats and ligature placement. Shortly thereafter, a small vessel was transected, and the laser beam was defocused and directed parallel to the surface of the vessel for hemostasis. Throughout the video, you can see the separation of SC adipose tissue and fascial planes from the deeper musculature during the careful dissection around the flipper. Maintaining this control of depth is crucial throughout the procedure.

Video 21.4 CO_2 laser excision of a large cluster of fibropapilloma tumors from the left ventral shoulder region of a juvenile green sea turtle (*Chelonia mydas*) (*This video does not include audio commentary.*). Highlights of a surgical excision of a large cluster of FP tumors from the left ventral shoulder region of a juvenile Green Sea Turtle. Dermal incisions, SC dissection, and maintaining adequate depth control are all depicted.

Considerations for Periocular FP Tumors

The effects of the CO_2 laser on deeper structures of the eyes of turtles has not been well studied. Therefore, it is unknown if there are negative impacts from laser use on and around periocular structures in sea turtles, including the scleral ossicles. Many surgeons find the laser more challenging and less precise for ocular procedures due to the viscous tear film production. However, some surgeons do utilize the laser in these regions. A water-based ophthalmic lubricant should be utilized to protect the cornea during these procedures, as petroleum-based lubricants may ignite under the laser.

Procedure: Scleral Tumors

The technique for excision of scleral tumors is similar to that of dermal tumors, with some minor adjustments. The cornea should be protected with saline-soaked gauze or ophthalmic ointment to prevent collateral damage. Using a 0.25 mm spot size, 7–8 W, a repeat pulse exposure in SuperPulse mode, pulsing

Figure 21.8 (a–e) Examples of surgical sites immediately following excision of fibropapilloma tumors from a juvenile green sea turtle (*Chelonia mydas*). (a, b) Small excision sites without concerns of hemorrhage that do not require bandaging. (c–e) Larger excision sites with concerns for hemorrhage; these should be bandaged for 24–72 hours postoperatively.

10 ms at 20 Hz, 20% power (Table 21.3), the tumor is dissected off the surface of the globe using lateral retraction in a "peeling motion" (Video 21.5). Rather than making a circumferential incision, the incision is started at one end of the tumor (usually the ventral aspect) and dissection is then continued circumferentially, gradually working around all margins of the tumor while carefully maintaining appropriate depth (Figure 21.10). Care is taken to maintain a perpendicular orientation of the laser tip to the cutting surface during dissection. Extreme caution must be used when incising the anterior portion of the tumor, as it is often along the corneal margin. If tumors involve the cornea (Figure 21.11), a scalpel blade is used to perform a partial keratectomy in that region. If the tumor involves a full-thickness penetration of the corneal tissue, an enucleation is performed. After excision, a 0.25–0.4 mm spot size at 2–4 W continuous wave SuperPulse defocused beam can be used for focal ablation and hemostasis as necessary (Figure 21.10e). The conjunctival defect is left open to heal by second intention. Some surgeons still prefer using a conventional blade and iris scissors for the excision of scleral tumors (Video 21.6).

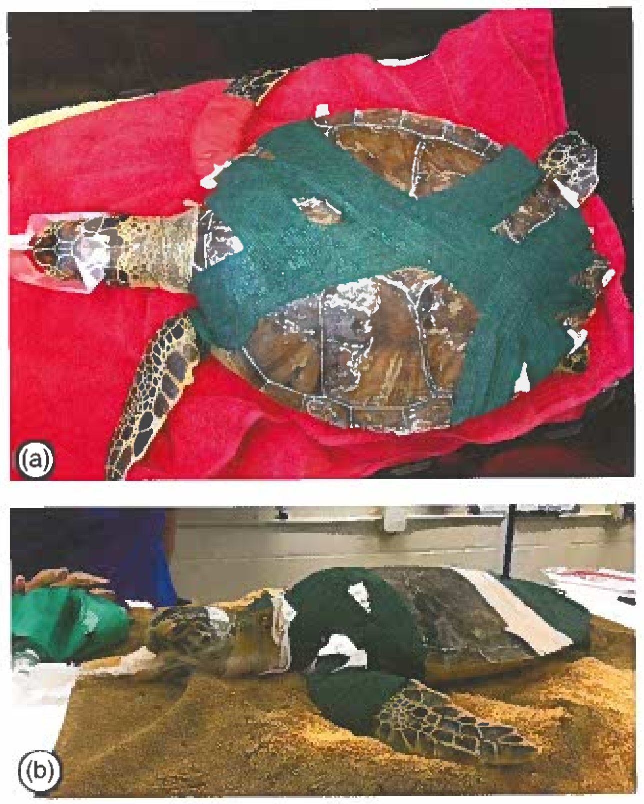

Figure 21.9 (a, b) Examples of bandages placed to protect incisions and control hemorrhage post-operatively for larger incisions in inguinal, shoulder, and flipper regions. Bandage layers most commonly consist of: hemostatic agent, hydrogel, nonadherent pad, gauze pads, and Vetwrap.

Video 21.5 Surgical excision of scleral fibropapilloma tumor from a juvenile green sea turtle (*Chelonia mydas*) using CO_2 laser (*This video does not include audio commentary*.) The eyelids are retracted open by an ophthalmic speculum to aid in visualization during the procedure. Using a 0.25 mm focal spot size and 7 W repeat pulse exposure in SuperPulse mode (pulsing at 10 ms, 20 Hz, 20% power), the tumor is dissected off the surface of the sclera using lateral retraction in a peeling motion. The incision is started along the ventral aspect of tumor and continued in a lateral direction circumferentially around the tumor, maintaining appropriate depth along the surface of the globe. Note how the surface of the cornea and the deeper structures of the eye are protected with saline soaked gauze. Ophthalmic ointment can also be used. Once the tumor has been completely excised, the focusing tip is distanced from the cutting surface to defocus the laser beam for surface ablation and hemostasis.

Video 21.6 Surgical excision of scleral fibropapilloma tumor from a juvenile green sea turtle (*Chelonia mydas*) using steel instruments (*This video does not include audio commentary*.). An incision is made through the conjunctiva along the lateral aspect of the scleral tumor using iris scissors. Dissection continues along the surface of the globe circumferentially around the tumor using iris scissors and a beaver scalpel blade.

Table 21.3 Laser settings for periocular fibropapillomatosis tumors.

Procedure	Periocular FP tumors		
Laser type and wavelength (nm)	CO_2 (10 600)	CO_2 (10 600)	CO_2 (10 600)
Spot size (mm)	0.25	0.4	0.25
Power (W)	7–8	2–4	10
Exposure	Repeat pulse	Continuous wave (defocused)	Continuous wave
Mode	Superpulse	Non-Superpulse	Non-Superpulse
Frequency (Hz)	20 Hz, 10 ms	—	—
Duty cycle (%)	20	100	100

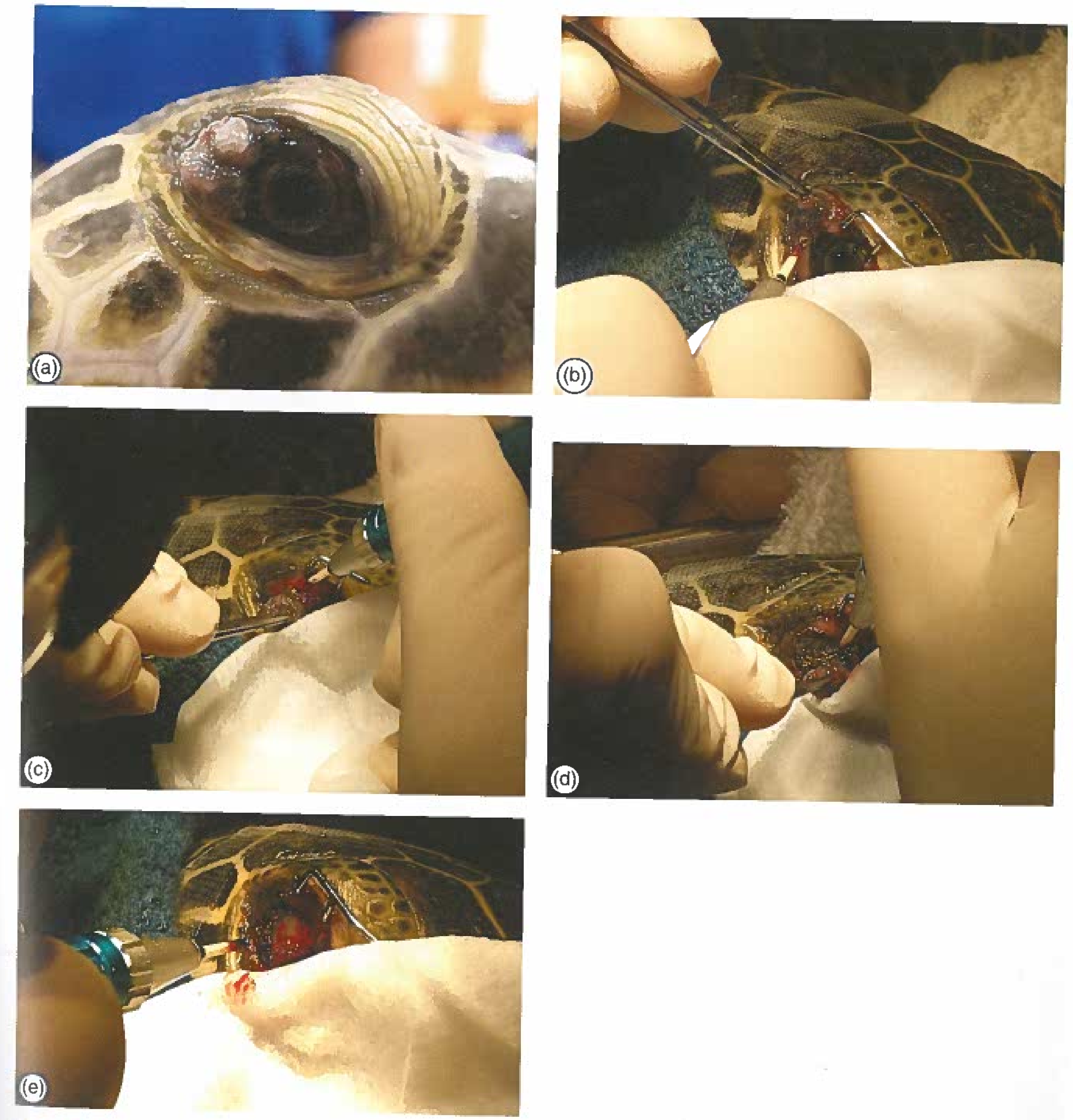

Figure 21.10 (a–e) Excision of a scleral tumor from the left eye of a juvenile green sea turtle (*Chelonia mydas*) using a CO_2 laser. (a) Common appearance of scleral and conjunctival/nictitating membrane fibropapilloma tumors. (b–d) The cornea is protected using saline-soaked gauze. An incision is made through the conjunctiva along the ventral aspect of the tumor, including 3–5 mm of healthy conjunctiva for margins. The tumor is retracted laterally and dissection is continued around and underneath the tumor, carefully following the surface of the globe to control depth. (e) After excision, the tip is distanced from the cutting surface to defocus the beam for ablation and hemostasis of the globe surface and remaining conjunctiva.

Figure 21.11 Juvenile green sea turtle (*Chelonia mydas*) with corneal fibropapilloma, requiring partial keratectomy.

Procedure: Eyelid and Conjunctival Tumors

For eyelid tumors, care is taken to preserve as much of the dermal eyelid margin as possible. Most of the time, the tumors originate from the conjunctival surface, and do not actively infiltrate the margin (Figure 21.12a). However, tumors that originate from or infiltrate the dermal aspect of the eyelids require resection of that region (Figure 21.13). The cornea is covered in ophthalmic ointment for protection. Saline-soaked gauze is placed over the ointment to create a safe cutting surface. The tumor and associated eyelid or conjunctiva are retracted over the saline-soaked gauze. A 0.25 mm focal spot size at 10 W continuous wave SuperPulse mode is used to make a linear, full thickness incision 1–3 mm proximal to the tumor base for excision (Figure 21.14a–b and Video 21.7). For conjunctival tumors on the medial eyelids, the same settings are used to dissect the conjunctiva from the dermal layer of the eyelid for excision. The conjunctival defect is left open to heal by second intention (Figure 21.14c). Some surgeons still prefer using a conventional scalpel blade and iris scissors for excision of conjunctival tumors (Figures 21.12b,c and 21.15a–c). If upper eyelid conjunctival tumors are removed in conjunction with scleral tumors, there is a risk of adhesions forming that may restrict the movement of upper eyelid, inhibiting closure over the cornea after healing. To facilitate healing in a more functional manner, a temporary tarsorrhaphy is often necessary for the first 7–10 days postop.

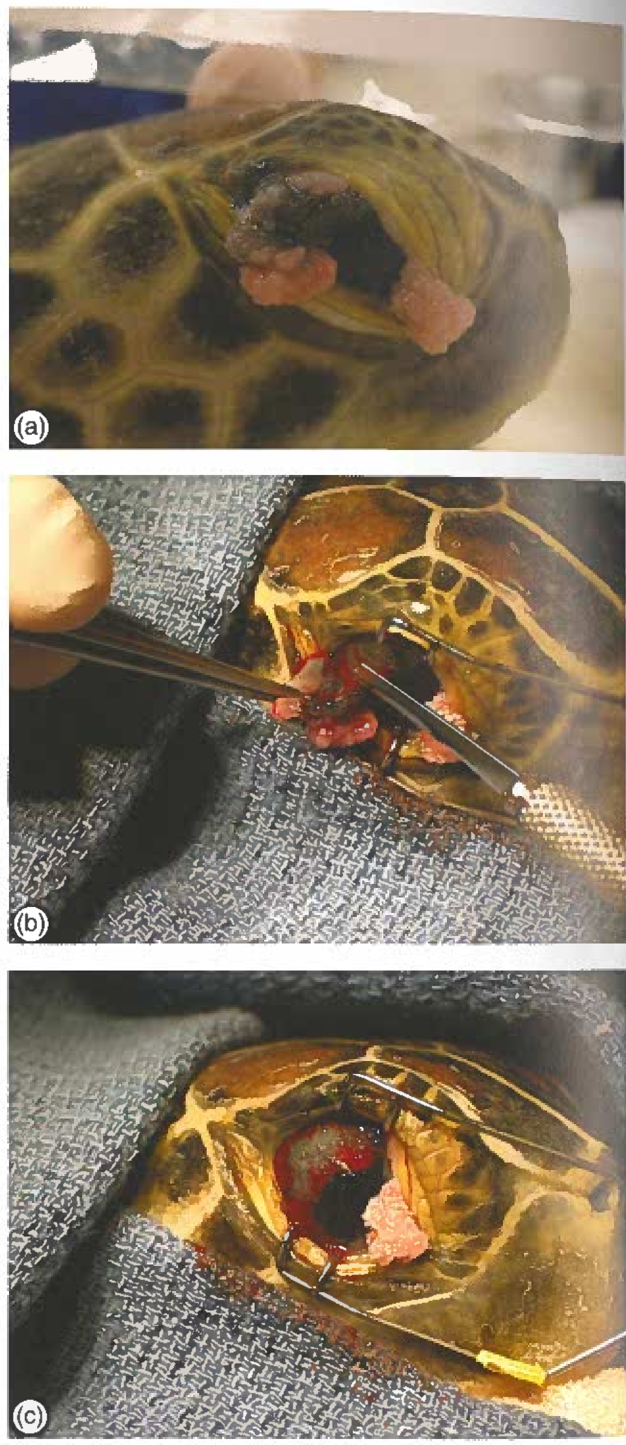

Figure 21.12 (a) Juvenile green sea turtle (*Chelonia mydas*) with common scleral and conjunctival fibropapilloma tumors. (b, c) Excision of scleral tumors using conventional scalpel blade. The tumor is retracted laterally. A full thickness conjunctival incision is made along the limbus and continued along the surface of the globe, peeling away the tumor.

Figure 21.13 A juvenile green sea turtle (*Chelonia mydas*) with fibropapilloma tumors originating from sclera and dermal surface of the ventral eyelid.

Video 21.7 Surgical excision of fibropapilloma tumor from corner of eyelids of a juvenile green sea turtle (*Chelonia mydas*) using CO_2 laser (*This video does not include audio commentary.*). Saline soaked gauze is used to protect the cornea and nearby tissues from the surgical laser. A 0.25 mm focal spot size at 10 W continuous wave SuperPulse mode setting is used. The tumor is retracted, allowing an incision to be made full thickness through the dermis and conjunctiva immediately adjacent to the tumor. Saline soaked gauze is placed underneath the tumor to provide a safe cutting surface for the final transection of medial tissue. The tip is then distanced from the cutting surface for ablation and hemostasis.

Considerations for Tumors Near Bone

In many other species and their anatomical regions, the density and depth of soft tissues is such that the power of the laser can be precisely controlled to minimize collateral thermal damage beyond a few cell layers. Sea turtle anatomy differs, however, and there are several regions where the very thick epidermal tissue of these animals is directly associated with underlying bone. The power required to cut through the tissue generates collateral thermal energy that is transferred into the surrounding bone. This thermal energy has been demonstrated to vary in severity based on power and exposure time. The damage to outermost bone is mild, showing carbonized tissue. However, as laser surgery continues to approach this contact region, the tissue exhibits more pronounced zones of thermal necrosis and damage. These effects have caused focal

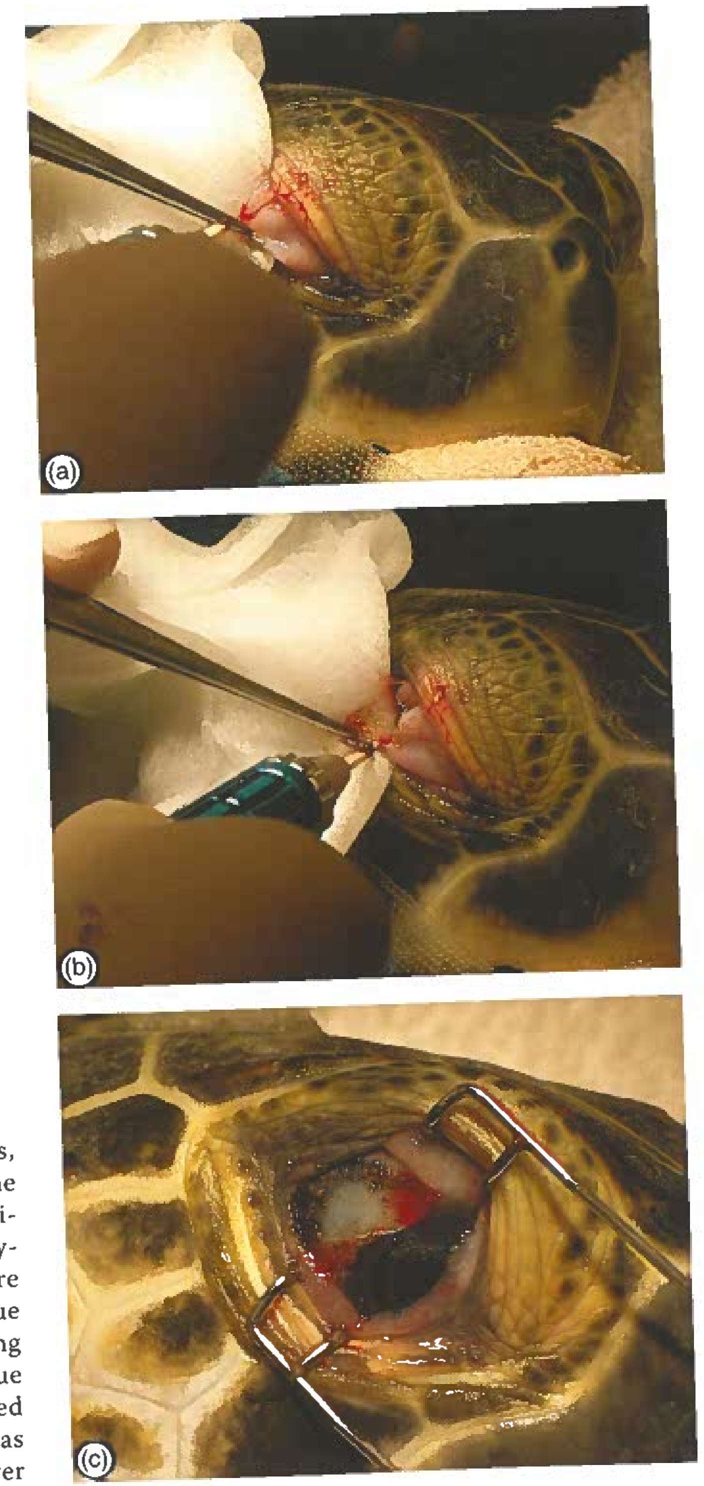

Figure 21.14 (a, b) Surgical excision of a small fibropapilloma tumor from the margin of the nictitating membrane (third eyelid) of a juvenile Green sea turtle (*Chelonia mydas*) using CO_2 laser. The cornea is protected with saline soaked gauze. The nictitating membrane is retracted over the saline soaked gauze. A full thickness incision is made through the third eyelid 3 mm proximal to the tumor margin for excision. (c) Postoperative photo following excision of the tumor from the margin of nictitating membrane. A tumor was also removed from the sclera (see Figure 21.10) exposing the scleral ossicle.

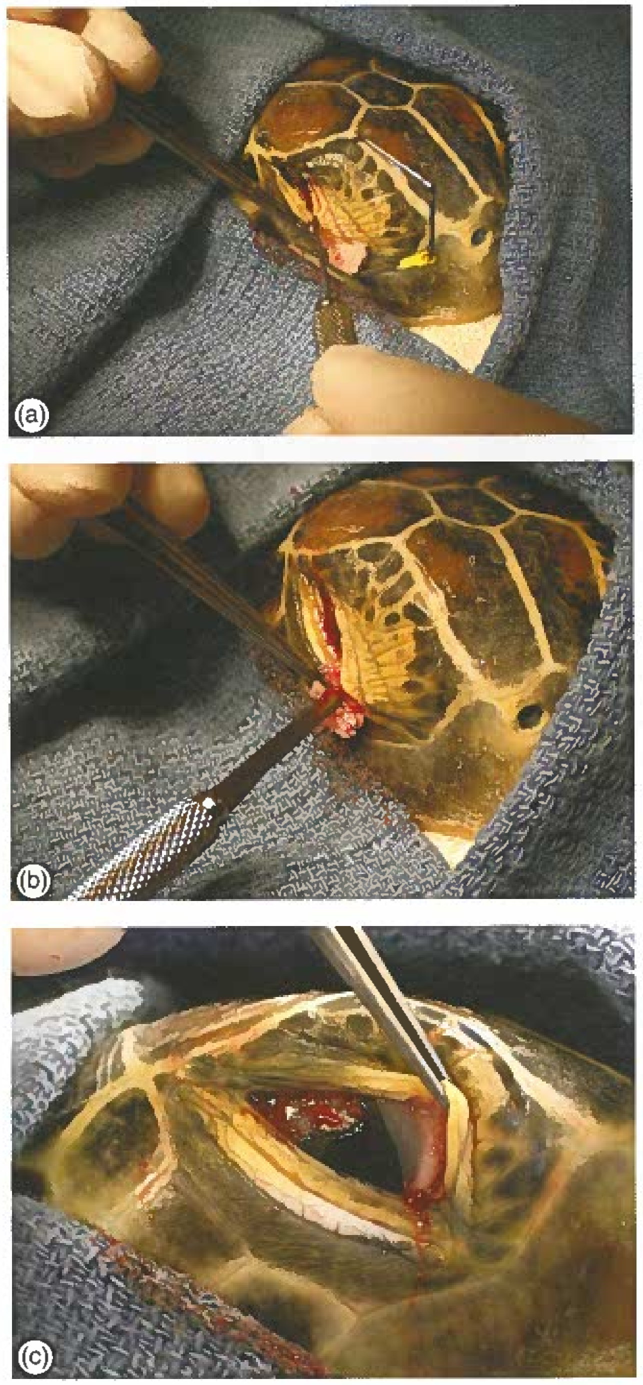

Figure 21.15 (a–c) Excision of upper eyelid conjunctival fibropapilloma tumors from a juvenile green sea turtle (*Chelonia mydas*) using conventional steel instruments. (a) The tumor and conjunctiva are retracted laterally. (b) The incision is started along the dermal margin of the eyelid, preserving as much of the eyelid margin as possible. The excision is extended along the conjunctival surface until only normal conjunctival tissue is present, denoting complete excision. (c) Photo of conjunctival incision site after complete excision.

Table 21.4 Laser settings for FP tumors near bone.

Procedure	FP tumors near bone	
Laser type and wavelength (nm)	CO_2 (10 600)	CO_2 (10 600)
Spot size (mm)	0.25–0.4	0.4–0.8
Power (W)	12–14	10–12
Exposure	Continuous wave	Continuous wave (defocused)
Mode	SuperPulse	Non-SuperPulse
Duty cycle (%)	100	100

infarcts and abscesses within the underlying bone (Rayan et al. 1992; Krause et al. 1997). Therefore, the laser can be used cautiously for the initial approach to tumor resection around bone, but then conventional blade and steel instruments are used to complete the procedure (Table 21.4).

Procedure

Radiographs with or without CT are performed prior to surgery to identify and evaluate the extent of boney involvement for surgical planning. Small tumors in earlier stages of growth can be hidden underneath the keratin and are not easily identified on physical exam alone. However, bone destruction is visible on CT (Figure 21.16). For tumors on the plastron, carapace, or face, the CO_2 laser is used initially to cut through keratin and superficial epithelial tissue. A circumferential incision is made around the tumor including 1 cm margins beyond lytic area of bone as anatomically able, using a 0.25–0.4 mm spot size and 12–14 W continuous wave in SuperPulse mode (Figure 21.17a). From there, a #11 scalpel blade is used to deepen the incision to the level of bone. The scalpel blade or a sharp periosteal elevator is used to continue sharp dissection around and underneath the tumor for excision (Figure 21.17b). Once the tumor and surrounding epithelial tissue has been removed, the affected bone margins are excised using curettes, rongeurs, or bone saw as needed. Care must be taken to avoid damaging the coelomic lining. A defocused laser beam, at 0.4–0.8 mm spot size and 10–12 W continuous wave in non-SuperPulse mode can be used for hemostasis as needed at the end of the procedure, although this will not be effective for cortical bleeding (Figure 21.17c). These areas are then packed with

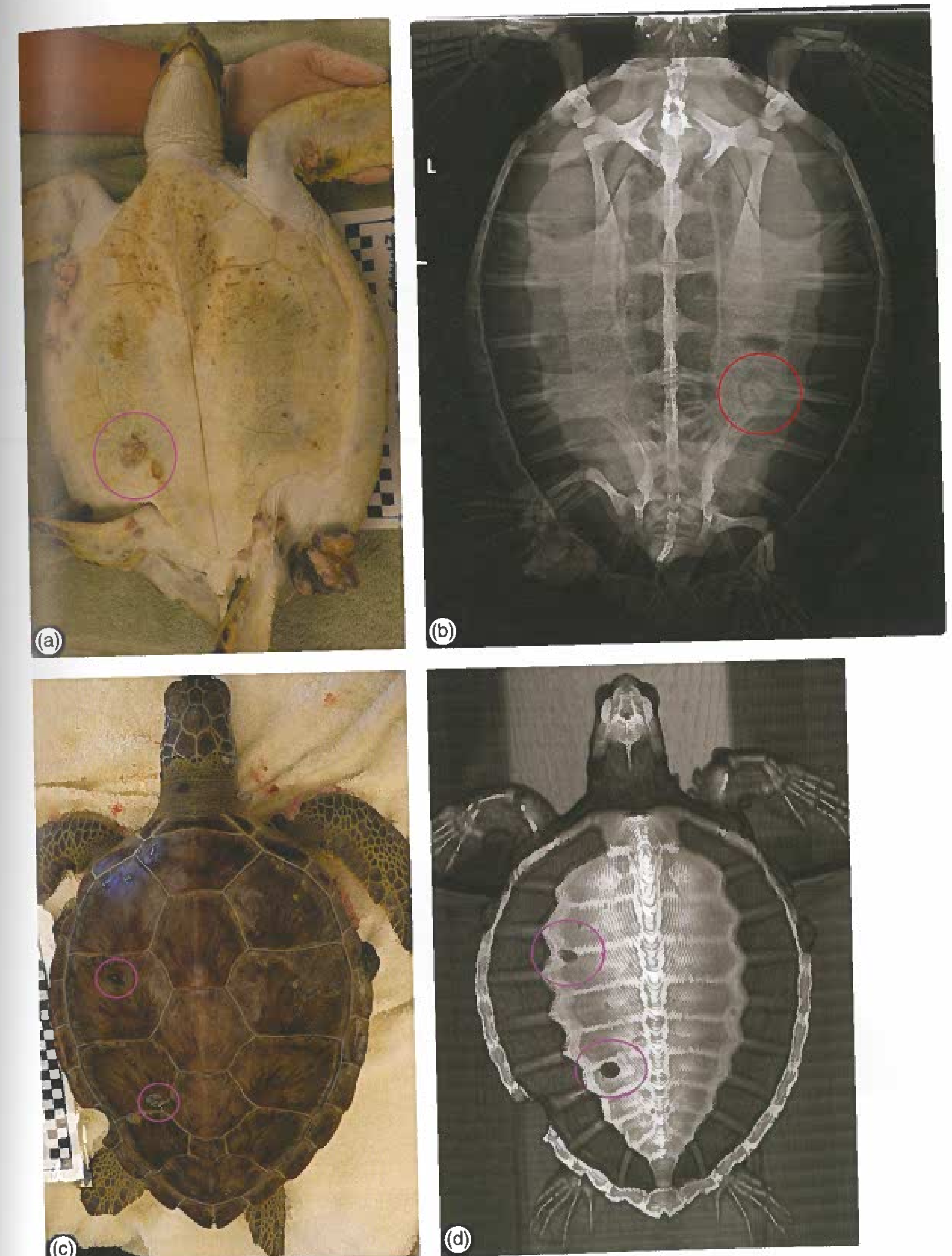

Figure 21.16 (a–d) CT scans are utilized to identify bony involvement of FP tumors on the carapace and plastron. Margins of the affected bone must be debrided during tumor excision to prevent recurrence. (b, d) Image of 3D reconstruction of CT demonstrating lysis of bony carapace deep to external fibropapilloma tumors. There was previous trauma to the left posterior bridge of the carapace. There are two FP tumors on the right anterior bridge of the carapace also demonstrating associated bone lysis, not adequately visible on this image. (a, c) Photo of carapace of the same turtle showing gross appearance of the lytic lesions identified on CT. Note that the anterior lesion does not have a visible external tumor. There is only a discoloration of keratin. The tumor was visible after keratin was removed from that area.

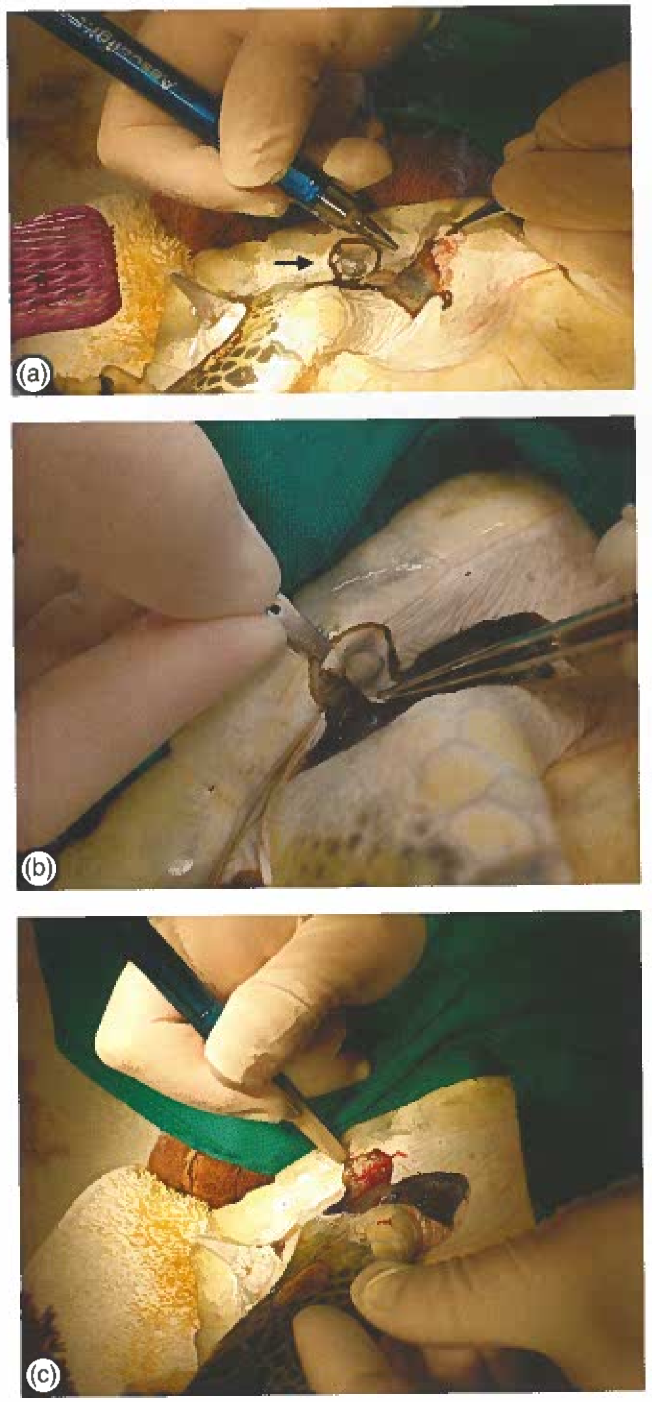

Figure 21.17 (a–c) Excision of FP tumors in regions with underlying bone (carapace, plastron, skull) require a combination of laser for initial approach and a conventional blade to prevent excessive collateral thermal damage and abscessation of the surrounding bone. (a) The laser is used to make a circumferential incision through keratin and epithelium. (b) #11 scalpel blade being used to sharply dissect the tumor and associated soft tissue from underlying bone. (c) A defocused laser beam and wide ablation tip is used along the margins of the incision and soft tissues for hemostasis.

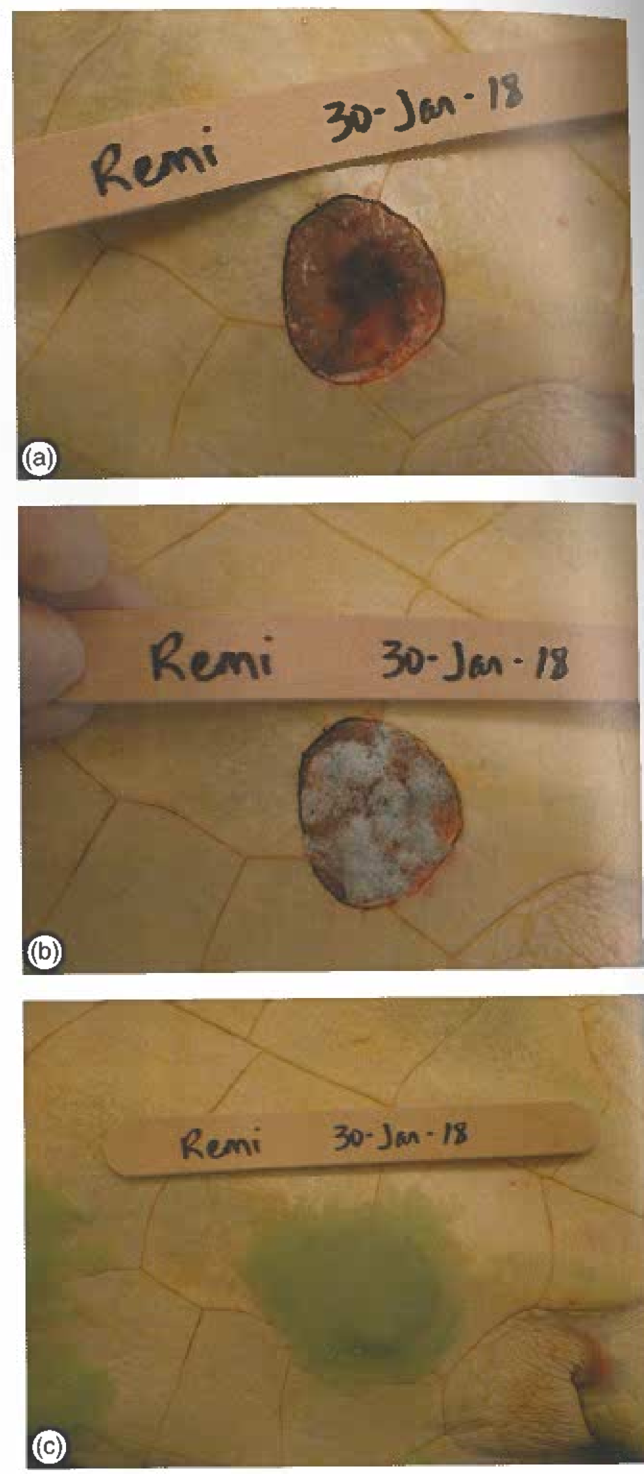

Figure 21.18 (a) Postoperative excision site of a fibropapilloma tumor removal on the plastron of a juvenile Green sea turtle (*Chelonia mydas*). (b) Incision packed with hemostatic agent to control hemorrhage postoperatively. (c) The incision covered in bone cement for protection during initial stages of healing.

hemostatic agents and pressure bandaged. Incisions that are completely surrounded by bone can be packed with honeycomb, dental wax, or may covered in bone cement to help create pressure within the incision (Figure 21.18).

Postoperative Care

Recovery times allotted between surgical procedures vary based on the individual animal but are typically about two to four weeks. Postoperative care is similar to that of most species but also quite unique when caring for sea turtles due to the aquatic environment and stress. Primary factors that must be addressed include controlling hemorrhage, controlling pain, preventing infection, minimizing stress, and encouraging healing. In debilitated patients, this also includes managing other comorbidities such as anemia, emaciation, pneumonia, and other conditions. Postoperative hemorrhage is most critical during the initial 24-hour period following surgery. Although hemorrhage can be well controlled intraoperatively, it may increase during recovery as blood pressure normalizes and the turtle becomes active, sometimes traumatizing the area. If bleeding is severe, additional radiocautery or ligature placement may be necessary. Most of the time, pressure bandages with hemostatic agents are effective, but these may need to be changed every few hours until controlled. Once the hemorrhage has stopped, a clean nonadherent bandage is left in place for 24–48 hours to prevent recurrence.

Turtles are returned to the water as soon as possible based on recovery (Figure 21.19). Average times range from 3 to 24 hours postop, depending upon anesthetic recovery and postoperative bleeding. Bandages can remain in place while in water, as long as they do not prohibit swimming and surfacing. The water depth is adjusted to accommodate the turtle's strength, pain, and abilities postop.

Analgesics, most commonly meloxicam and tramadol, are administered for one to four weeks, depending upon the size and location of incisions (Norton et al. 2017).

Infection risk is high after FP tumor excision due to open incisions and the aquatic environment. Good water quality is imperative during wound healing. Broad spectrum antibiotics are administered during healing for prophylaxis. Wound cleaning and topical wound care is provided during the initial 24–48 hours postop, then continued every 72 hours for the first two to three weeks, then once weekly until healed. Wounds are cleaned with dilute betadine or chlorhexidine and saline, and loose caseous scab material is gently debrided once granulation has begun. Topical colloidal silver or zinc spray followed by hydrogel or collagen spray is applied. Topical antibiotic ointments are discouraged unless infection is present due to the risk of antibiotic resistance. The exception is for ocular incisions; triple antibiotic ophthalmic ointment is applied for three to seven days postop. Wound healing occurs quickly over several weeks (Figure 21.20).

At our sea turtle rehabilitation facilities, therapeutic laser treatments (Class IV 12 W) are performed during the initial postop period to help control pain and inflammation (Figure 21.21).

While overall healing time may not be altered (Kurach et al. 2015), decreased redness, swelling, and pain have been consistently observed during the acute healing phase. Laser therapy is performed every 72 hours with prescribed wound care during the initial two to three weeks postop. Beneficial effects of the laser are present with treatments as frequent as every 24–36 hours, but they are not significant enough to warrant the stress of additional animal handling for sea turtles.

Prognosis and Conclusion

Sea turtles heal quickly from dermal FP excisions, and once tumors are completely removed, they can successfully be released under the guidance of regulatory authorities. However, recurrence of FP tumors is common. Up to 60% of tumors regrow postoperatively (Page-Karjian et al. 2014). Animals need to be monitored closely postop for development of new tumors and regrowth (Figure 21.22). When regrowth occurs, it is typically noted within 36 days of surgery (Page-Karjian et al. 2014).

The risk factors of regrowth, as with initial tumor development, are multifactorial and not completely known. As with all herpesviruses, stress and immunosuppression are likely critical factors. It is also dependent upon surgical margins, tumor stages, tumor aggression, internal tumors, and other unknown factors. Recurrent tumors are excised with the same techniques as previously described. If animals have extensive regrowth, additional or repeat diagnostics should be performed to screen for internal FP tumors.

Recent genomic studies indicate that FP tumors share molecular characteristics with human basal cell carcinoma (Duffy et al. 2018). There are a number of effective therapies for treating basal cell carcinoma, including the topical application of fluorouracil (5-FU)

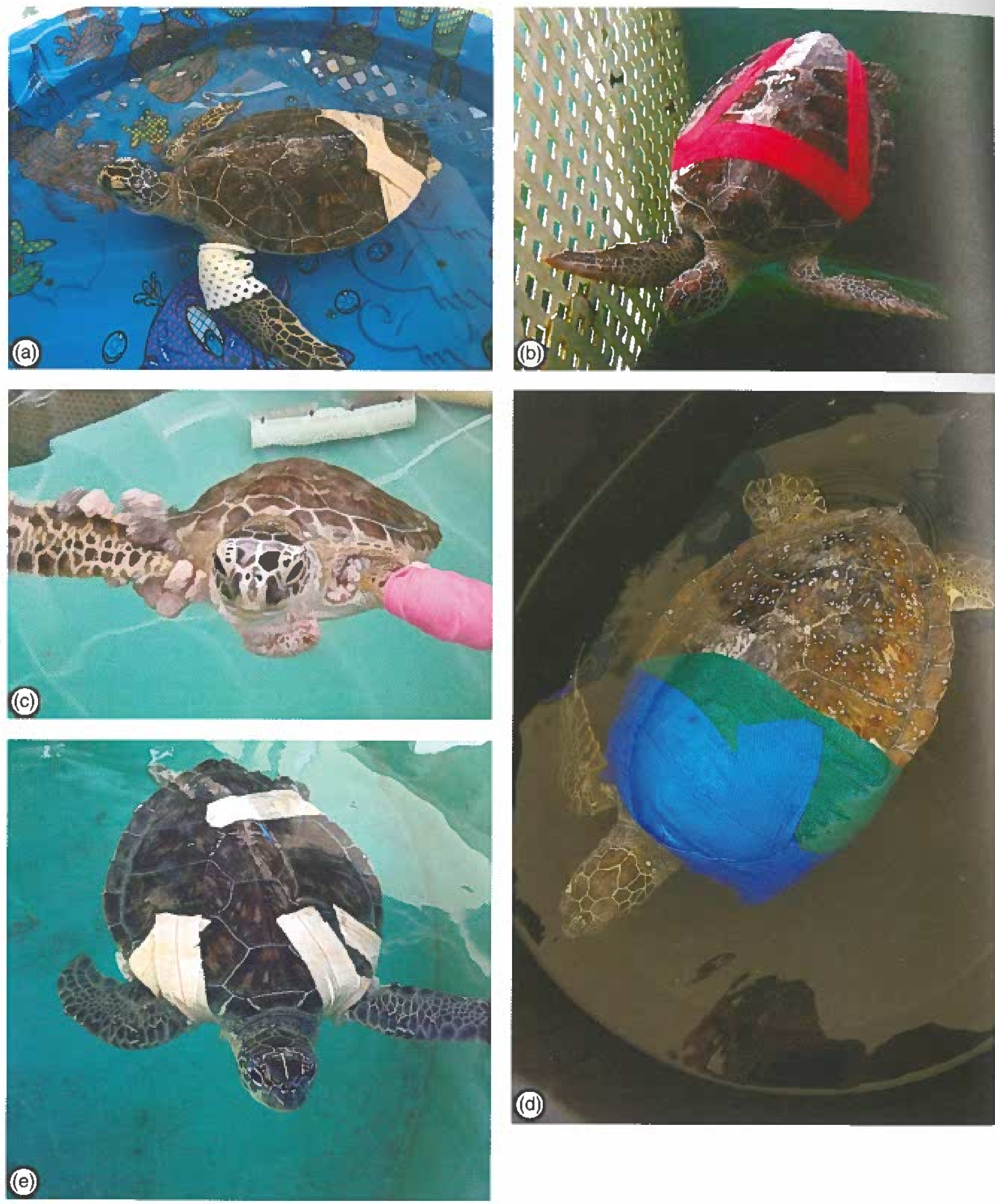

Figure 21.19 (a–e) Juvenile green sea turtles (*Chelonia mydas*) in various depths of water with multiple types of bandages in place during the initial 4–36-hour postoperative period following excision of fibropapilloma tumors.

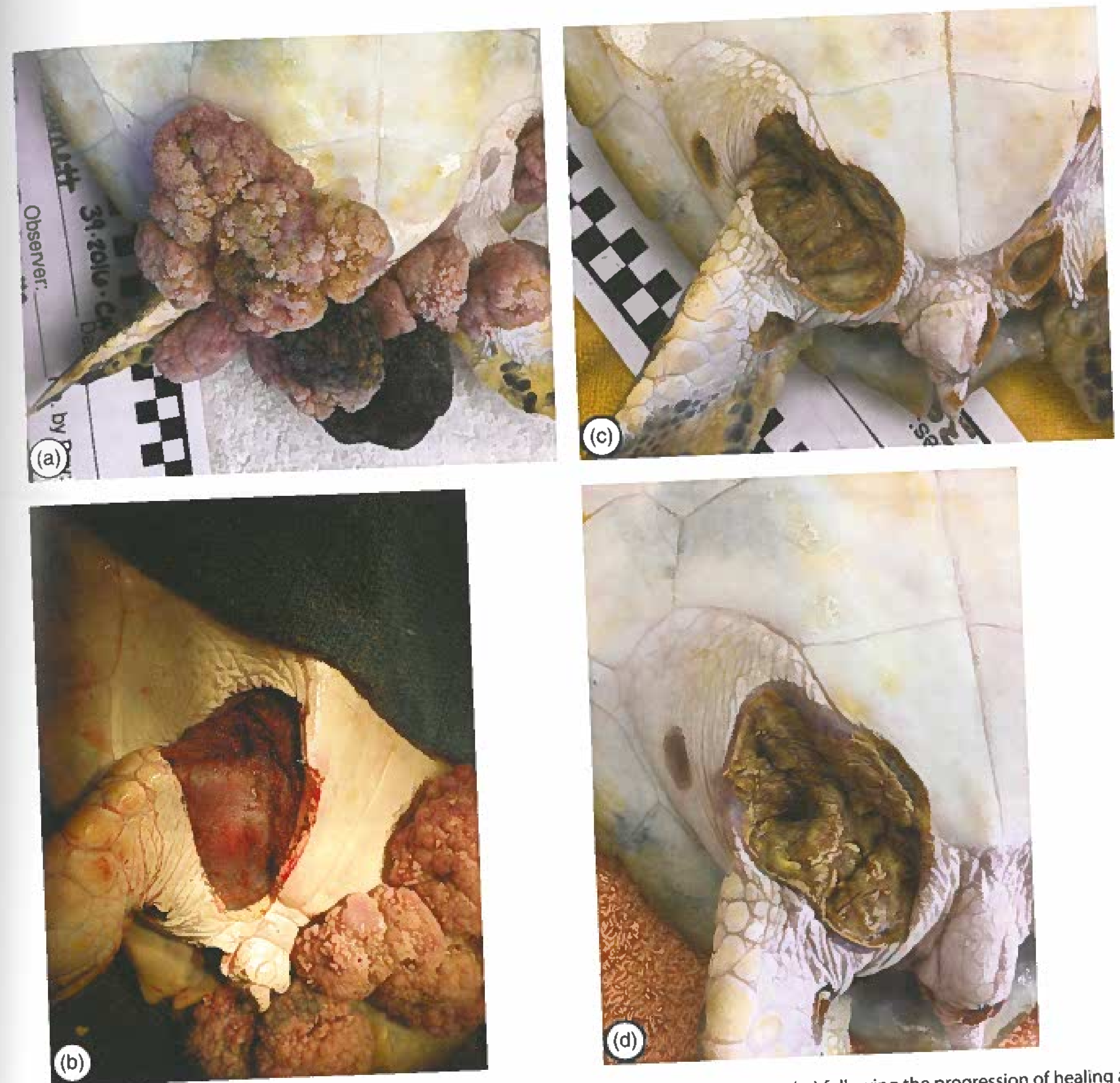

Figure 21.20 (a–h) A series of photographs taken of a juvenile green sea turtle (*Chelonia mydas*) following the progression of healing after fibropapilloma tumor excisions. (a) Preoperative tumors present in the left inguinal fossa and peri-cloaca. (b) Immediate postoperative excision from the left inguinal quadrant: exposed muscle and SC tissue present. No closure performed. (c) Two weeks postoperative: caseous scab material is completely covering all incisions, beginning to thicken as a protective layer while granulation tissue begins to form. (d) Four weeks postoperative: thick, healthy caseous scab material tightly adhered to underlying granulation bed. The margins are loosening and beginning to peel away as epithelialization begins. The smaller, more superficial anterior incision is fully epithelialized at this stage. (e) Six weeks postoperative: caseous scab material continues to loosen and peel away as epithelialization progresses. (f) Eight weeks postoperative: the remaining granulation bed and caseous scab material are very superficial, with continued wound contraction and epithelialization. (g) Ten weeks postoperative: remaining caseous scab material ready to slough to allow epithelialization of remaining central area. (h) Incisional scar tissue fully healed prior to release.

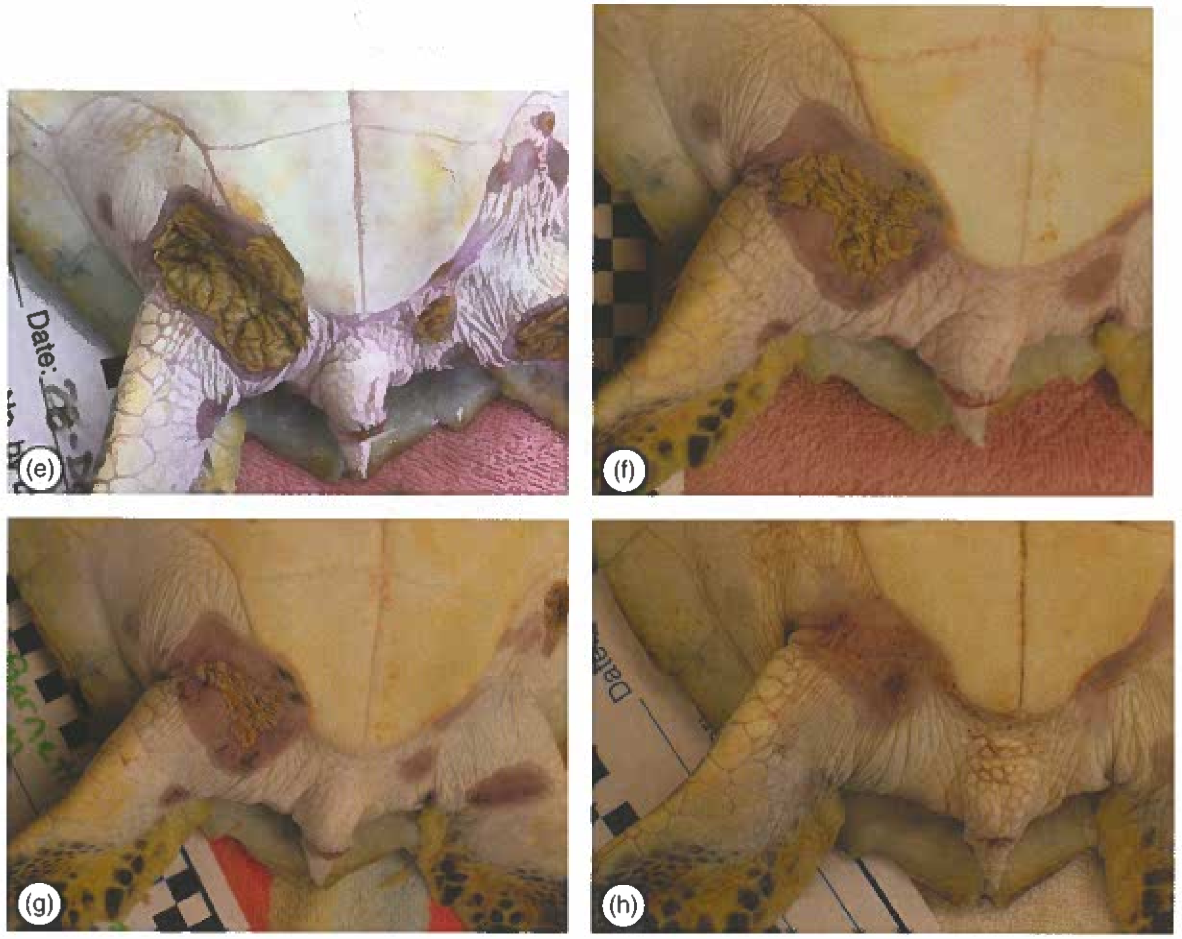

Figure 21.20 (Continued)

Figure 21.21 A juvenile Green sea turtle (*Chelonia mydas*) receiving laser therapy on incisions following fibropapilloma tumor excisions. Treatments are performed immediately postop, then repeated every 72 hours for two–three weeks to help control pain and inflammation.

Figure 21.22 A juvenile green sea turtle (*Chelonia mydas*) with fibropapilloma tumor regrowth noted within scar tissue of a previous surgical excision site on the left inguinal quadrant. A large cluster of FP tumors is visible adjacent to the right inguinal quadrant.

onto affected skin regions (Duffy et al. 2018). A 5-FU treatment has been used experimentally as 1% ophthalmic solution, applied topically twice daily for six to eight weeks into the eyes (with a 15 minute "dry dock" time for the turtle to allow for sufficient contact). Initial studies have shown a decrease in recurrence of up to 50% with this treatment (Duffy et al. 2018). It has also been used topically on areas of skin of early regrowth or boney regions postop to prevent recurrence. There is some evidence that it is effective in treatment or prevention, and further research is currently being done to find other chemotherapeutics for FP tumors. Until more advancements are made in the understanding of the disease and treatment options, surgical excision with CO_2 laser remains the treatment of choice for fibropapillomatosis.

The CO_2 laser has many other applications in sea turtles and other aquatic animal species. It is commonly used to assist in flipper amputations. Similar settings for such procedures are used as described above for dermal FP excision procedures. Vessels larger than 0.5 mm diameter require ligation. The bone is disarticulated at the joint, or cut with giggly wire or rongeurs, depending on the location of the amputation. Surgical lasers are also commonly used for esophagostomies for fish hook removals and esophagostomy tube placement. They can also be used for enucleations, abscess lancing, and other soft tissue surgeries. Based upon the surgeon's comfort and skill level, CO_2 lasers have a wide variety of practicalities for soft tissue surgeries in aquatic species.

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Part V

Integrating Surgical Lasers in Your Veterinary Practice