Background:
Resection of oral, cutaneous and subcutaneous tumors now occupies a significant portion of our soft tissue surgery referral practice. Cutaneous mast cell tumors are the most common skin tumor in dogs, comprising up to 21% of cutaneous malignancies. The incidence of soft tissue sarcomas is only slightly less, with these invasive malignancies constituting approximately 15% of all skin and subcutaneous tumors in dogs. Interestingly, oral malignancies, soft tissue sarcomas (STS) and mast cell tumors (MCT) are all characterized by a high rate of local recurrence unless they are excised with wide margins of normal tissue. This biological behavior led to the recommendation that STS and MCT should be removed with a minimum of 2 cm lateral skin margins, and including a deep fascial plane. Oral tumors are removed with a 1-2 cm margin which can cause significant morbidity due to the location. Adherence to this dogma led to a need for advanced reconstructive procedures to repair tissue defects created by aggressive resections. Tumors on the limbs were often treated by amputation. Over the last decade, this trend has reversed. With the increasing availability of radiation therapy and novel chemotherapeutic agents, oncologists are now requesting cytoreductive therapy in lieu of wide resection, preserving limb function and avoiding reconstructive procedures by using adjunctive therapies to prevent tumor recurrence. Nonetheless, complete resection and tissue reconstruction often remains the most economical, single stage therapy for locally aggressive neoplasia.

Pre-surgical planning:
In order to formulate a comprehensive plan for the treatment of cancer, it is necessary to answer some basic information regarding the extent of the disease process- this process is termed tumor “staging”. The staging process may be standardized for the clinician using the TNM methodology espoused by the World Health Organization. In this classification, each aspect of the staging process is designated by a letter and number, as follows:

\[ T = \text{Type and local extent of tumor} \]
Scored from 1-4 with increasing size and invasiveness.
For example, a 10 cm ulcerated mammary mass would receive a score of \( T_4 \)

\[ N = \text{Spread to regional lymph nodes} \]
\( N_0 = \) No tumor cells in regional lymph node
\( N_1 = \) Metastatic cell identified in regional lymph node
(Some centers expand this classification to include \( N_2 \) and \( N_3 \), indicating spread to multiple and distant lymph nodes)

\[ M = \text{Metastasis to distant organs (e.g. lungs, liver)} \]
\( M_0 = \) No distant metastasis
\( M_1 = \) Distant metastasis identified

The TNM system is useful in a variety of ways- the scale allows for standardized classification of tumor stage in scientific publications, it provides a rigid structure for trainees in the diagnostic evaluation of tumors, and it provides a simple method of explaining the staging process to pet owners.
Often performed at the initial visit, tumor “staging” consists of 3 steps:

1) **Identification of tumor type and local invasion (T):**

   Preoperative biopsy: Tumor identification is essential to predict biological behavior of the mass. While tumor identification is often achieved by a fine needle aspirate and cytologic examination, this technique is associated with a less than desirable level of sensitivity and specificity, particularly with sarcomas that tend to show poor exfoliation. In addition, cytology is highly user dependent (correct interpretation requires significant training and experience). For these reasons, I prefer to have biopsy confirmation of tumor type when aggressive resection is planned or for tumors in locations that would involve significant morbidity (e.g. the face, paw, anus, etc). Biopsy is also indicated when cytology results are inconsistent with other diagnostic findings. Contrary to the recommendations of dermatologists in obtaining skin biopsies, diagnostic tumor biopsies are most consistent when obtained from the center of the mass rather than at the periphery or junction with normal tissue. Biopsies should be obtained by the surgeon that will be performing the resection so that the biopsy site can be placed in a location that is easily excised at the time of definitive surgery. Tru-cut needle biopsies can typically be obtained under injectable sedation. The tumor itself is typically insensate and local anesthetic is only required to reduce cutaneous pain at the needle insertion site. I use a 14 gauge Tru-cut needle biopsy for most large sarcomas. A single entry incision into the skin is made using a #11 scalpel blade and the spring loaded biopsy needle is used to take 3-4 biopsies by aiming the device in various directions from the entry incision. Oral and gingival masses are not amenable to needle biopsy, but diagnostic samples are easily obtained using a 4-6 mm skin biopsy punch. Hemorrhage is minimal and often can be controlled with direct pressure, but can be augmented with topical gelatin and placement of a mattress suture across the defect.

   Imaging: Determination of local invasion is initially assessed by palpation of the mass during physical examination. Inability to elevate the mass from the deeper tissues consistently predicts local invasion. When physical exam findings suggest deeper invasion, or when preoperative biopsy identifies a tumor with locally aggressive behavior, advanced imaging is required to plan lateral and deep margins that will be resected at the time of surgery. For oral, skin, subcutaneous and muscle tumors I find computerized tomography to be the most rapid, economical and informative imaging method to use in preoperative planning. Pre and post contrast images are used identify tumor margins and specific muscles that will be used as a deep margin during resection. Adjacent vasculature can also be identified and avoided (or addressed) in a safe manner at the time of surgery. Modern CT scanners can complete an image series in 3-5 minutes, allowing imaging and surgery to be performed under one anesthetic episode decreasing the cost and morbidity associated with treatment. CT imaging can also be used to plan postoperative radiation therapy- providing a dual benefit. Magnetic resonance imaging can provide excellent detail in soft tissue imaging, but this technology is more expensive and time consuming that CT, with multiple series requiring in excess of an hour in many cases. In my opinion, the benefits of MRI are currently outweighed by its disadvantages in extracranial cancer imaging.

2) **Lymph node metastasis (N):**

   Lymph node sampling: Lymphatic metastasis is not consistently predictable and may skip the local lymph node, while more distant regional lymph nodes can be infiltrated. In addition, palpation of the lymph node is not a consistent predictor of tumor infiltration. Up to 40% of “normal” sized lymph nodes were found to contain neoplastic cells on cytologic evaluation of dogs with oral melanoma. Based on this information, regional lymph node palpation is
recommended in all animals with malignant cutaneous, subcutaneous or oral neoplasia. Abnormally enlarged or firm lymph nodes are sampled by fine needle aspiration in all cases. In animals with known highly metastatic tumors (melanoma, MCT), local lymph nodes are sampled even when palpation is normal.

3) Distant metastasis (N):

Detection of metastasis: Screening for distant metastases typically involves use of imaging modalities, though the surgeon must have some understanding of the biological behavior of the tumor in order to direct this imaging. It is widely known that thoracic radiographs are recommended to evaluate for pulmonary metastasis in dogs with solid tumors. However, only 30% of metastases occur in the lung, while the liver (nearly 30%), spleen, bone and other distant sites are frequently ignored. In fact, thoracic radiographs would be extremely low yield in dogs with mastocytosis. Instead, dogs with MCT should undergo abdominal ultrasonography with splenic aspirate to investigate more common sites of visceral metastasis.

Cancer surgery:

The best chance to achieve complete surgical removal of cancer is during the first surgical procedure. Thus, it is important for the veterinarian performing the surgery to have the training and experience that will allow them to achieve the best outcome. The principles of successful cancer surgery are:

- Obtain preoperative identification of tumor type, with the primary surgeon selecting a biopsy site that will allow subsequent resection of the biopsy tract.
- Remove of the tumor with “clean margins”- for aggressive cancers; this can involve removing 3cm of normal tissue around the borders of the tumor and including at least one fascial plane underlying the tumor.
- Mark the skin around the tumor using a ruler and sterile marking pens to guide surgical incisions.
- Ensure that bleeding is controlled and avoid leaving “dead space” that can fill with fluid.
- Use closed suction drains to eliminate dead space as needed
- Change instruments and gloves before closing the incision to avoid contamination with tumor cells.
- Mark the tumor before submission to aid the pathologist in identifying margins.
- If radiation surgery is planned, mark the location of the tumor in the body using metallic (radiopaque) hemoclips, allowing the radiation oncologist to locate the area that needs to be treated.
- Close the incisions without tension, in order to avoid problems with wound healing.

Reconstruction:

The ultimate goal of oncologic surgery is to achieve maximal control of local disease while preserving (or improving) function. This lecture will discuss commonly used skin flaps and grafts used to reconstruct skin defects created by resection of cutaneous and SQ tumors. Special surgical techniques are required for more difficult tumors located on the face, inside the mouth, on the distal limbs or near mucocutaneous junctions.

Classification of Skin Flaps:

There is no such thing as a “standard wound”; there are always variables like the location and size of the defect, the vascularity of the wound bed, the degree of contamination, the age of
the patient, concurrent administration of chemotherapeutic agents. As a result, reconstructive surgery requires that the surgeon has extensive knowledge of basic principles and is able to adapt them with creativity to each problematic wound. This need for variability in closure techniques has led to skin flaps that are often created “on the spot” and may not have specific names. Rather, they are classified using general descriptive terminology. The following classification schemes are commonly used in the veterinary literature and should be learned:

1) Classification by blood supply:
   Vascularized skin flaps:
   Subdermal plexus flap (random pedicle flap)- a flap that depends upon terminal branches of direct cutaneous arteries in the subcutaneous tissue and panniculus muscle.
   Axial pattern flap- a flap that is supplied by a named direct cutaneous artery and vein (Figure 20-7, from Slatter, Textbook of Small Animal Surgery, 3rd edition, Saunders)
   Non-vascularized skin grafts
   Full thickness vs partial thickness skin grafts
   Meshed versus non-meshed skin grafts

2) Classification by composition
   Cutaneous flaps- flaps that are composed of skin only
   Composite flaps- flaps that are composed of combinations of tissue types
      Myocutaneous flaps are composed of muscle and skin
      Osteomyocutaneous flaps are composed of bone, muscle and skin

3) Classification by location
   Local flaps are based on tissue that is adjacent to the defect
   Advancement flaps- subdermal plexus flaps that are elevated and pulled directly over a defect
   Rotational flaps- subdermal plexus flaps that involve rotation of a piece of skin that is continuous with one portion of the defect.
   Distant flaps are subdermal plexus flaps that are based on tissue that is obtained from a site that is not continuous with the recipient bed. This tissue can be “tubed” and slowly advanced to a distant site

Figure 20-7. Superficial arteries of the canine trunk. 1, Superficial cervical branch of occipital; 2, cranial circumflex humeral; 3, caudal circumflex humeral; 4, proximal collateral radial; 5, lateral thoracic; 6, cutaneous branch of thoracodorsal; 7, cutaneous branch of subscapular; 8, distal lateral cutaneous branches of intercostalis; 9, proximal lateral cutaneous branch of intercostalis; 10, ventral cutaneous branches of internal thoracic; 11, cranial superficial epigastric; 12, caudal superficial epigastric; 13, medial genicular; 14, cutaneous branch of caudal femoral; 15 pectoral; 16, deep circumflex iliac; 17, tuber coxae; 18, cutaneous branches of superficial lateral coccygeal. (From Evans HE [ed]: Anatomy of the Dog, 3rd ed. WB Saunders, Philadelphia, 1992.)
Principles of Advanced Reconstructive Surgery:
1) KNOW YOUR ANATOMY
2) Use the simplest technique possible to close any tissue defect.
3) Have multiple plans available for wound closure and be prepared to use all of them
4) Warn clients of the frequent need for revision surgeries
5) Shave and aseptically prepare LARGE areas of skin before reconstructive surgery.
   You will be very sad if you are pulling haired skin into your surgical site to close a large wound.

Problem Areas:
The incredible amount of redundant skin on the trunk of small animals allows us to close virtually any wound, no matter how large, by advancement of local tissues (walking sutures, advancement flaps, skin stretchers, etc). Unfortunately, this statement does not apply to the head and distal extremities of small animals. The lack of local tissue for simple closure of wounds in these areas leads to a need for more advanced methods of reconstruction. The increased interest in treatment of animals cancer has fueled this field more than any other, with a goal of radical resection of local tissues and a rapid return to function. We will cover the most commonly employed reconstructive techniques for extremities in the most depth: axial pattern flaps and free skin grafts.

Axial Pattern Flaps:
Axial pattern flaps have several advantages for use in wound closure. Due to their robust blood supply through direct cutaneous vessel, axial pattern flaps can be much longer than subdermal plexus flaps and still maintain viability. This direct blood supply makes axial pattern flaps preferable for tumor resection sites that may require radiation therapy, which would cause rapid necrosis of a non-vascularized skin graft. Since they are full thickness flaps, axial pattern flaps maintain hair growth and cosmesis and provide relatively durable skin covering. One of the greatest advantages of axial pattern flaps is that they allow instant, complete closure of large defects without the laborious bandage changes required for free skin grafts. There are a large number of direct, cutaneous vessels available over the trunk and head, providing great versatility in closing wounds over this area (Figure 20-7, from Slatter, Textbook of Small Animal Surgery, 3rd Edition, Saunders, Philadelphia, USA, 2003).

The primary disadvantage of axial pattern flaps is that they do not reach the distal extremities in dogs or cats. Another disadvantage of axial pattern flaps is the large donor site incision which increases surgical time and patient morbidity.

Axial pattern flaps are harvested using described anatomic landmarks and the flaps are named for their nutrient artery and vein (Figure 20-7, from Slatter, Textbook of Small Animal Surgery). It is useful to know the location of the major vessels on this diagram, including the thoracodorsal, caudal superficial epigastric and superficial cervical arteries, so that these vessels may be preserved during surgical approaches or for use in axial pattern flaps. When elevating tissue, it is important to elevate the flap deep to the subcutis and panniculus muscle to preserve the blood supply. I find trans-illumination of the flap helpful in locating the vascular pedicle. The flap may be elevated and rotated up to 180 degrees to cover the adjacent skin defect if the cutaneous pedicle is divided, leaving only the vascular pedicle attachment (an island flap). Flaps
that are not directly adjacent to the recipient site may be “tubed” (sutured upon themselves), but I prefer to make a bridging incision to connect the donor and recipient sites. Flaps are typically sutured only at the periphery. I avoid placing many sutures to tack down the flap to the underlying tissue due to fear of compromising blood supply to the flap. Instead, I place a closed suction drain to remove fluid and eliminate dead space.

The two most commonly utilized axial pattern flaps in clinical practice are the **thoracodorsal** and **caudal superficial epigastric flaps**. The thoracodorsal flap is based on the thoracodorsal artery and vein, arising from the caudal shoulder depression palpable at the level of the point of the acromion. The skin boundaries for flap elevation are: cranial- spine of scapula, caudal- a line parallel to the spine of the scapula and double the distance from the spine of the scapula to the caudal shoulder depression, dorsal- extends to dorsal midline. The thoracodorsal flap will rotate **to cover the shoulder, cranial thorax and axilla**, but is used most often to cover **skin defects over the elbow**- an area that is not amenable to skin grafting due to the high degree of motion and low vascularity of the donor bed. The thoracodorsal flap extends maximally to the mid antebrachium and is not helpful for defects of the carpus or distal thoracic limb.

The caudal superficial epigastric flap is based on the caudal superficial epigastric artery and vein which arise from the inguinal ring. The flap length includes the caudal 4 mammary glands and associated skin in dogs, but only the caudal 3 glands in cats. The medial border is the abdominal midline, the lateral border is parallel to midline and is an equal distance from the teats. The caudal superficial epigastric flap can be used to cover **defects in the flank, perineal area, lateral thigh, inguinal area, stifle, hip and prepuce**. Owners should be warned about the cosmetic appearance of this flap, as the skin over the mammary glands is thin and sparsely haired, not to mention the fact that the dog will have teats on it’s knee...

Flap viability is often difficult to assess in the postoperative period, as discoloration does not necessarily equate with ischemia. Methods to assess flap viability include:

1) **Fluorescein dye** may be administered intravenously- flap perfusion is examined with a Wood’s lamp. This method requires special equipment, doesn’t work well in pigmented skin and is not perfect in predicting viability.

2) **Disulphine blue** is another intravenous dye that is not as safe as fluorescein, but does work in pigmented skin.

3) “**Stab wound analysis**” involves puncture of the flap with a needle and measuring PCV and pH of the blood. PCV>54% is well correlated with flap necrosis.

4) Visual and tactile evaluation of skin is always helpful as well. Signs of necrosis include stiffness of the skin, black or white discoloration, and loss of sensation to a needle prick. Unfortunately, these signs typically occur approximately 5 days AFTER the ischemia at a point when it is too late to prevent flap failure.

If flap viability is in question, there are a variety of actions that may be taken to prevent necrosis. These include:

1) **Colloid administration** (Dextrans) to decrease blood viscosity and inhibit platelet adherence.

2) **Vasodilators** may be used (isoxupraine)

3) **Medical leeches** may be applied to the flap when venous congestion is suspected.
Skin Grafts:

Skin grafting is a long utilized technique to provide epithelial coverage to skin defects. In veterinary surgery the term “skin graft” typically refers to non-vascularized autogenous (from the same animal) tissue. Skin grafts may be either partial thickness or full thickness. Partial thickness grafts are harvested using a dermatome (a moving blade) or a freehand knife which “shave” off a piece of skin that is 0.015-0.03 in. The donor site heals rapidly by a process called adnexal re-epithelialization. Advantages of partial thickness skin grafts are increased viability compared to full thickness grafts and decreased contraction of the graft during healing. Disadvantages of partial thickness grafts are cosmesis (hair growth is minimal to absent), poor durability, loss of hair at the donor site, and the requirement for specialized equipment. Partial thickness grafts are not used in cats, because the skin is too thin to be useful with this technique. Full thickness grafts are harvested by simply removing a piece of skin from the trunk using a standard scalpel. The subcutaneous tissue is scraped off the deep surface of the graft using metzenbaum scissors so that the dermis will be in direct contact with the wound bed. Full thickness grafts have improved cosmesis and durability, with a potential for hair regrowth and may be performed without specialized equipment. Both types of grafts are typically “meshed” before application, increasing the area covered by up to 3 times the original size of the graft. The graft is sutured down to the wound bed with simple interrupted sutures at the periphery and throughout the center of the graft to prevent movement of the graft during healing. The wound is bandaged and the initial bandage is not changed for 3 days after surgery to avoid disruption of the tenuous blood supply to the graft. The recipient site is immobilized for 10-14 days.

Skin grafts become vascularized though a 4 step process:

1) Adherence: initial fibrin seal followed by fibroblast ingrowth
2) Plasmatic imbibition: blood vessels in the graft dilate and take up serum-like fluid in the wound bed by capillary action, absorbing nutrients to sustain the graft.
3) Inosculcation: anastomosis of the graft vessels with vessels in the wound bed
4) Penetration and ingrowth of new vessels: vessels from the wound bed enter the graft tissue

Based on this description, it is clear that application of a non-vascularized skin graft is a “race” in which the wound bed must establish a delicate blood supply to the graft before necrosis occurs. Because of the requirement for vascular supply from the wound bed, only certain types of tissue are appropriate for application of skin grafts. The ideal wound bed is clean, uninfected and well vascularized such as granulation tissue or muscle. Skin grafts should not be applied over exposed bone, tendon, infected areas, fat, chronic ulcers, or in areas where radiation therapy is planned.

The most commonly used skin graft technique for wounds of the distal extremity is a full thickness, meshed skin graft. Because tendons or bone are often exposed in distal limb wounds, it is necessary to apply wet to dry bandages until a granulation tissue bed is established to nourish the graft.

Free vascularized skin flaps

With the advent of microvascular surgical techniques, it is now possible to detach a piece of skin with its vascular pedicle and transfer it to a different site where it is anastomosed to a recipient blood vessel. This process is very similar to preparing an axial pattern flap, except that the vessels are cut and the flap may be transferred to any location with a recipient blood vessel. Advantages of this technique are that full-thickness, haired skin may be immediately applied to
any wound bed without waiting for granulation tissue to form (even over exposed bone or tendons in the distal wound). Because vascularized flaps have a direct blood supply, they can be used to cover a site that will later require radiation therapy. The obvious disadvantage to these flaps is the specialized training and equipment required to perform the vascular surgery.