A review of wound healing, wound management, and treatment options

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Lecture outline

1. Skin anatomy
2. Initial triage
3. Wound classification
4. Phases of healing
5. Antimicrobial therapy
6. Complications
7. Closure types
8. Management of open wounds
9. Alternative/novel therapies
10. Case series

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Lecture goals

1. Understanding of initial wound management/triage
2. Understanding wound severity/classification
3. Expectations for healing timeline
4. Treatment options
    a. Feeling more comfortable!
    b. What patients can be managed in a primary care setting?
    c. When to refer?

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Skin anatomy

Layers

“Ogres are like onions”
“They stink? … they make you cry? You leave ‘em out in the sun and they get all brown and pruney–”
“NO! Onions have layers! Ogres have layers…”
(credit Dreamworks - Shrek)

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Skin anatomy

So does the skin… LAYERS

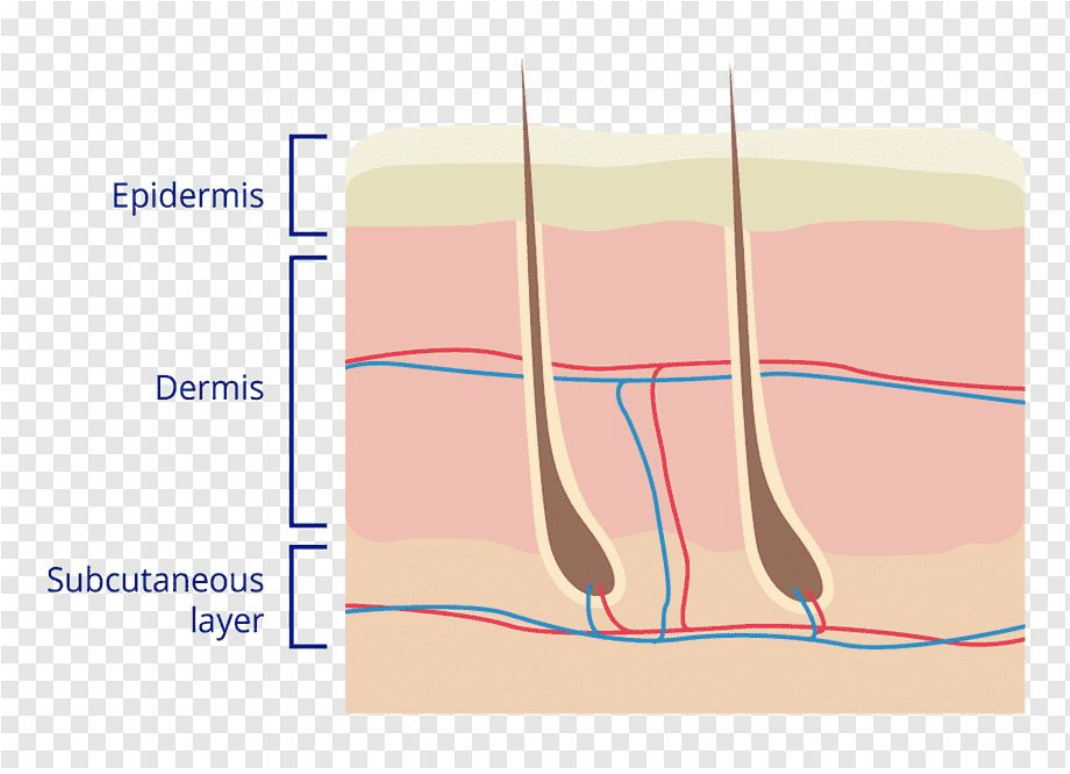

Image courtesy of pngwing.com

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Skin anatomy

Epidermis

-Outermost layer of the skin

-Thin, avascular

    -Serves protective purpose

-Nourished by deeper layers

-Where hair is thin, epidermis is thicker

    -Paw pads, nose

    -Tissue is keratinized

    -Keratin = insoluble protein

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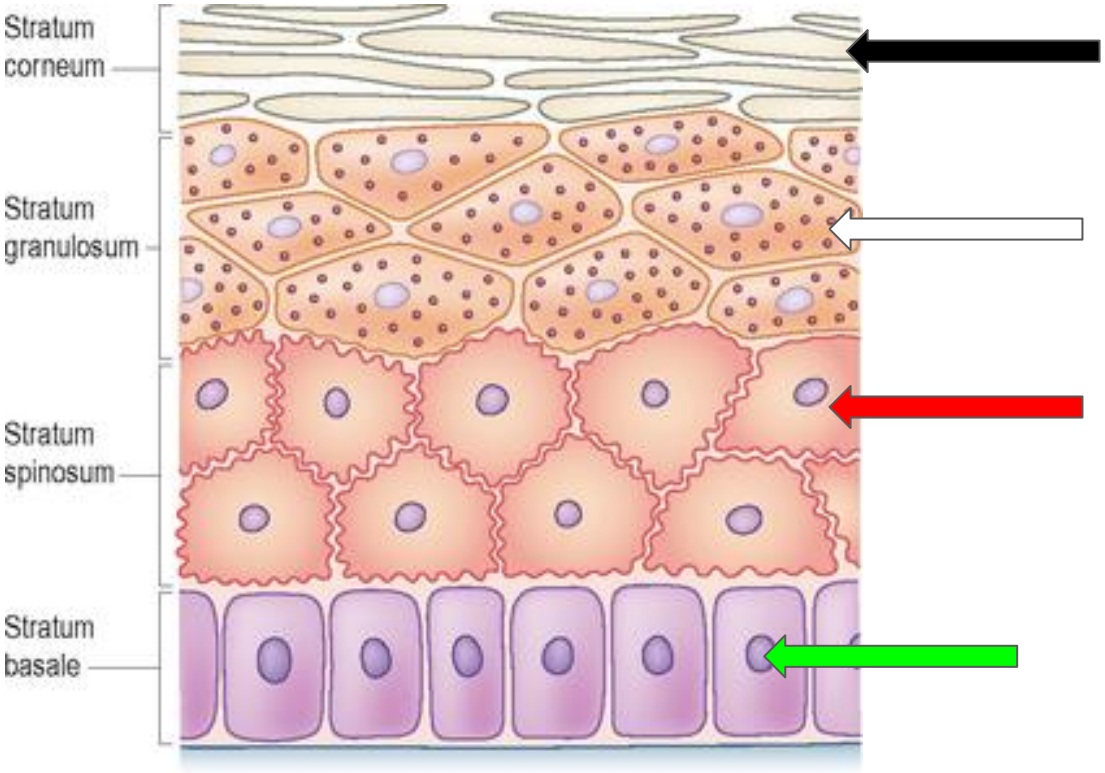
Skin anatomy

Epidermis



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Skin anatomy

Dermis

-Thicker and vascular

-Contains lymph and blood vessels, nerves, hair follicles, gland ducts, smooth muscle fibers

-Nourishes and supports epidermis

-Composed of a mixture of collagenous, reticular, and elastic fibers

    -Mucopolysaccharide ground substance

-Fibroblasts, macrophages, plasma cells, and mast cells found throughout

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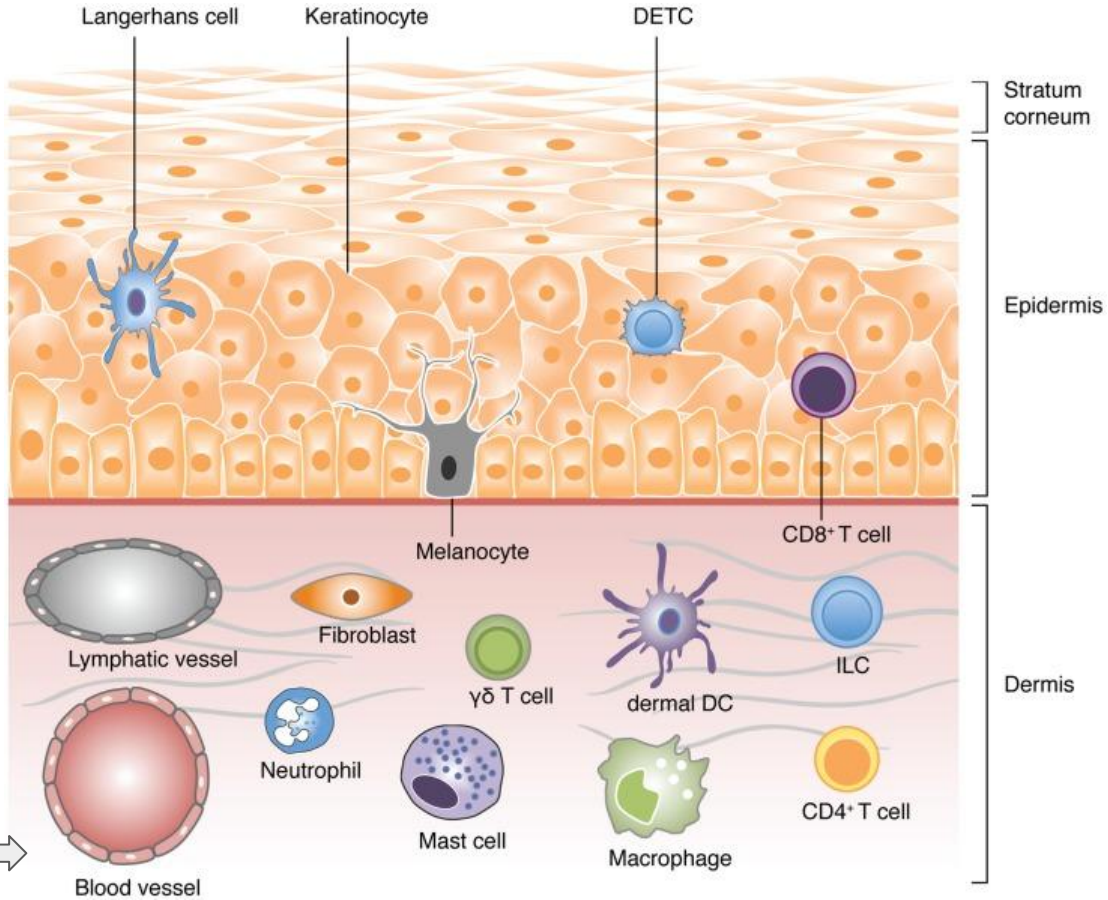
Skin anatomy



Pink background is the collagen matrix

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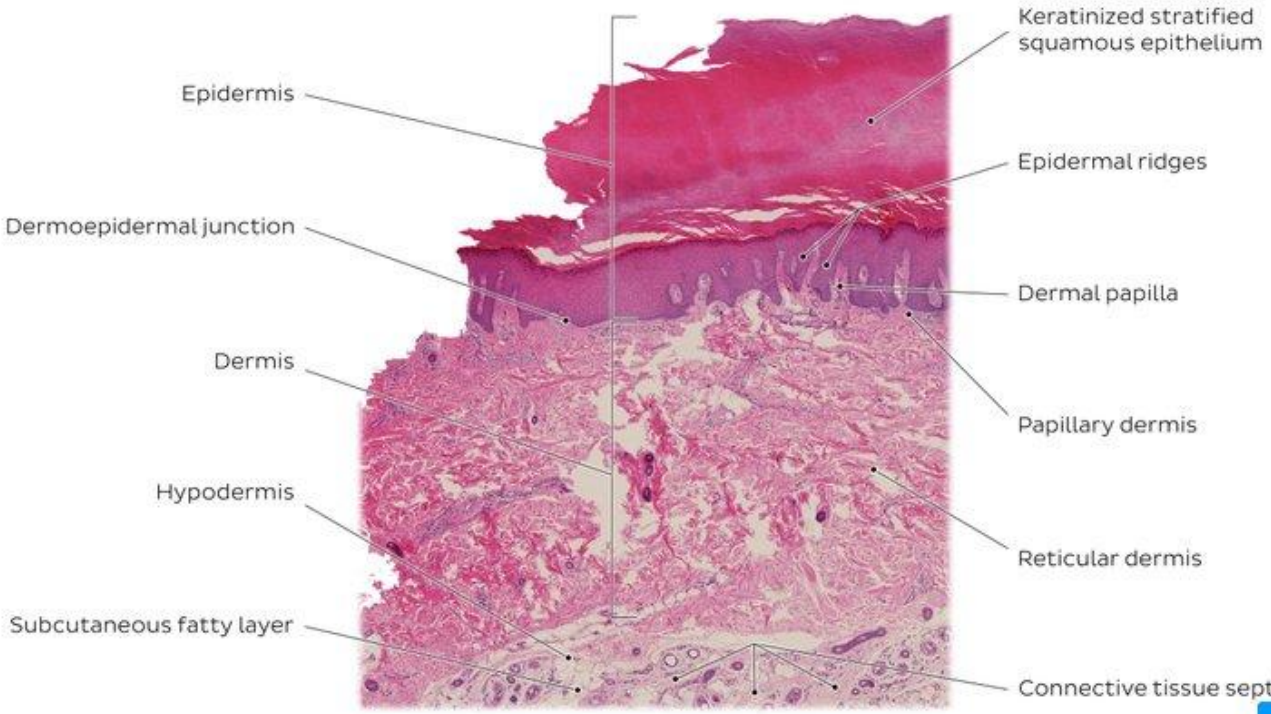
Skin anatomy



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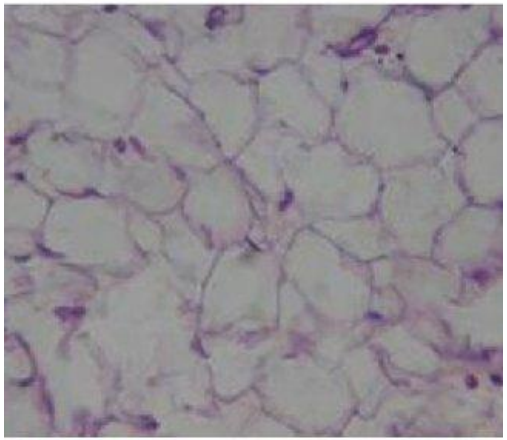
Skin anatomy

Subcutis/hypodermis



(b)

-Deep to the dermis

-Location of subcutaneous fat and connective tissue

-Variable thickness

Image courtesy of http://www.adfg.alaska.gov/index.cfm%3Fadfg%3Dmarinemammalprogram.harbordiet

Image courtesy of:
Yanina, Irina & Tuchin, Valery & Navolokin, Nikita & Matveeva, Olga & Bucharskaya, Alla & Maslyakova, Galina & Altshuler, Gregory. (2012). Fat tissue histological study at indocyanine green-mediated photothermal/photodynamic treatment of the skin in vivo. Journal of biomedical optics. 17. 058002. 10.1117/1.JBO.17.5.058002.

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Initial triage

What do you see?

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Initial triage

What do you see?

Bleeding - yes, there is a wound
Actually a rather bad wound → large degloving on the left biceps wrapping around the leg

But WHAT ELSE???

This patient came in after being dragged by her leash behind the family's car.

- HR sky high
- Pale gums
- "Shocky"

What does this patient NEED first?

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Initial triage

Overall patient stability - check AND TREAT the major systems

*****DO NOT OVERLOOK LIFE THREATENING INJURIES BECAUSE OF A BIG BLOODY WOUND*****

1. Respiratory
2. Cardiovascular
3. Neurologic
4. Urogenital

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Initial triage

Can the wound wait? YES

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Thought process…

If you were in a car accident and presented to the ER unstable, in shock, painful, with unknown injuries, and some really impressive wounds, how would you want your doctor and nurses to treat you to ***save your life***?

a. Examine/assess you
b. Place IVC and start diagnostics
c. Check blood pressure and hook up ECG for monitoring
d. Give pain medication
e. Give IV fluids (or other resuscitation) and antibiotics
f. Provide oxygen
g. Bandage and protect the lacerations you can see

Image courtesy of istock.com

The exception – Arterial bleeding

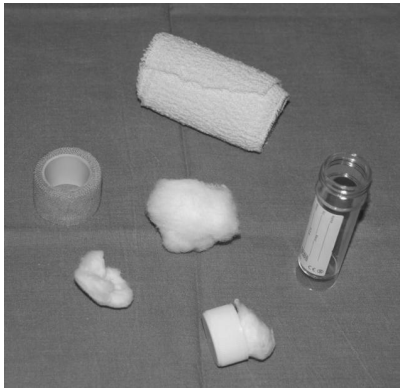
“Arterial blood pressure causes the blood to bleed out at a rapid, intermittent rate in a spray or jet, coinciding with the pulse, rather than the slower, but steady flow of venous bleeding.”

Image courtesy of istockphoto.com

The exception – Arterial bleeding

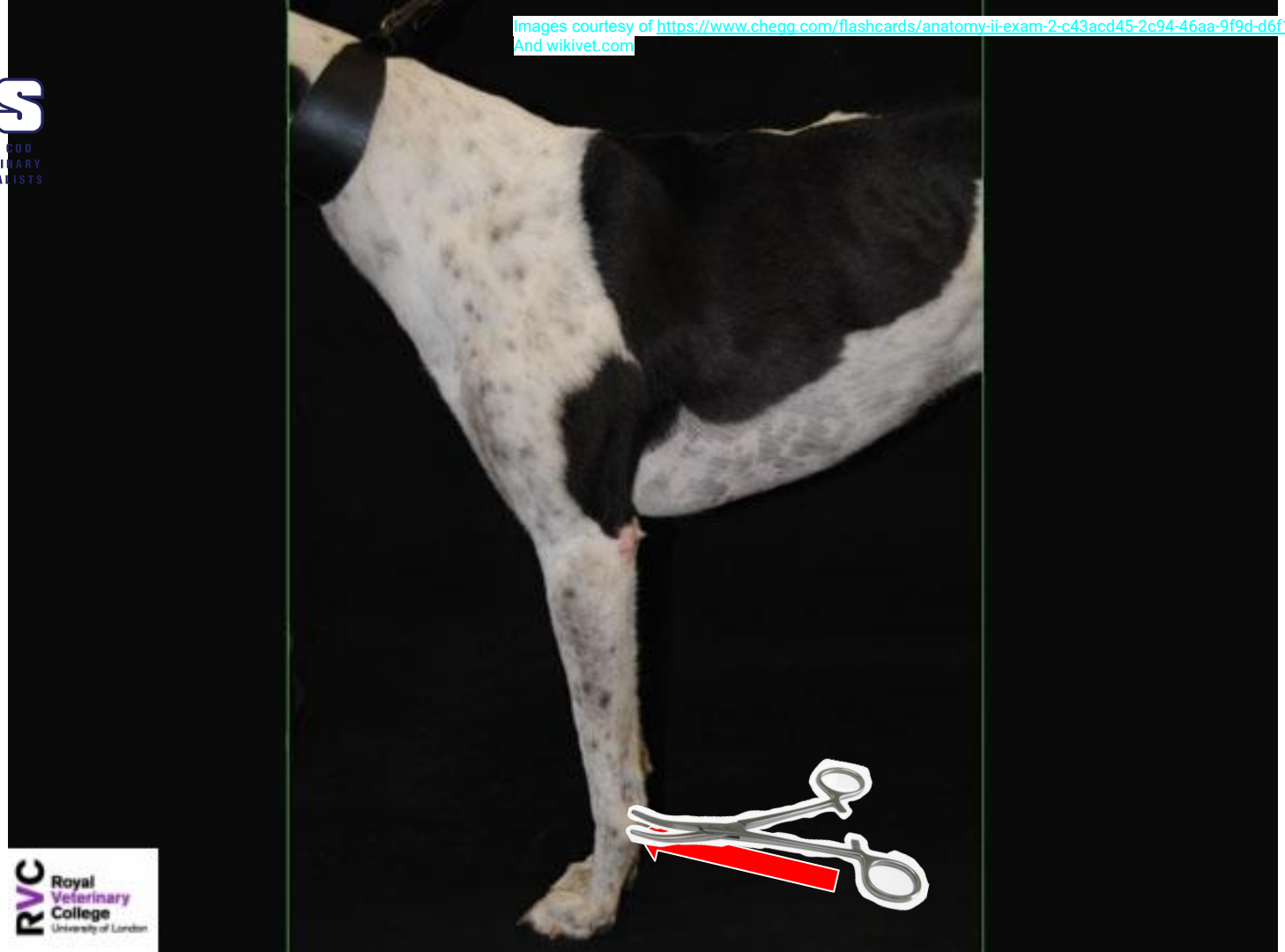
In human trauma, hemorrhage remains a major problem

- Death due to uncontrolled bleeding still accounts for ~40% of cases!
  - Timeframe to exsanguinate due to arterial laceration varies by artery size and whether transection is partial or complete
  - Caused by a combination of coagulopathy and vascular injury
- Partially transected artery is potentially worse than complete transection due to lack of vasoconstriction



Images courtesy of Rudge WB, Rudge BC, Rudge CJ. A useful technique for the control of bleeding following peripheral vascular injury. *Ann R Coll Surg Engl*. 2010;92(1):77-78.

Images courtesy of https://www.chegg.com/flashcards/anatomy-ii-exam-2-c43acd45-2c94-46aa-9f9d-d6f194bd1fbf/deck
And wikivet.com



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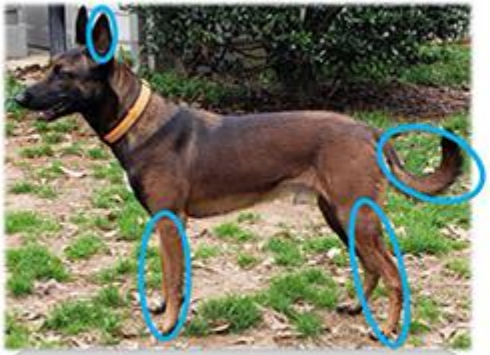
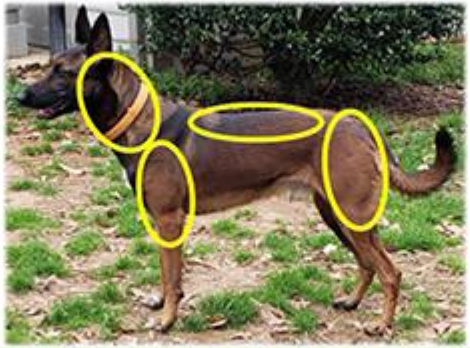
COMPRESSIBLE



- DIRECT PRESSURE
- CIRCUMFERENTIAL PRESSURE DRESSING

Partially Compressible



- Direct Pressure
- WOUND PACK
- HEMOSTATIC AGENT

Non-Compressible Intracavitary

Internal Hemorrhage
THORACIC / ABDOMINAL
IMMEDIATE TRANSPORT

Image courtesy of https://www.frontiersin.org/articles/10.3389/fvets.2020.571368/full

TOURNIQUETS

SWAT - stretch, wrap, and tuck tourniquet applied to a canine limb

- Difficulty of tapering canine leg conformation which causes slipping of traditional tourniquets bypassed by this design
- Direct pressure believed to be sufficient to stop bleeding in most distal extremity wounds on canine limbs
- True tourniquet not generally necessary

Image courtesy of https://www.frontiersin.org/articles/10.3389/fvets.2020.571368/full

Wound treatment on triage

Triage ***protection*** of the wound

1. LUBRICATE!!!
2. Non stick dressing and bandage for protection
3. Antibiotics - broad spectrum coverage

Image courtesy of clipartmax.com

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Wound treatment on triage

Triage protection of the wound

1. ***LUBRICATE!!!***
    a. Keep the wound *moist*
        i. Desiccated tissue does not heal well
        ii. Dry tissue = dead tissue

    b. Make clipping/cleaning more effective later
        i. What happens when you shave around a wound that isn't lubricated? SO MUCH HAIR in the wound.

Image courtesy of avacaremedical.com

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Wound treatment on triage

Triage protection of the wound

2. Non stick dressing and bandage for protection

Image courtesy of NRWworld.com

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Wound treatment on triage

Triage protection of the wound

3. ***Antibiotics - right away? Yes!***

Class I - Clean	Class II - Clean contaminated	Class III/IV - Contaminated
-atraumatic wound -no inflammation -no break in aseptic technique -no entry of biliary, resp, GI, or UG tracts	-atraumatic wound -no inflammation -minor break in aseptic technique -biliary, resp, GI, or UG tracts entered with either minimal spillage or prior preparation	-traumatic wound with delay in therapy or exogenous contamination -inflammation or purulence -Major break in aseptic technique -Entry of biliary, resp, GI, or UG tract with gross spillage of contents
1-4%	3-8%	5-35%

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Wound treatment on triage

Triage protection of the wound

Which antibiotics?

What contaminants are you worried about?

a) All external wounds - skin pathogens, the object/surface that *caused* the wound!
b) Bite wounds - oral pathogens
c) Into the abdomen cavity - GI contents? UG contents?

Other factors?

a) Good tissue penetration!
b) Broad spectrum (unknown cause of wound)

Reasonable choice? Unasyn (ampicillin sulbactam)

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Wound treatment on triage

Initial debridement and assessment

1. Debridement should NOT be performed at cost to patient stability
   → **it CAN wait**
2. If you sedate/anesthetize a systemically unstable patient, they can decompensate!!!
3. Potential *benefit* in delayed debridement
   a. Tissue has more time to declare itself

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Owner expectations

Owner expectations!

1. How much WILL this cost?
2. When will we know if “questionable areas” will be okay?
3. How LONG will it take to heal?
4. WILL it actually heal???

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Lecture outline

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3. **Wound classification**
4. Phases of healing
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Wound classification

How bad is it???

Image credit:
Monty Python and the Holy Grail

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Wound classification

Before we classify them… what causes wounds?

Major forces involved…

- Compression
- Shearing
- Tension
- Friction

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Wound classification

The forces of trauma

- **Compression**

- Direct tissue trauma
- Ischemic reperfusion injury
- Swelling post trauma
  - Tissue necrosis
  - Hemorrhage
- Ex. The dog bite that falls apart day 3

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Wound classification

Before we classify them… what causes wounds?

- **Tension**

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Wound classification

Before we classify them… what causes wounds?

- **Friction**
  - Simple separation of skin layers cause by dragging rather than sliding
  - Epidermis affected!
  - Removal of the outermost skin surface when the body is dragged across something

Image courtesy of homefureverrescue.wordpress.com

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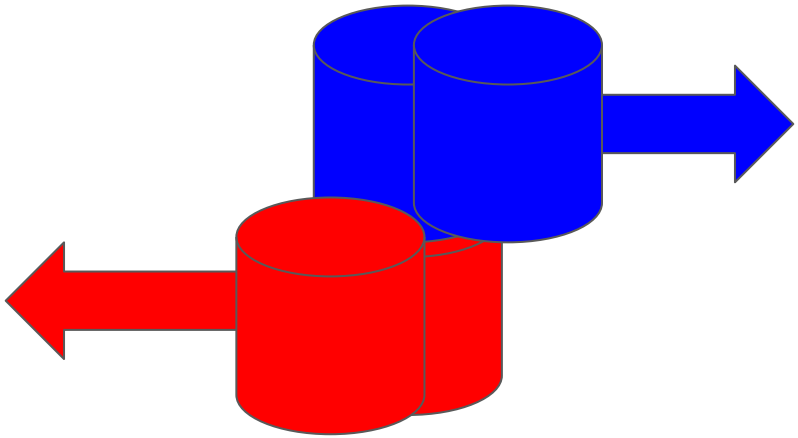
Wound classification

Before we classify them… what causes wounds?

- **Shearing**



= combination of friction and pressure causing injury simultaneously

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Wound classification

Why do we do this?

“The Centers for Disease Control and Prevention created a surgical wound classification system… to preemptively identify patients at risk of surgical site infection (SSI).”

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Wound classification

Depth

Superficial - only involving the epidermis

Partial Thickness - epidermis and part of the dermis

Full Thickness - through the entire dermis

Nature of wound likely to impact this

- Abrasion → more superficial
- Puncture or degloving → deeper

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Wound classification

Level of contamination

1. Clean - surgically created under aseptic conditions (e.g. incision)
    a. Ex - FHO with no skin infection
2. Clean contaminated - minor break in aseptic surgical technique
    a. Minimal or easily removed contamination
    b. Ex - GI surgery with minimal leakage of contents intra-op
3. Contaminated - recent wound related to trauma with bacterial contamination
    a. Sources: street, soil, oral cavity, etc.
4. Dirty/infected - older wound with exudate or obvious infection
    a. Abscessed bite wounds, punctures, traumatic wounds with retained necrotic tissue

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Wound classification

Level of contamination - significance?

How does this change what we do clinically?

Clean - surgically created under aseptic conditions (e.g. incision)

a. Antibiotics only intra-op to peri-op

Clean contaminated - minor break in aseptic surgical technique

b. Antibiotics only intra-op to peri-op

No benefit shown in antibiotic sources longer than 24 hours in surgical wounds like this!

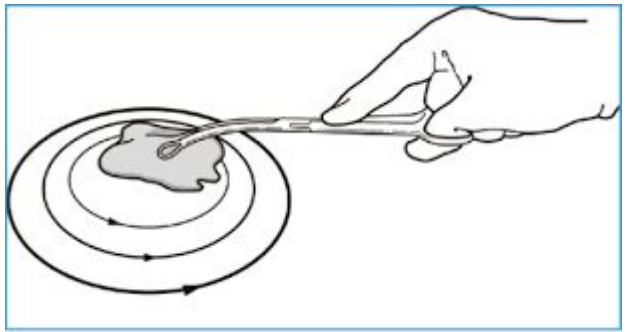

Image courtesy of theveterinarynurse.com

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Wound classification

Level of contamination - significance?

How does this change what we do clinically?

Contaminated - recent wound related to trauma with bacterial contamination

Dirty/infected - older wound with exudate or obvious infection

Full course of antibiotics (7 days), ideally guided by culture, recommended

Image courtesy of theveterinarynurse.com

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Wound classification

Comment on Culture…

When should we culture?

- Benefit/change in outcome has **not** been found by culturing day of with acute trauma
- Useful in wounds that already show evidence of infection
    - The older, abscessed wounds presenting!
    - NOT the dog that was bitten an hour ago

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Wound classification

What comes through our doors?

Vast majority of wounds that come to us “emergently” will be contaminated or dirty wounds
-bites
-punctures (sticks and other objects)
-polytrauma
-old wounds that have been hidden by fur
-abscesses

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Wound classification

What comes through our doors?

What about burns?
These present their own challenges…

Possible causes…

- Thermal
- Chemical
- Electrical
- Radiation

Image courtesy of gcvs.com

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Wound classification

A little more about burns…

What happens to the body?

- Shock
- Fluid loss
  - IV fluid therapy = treatment mainstay
- Decreased cardiac output for first 48 hours post burn injury
- Post 48-72 hours → severe hypermetabolic state
  - Monitor albumin levels, protein catabolism is high → impacts healing
- High risk of infection and sepsis
  - Antibiotic/antimicrobial therapy is a MUST

Major sequelae?

- Sepsis
- DIC
- MODS
- Hypoalbuminemia
- Severe/complicated scarring

Lecture outline

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Phases of healing

4 Recognized Phases

1. Inflammation
2. Debridement
3. Repair/proliferation
4. Maturation

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Phases of healing

Set order? Nope.

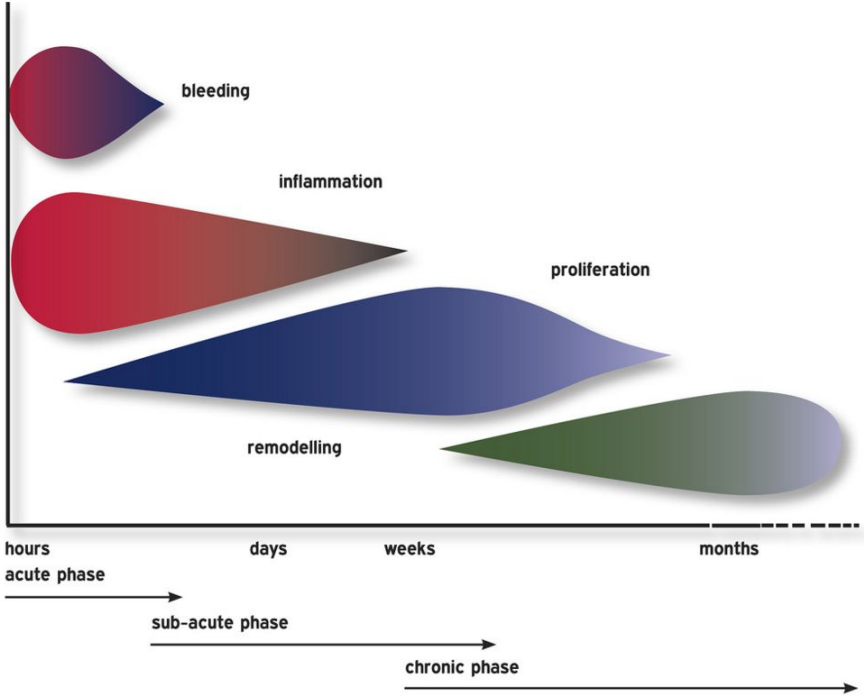

Figure 2: Basic response to tissue injury, and the subsequent overlapping phases of healing

- No stark start and finish for each phase
- Multiple phases occur simultaneously
- Transitions are not visible to the naked eye

- 3-5 day lag phase – inflammation and debridement predominate
  - No increase in wound strength during this time

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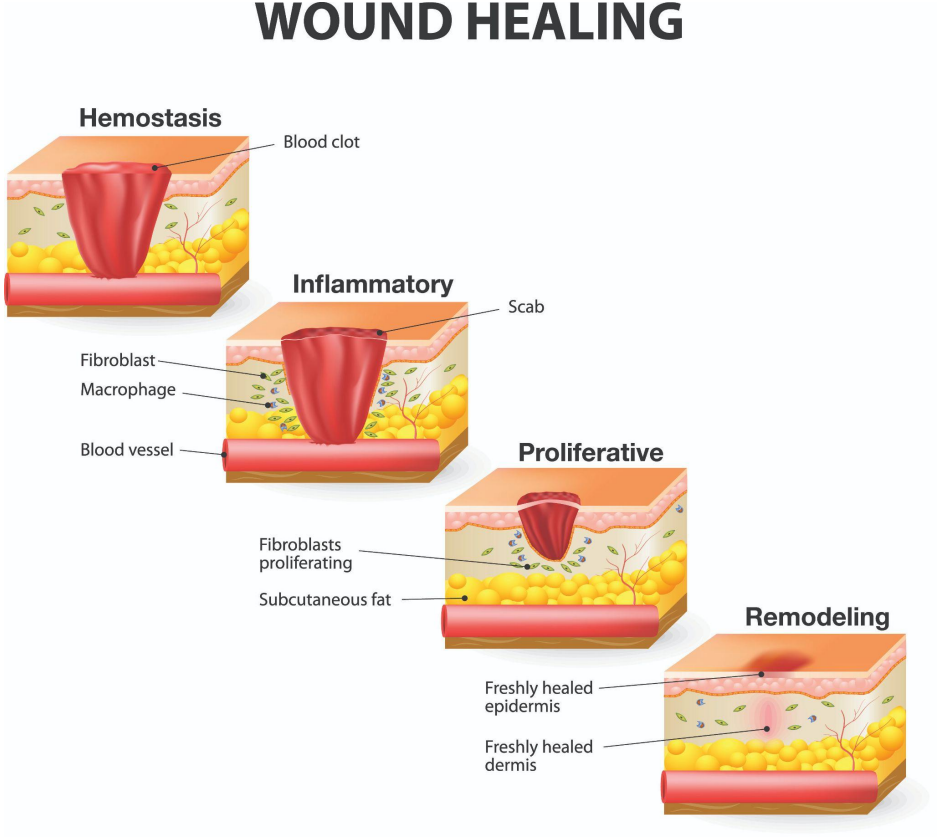
Phases of healing



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Phases of healing

Inflammation

INFLAMMATORY PHASE

- Blood vessel disruption/hemorrhage

  → coagulation in area of wound + clot development

- Scaffolding for invading neutrophils, monocytes, fibroblasts, endothelial cells
  - Additional plasma inflammatory mediators attracted
    - Cytokines, histamine, prostaglandins, leukotrienes, complement, growth factor
  - Cause of erythema and swelling around wound
    - Increases **pain**

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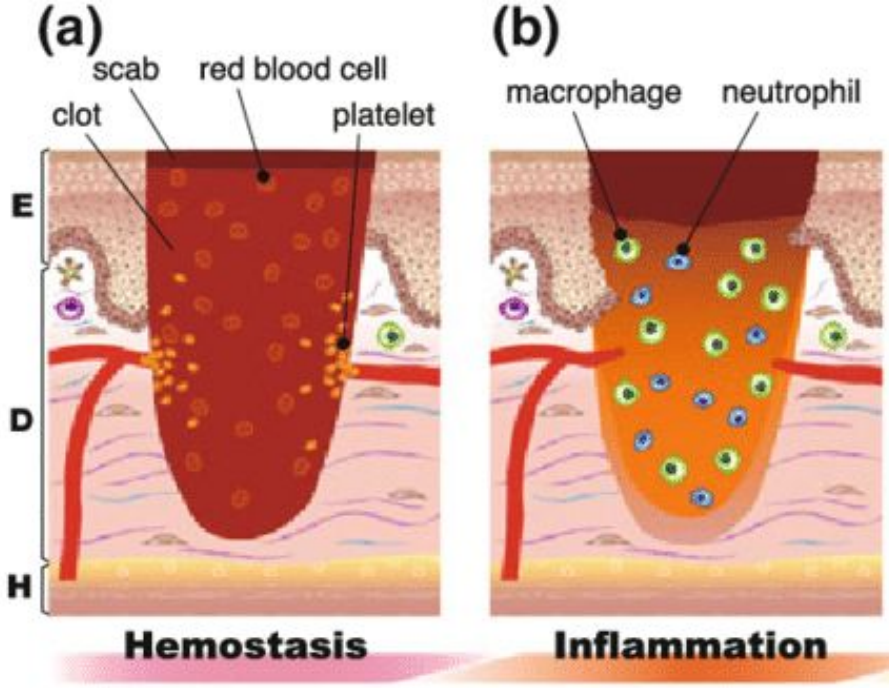
Phases of healing

Inflammation



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Phases of healing

Debridement

Collectively the debridement phase is the body's effort to clean the wound.

DEBRIDEMENT PHASE

→ Characterized by white blood cell entry into wound

-Neutrophils = pre

-Monocytes = pre

→ Become

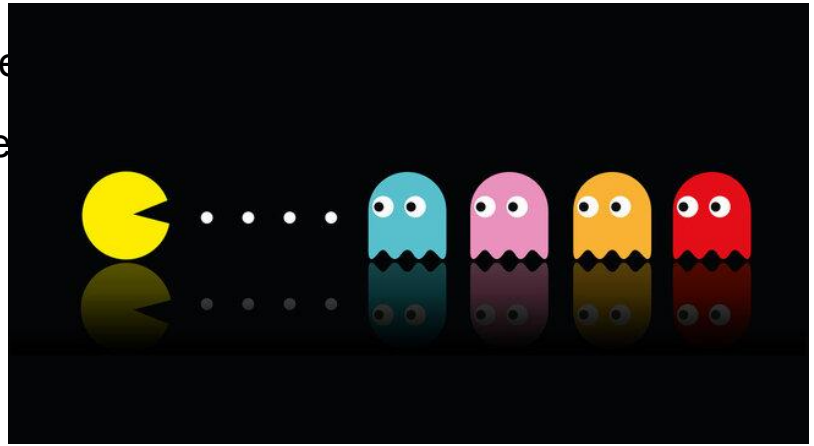

Photo credit pacman vector images

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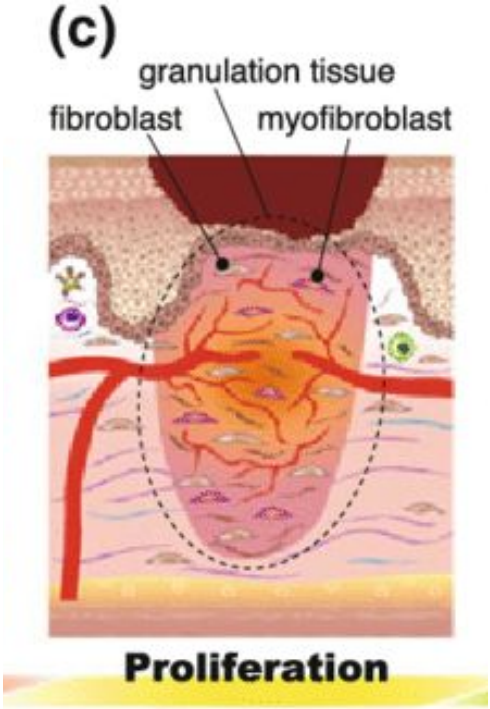
Phases of healing

Repair/proliferation

REPAIR PHASE

- Begins 3-5 days post injury
- Lasts 2-4 weeks
- Most *dramatic* healing phase
- Angiogenesis, granulation tissue formation, epithelialization



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Phases of healing

Repair/proliferation cont'd

- Fibroblasts proliferate and synthesize collagen
- Capillary beds grow into the collagen → granulation tissue forms!
- Granulation tissue = necessary surface for epithelialization

→ also source of *myofibroblasts*

- Function → wound contraction

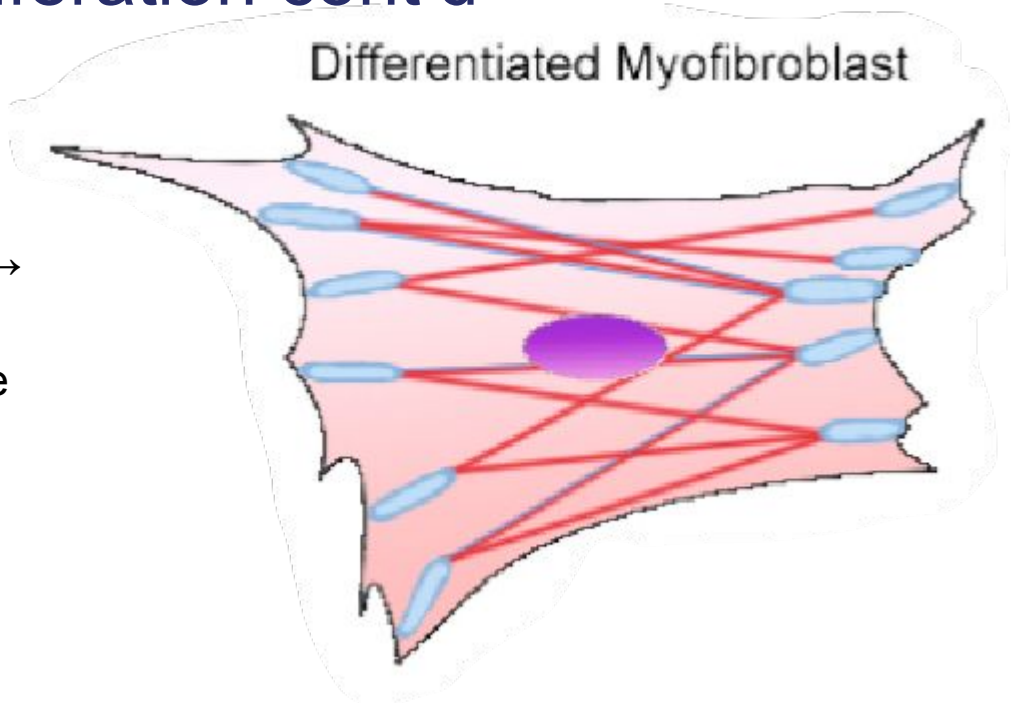


Image courtesy of:
@inproceedings{Midgley2014CellularMO,title={Cellular mechanisms of myofibroblast differentiation and dysfunctions in wound healing}, author={Adam C. Midgley},year={2014}

Phases of healing

Repair/proliferation cont'd

Myofibroblasts develop from fibroblasts

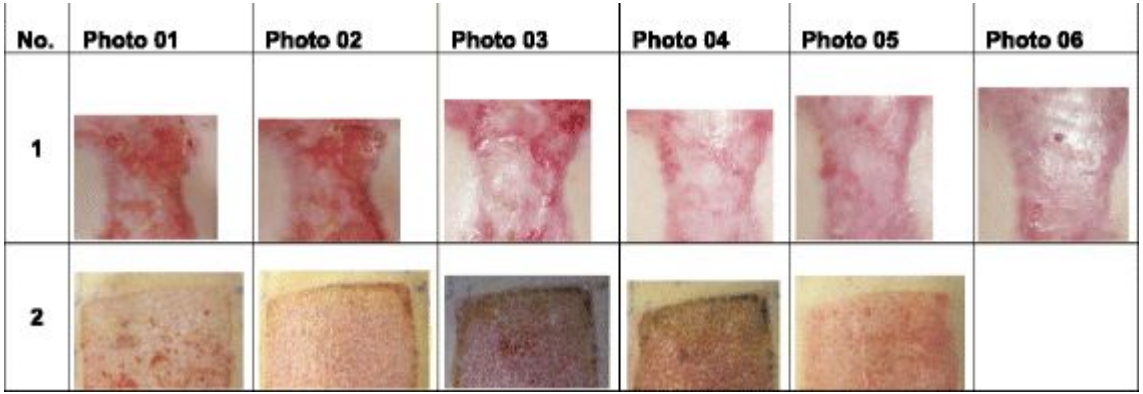
- Have *contractile* elements that function in wound contraction
- Slow progression, <1mm per day

Think about what this means for our patients

- Big gaping wounds that cannot be primarily closed will take TIME to heal
- Prepare the family!

Phases of healing

Repair/proliferation cont'd



- New epithelium becomes visible 4-5 days post injury
- Potentially develops faster in a moist environment
- Wound contraction first noticeable 5-9 days post injury
    - Progresses at 0.6-0.7mm per day

Image courtesy of Rennekampff, HO., Fimmers, R., Metelmann, HR. *et al.* Reliability of photographic analysis of wound epithelialization assessed in human skin graft donor sites and epidermolysis bullosa wounds. *Trials* 16, 235 (2015).

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Phases of healing

Repair/proliferation cont'd

Impact of tension and motion?

The answer is actually about tissue oxygenation…

- Increased wound *tension* → increased tissue pressure → decreased microperfusion → decreased O2 to the wound!
- Increased wound **motion** → increased fluid in tissues → increased distance from vasculature to wound → decreased O2 to wound!

BOTH tension and motion impact wound healing due to ***decreased O2!***

Image courtesy of theincredibles.fandom.com

Phases of healing

Repair/proliferation cont'd

What's the deal with oxygen and wound healing?

- Impact of **Oxygen**
  - Needed for cell metabolism → energy production by ATP
    - High metabolic rate while healing!
  - Combats infection
  - Induces angiogenesis
  - Increases keratinocyte differentiation, migration, and re-epithelialization
  - Enhances fibroblast proliferation and collagen synthesis
  - Promotes wound contraction

Phases of healing

Maturation

MATURATION PHASE

- Starts 17-20 days post injury
  - May continue **SEVERAL YEARS**
- Wound contraction
- Remodeling of collagen fiber bundles
  - Requires adequate collagen deposition
  - Remodeling → alters collagen fiber orientation and increases cross linking

→ INCREASED wound strength

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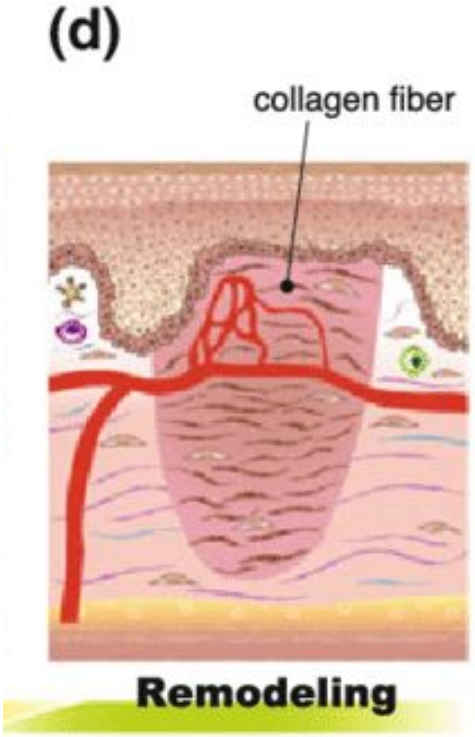
Phases of healing

Maturation

- Gradual decrease of type III collagen fibers and increasing type I fibers
- Scar from healed wound never reaches full strength of original tissue
  - Max 80% original strength
  - Different orientation of collagen fibers in scar!



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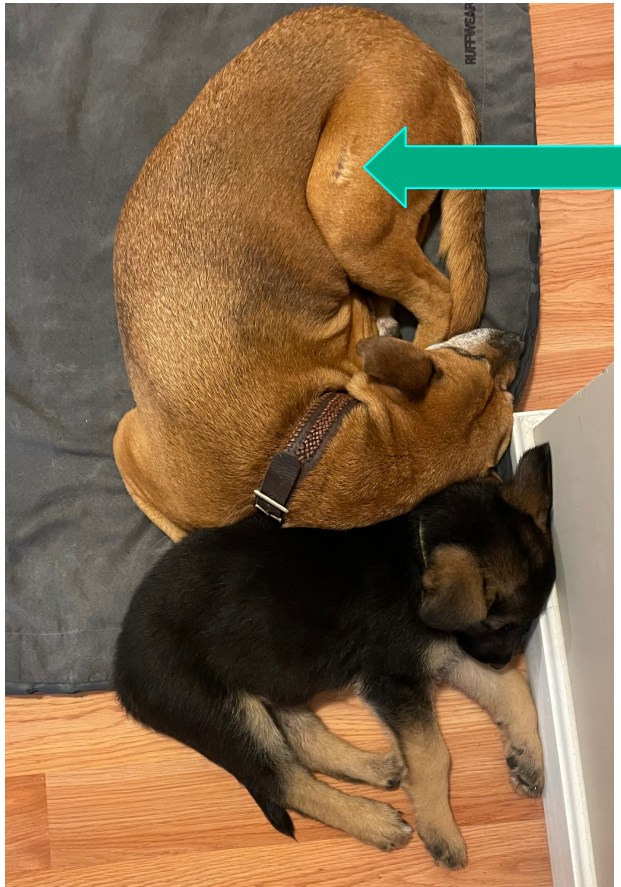
Phases of healing

Maturation

"In humans and other tight-skinned animals… collagen has a cross-weave structure in normal tissue, whereas in scar tissue it is aligned parallel to the plane of the skin."



The scar is never 100% of the original

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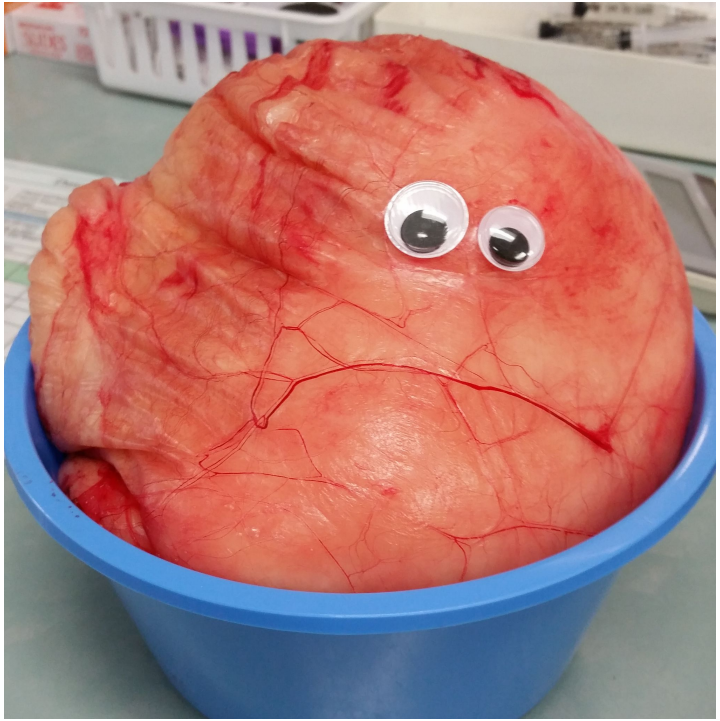
…Still with me?



On to treatments!

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Lecture outline

1. Skin anatomy
2. Initial triage
3. Wound classification
4. Phases of healing
5. **Antimicrobial therapy**
6. Complications
7. Closure types
8. Management of open wounds
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10. Case series

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Antimicrobial therapy

Bacterial contaminants of wounds

In a systemically healthy patient…

- Prolonged course of antibiotics not needed
- ***If possible, 1st dose in hospital IV!***
- 5-7 days of oral antibiotics
- Ideal to select antibiotics/de-escalate based on culture results when possible
- Presence of granulation tissue in chronic wounds indicates better infection resistance
- If “film” develops on your wound, REASSESS!

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Antimicrobial therapy

Bacterial contaminants of wounds

Gram positive contaminants - most common

- Staphylococcus (S. Pseudintermedius pictured at right)
- Streptococcus

- *Antibiotic recommendations*
- *Oral: clavamox (fair), cefpodoxime (fair)*
- *IV: unasyn, cefazolin*

Photo credit science photo library

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Antimicrobial therapy

Bacterial contaminants of wounds

Photo credit sciencephoto.com

Pasteurella multocida in common in dog/cat bite wounds because it is a common oral pathogen

- *Abx recommendations*
- *Oral: amoxicillin, amoxi-clavulanate (clavamox), enrofloxacin (baytril)*
- *IV: ampicillin, unasyn, baytril*

Anaerobic pathogens

- Bacillus species
- Clostridium species
- Corynebacterium species
- *Abx recommendations: clindamycin, clavamox/unasyn*

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Antimicrobial therapy

Deciding treatment… Systemic antibiotic use

- Consider in-house gram stain initially
- Culture = gold standard
    - To be performed on dirty/infected looking wounds
        - Culture at time of presentation in ACUTE trauma has not been demonstrated to help guide antibiotic therapy or change outcome
    - Goal → obtain sample of bacterial population from the wound causing infection
        - Grow this by plating the sample at the lab
        - Determine antibiotic sensitivity of the sample to determine appropriate abx regimen
- How to obtain appropriately?

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Antimicrobial therapy

Deciding treatment… Systemic antibiotic use

The Levine Quantitative Swab Technique:

1. *Cleanse wound with normal saline.*
2. *Pat dry wound bed with sterile gauze.*
3. *Culture the healthiest looking tissue, excluding exudate, purulent, devitalized tissue.*
4. *Spin the end of the sterile applicator over a 1cmx1cm area for at least 5 seconds.*
5. *Apply sufficient pressure to swab, causing tissue fluid to be expressed.*

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Antimicrobial therapy

Culture - how do we sample?

What about…
- Deep wounds?
- Wounds with necrotic tissue?

Can try to get access to deep portions of the tissue with a culturette
Or…
Can obtain a tissue biopsy to submit for culture

Is one superior?

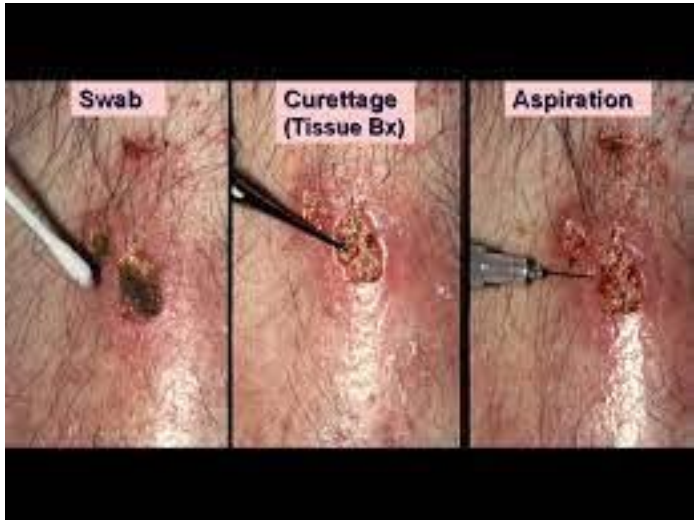

Image courtesy of antimicrobe.org

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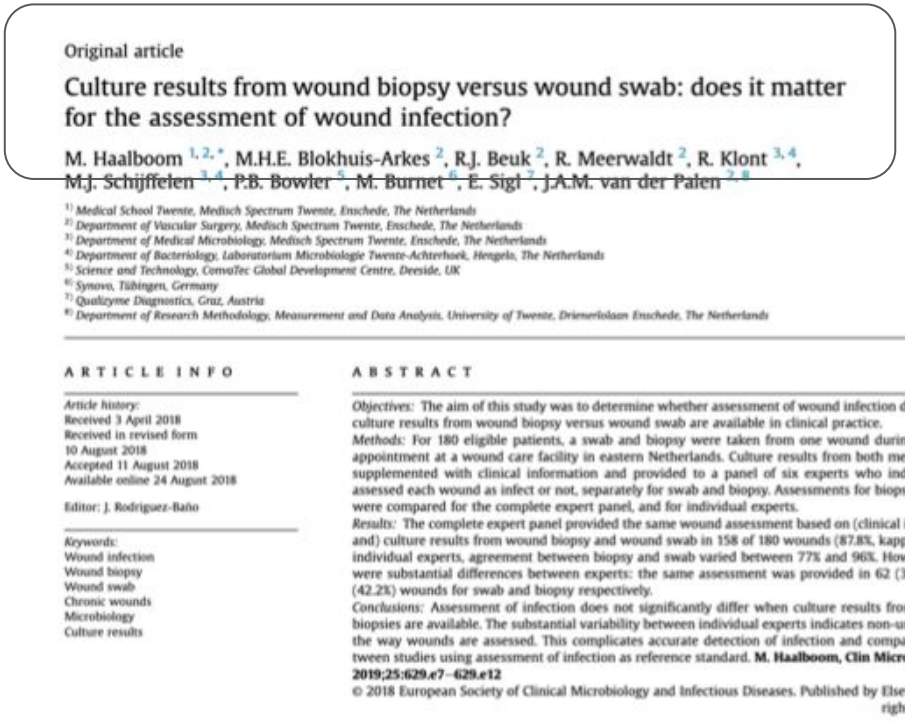
Antimicrobial therapy

Deciding treatment… Systemic antibiotic use



Original article

Culture results from wound biopsy versus wound swab: does it matter for the assessment of wound infection?

M. Haalboom [1, 2, *], M.H.E. Blokhuis-Arkes [2], R.J. Beuk [2], R. Meerwaldt [2], R. Klont [3, 4], M.J. Schijffelen [3, 4], P.B. Bowler [5], M. Burnet [6], E. Sigl [7], J.A.M. van der Palen [2, 8]

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ABSTRACT

Objectives: The aim of this study was to determine whether assessment of wound infection differs when culture results from wound biopsy versus wound swab are available in clinical practice.
Methods: For 180 eligible patients, a swab and biopsy were taken from one wound during a regular appointment at a wound care facility in eastern Netherlands. Culture results from both methods were supplemented with clinical information and provided to a panel of six experts who independently assessed each wound as infect or not, separately for swab and biopsy. Assessments for biopsy and swab were compared for the complete expert panel, and for individual experts.
Results: The complete expert panel provided the same wound assessment based on (clinical information and) culture results from wound biopsy and wound swab in 158 of 180 wounds (87.8%, kappa 0.67). For individual experts, agreement between biopsy and swab varied between 77% and 96%. However, there were substantial differences between experts: the same assessment was provided in 62 (34.4%) to 76 (42.2%) wounds for swab and biopsy respectively.
Conclusions: Assessment of infection does not significantly differ when culture results from swabs or biopsies are available. The substantial variability between individual experts indicates non-uniformity in the way wounds are assessed. This complicates accurate detection of infection and comparability between studies using assessment of infection as reference standard. **M. Haalboom, Clin Microbiol Infect 2019;25:629.e7–629.e12**

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Antimicrobial therapy

Deciding treatment… Systemic antibiotic use

Research Article

A Comparison of Tissue versus Swab Culturing of Infected Diabetic Foot Wounds

Ying Huang, Ying Cao, Mengchen Zou, Xiangrong Luo, Ya Jiang, Yaoming Xue, and Fang Gao

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Academic Editor: Andre P. Kengne

Objective. To compare the efficacy of swabbing versus tissue biopsy for microbiological diagnosis of diabetic foot infection. *Methods*. This was a prospective trial. Fifty-six patients with diabetic foot infection were divided into the following 3 groups according to the PEDIS grading system: grade 2 ($n = 10$), grade 3 ($n = 29$), and grade 4 ($n = 17$). Two specimens were collected from each wound for microbial culturing after debridement, including a superficial swab and a deep tissue punch biopsy specimen. *Results*. Swab culturing identified all of the microorganisms isolated from the corresponding deep tissue specimens in 9/10 of grade 2 wounds (90.0%), and this proportion decreased to 12/29 (41.4%) and 7/17 (41.2%) for grades 3 and 4 wounds, respectively ($p = 0.02$). Moreover, the sensitivity for identifying Gram-negative bacteria, such as *E. coli* and *Citrobacter*, by swabbing was low (33.3%). In addition, some Gram-negative bacteria, such as *Serratia* and *Ralstonia pickettii*, were isolated from deep tissues but not from swabs. *Conclusions*. Swab culturing may be reliable for identification of pathogens in diabetic foot wounds classified as grade 2. However, it is advisable to culture deep tissue specimens for wounds of grade ≥3 because swab culturing is associated with a high risk of missing pathogens, especially Gram-negative bacteria.

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Antimicrobial therapy

Deciding treatment… Systemic antibiotic use

- *Fluoroquinolone specific risk…*

INFECTION AND IMMUNITY, June 2003, p. 3028–3033 Vol. 71, No. 6
0019-9567/03/$08.00+0 DOI: 10.1128/IAI.71.6.3028–3033.2003

A Fluoroquinolone Induces a Novel Mitogen-Encoding Bacteriophage in *Streptococcus canis*

Keely T. Ingrey,† Jun Ren, and John F. Prescott*

Department of Pathobiology, University of Guelph, Guelph, Ontario N1G 2W1, Canada

Received 26 June 2002/Returned for modification 2 December 2002/Accepted 25 February 2003

This study investigated whether the recently recognized emergence of canine streptococcal toxic shock syndrome (STSS) and necrotizing fasciitis (NF) might be partly attributed to the use of fluoroquinolones to treat *Streptococcus canis* infections in dogs. Both mitomycin and the fluoroquinolone enrofloxacin caused bacteriophage-induced lysis of *S. canis* strain 34, an isolate from a case of canine STSS and NF. Fluoroquinolone-evoked, bacteriophage-induced lysis occurred over a range of concentrations similar to those that would occur after treatment of dogs with these agents. To search for a possible bacteriophage-encoded streptococcal superantigen gene(*s*), a library of the 36.5 (±1.1)-kb bacteriophage, designated ϕsc1, was made by ligating 3- to 7-kb *Tsp*5091-digested ϕsc1 fragments into an *Eco*RI-digested λZapII vector. Recombinants were screened for mitogenic activity by using canine peripheral blood lymphocytes. Of 800 recombinants screened, 11 recombinants with mitogenic effects were identified, and their inserts were sequenced. The highest homology of 11.6 kb of sequenced ϕsc1 DNA was to the completely sequenced *Streptococcus pneumoniae* bacteriophage MM1. Seven of the 11 ϕsc1 sequenced inserts contained a 552-bp open reading frame, *scm*, with 27% amino acid similarity to pokeweed (*Phytolacca americana*) mitogen. PCR showed this gene to be present in 22 of 23 *S. canis* isolates tested. Quantitative reverse transcription-PCR showed that bacteriophage induction was associated with a 58-fold enhancement of expression of this gene relative to that in a noninduced culture of a similar age. The presence of this gene on a fluoroquinolone-induced bacteriophage may explain the association observed between fluoroquinolone use in dogs and the development of canine STTS and NF.

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Antimicrobial therapy

Deciding treatment… Systemic antibiotic use

- *What if you can't wait for the culture???*
- *Quick in-house way to look for staph vs. strep?*

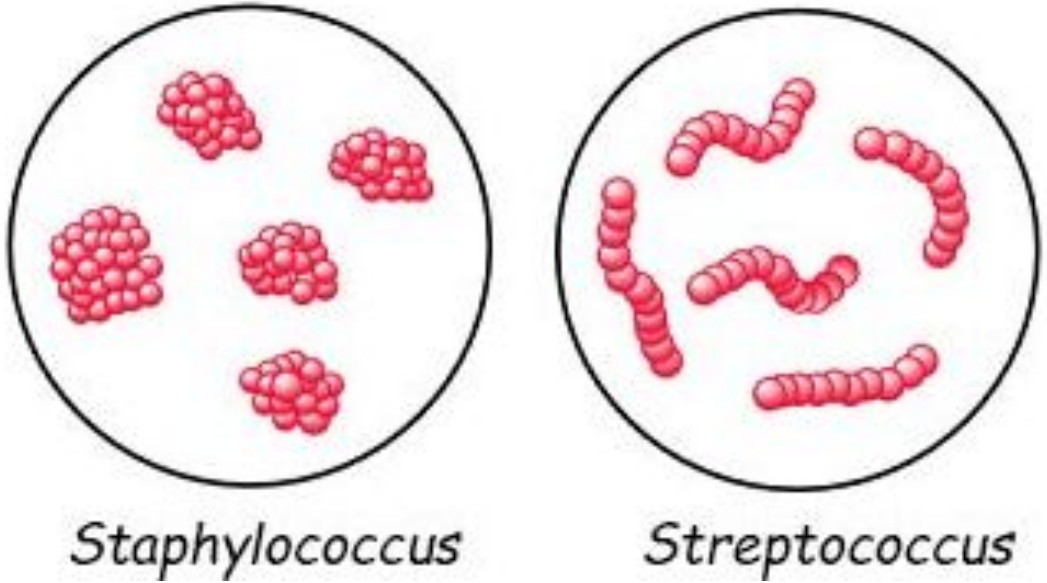

Image courtesy of https://microbiologyinfo.com/differences-between-staphylococcus-and-streptococcus/

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Antimicrobial therapy

Topical antimicrobial options

Gentamycin spray

- Effective in pseudomonas cases
- Used on open wounds prior to skin grafting

DOGS ONLY

Silver sulfadiazine cream

- Favorable broad spectrum therapy
- First choice topical therapy for burns

Nanocrystalline silver bandages

- Provide sustained release of silver → antimicrobial properties
- Decreased frequency of bandage changes to Q3d rather than Q24h

Silver products…

- Potentially **toxic** to keratinocytes and fibroblast
- Caution in wounds at the point of epithelializing

Antimicrobial Therapy

Discontinuation of antibiotics

-Once mature granulation tissue is established, the wound is fairly resistant to infection and antibiotic therapy is often unnecessary

-Use culture results to de-escalate/shape antibiotic therapy

Photo credit https://lms.vet.unimelb.edu.au/pathology_prac/250214/pracs/wh/intro/granulation.html

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Lecture outline

1. Skin anatomy
2. Initial triage
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Complications

What interferes with healing?

Infection, delayed or failed wound healing → WHY does this happen?

1. Comorbidities - endocrine, nutritional, neoplastic
2. Species specific - feline vs. canine
3. Prognosis
    a. Distal extremities
    b. Timeline
    c. Cost

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Complications

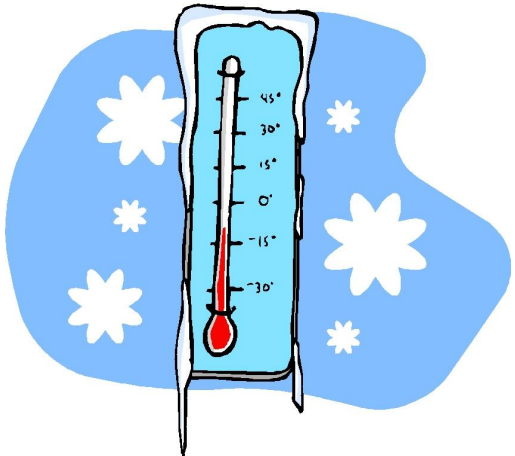
What interferes with healing?

Infection, delayed or failed wound healing → WHY does this happen?

Anesthetic concerns:

Factors associated with increased rate of wound infection…

1. Hypothermia
2. Prolonged anesthesia



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Complications

What interferes with healing?

Continued…

Wound specific factors!

- Tension
- Motion
- Weight bearing location
- Self traumatizing
    - This can be DRAMATIC!

Image courtesy of unsplash.com

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Complications

Comorbidities

-Systemic abnormalities that *decrease oxygen delivery to tissue* contribute to difficulty healing

- Anemia, **severe trauma**, hypovolemia, causes of poor perfusion

-Serum protein <2g/dL decreases fibrous tissue deposition → delayed wound healing

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Complications

Comorbidities

-*Poor nutritional status* or **underlying systemic illness** may contribute to patient ability to heal and fight infection

-Examples of potential causes:

- Neoplasia, radiation therapy, diabetes mellitus, uremia, liver dz, hyperadrenocorticism, steroid administration

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Complications

Species specific

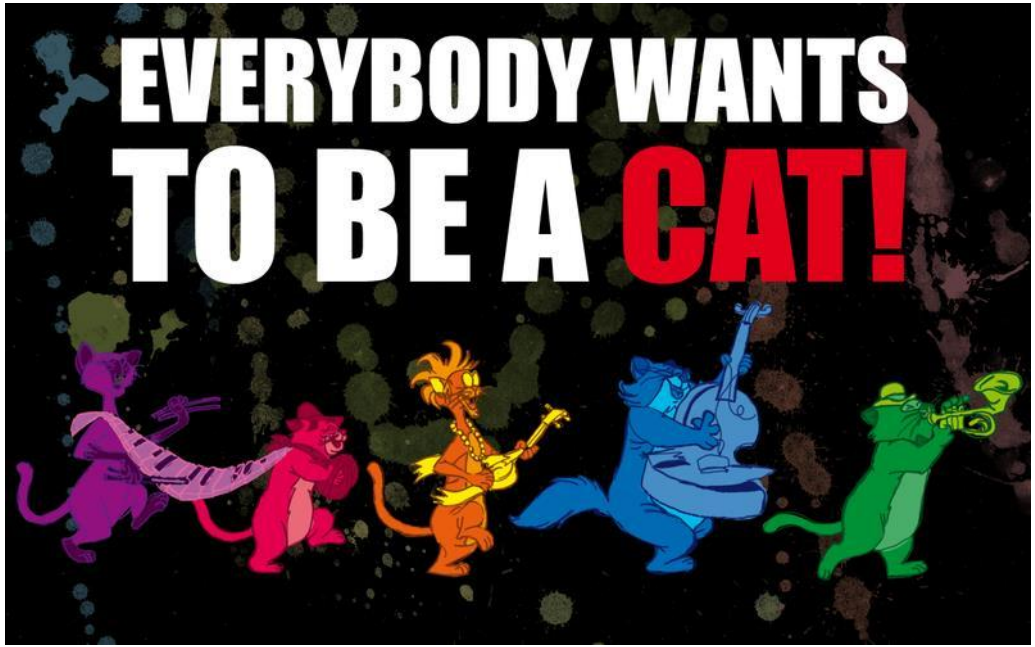

Image credit: Disney's The Aristocats

Or do they??

Cats produce significantly less granulation tissue than dogs…

- Wounds have ½ the strength of dogs 7 days post injury
- Longer healing time for large wounds than a dog with comparable wound

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Complications

Prognosis

Additional considerations…

Compromise to a limb with a significant wound

- Early AND repeated assessment of vascular and nervous supply very important!
- May necessitate amputation of the limb
    - Important for owner to be aware of for decision making

High motion area impacted

- Scar tissue MAY cause contracture and limit range of motion
- Severe cases can require revision surgery to help achieve return of mobility

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Closure types

Classification

Do you know the different types?

1. Primary closure
2. Delayed Primary closure
3. Secondary closure
4. Second intention

Closure types

Brief aside…

Before you close…

1. Flush
    a. 18g catheter on a 60ml syringe = ideal pressure to flush!
    b. Harder may drive debris/contaminants INTO the tissue

Closure types

Classification

Primary closure

a. Involves clean fresh wounds, small contaminated wounds, or infected wounds that can be completely excised
b. Completely closed same day they are assessed
    i. Monofilament absorbable sutures are used in the muscle and subcutaneous tissues (if needed)
    ii. Nonabsorbable suture is used in the skin

Delayed Primary closure

c. Wounds closed 2-5 days after the injury occurred.

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Closure types

Classification

Secondary closure

a. Closure performed >5 days post injury
b. Usually for “dirty” wounds
c. Delay in contaminated wounds allows greater time for debridement or declaration of non-viable tissues
d. Resist the urge to close everything on day one!
e. Goal is healthy granulation tissue throughout the wound bed
    i. Pink, smooth to slightly bumpy, bleeds on cut surface or when adherent dressing removed

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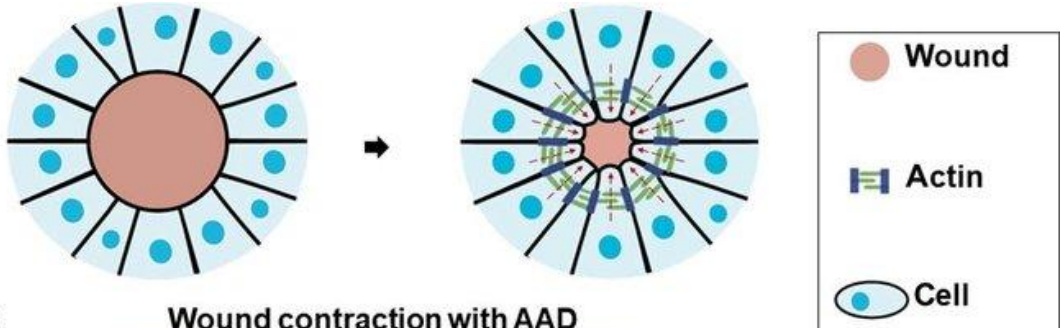
Closure types

Classification

Second intention

a. Healing by wound contraction and epithelialization
b. Majority of closure by contraction
c. **Wound contraction normally peaks out by 42 days after its initiation**
d. When contraction effectively ceases, any remaining open wound would require coverage by epithelialization
    i. If sizeable defect remains → decision of surgical intervention vs. prolonged open management

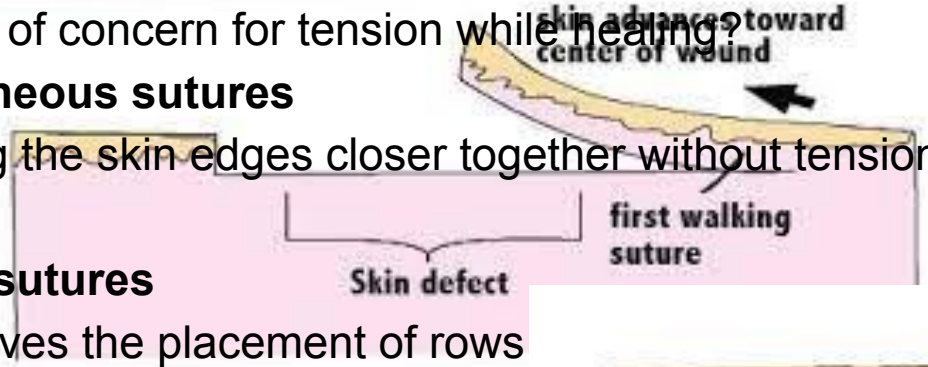


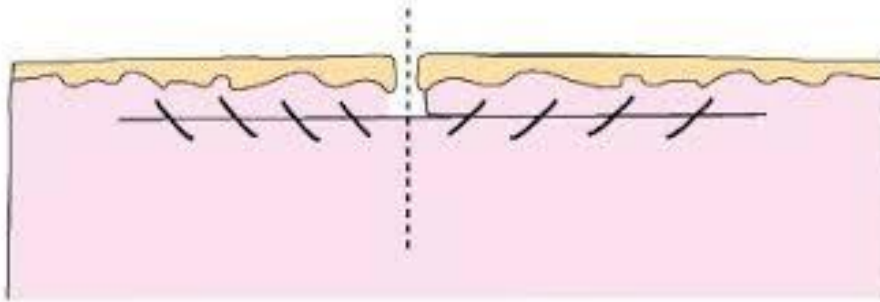
Wound contraction with AAD

Closure types

Tension relieving - Sometimes… a single layer closure of skin alone *just won't cut it.*

- What about larger gaping wounds?
- Areas that are of concern for tension while healing?
  - **Subcutaneous sutures**
    - Bring the skin edges closer together without tension directly into skin
  - **Walking sutures**
    - Involves the placement of rows to help advance the skin—these the skin





Images courtesy of dvm360.com

Closure types

Tension relieving

- More advanced options
  - Tension relieving techniques and reconstructive surgery
    - Variety of strategies including undermining wound edges (must be deep to panniculus to maintain the blood supply)
    - Relief incision such as V to Y plasty or Z plasty
    - Alternative sutures patterns:
      - mattress sutures, cruciate sutures, or alternating wide and narrow simple interrupted sutures as opposed to typical simple interrupted sutures.
    - Stents!

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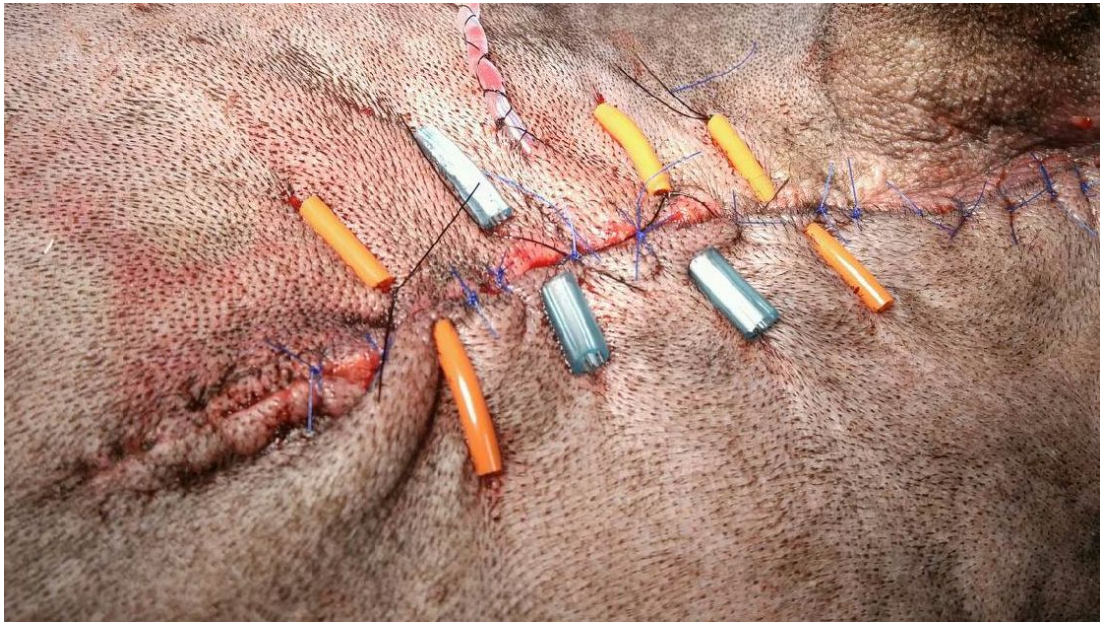
Closure types

Tension relieving

STENTS! → spread out the tension



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Closure types

Tension relieving

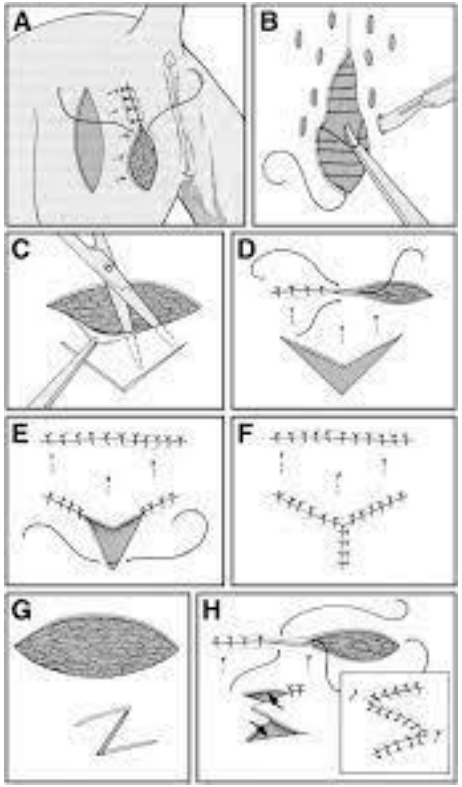

Image courtesy of https://www.vetsmall.theclinics.com/article/S0195-5616(06)00020-9/pdf

Detail of exactly how to perform these procedures is beyond the scope of this talk…

Please take this as a friendly reminder that there are more closure options available than suturing the wound exactly as it came!

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Advanced surgical techniques

Skin grafts and pedicle flaps

Other options:

- Tissue expanders can also be considered in cases where extensive reconstruction is anticipated
- Device inflated in the subcutaneous tissue to stretch the overlying skin
- More advanced surgical techniques
    - Pedicle flaps and skin grafts
    - If use of these procedures is anticipated, referral for evaluation by a surgeon is recommended as they are technically challenging

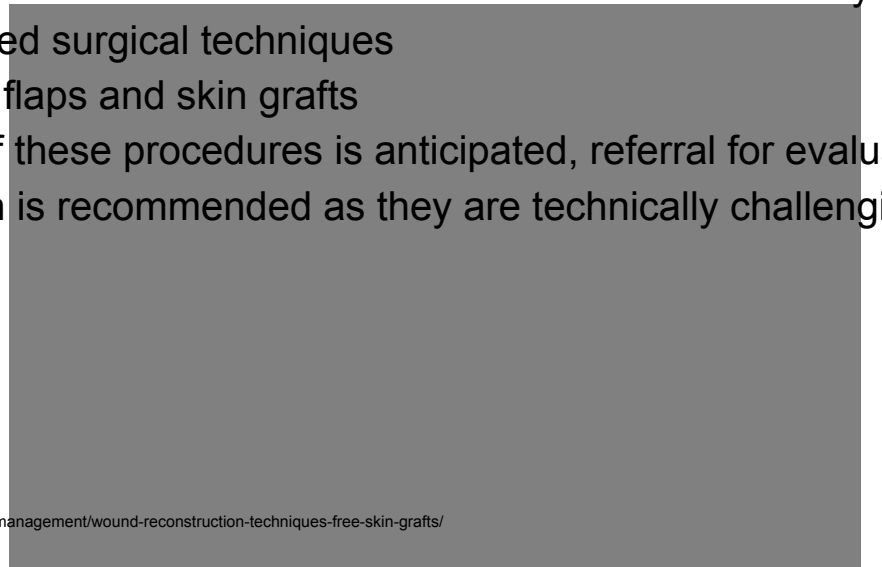

Image courtesy of https://todaysveterinarypractice.com/wound-management/wound-reconstruction-techniques-free-skin-grafts/

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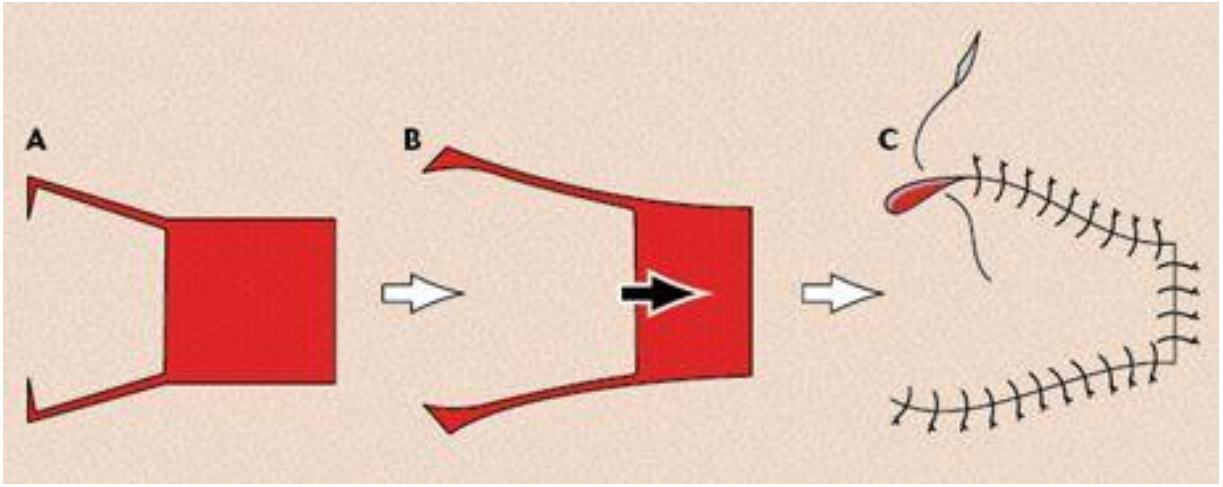
Advanced surgical techniques

Skin grafts and pedicle flaps



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Closure types

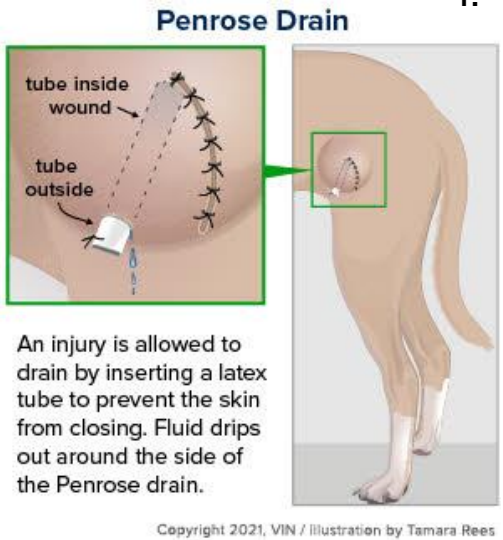
What about drains?

a. Drain selection/placement

Drains are used in cases with excess dead space, high chance of fluid accumulation, or known infected or contaminated wounds

i. Penrose

1. Passive drain, seen commonly
   a. Should they be?
2. Secured dorsally and ventrally with suture, exit from dependent portion of wound via a *separate* stab incision
3. No incision at the proximal end of wound → bacteria migrate in
4. VERY possible for bacteria to ascend this drain → SHORT term
5. Keep wound open to allow fluid to drain *around* the tube



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Closure types

What about drains?

a. Closed suction
   i. Preferable for infection control
   ii. Fenestrated tube that is placed deep in the wound bed, then connected to a vacuum apparatus.
   iii. Most common = Jaxson Pratt (JP) drains
      1. have a grenade style collection apparatus that serves as a closed vacuum by manually squeezing or suctioning out the air via syringe
      2. Added benefit of monitoring fluid output from the wound→ highly active drain is not one that you want to remove yet.
         a. Aiming for <2ml/kg/day before removal

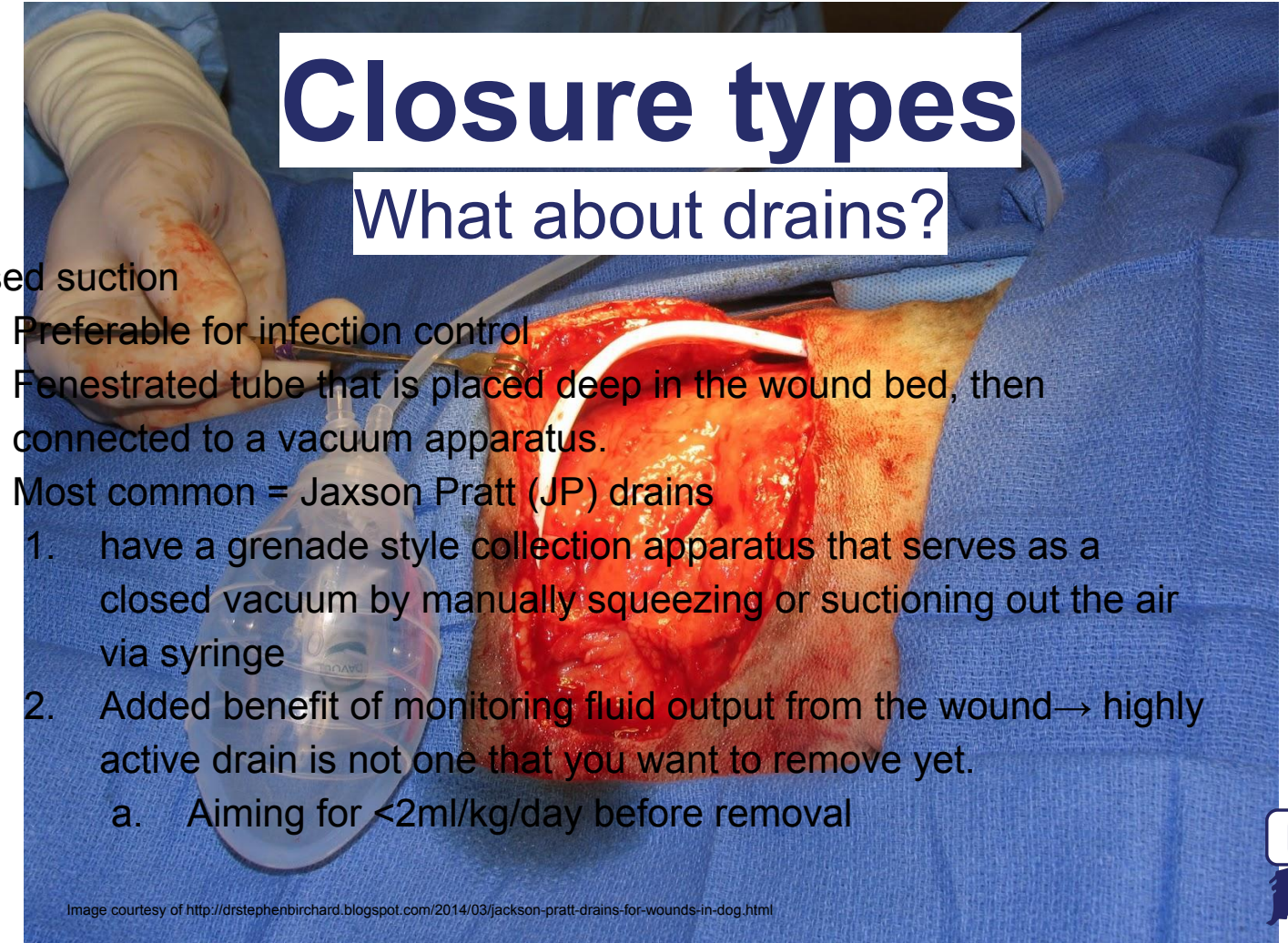

Image courtesy of http://drstephenbirchard.blogspot.com/2014/03/jackson-pratt-drains-for-wounds-in-dog.html

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Open wounds

Management options…

Several points that should be evaluated on a ***DAILY*** basis:

1. Assess need for antibiotics
2. Debride/remove necrotic tissue and flush wound
    a. *Sharp* debridement with scalpel to achieve fresh bleeding margins
    b. *Painful* → need analgesia, sedation, or anesthesia
3. Can the wound be closed?
    a. Generally this IS the eventual goal for your patient!
    b. Some cases → second intention is allowed rather than surgical closure
4. Protect the wound
    a. Bandage and/or elizabethan collar
    b. Not uncommon to need a few *weeks* of bandage changes

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Open wounds

Management options…

Of note…
Starting with the goal of one closure type does NOT mean it is the one you will finish with.

Ex.

- Primary closure fails in 30% of your wound on a hind limb
- Surgically debrided and 1 day of wet-to-dry
- Non adherent bandage placed for several days
- Remainder of wound allowed to close by second intention due to healthy granulation tissue development and contracture

Adjust your process based on your patient!

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Open wounds

Management options…

1. Management of open wounds
    a. Adherent vs. non-adherent bandages
    b. Tie over bandages
    c. Sugar and honey bandages

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Open wounds

Bandage basics

Multiple bandage types in cases where wound *cannot* be closed

- Several layers to each bandage
- Primary layer
  - Material applied directly to the wound
  - Determines adherent vs. non-adherent
- Secondary layer
  - Absorbent material → to collect exudates from wound
- Tertiary layer
  - Outermost layer
  - Water resistant
  - Holds other layers in place

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Open wounds

Adherent vs. non-adherent bandages

Figure 4. Secondary layer from a bandage made of cast padding.

Figure 5. Tertiary layer of a bandage (conforming stretch gauze).

Figure 6. Outer layer of a bandage (ie, Vetrap, Elastikon).

Placement of Wet-to-dry bandage

- Sterile gauze sponges are soaked in LRS or 0.9% NaCl→ wring out
- Apply wet sponge to wound→ cover with thick layer of dry sterile sponges
- Wrap/protect the absorbent layer
  - On a limb–wrap with a 3 layer (cast padding, kling wrap, vetwrap) bandage
  - On trunk or difficult points, consider a tie over bandage (explained momentarily!)

Image courtesy of https://todaysveterinarynurse.com/wound-management/todays-technician-principles-of-wound-care-bandaging-techniques/

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Open wounds

Adherent vs. non-adherent bandages

Adherent Bandage → Wet-to-dry

- Well known *but* controversial
  - Typically changed 1-3 times per day, quite painful
  - Potentially traumatic→ may remove healthy tissue in addition to necrotic material
- Used during debridement phase
- NOT a replacement for surgical debridement

How does it work?

- Creates a wicking action so necrotic tissue and debris to adhere to the sponge
- Provides mechanical debridement when the bandage is removed

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Open wounds

Adherent vs. non-adherent bandages

Moist wound management principles:

- Moist environment optimizes wound healing, increases epithelialization, and encourages more effective autolytic debridement

- Most non-adherent dressings follow moist wound management principles
- Examples: alginates, foams, hydrogels, hydrocolloids, and transparent films
    - Calcium alginate → increased collagen production in the wound

- With Adaptix and Telfa pads→reportedly most effective once there is a bed of healthy, pink, non-infected granulation tissue in the wound bed

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Open wounds

Tie-over bandages

Location of the wound may be a factor…

→ Difficult points

- Hips
- Head
- trunk

→ May not be possible to cover with a traditional bandage

Answer? Tie-over bandage!

Image credit dvm360.com

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Open wounds

Tie-over bandages

Placement:

- Loose
- Primar
- Secon
- Tertiar
- Umbilical tape laced through the loop sutures like a shoelace

Image courtesy of https://www.jprasurg.com/article/S0007-1226(05)00100-1/fulltext

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Open wounds

Sugar and honey bandages

Image courtesy of karol Mathews, https://www.veterinarypracticenews.com/the-sweet-side-of-managing-open-wounds/

- Used for wounds that are infected or require additional debridement
  - Materials are cheap and readily available.
  - Both should be discontinued once healthy granulation tissue is present

- Sugar indicated for degloving, shearing, burns, or infected wounds
  - Especially E. coli, strep, and pseudomonas
  - Sugar layer draws macrophages to the wound → helps to accelerate the sloughing of necrotic tissue
  - Sugar has bactericidal effects through osmotic action
  - Bandages are applied following manual debridement, lavage, and patting the wound dry
  - ***Need a thick layer of sugar to be effective–1cm over entire wound described***
    - Layered with sterile sponges or towels
    - Thick absorbent secondary layer
    - Tend to be extremely effusive and require at least daily bandage changes

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Open wounds

Sugar and honey bandages

Honey bandages

- Which honey? → Either manuka or medicinal honey can be applied
- Aid in healing by decreasing edema, accelerating sloughing of necrotic tissue, and provide rich cellular energy source to promote a healthy granulation tissue bed
- Antibacterial properties including high osmolarity, acidity, and a high hydrogen peroxide content
- Used during the debridement phase and over infected granulation tissue

Application:

- Flush and debride visibly necrotic tissue
- A layer of sterile gauze is soaked in honey and applied to the wound
- Covered with an absorbent layer to prevent leaking

These bandages are effusive and require frequent changing

Image courtesy of karol Mathews, https://www.veterinarypracticenews.com/the-sweet-side-of-managing-open-wounds/

Open wounds

Bone exposure… yikes!

IMPORTANT → slow healing, should NOT be closed until there is a full layer of healthy granulation tissue present

- Most common = carpal or tarsal shearing injuries in hit by car patient
- Bone perforation may enhance wound healing
- Often non-adherent dressing with antibiotic ointment to prevent infection is sufficient
    - Bandage should be changed at 3-5 day intervals
    - 7-10 days post injury (or when granulation tissue covers the wound), decide to attempt a flap or continue ongoing open management to allow second intention healing.

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Open wounds

Bone exposure… yikes!

Bone perforation may enhance wound healing

… performed using K wire

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Lecture outline

1. Skin anatomy
2. Initial triage
3. Wound classification
4. Phases of healing
5. Antimicrobial therapy
6. Complications
7. Closure types
8. Management of open wounds
9. **Alternative/novel therapies**
10. Case series

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Alternative/novel therapies

Negative pressure wound therapy

Potential indications:

- Highly exudative, grafting or skin flaps anticipated

General concept → promote/hasten healing by applying a closed vacuum to the wound

- Increases vascularization and granulation tissue formation
- Decreases volume/size of the wound
- Reserved almost exclusively for hospitalized patients

The VAC = vacuum assisted closure

- Placed under anesthesia
- Contact layer - open weave polyurethane foam or open weave gauze sponge connected to suction tubing
- Adhesive occlusive film is placed over the contact layer and overlaps with wound edges by at least 5cm to create the necessary *leak proof seal* to maintain vacuum
- Suction tubing is attached to a suction device and collection canister.

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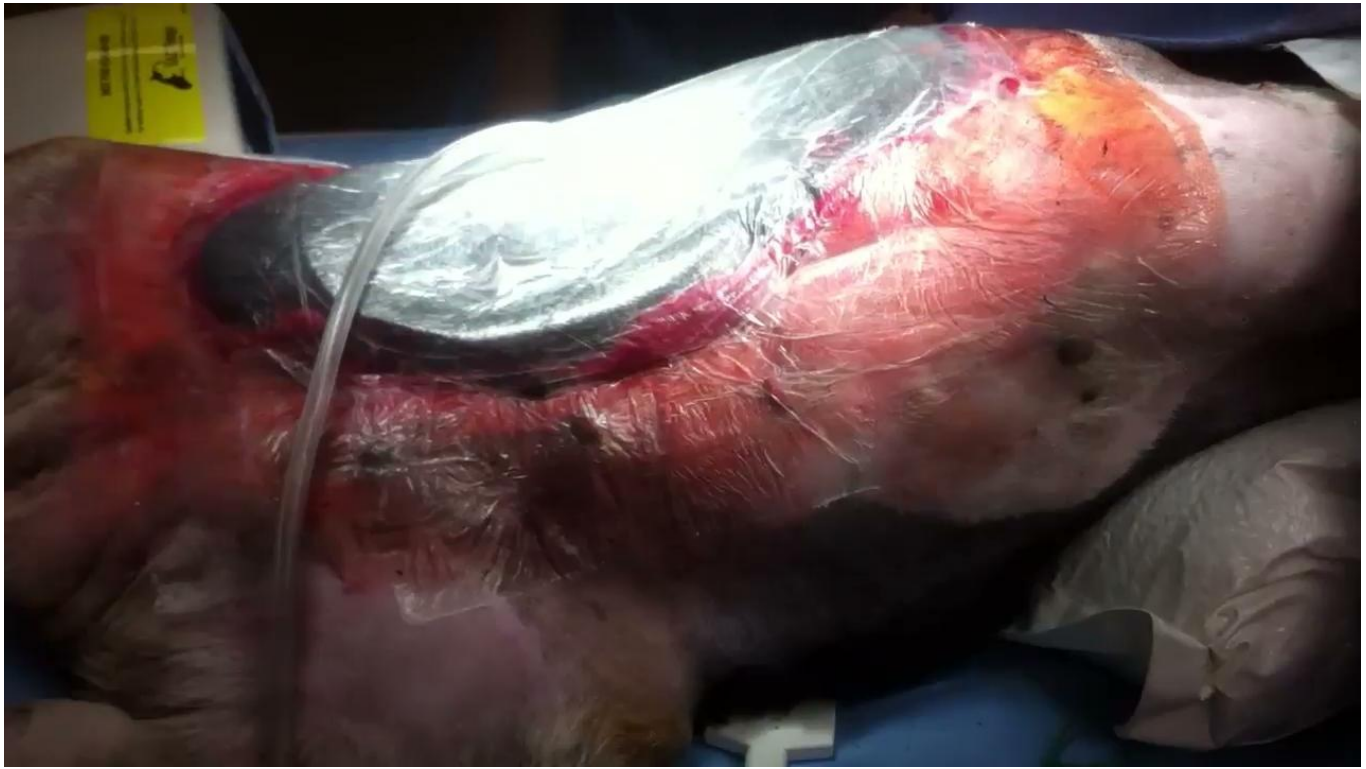
Alternative/novel therapies

Negative pressure wound therapy



Video courtesy of Dr. Abby Mariano

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Alternative/novel therapies

Fish skin dressings

Area of active interest/exploration!

Recent studies/trial efforts using both sterilized tilapia and cod skin as an alternative bandage technique!

- Use thus far confined to thermal or chemical burns
  - Use of fish skin for degloving or other large wounds has not yet been investigated.
- Collagen composition of the skin promotes healing
  - Anecdotally appears to significantly increase patient comfort
  - Bandage must be placed surgically under anesthesia, and is sutured to the wound margins after debridement.
- Cases thus far show *significantly decreased* frequency of bandage changes compared to traditional SSD burn dressings.

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Alternative/novel therapies

Fish skin dressings

Images courtesy of https://www.ucdavis.edu/health/news/healing-animals-with-fish-skins

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Alternative/novel therapies

Hyperbaric oxygen

- Treatment that involves placing the patient in a chamber with 100% oxygen under pressure
- Increases the arterial oxygen gradient
- May promote angiogenesis, increase fibroblast activity, and increase oxidative bacterial killing by leukocytes.

Image courtesy of https://www.suncoastveterinary.com/features/hyperbaric-oxygen/

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Alternative/novel therapies

Medicinal Maggots

- Use of germ free “disinfected” larvae of therapeutic fly species → medical grade maggots
- Potential benefits
  - Debride (clean) the wound by dissolving dead and infected tissue with their proteolytic, digestive enzymes
  - Disinfect the wound (kill bacteria) by secreting antimicrobial molecules, by ingesting and killing microbes within their gut, and by dissolving biofilm
  - Stimulate the growth of healthy tissue.

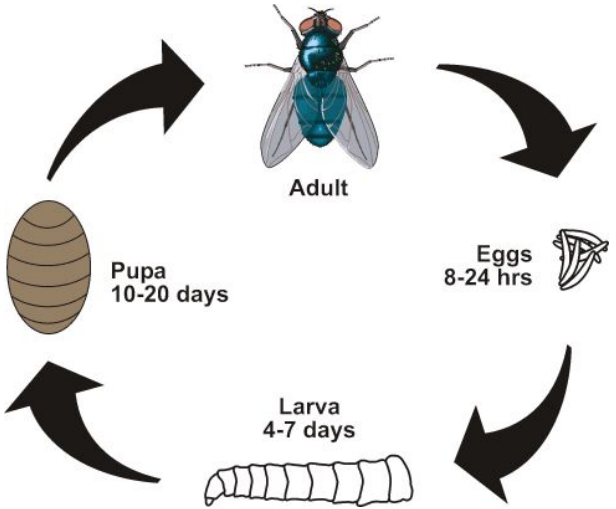

Image courtesy of https://www.suncoastveterinary.com/features/hyperbaric-oxygen/

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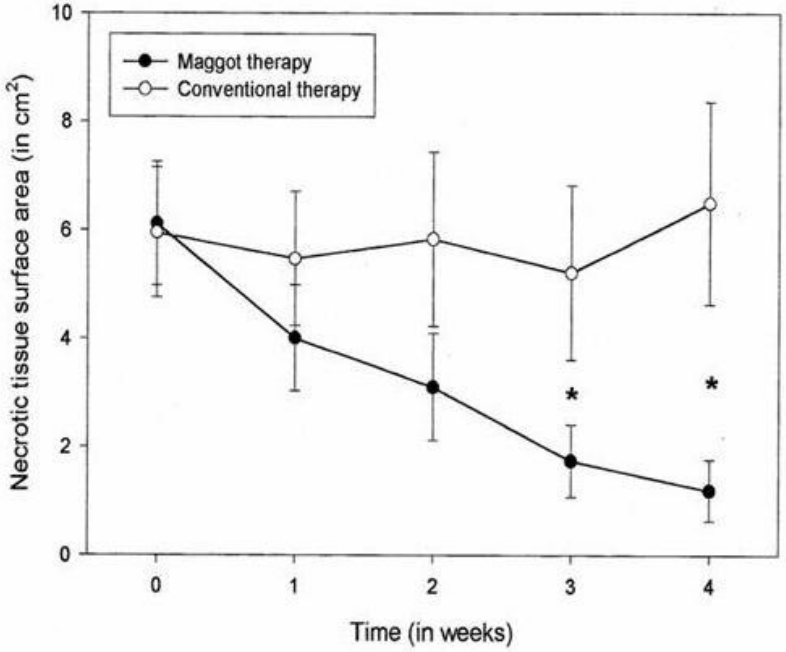
Alternative/novel therapies

Medicinal Maggots



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Alternative/novel therapies

Laser

- Treatment option becoming increasingly available
- Predominantly empirical evidence at this time
  - Triple blinded study showed improved wound contraction of partial thickness wounds in people with laser treatment vs. sham
- Low level laser light therapy and cold laser
  - *Potential* benefits:
    - Increase ATP production in the mitochondria of chromopores
    - Increase activation of fibroblasts
    - Decrease inflammation
    - Promote wound healing

Image courtesy of https://london.vetshow.com/press-release/anti-bacterial-properties-of-k-laser-therapy

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Need a break? We'll switch it up…

Lecture outline

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9. Alternative/novel therapies
10. **Case series**

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Case discussion

Case #1

5yo FS Mini labradoodle
-Attacked by coyote
-Multiple bite wounds over the epaxial region
-Possible abdominal cavity penetration
-Previously healthy dog

How would you proceed?

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Case discussion

Case #2

8yo MI Mastiff
-Rash/wound of unknown origin on the cranioventral chest
-Spends time running in the woods
-Historically healthy

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Case discussion

Case #3

7yo MN mixed breed dog
-Chasing a rabbit in the yard, caught on a sharp stick, tore open side
-Previously healthy

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Lecture goals

1. Understanding of initial wound management/triage
2. Understanding wound severity/classification
3. Expectations for healing timeline
4. Treatment options
    a. Feeling more comfortable!
    b. What patients can be managed in a primary care setting?
    c. When to refer?

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Closing thoughts…

- There are MANY treatment and dressing options available for wounds in the veterinary world
  - Do not need a specialist/surgeon to perform repair or manage follow up with a large portion of these cases
- Assess EACH WOUND on an individual basis to determine treatment
  - There is no one size fits all method here!
- When to refer???
  - Systemically unstable patients!
  - Increased anesthetic risk cases
  - Multi-day IV antibiotics indicated
  - Burn wounds
  - Need for advanced surgical techniques
    - Skin grafting or flaps
  - Potential alternative/novel therapy candidate
  - IF you are uncomfortable managing it
    - This is always a fair reason!

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QUESTIONS?

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NOTICE

CE credit certificates & presentation slides will be emailed to you. If you do not receive an email with this information within a week, contact Nichole - *nicholemanfredi@capecodvetspecialists.com*

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