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## A Journey Through Burns

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Assistant Professor of Plastic Surgery  
Medical Director Richard M Fairbanks Burn Center, Eskenazi Health  
Medical Director Speedway Riley Burn Center  
Indiana University

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## Eskenazi Health



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## The Richard M. Fairbanks Burn Center

- Approximately 400 Acute Burn Admissions Annually
- Over 4,000 Outpatient Visits in our Burn Clinic
- 15 Inpatient Beds
- Dedicated 12 room burn clinic
- Dedicated therapy gym
- 2 Dedicated Operating Rooms Within the Center
- Medical Spa



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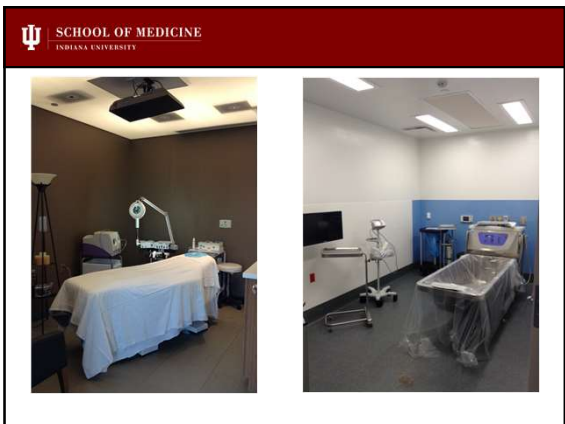
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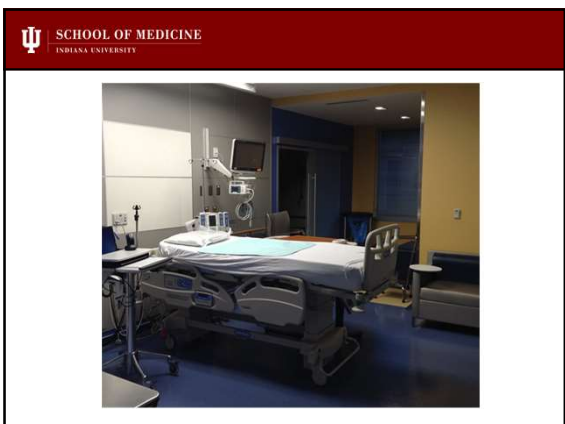
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### Riley Hospital for Children



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### Riley Speedway Burn Center

- Over 180 admissions/year
- Over 3000 outpatients/year
- 10 inpatient beds
- Dedicated burn clinic rooms
- Dedicated therapy gym
- Dedicated burn OR (currently in process)

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### American Burn Association

- The only ABA verified adult and pediatric burn units in the state of Indiana:
  - Provides a true mark of distinction for a burn center
  - An indicator that the center provides the highest level of care to burn patients from the time of injury through rehabilitation

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### Epidemiology

- Acute thermal injuries requiring medical treatment affect 500,000 Americans annually
- Hospitalizations:
  - 40,000
- Deaths:
  - 3,400
- Survival Rate:
  - 97%

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### Epidemiology

- Length of hospital stay correlates best with % TBSA burn
- Predictors of mortality:
  - Age >65 years old
  - % TBSA
  - % 3<sup>rd</sup> degree burn
  - Inhalation injury
  - Etiology of burn

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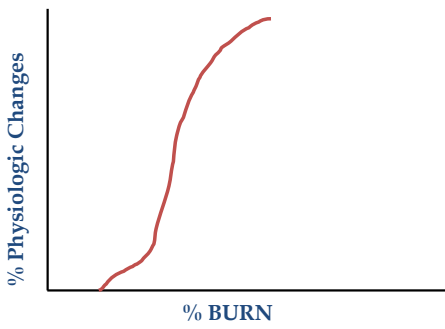
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The graph plots % Physiologic Changes on the y-axis against % BURN on the x-axis. A red sigmoidal curve shows that as the percentage of burn increases, the percentage of physiologic changes also increases, following a characteristic S-shaped curve that levels off at higher burn percentages.

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**WHAT WE SEE...**

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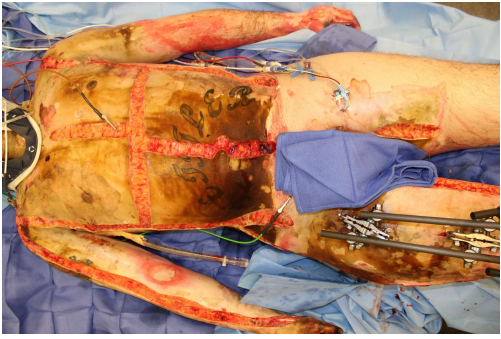
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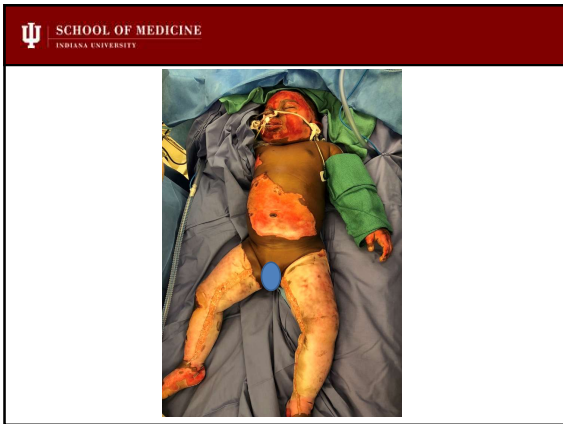
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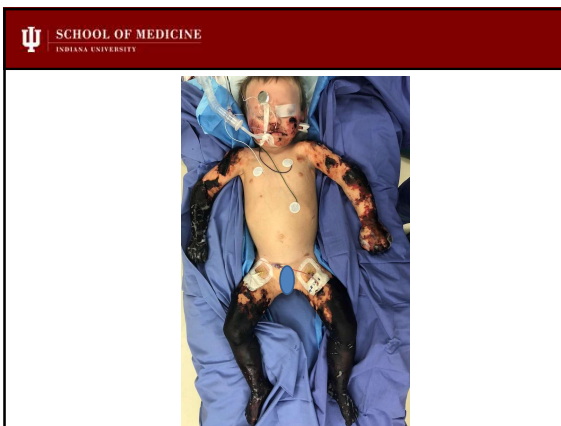
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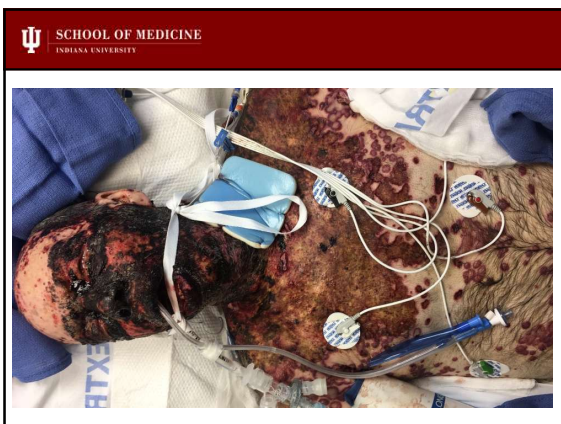
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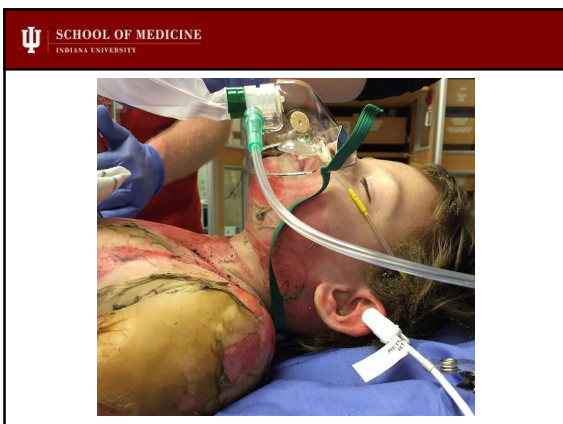
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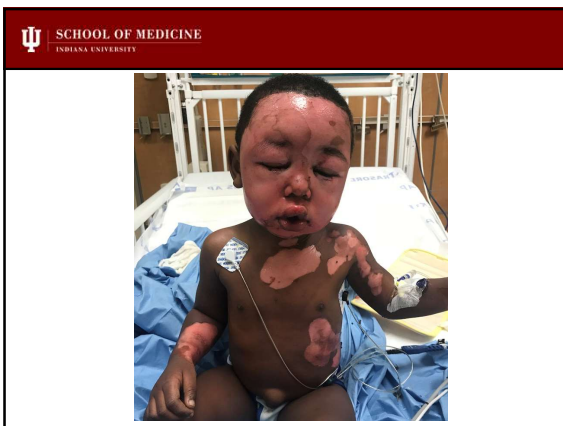
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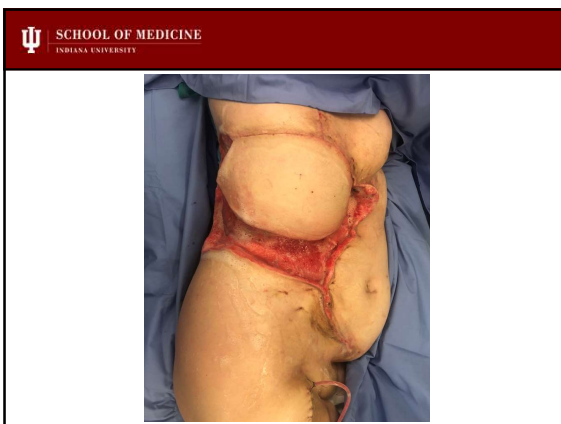
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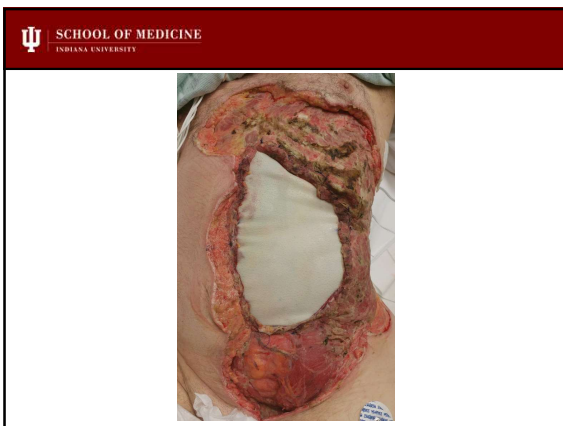
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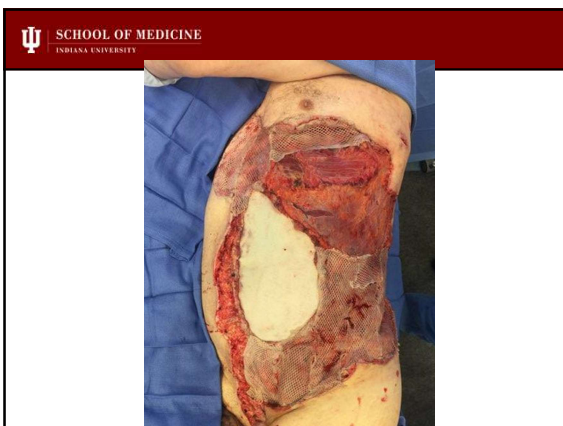
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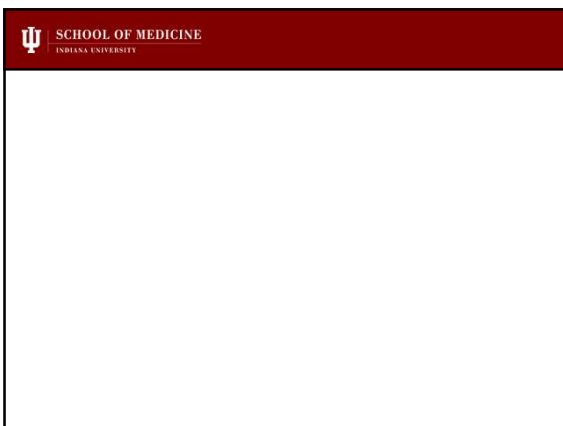
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### Acute Burn Care

- Multi-disciplinary approach to burn care
- Active involvement of:
  - Nurses, Dieticians, Therapists – speech, occupational, physical, respiratory
  - Pharmacists, PA's, NP's
  - Psychiatry, Child Life specialists, Social Workers
  - Paramedics, EMT's
- All roles in functional recovery are critical

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### American Burn Association Referral Criteria

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### Burn Center Referral Criteria

- Burn injuries that should be referred to a burn center include:
  1. Partial thickness burns greater than 10% total body surface area (TBSA).
  2. Burns that involve the face, hands, feet, genitalia, perineum, or major joints.
  3. Third degree burns in any age group.
  4. Electrical burns, including lightning injury.
  5. Chemical burns.
  6. Inhalation injury.
  7. Burn injury in patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality.
  8. Any patient with burns and concomitant trauma (such as fractures) in which the burn injury poses the greatest risk of morbidity or mortality. In such cases, if the trauma poses the greater immediate risk, the patient may be initially stabilized in a trauma center before being transferred to a burn unit. Physician judgment will be necessary in such situations and should be in concert with the regional medical control plan and triage protocols.
  9. Burned children in hospitals without qualified personnel or equipment for the care of children.
  10. Burn injury in patients who will require special social, emotional, or rehabilitative intervention.

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## Depths of Burn Wounds

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## BURN DEPTH

- SUPERFICIAL EPIDERMAL
- SUPERFICIAL PARTIAL THICKNESS
- DEEP PARTIAL THICKNESS
- FULL THICKNESS
- SUB-DERMAL
  
- ESTIMATION OF BURN DEPTH DIFFICULT

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## Superficial Partial Thickness

- Epidermis disrupted
- Pink in appearance
- Blanches upon compression
- Moist
- Painful
- Blisters
- Will heal with proper treatment

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### Mid Partial Thickness

- Papillary dermis involvement
- Areas of eschar (denatured protein in skin)
- Some areas of delayed blanching present
- May be pale pink in appearance
- Painful
- Can heal on own with proper wound care

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### Deep Partial Thickness

- Reticular dermis and skin appendages involved
- Dry in appearance
- Eschar present
- Minimal blanching
- Still may be painful
- Will likely need skin grafting to heal wounds with 2-3 weeks

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**Full Thickness**

- Burn through epidermis and dermis, into subcutaneous tissue
- Thick white leathery eschar or black charred skin
- Insensate
- Dry
- Will not heal without skin grafting

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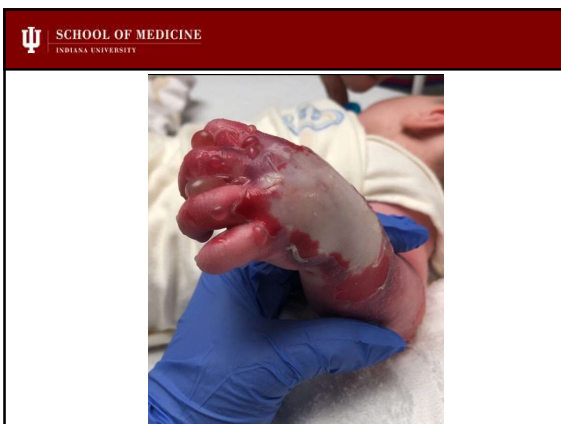
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### Fourth Degree Burn

- Burn through all layers of skin into muscle or bone
- Likely electrical burn or prolonged exposure to flames
- Will need to assess compartment pressures
- Will need surgical intervention for wound closure i.e. skin graft, flap or amputation

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### Pathophysiology

- Burn Shock:
  - Increased capillary permeability
  - Increased hydrostatic pressure across microvasculature
  - Protein and fluid movement from intravascular space into the interstitial space
  - Increased SVR
  - Decreased CO
  - Hypovolemia requiring fluid resuscitation

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### Pathophysiology

- The edema that forms in the interstitial space forms rapidly in the first 8 hours
- Continues to form more slowly for at least 18 hours
- Volume requirements for resuscitation based on:
  - TBSA
  - Weight
  - Inhalational injury
  - Full thickness burns

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### Pathophysiology

- Following successful resuscitation, patients enter a more prolonged period of:
  - Hypermetabolism
  - Chronic inflammation
  - Lean body mass wasting

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## Pathophysiology

- Burn wound can be divided into three zones based on the severity of tissue destruction:
  - Zone of Coagulation:
    - Complete cellular necrosis, irreversible
    - Proteins denature above 106 °F
  - Zone of stasis:
    - Zone of ischemia, decreased perfusion, potentially salvagable, leads to tissue necrosis within 48 h in the absence of intervention
  - Zone of Hyperemia:
    - Receives increased blood flow via inflammatory vasodilation, will likely recover

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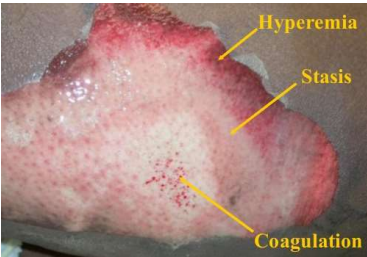
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## Zones




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## Pathophysiology: Phases of Wound Healing

Phase	Characteristics	Key players
Inflammatory	Vasodilation	Neutrophils
	Fluid extravasation	Monocytes
	Edema	Macrophages
Proliferative	Wound closure	Keratinocytes
	Revascularization	Fibroblasts
Remodeling	Wound maturation	Collagen
	Scarring	Elastin
		Fibroblasts/myofibroblasts

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## Pathophysiology

- Inflammatory phase:
  - Prevent infection, degrade necrotic tissue, activate signals required for wound repair
- Proliferative phase:
  - Keratinocytes migrate
- Remodeling phase:
  - Deposition of collagen and elastin
  - Fibroblasts become myofibroblasts

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## Optimization of Burn Wound Healing

- Inflammation
- Infection
- Nutrition
- Resuscitation
- Wound coverage and grafting

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## Optimization of Burn Wound Healing

- **Inflammation:**
  - Vital to successful burn wound healing
  - Inflammatory mediators provide immune signals to recruit leukocytes and macrophages that initiate the proliferative phase
  
  - Excessive or prolonged inflammation may exacerbate pain and impair wound healing

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### Optimization of Burn Wound Healing

- **Inflammation:**
  - Can have both detrimental and beneficial effects on burn wound healing
  - Management becomes a challenge
  - Early excision and grafting has become the gold standard

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### Optimization of Burn Wound Healing

- **Infection:**
  - Skin functions as a barrier to the external environment
  - Damage to this barrier disrupts the innate immune system and increases susceptibility to bacterial infection

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### Optimization of Burn Wound Healing

- Burn wound infection was defined in a rat model with *Pseudomonas aeruginosa*:
- Progression was observed:
  - Burn wound colonization
  - Invasion into subjacent tissue within 5 days
  - Destruction of granulation tissue
  - Visceral hematogenous lesions
  - Leukopenia
  - Hypothermia
  - Death

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### Optimization of Burn Wound Healing

- **Infection:**
  - Leading causes of death following a severe burn:
    - Sepsis and multisystem organ failure
  - Prevention and management is a primary concern
  - Early and accurate diagnosis of infection is difficult
  - Gram-positive and Gram-negative bacterial infections still remain one of the most common causes of mortality

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### Bacterial biofilm is a major barrier to wound healing

Bacteria protected from topical agents

Low oxygen in biofilm niches

Impaired migration and proliferation of keratinocytes

Bacteria protected from systemic antibiotics

Host defenses unable to clear infection

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### Optimization of Burn Wound Healing

- **Nutrition:**
  - Sustained hypermetabolism and muscle wasting contribute to clinical outcome, with magnitude and duration that are unique to burns
  - Nutritional support following burn injury is a complex issue

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### Optimization of Burn Wound Healing

- **Nutrition:**
  - Ex: Early excision and aggressive feeding in children does not diminish energy expenditure but is associated with:
    - Decreased muscle protein catabolism
    - Decreased rate of burn sepsis
    - Significantly lower bacterial counts from excised tissue

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### Optimization of Burn Wound Healing

- Several nutritional factors must be considered:
  - Excess carbohydrate consumption:
    - Leads to hyperglycemia which can exacerbate inflammation and muscle degradation
  - Excess fat consumption:
    - Exaggerates the immunosuppressed state which may increase the risk for infection and sepsis

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### Optimization of Burn Wound Healing

- **Nutrition:**
  - Amino acids
  - Vitamins
  - Insulin:
    - Decreases healing time by reducing protein catabolism and increasing skeletal muscle protein synthesis
  - Oxandrolone

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### Optimization of Burn Wound Healing

- **Resuscitation:**
  - Despite extensive research into fluid resuscitation, little is known about the effect of resuscitation on wound healing
  - Recent meta-analysis showed a positive association between number of grafting procedures and hypernatremia, suggesting that high serum sodium levels may inhibit graft take
  - Rate of wound closure is significantly faster in patients who received lower 24 hour fluid resuscitation volumes

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### Optimization of Burn Wound Healing

- **Wound coverage and grafting:**
  - Dressing depends on several factors:
    - Depth of burn
    - Condition of the wound bed
    - Wound location
    - Desired moisture retention and drainage
    - Frequency of dressing changes
    - Cost

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### Optimization of Burn Wound Healing

- Major classes of dressings:
  - Alginate (Aquacel)
  - Antimicrobial (Acticoat)
  - Collagen (Puracol)
  - Hydrocolloid (Duoderm)
  - Hydrogel (Dermagel)
  - Polyurethane foam (Allevyn)

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### Advances in Burn Care

- ReCell Spray Skin
- Cultured Epidermal Autograft
- Artiss

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### ReCell Spray Skin

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### ReCell

- Autologous cell harvesting kit
- Allows harvesting of:
  - Keratinocytes
  - Melanocytes
  - Fibroblasts
  - Langerhans cells (from a split thickness skin graft)
- Cells available within 20 minutes

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### Harvest Skin Sample

- Take thin, split thickness biopsy: 0.2-0.3 mm thick

Biopsy Size	Treatment Area
1cm x 1cm	80 cm <sup>2</sup>
2cm x 2cm	320 cm <sup>2</sup>

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### Spray Skin

- **FDA Clinical Trial**  
Evaluating the Compassionate Use of Spray Keratinocytes in Large TBSA burns



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### Cultured Epidermal Autograft

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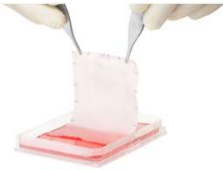
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### Cultured Epidermal Autograft

- KEY ASPECTS:
  - Early biopsy planning
  - No charge up front
  - No commitment
  - No need for additional biopsy if staged procedure



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### Case Example

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11 y.o. female sustained 93% TBSA burn throwing gasoline on a fire

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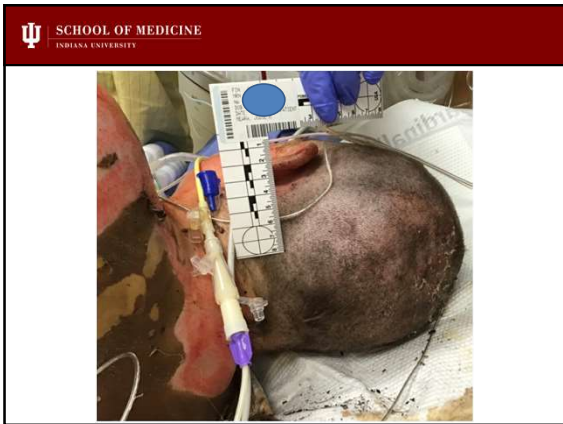
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### Timeline

- 10/04 – Escharotomies
- 10/06 – Initial debridement and allograft, **CEA biopsy**
- 10/09 – Debridement and allograft to feet and hands
- 10/13 – Autograft, 4:1, plus spray keratinocytes to back, remove and replace allograft
- 10/23 – Autograft, 4:1, plus spray keratinocytes bilateral buttocks, remove and replace allograft
- 10/30 – Integra to left hand, remove and replace allograft to legs
- **11/03 – CEA, autograft, 4:1 and 6:1 to legs, chest, abdomen, arms**
- 11/11 – CEA takedown
- 12/01 – Autograft areas of bilateral arms and chest
- 12/15 – Autograft areas of bilateral legs and feet

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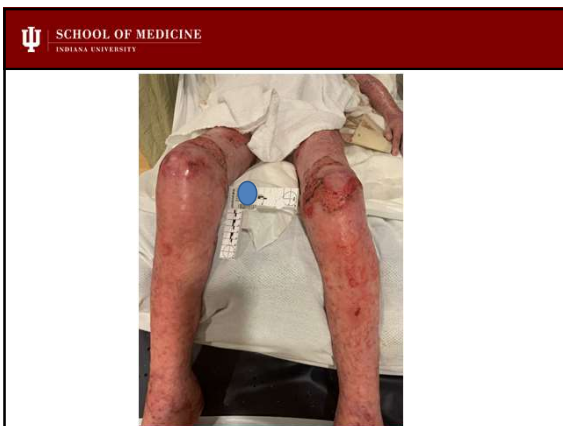
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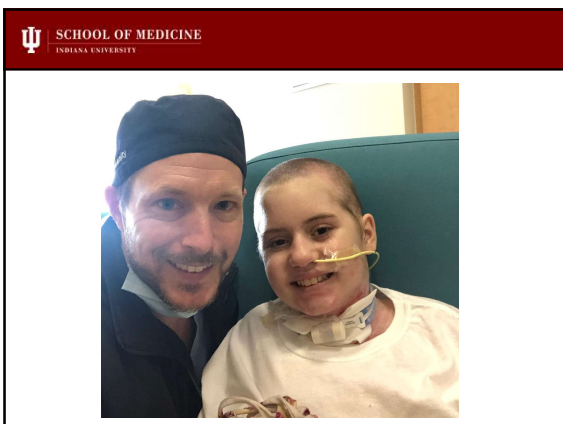
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**93% TBSA Burn**

- Admitted: 10/04/2020
- Discharged: 01/13/2021
- 101 Inpatient days

- Rehab: 01/13/2021 – 03/03/2021
- 49 Rehab days

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**Thank You!**

**Questions?**

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 **Riley Children's Health**  
Indiana University Health

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