Underrecognized, Recurring Tourniquet Problems

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Tourniquet Working Group

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Overview:

Problems that are not being recognized continue to be evident in:

- Tourniquet use
- Tourniquet training
- Tourniquet understanding

Let’s contribute toward reducing these problems by raising awareness of them among:

- Trainers
- Users
- Authors
- Reviewers
- Guidelines groups of our various organizations

Problem areas:

1. Application technique
    a. Orientation
    b. Strap pulling
    c. Tightening amount
    d. Securing steps
2. Minimizing bleeding while applying & releasing
3. Understanding advantages of self-securing systems
4. Understanding advantages of finer resolution tightening systems
5. Importance of as distal as possible for as short a time as possible
6. Recognizing visual indications of time periods without arterial occlusion

Application Technique: Strap Pulling

Indicators of adequate pulling

1. Limb indentation
2. Arterial occlusion on small circumference locations (<30cm) with no tightening system use
3. Appropriate tightening system use

Consequences of poor pulling

1. Can't reach arterial occlusion
2. More time to arterial occlusion
3. Tourniquet damage/breakage
4. Can't secure tightening system
   - SOFT
   - TMT
   - Yellow and Blue
5. Increased discomfort

Optimal to acceptable amount of tightening system use for arterial occlusion

Redirect Buckle	Tightening System	Examples	Amount of Use of Tightening System	
			Thigh	Upper Arm
Simple	Windlass Rod	CAT, SICH, PULS, DNIPRO	Optimal ≤270° (1turn) Acceptable ≤450° (2turns)	Optimal ≤90° (0turns) Acceptable ≤270° (1turn)
Triglide	Windlass Rod	TMT	Optimal ≤450° (2turns) Acceptable ≤630° (3turns)	Optimal ≤270° (1turn) Acceptable ≤450° (2turns)
Slider	Windlass Rod	SOFT	Optimal ≤450° (2turns) Acceptable ≤630° (3turns)	Optimal ≤270° (1turn) Acceptable ≤450° (2turns)
Double Simples	Ratcheting Dial	X8T	Optimal ≤15clicks (270°) Acceptable ≤20clicks (360°)	Optimal ≤5clicks (90°) Acceptable ≤10clicks (180°)
Simple	Ratcheting Buckle	OMNA Marine	Optimal ≤6clicks Acceptable ≤9clicks	Optimal ≤3clicks Acceptable ≤4clicks
Overlapping Rings	Ratcheting Buckle	Tac RMT	Optimal ≤7clicks Acceptable ≤11clicks	Optimal ≤3clicks Acceptable ≤5clicks
Double Simples	Ratcheting Buckle	RST	Optimal ≤6clicks Acceptable ≤9clicks	Optimal ≤3clicks Acceptable ≤4clicks

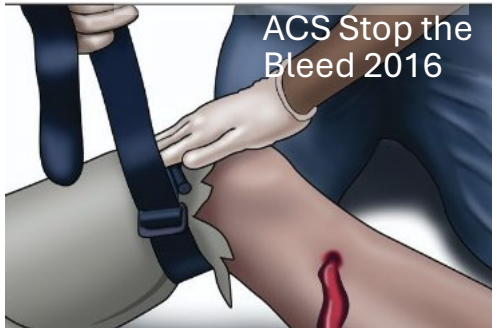
Most common rod turn counting is to ignore the first 90° and count each 180° thereafter as 1 turn. The first rod turn = 270°. The second rod turn = 270° + 180° = 450°.

Suboptimal Orientations for Pulling

Optimal tourniquet orientation

1. Perpendicular to limb long axis
2. Pull into space lateral to casualty (buddy applications)
3. When the limb is horizontal, pull downward (buddy applications)

In Training



In Use

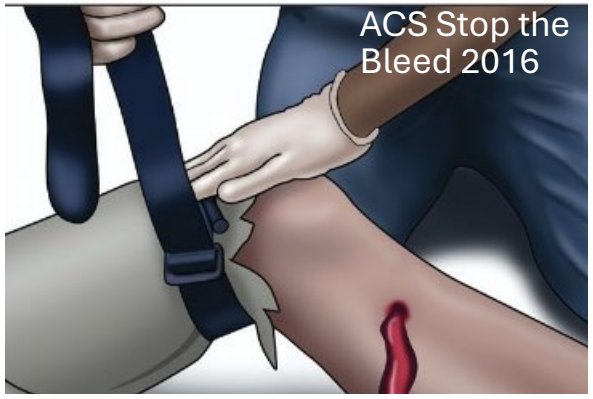
In ED

Suboptimal Pulling

Optimal pulling techniques

1. Pull strap 180° from entrance into redirect buckle
2. **Pull as tight as possible** (use body weight during pull, esp. thigh)
3. Visible indentation necessary.

Terrible Pulling Direction In Training



Minimal Indentation

In Training

In Use

Complete Failure to Pull (No Effort and No Indentation)

Suboptimal Pulling Is Common

2 tourniquets on arm
= suboptimal pulling

>3 rod turns suggested by:

strap bunching

rod angle

strap bunching & rod angle

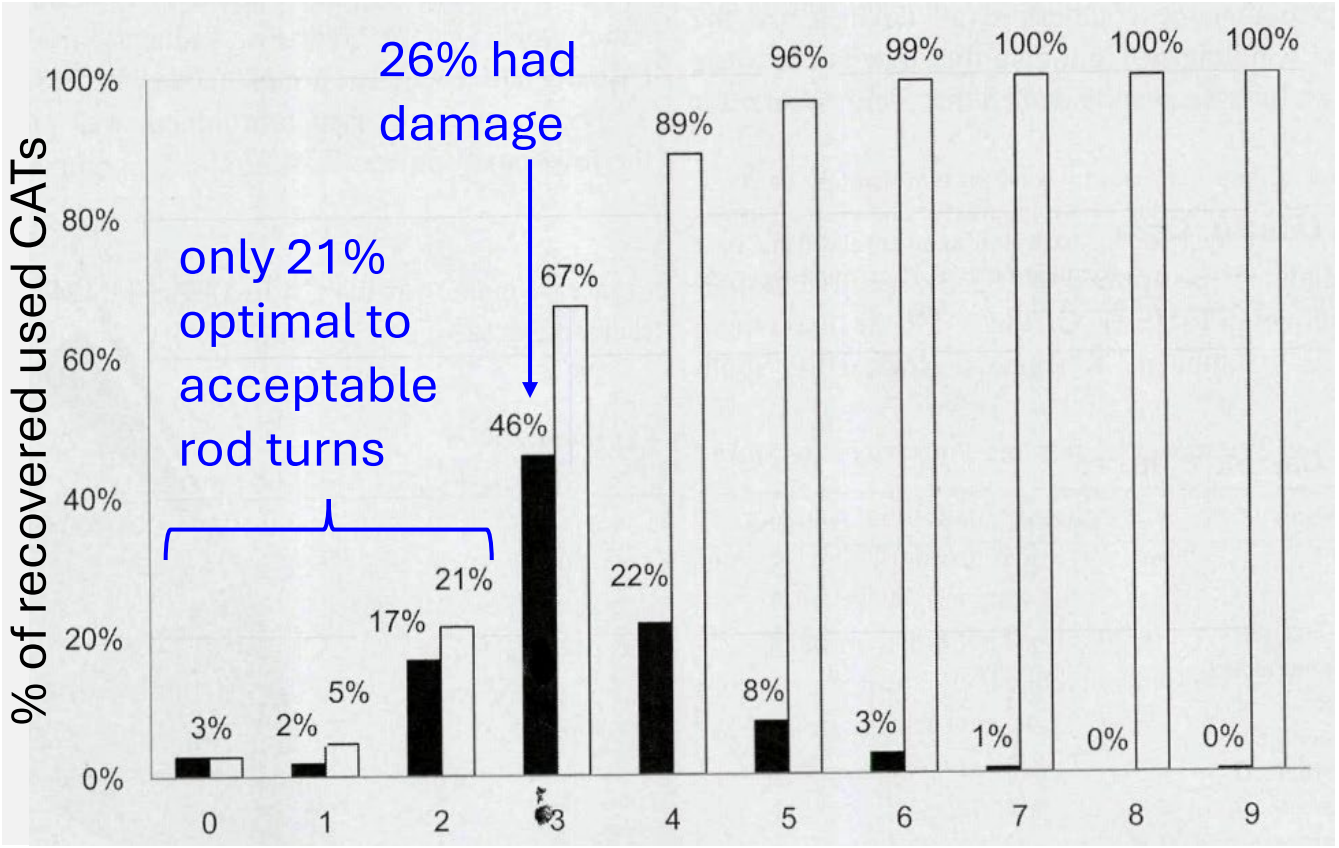
still bleeding, not arterially occlusive

Suboptimal Pulling Is Common

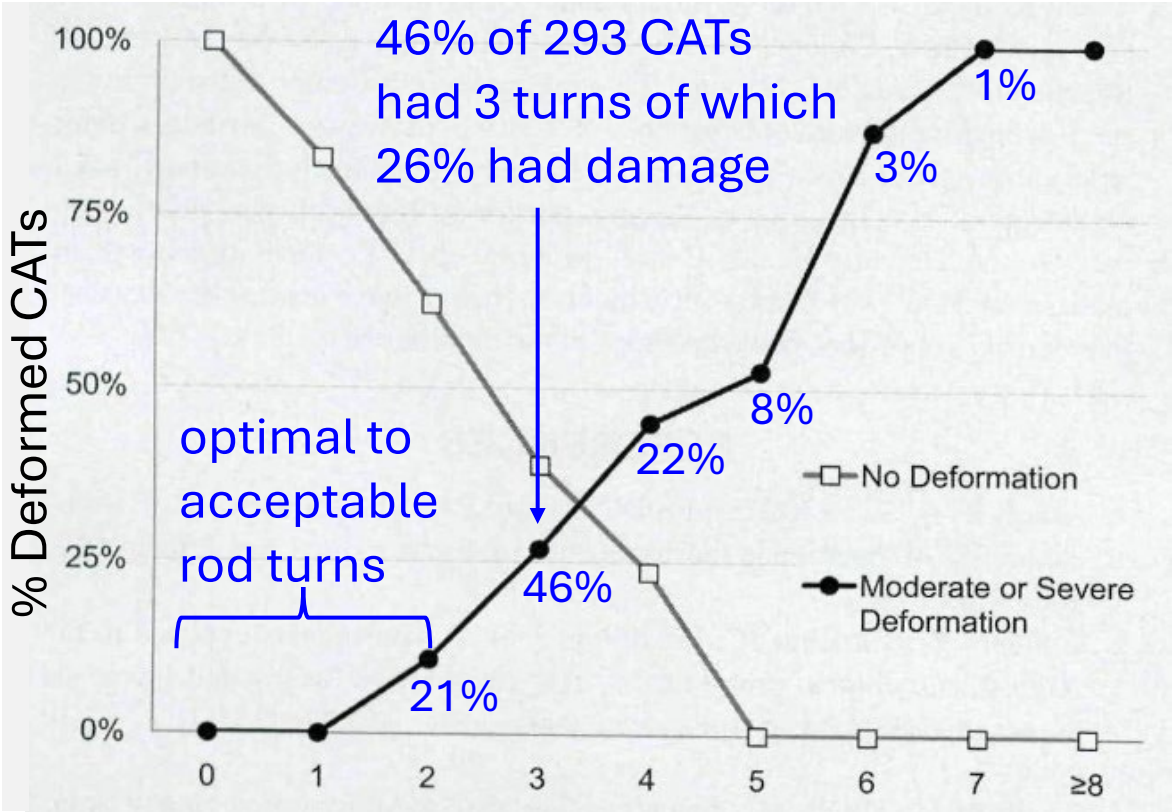
Kragh et al. Mil Med 2013
Tourniquets recovered from US service personnel in the Iraq and Afghanistan Wars

79% of CATs had suboptimal number of rod turns, 74% of those had damage

(Despite 37% of used CATs routed as simple redirect)



Rod turns of recovered used CATs (n≤293)



Rod turns of recovered used CATs (n≤293)

Recognizing Suboptimal Pulling Is Uncommon

Weppner et al. Mil Med 2013

Research
Military adults
CAT proximal thigh

852 of 1,321 had suboptimal number rod turns at occlusion

TABLE II. Number of Turns Required to Eliminate the Pedal Pulse for 30 Seconds

Number of Turns	Control, *n* (%)	Plate Carrier, *n* (%)	IFAK (With Manufacturer Packaging), *n* (%)	IFAK (Without Manufacturer Packaging), *n* (%)
1	39 (10.1)	9 (2.3)	37 (9.6)	39 (10.1)
2	91 (23.4)	72 (18.7)	93 (24.2)	89 (22.9)
3	221 (57.0)	128 (33.3)	219 (56.7)	223 (57.4)
4	18 (4.6)	10 (2.7)	16 (4.1)	17 (4.4)
Not Efficacious	19 (4.9)	165 (43.0)	21 (5.4)	20 (5.2)

Weppner et al. "results support previous reports that most CATs require 3 turns to be efficacious" (referenced Childers et al. Mil Med 2011 "59% of CATs required 3 turns to be efficacious" n=332)

Ünlü et al. Eur J Trauma Emerg Surg 2017

Research
Military adults
CAT mid-thigh

97 of 101 occluded

Table 1 Cumulative turn degrees of both successful and corrected failed participants ($n = 145$)

Turn degrees	Frequency	Cumulative percent
270.00	14	9.7
450.00	37	35.2
540.00	1	35.9
630.00	49	69.7
810.00	29	89.7
990.00	12	97.9
1170.00	2	99.3
1260.00	1	100.0
Total	145	

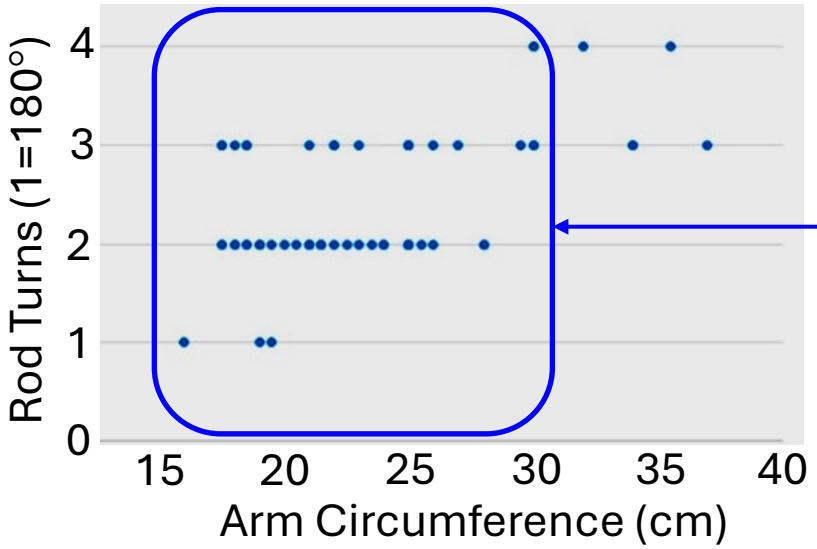
≤51 had optimal to acceptable rod turns at occlusion

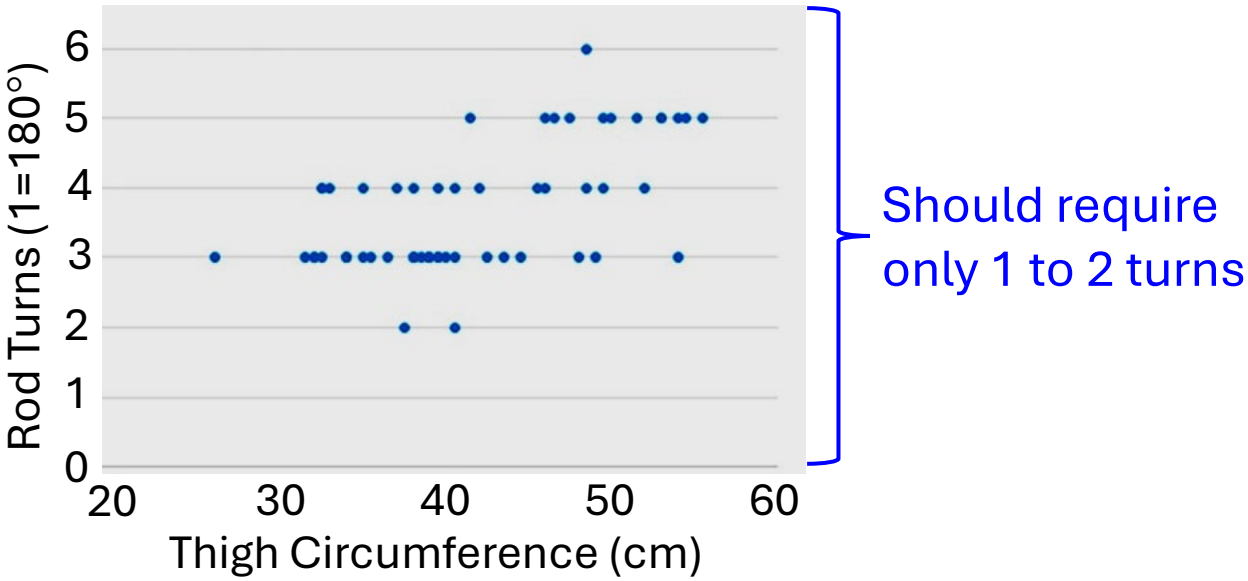
Ünlü et al. recommendation was to increase rod turns.

Recognizing Suboptimal Pulling Is Uncommon

Harcke et al. Ped 2019
Researcher-applied CATs **on children**

Poor pulling = too many rod turns





Tightening Amount

Secure tightening system past initial arterial occlusion

- ≥18° (a tenth of a rod turn) or 1click, probably 36° (two tenths of a rod turn) or 2clicks for arms, maybe 54° (three tenths of a rod turn) or 3clicks for thighs

Expect the need for additional tightenings over time

- Rapid pressure loss under tourniquets in first 5 minutes (physiology)
- Muscle relaxation
- Limb movement
- Blood pressure increases

Self-securing tightening systems allow:

- Faster additional tightenings
- Finer resolution additional tightenings

Hook-and-Loop Strap Securing Problems

Incorrect strap securing risks unintended release, especially with simple redirect routing (e.g. CAT7, DNIPRO, PULS, OMNA).

Correct hook-and-loop strap securing

1. Full side-to-side engagement
2. Full-length engagement
3. Strap-end securing techniques
   a. Open-top bracket (e.g. CAT, DNIPRO, PULS): limb-encircling strap over rod and **inside** bracket, then time strap over
   b. Modified triangle (e.g. SICH): limb-encircling strap through securing slot

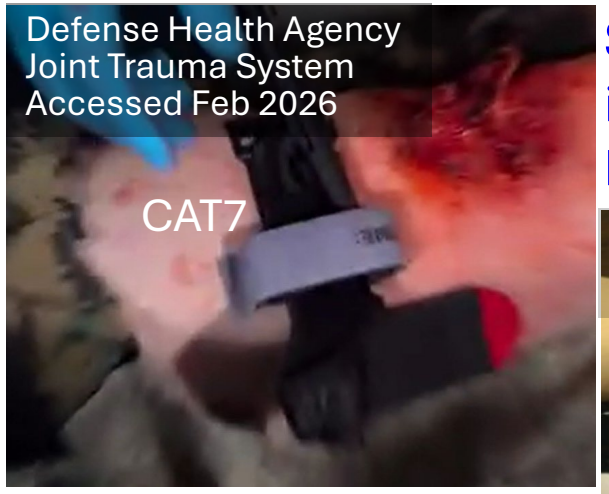
Triglide redirect routing diminishes unintentional strap release risk: built into TMT, option with SICH and CATs prior to Gen 7, but 37% of CATs used in Iraq and Afghanistan simple routed.

In Training

Terrible side-to-side engagement

Strap-end not inside open-top bracket

Not fully around limb



Strap end not inside open-top bracket

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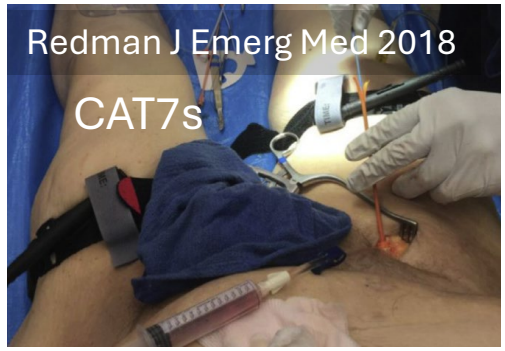
In Use

Not fully around limb



Strap end not inside open-top bracket under time strap

Minimize Bleeding While Applying

Techniques

- Direct pressure
- Proximal pressure on arterial pressure point (subclavian, brachial, or femoral)
- Proximal squeezing of forearm or calf

Bleeding severe enough to be life-threatening is rapid enough to warrant minimizing bleeding while accessing and applying tourniquets.

Minimize bleeding risk when releasing tourniquets should be part of removing, relocating, or converting (including to surgical definitive care).

This should be explicitly taught.

Example of Not Minimizing Bleeding While Applying

Kneeling on an arterial pressure point is only one of several methods available to minimize bleeding.
Kneeling across the inguinal crease for femoral artery occlusion may currently be controversial, but if the applier is kneeling on the pelvic area anyway, they should do so in a manner that minimizes bleeding while applying the tourniquet.

Advantages of self-securing redirect & tightening systems

1. Require less attention during application & tightenings
2. Avoid securing errors & unintentional releases during application & tightenings
3. Faster application & tightenings
4. Self-securing tightening systems
    a. Involve finer resolution tightening
    b. Prevent loss of tightness during application & tightening
5. Possible caveat:

    Self-securing tightening systems do not generally offer super slow pressure release. However, the releasing process should always include a method of preventing bleeding via direct or proximal pressure. Additionally, collapsible tube work suggests a lack of clinical relevance for used speeds of windlass rod releasing.

Finer resolution tightening systems

1. Magnitude and duration of tourniquet pressure cause direct tissue damage.
2. Non-linear relationship between tourniquet pressure and tightening system use
3. Because they are narrower, emergency-use limb tourniquets require higher pressures for arterial occlusion than OR pneumatic tourniquets and BP cuffs.
4. Fine resolution tightening systems allow completion pressures closer to their arterial occlusion pressures = lower completion pressures
5. Completion pressures cause direct tissue damage.

As distal as possible for **AS SHORT A TIME AS POSSIBLE**

1. Tourniquets are directly damaging to tissues according to pressure magnitude and duration. (Tourniquets also cause distal damage, especially when not arterially occlusive the entire time.)
2. Emergency-use limb tourniquets require higher pressures for arterial occlusion than do OR pneumatic tourniquets. Higher pressures increase direct damage in less time.
3. Smaller circumferences (i.e. distal) require less pressure for arterial occlusion, and use of less pressure decreases direct-pressure-created tissue injuries.
4. Distal locations minimize amount of tissue with ischemia/reperfusion injury to prevent systemic complications.
5. Distal locations maximize preservable limb length if an amputation is needed.

Arterial Occlusion Important

1. Suboptimal techniques impede achieving & maintaining arterial occlusion.
2. Frequent reassessments, with possible tightenings, are needed to ensure maintenance of arterial occlusion.
3. Failure to achieve and/or maintain arterial occlusion leads to
    a. Ongoing bleeding
    b. Venous congestion
    c. Venous distension
    d. Resumption of bleeding/oozing/venous bleeding (venous occlusion without arterial occlusion)
    e. Hematoma expansion
    f. Limb swelling
    g. Compartment syndrome with need for fasciotomy
    h. Hypovolemic shock
    i. Death

Visual Evidence of Time Without Arterial Occlusion

Resumption of bleeding with resuscitation

Dark, purplish skin

6hr tourniquets

Ongoing bleeding

Dark skin

17hr tourniquet

Limb swelling

Visual Evidence of Time Without Arterial Occlusion

7.5hr tourniquet

4.5hr tourniquet

11min tourniquet

Dark, purplish skin

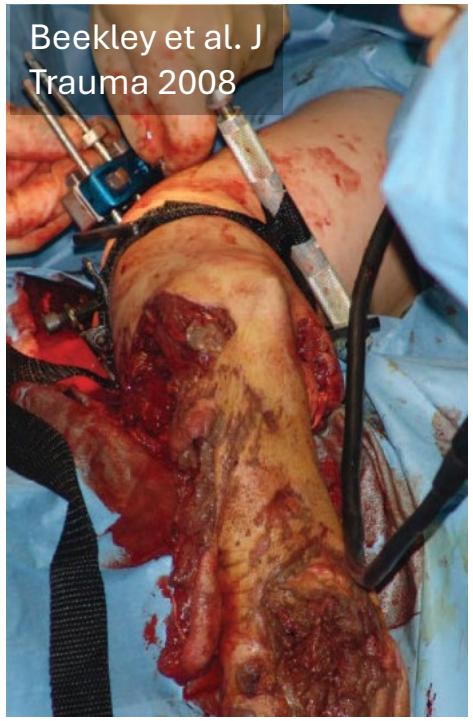
Still bleeding

Normal Skin Color Distal to Tourniquet

Skin color does not relate to tourniquet duration, it relates to venous congestion.

11.5hr tourniquet

14hr tourniquet



Normal Skin Color Distal to Tourniquet

Skin color does not relate to tourniquet duration, it relates to venous congestion.

156min tourniquet

(no arterial bleeding during resuscitation)

Normal Skin Color Because Ongoing Bleeding

Taylor et al. J Trauma 2011

Ongoing bleeding can prevent venous congestion, so normal skin color is not synonymous with arterial occlusion.

Tourniquet Areas to Improve:

1. Teach optimal techniques & explicitly point out suboptimal applications
    a. Application orientation
    b. Strap pulling technique and effort
    c. Tightening amount
    d. Securing steps
2. Explicitly teach minimizing bleeding while accessing, applying, & releasing tourniquets
3. Share understanding of advantages of self-securing systems
4. Share understanding of advantages of finer resolution tightening systems
5. Teach importance of “as distal as possible for as short a time as possible”
6. Teach & explicitly point out indicators of time not arterially occlusive

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