Tourniquets

- **History**
  - First recorded use by Roman surgeon in 2C-AD
  - 1817 – Jean-Louis Petit (French Surgeon) described and named hemostasis device → tourniquet
  - 1904 – Harvey Cushing – Pneumatic tourniquet introduced
  - Julian Bruner’s 10 Rules to Tourniquet (JBJS 1951) describe for hand surgery

- **Indications**
  - Achieve hemostasis or bloodless field during surgery to allow for vital structure visualization and increase speed of surgery.
  - Combat/civilian emergency situations
  - Decrease requirement for blood transfusions

- **Timing of / Application**
  - 1.) Well padded, usually with webril. Do not rotate cuff once tied down as can cause skin abrasion.
    - The Effect of Tourniquet Padding on the Efficiency of Tourniquets of the Upper Limb, Rajpura et al. JBJS (Br). 2007. (PMID – 17463125)
      - NOTE: Bruner’s 10 Rules to Tourniquet (JBJS 1951) –
        - #2 – The upper arm should be first padded with several turns of sheet wadding” to prevent skin trauma
    - Influence of padding on arm circumference and tourniquet efficacy (pressures)
    - Study –
      - 20 pts (10m/10f)
      - 2 pads (Cellona – monolayer; Velband – triple layer)
      - Arm tourniquet at 220mmHg
      - Measured arm pressures with 0, 2, 4, 8 layers
    - Results (Cellona/Velband)

    ![Graph showing mean pressure and 95% confidence intervals (CI) for Cellona and Velband padding against the number of layers applied](image)

    - 4 layers caused mean reduction of 5%/11%
8 layers caused mean reduction of 13%/18%
Difference possibly attributed to mono v. triple layer construction
Padding effect maybe exaggerated with increasing limb circumference and adipose tissue amounts

• **Conclusion** = More than 2 layers results in significant reduction in the transmitted pressure

2.) Administration of antibiotic prior to cuff inflation

  - Timing of antibiotic prophylaxis and occurrence of surgical-wound infections
  - 2847 patients
    - Early – 2-24 hrs before incision
      - 369 pts – 14 infections (3.8%)
    - Preoperatively – 2hrs before incision
      - 1708 pts – 10 infections (0.6%)
    - Perioperative - 3hrs after incision
      - 282 pts – 4 infections (1.4%)
    - Postoperative – 3-24hrs after incision
      - 488 pts – 16 infections (3.3%)
  - **Conclusion** = Administration of antibiotics within 2 hours of incision give lowest rate of surgical wound infection

3.) Exsanguination of the limb through

- Elevation 3-5 minute at 45° and cuff, or...
- *Esmarch to quickly exsanguate the extremity
  - * More aggressive; can dislodge tumor, disrupt infection, DVT (PE); reaches up to 1000mmHg pressure = nerve injury

4.) Pressures

- Ankle – proximal to malleoli. Set at 250mmHg, or 100mmHg above systolic.
- Thigh – proximal/middle of thigh. Set at 300-350mmHg. Should never exceed 500mmHg
- Pressures likely to be higher in HTN, obese, atherosclerotic pts
- AOP – Arterial Occlusion Pressure (Graham’s Formula)

\[
\text{AOP} = \frac{(\text{Systolic} - \text{Diastolic})(\text{Limb Circumference})}{(3)(\text{Cuff Width})} + \text{Diastolic}
\]

5.) Debated use of drape/protection at distal tourniquet margin from antiseptic solution protection. Examples are 3M Steri-Drape (1010 drape, $1/per) or Cut/Fingerless Latex Glove ($0.10/per).
- Tourniquet complication risk at 1:13,000 with rare mention of skin injury (*Middleton et al.*).
- Betadine
  - Free Iodine and H2O-I kills cells through iodination of cytoplasmic and membrane compounds
- Burns
  - Wetting/pooling continues iodination effect of Betadine
  - Tourniquet hides burn from view
  - Pts cannot feel noxious stimuli (anesthesia)
  - Results in unnecessary, prolonged hospitalization ($$$)

- Max Time / Reperfusion (Estebe et al.)
  - Recommended 10 minutes of reperfusion per 1 hr of ischemia, max 2 hrs of uninterrupted inflation before release of cuff to restore normal pH, pCO$_2$, and pO$_2$.
    - Creatinine phosphate and ATP deplete in 2 hours, causing a depletion of metabolic recovery of muscle
    - At 2 hours, pH starts to drop below 7.0 = Muscle fatigue and damage
  - Each additional inflation period should be shorter than the previous inflation period and each perfusion period should be longer than the previous inflation period.
  - Release causes 10% increase in limb girth (vessel refilling / hyperemia)
    - POD#1 – potential for 50% limb girth increase
    - Swelling remains significant for up to 6 weeks
  - Recommendation of releasing tourniquet before dressing application
    - Allow minimal reperfusion and swelling period reducing increased intracompartment pressure pains
  - “Post-Tourniquet Syndrome” – ischemia, edema, vascular congestion = stiffness, pallor, weakness, pain
Ddx from surgical induced trauma

  - After 40 minutes tourniquet time, pH < 7.0
  - Women and lighter patients reach acidotic pH values faster than men and heavier patients.

- Local adverse effects:
  - Nerve Injury
    - Injury is rare (0.1 – 7.7%), but does occur
    - Nerve palsy risk 1:13,000 LEA
    - Axonal degeneration from compromising local tissue nutrition due to nerve compression
    - Axial compression of nerves damages nodes of Ranvier
  - Muscle Injury (most susceptible tissue to ischemic injury)
    - Due to ischemia =↓ATP, ↑ROS/NO/CKs/AA, Acidosis causing mitochondrial dysfunction, cellular apoptosis, and necrosis on the ipsilateral limb
  - Vascular Injury: rare; increase risk in PVD pts (plaque break-off)
  - Skin Injury: rare; pressure, friction, chemical burns

- Tourniquet Pain:
  - Dull and vague pain
    - Caused by an increase in HR and BP which results with the anesthetist increasing the depth of anesthesia
      - HTN occurred 67% of the time with patient under general anesthesia
  - Tourniquet pain is thought to be related to a cutaneous neural response as well as hypertension mediated by a humoral response to pain
  - Pain is mediated by unmyelinated, slow conducting C fibers that are normally inhibited after A-delta fibers
    - Compression causes loss of conduction in nerve fibers and large A-delta nerve fibers are blocked before small C fibers. Therefore still functioning C fibers will be uninhibited and cause pain
  - Increases in tourniquet pain correlated with increasing patient age, duration of SX and more common in lower limb SX

- Systemic adverse effects:
  - CV: increase in circulating blood volume (15%) and systemic vascular resistance (↑BP, ↑HR)
  - Respiratory: tourniquet deflation associated with ↑CO2 = increase in cerebral arterial BF and ICP = 2° brain injuries
Hematological: inflation promotes TPA & anticoag pathways \( \rightarrow \) thrombolytic event upon release (DVT/PE)

Venous Tourniquet: occlusion of the venous vasculature without arterial occlusion (P-vein < P-art)
- Pooling of blood distally; engorging of veins \( \rightarrow \) limb congestion \( \rightarrow \) edema; hematoma; compartment syndrome, shock (hemorrhagic and hypovolemic)

- Contraindications:
  - Active infection, malignant disease, open fracture or wound, PVD, recent arterial graft, history or genetic predisposition of DVT/PE/VTE, hypercoagulability (Factor 5, Protein C/S deficiency, PO Contraception, Cancer), tumors, and skin grafts at the site of application.
  - Sickle Cell Anemia – Tourniquet may lead to circulatory stasis, acidosis, and hypoxemia – the triad of clinical conditions that are known to induce sickling

  - Key Points (Retrospective Review Article)
    - Post-op complications in 12.5% SC pts (12/96pts)
    - Extremity swelling occurred in both non/SC pts
    - Tissue distal to tourniquet experience hemostasis, decreased pH, and hypoxemia (and dehydration)
    - 1/50000 AA have SC anemia (SS); 1 in 12 AA has the SC trait (SA)

  - Conclusion = No clear consensus – “Risk versus benefit”

  - Helping factors intra-op
    - Hyperoxygenation, hyperventilation, pre-op hydroxurea (inc HbF over HbS), adequate hydration, careful exsanguination, pre-op transfusion, monitor acid-base status (+7.0)

Works Cited:
- Articles as cited in document.