ADULT BRACHIAL PLEXUS INJURIES

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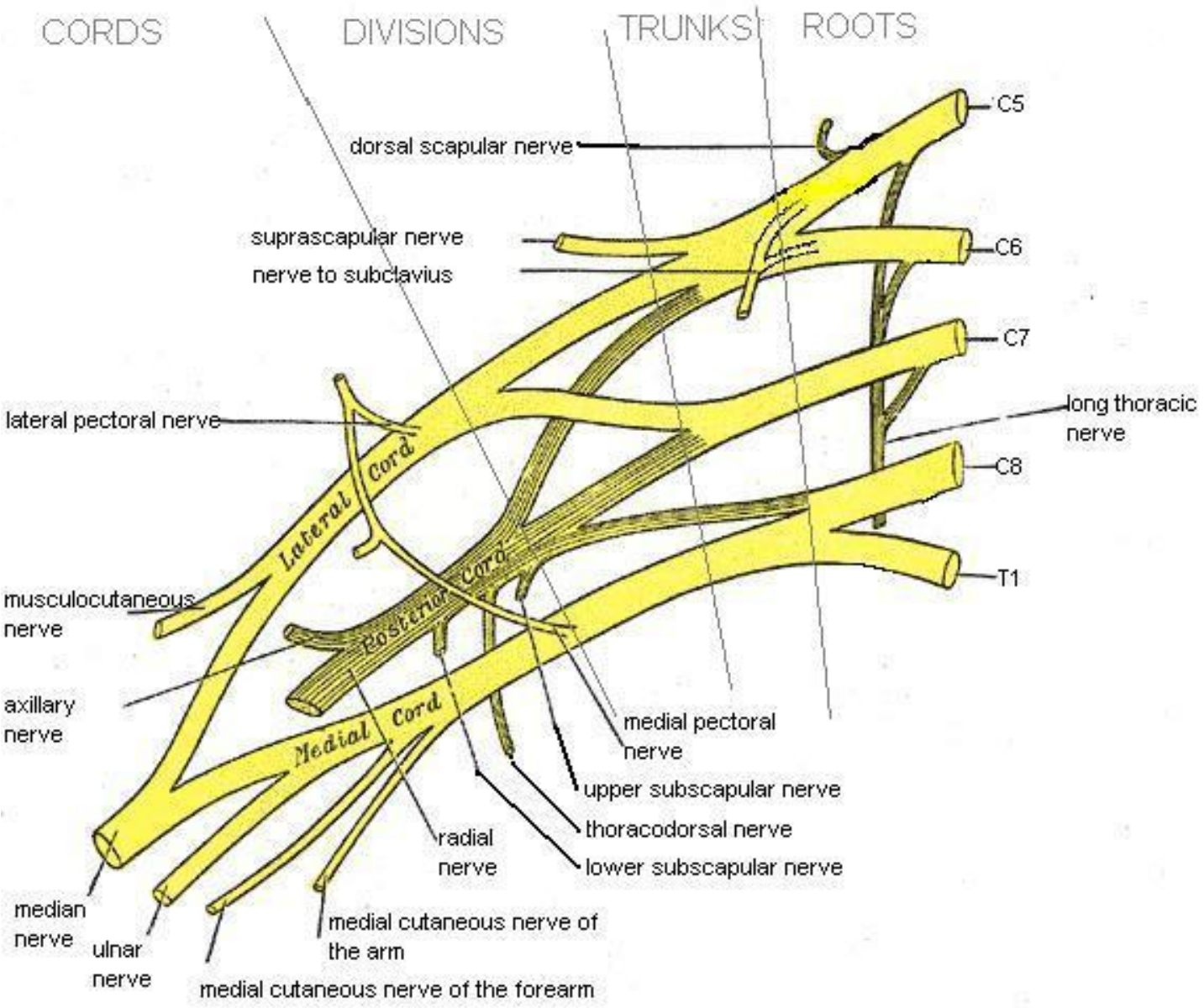
Anatomy


CORDS
DIVISIONS
TRUNKS
ROOTS
C5
dorsal scapular nerve
suprascapular nerve
nerve to subclavius
C6
C7
long thoracic nerve
lateral pectoral nerve
Lateral Cord
C8
Posterior Cord
T1
musculocutaneous nerve
axillary nerve
Medial Cord
medial pectoral nerve
upper subscapular nerve
thoracodorsal nerve
lower subscapular nerve
radial nerve
median nerve
ulnar nerve
medial cutaneous nerve of the arm
medial cutaneous nerve of the forearm

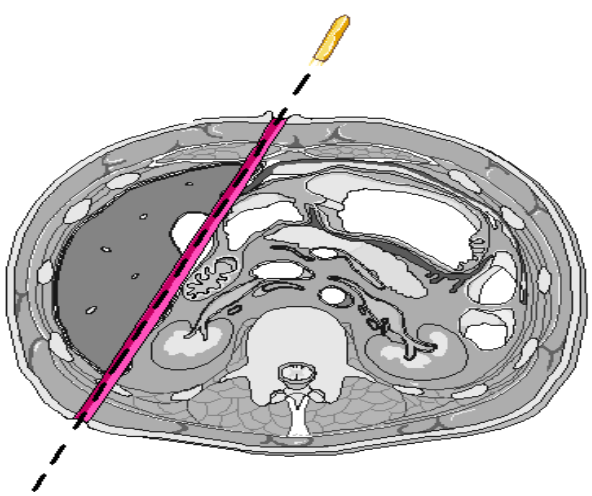
Mechanisms of Brachial Plexus Injury: Trauma

Mechanisms of Injury: Trauma

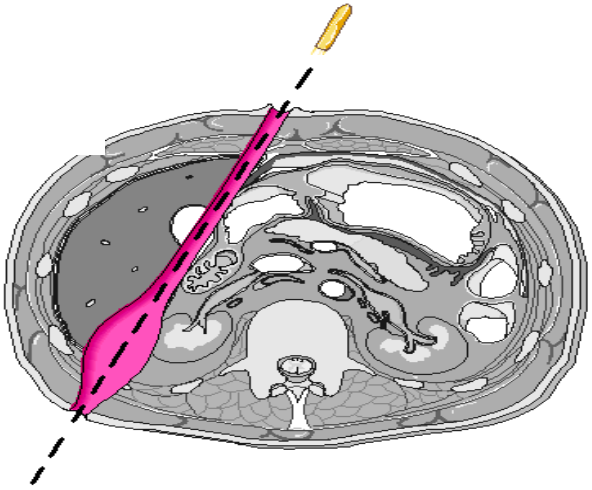
- Laceration/Penetrating Trauma

Mechanisms of Injury: Trauma

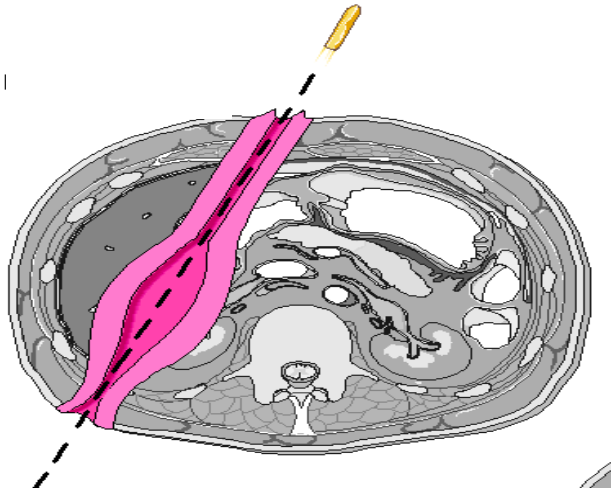
- Gunshot Wounds



Handgun



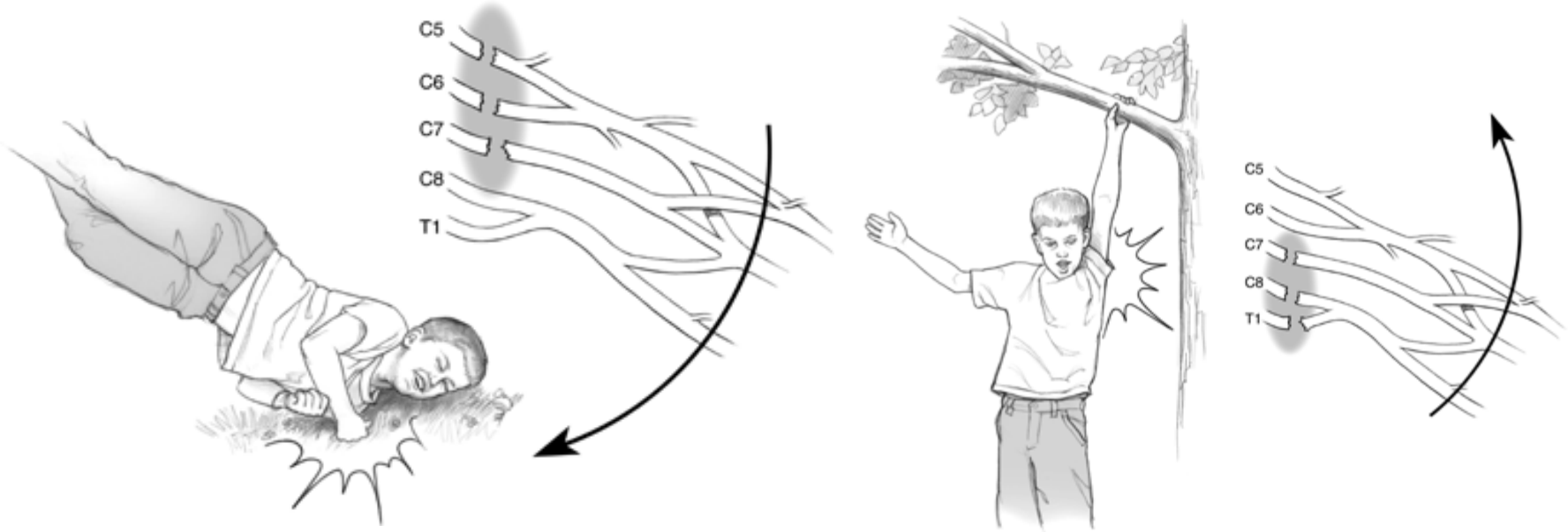
Rifle



Military Grade

Mechanisms of Injury: Trauma

- Traction
  - Falls, MVA

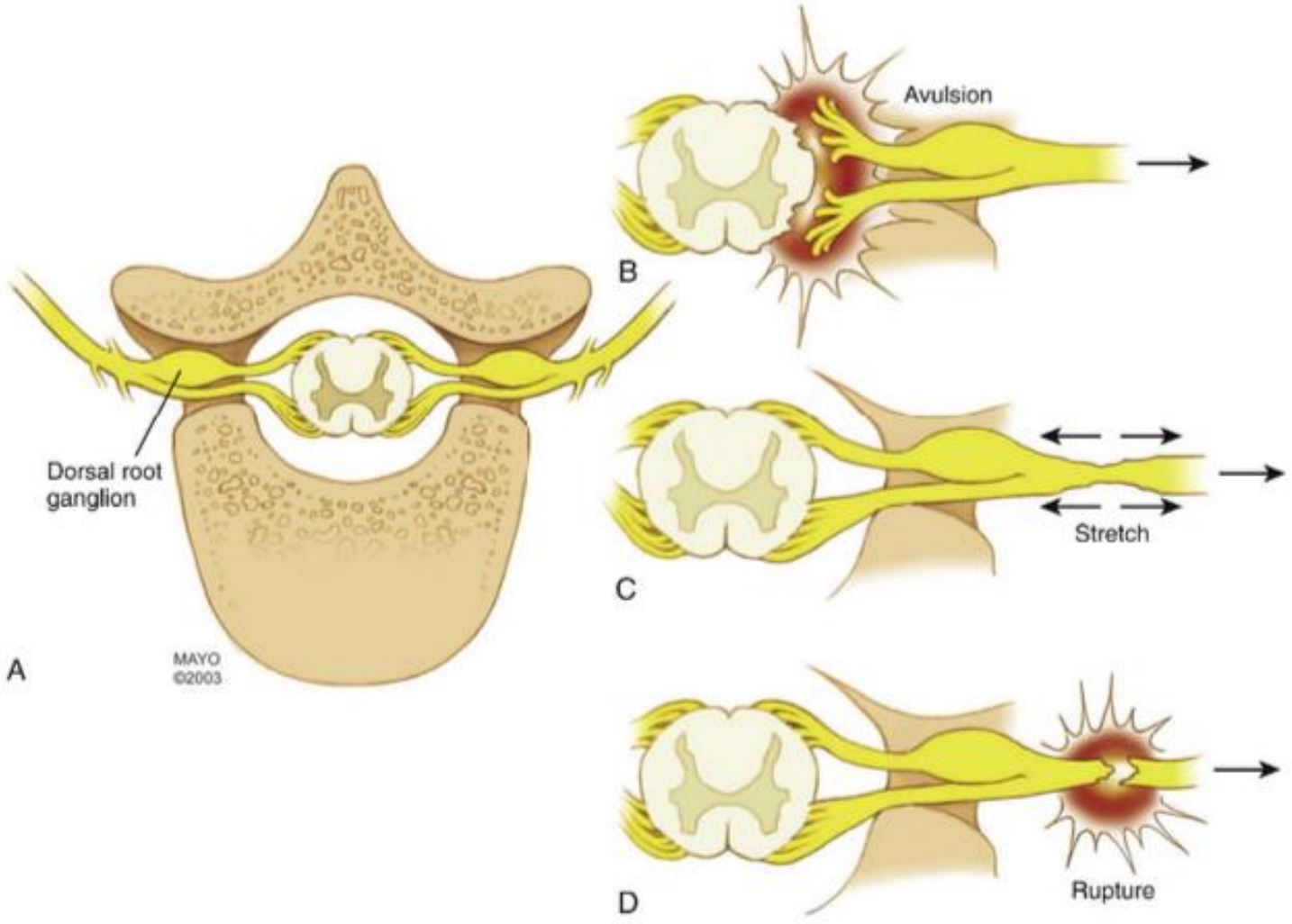


Songcharoen P, Shin AY: Brachial Plexus Injury: Acute Diagnosis and Treatment. Hand Surgery, 1st Edition. 2004 Lippincott Williams and Wilkins, Philadelphia, 1005-1025

Mechanisms of Injury: Trauma

- Traction
  - Falls, MVA
  - Sports-related

Traction Injuries



Spinner RJ, et al: Traumatic Brachial Plexus Injury. Green's Operative Hand Surgery, 6th ed. 2011 Churchill Livingstone, Philadelphia, 1236-1292

Mechanisms of Brachial Plexus Injury: Iatrogenic

Mechanisms of Injury: Iatrogenic

- Shoulder surgery

Iatrogenic Nerve Injuries During Shoulder Surgery

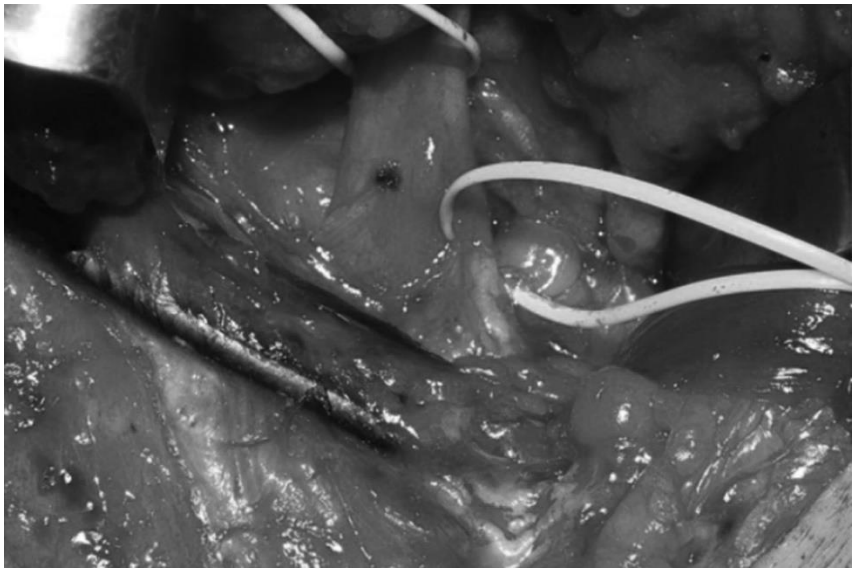
Bradley C. Carofino, MD, David M. Brogan, MD, Michelle F. Kircher, RN, Bassem T. Elhassan, MD, Robert J. Spinner, MD, Allen T. Bishop, MD, and Alexander Y. Shin, MD

Investigation performed at the Mayo Clinic, Rochester, Minnesota

- 26 patients over 10 years
  - open procedures for instability - 7
  - Arthroscopic procedures – 9
  - TSA – 4
  - Combined open/arthroscopic - 6

Mechanisms of Injury: Iatrogenic

- Clavicle Fixation



Jeyaseelan L, Singh VK, Ghosh S, Sinisi M, Fox M. Bone Joint J. 2013 Jan;95-B(1):106-10.

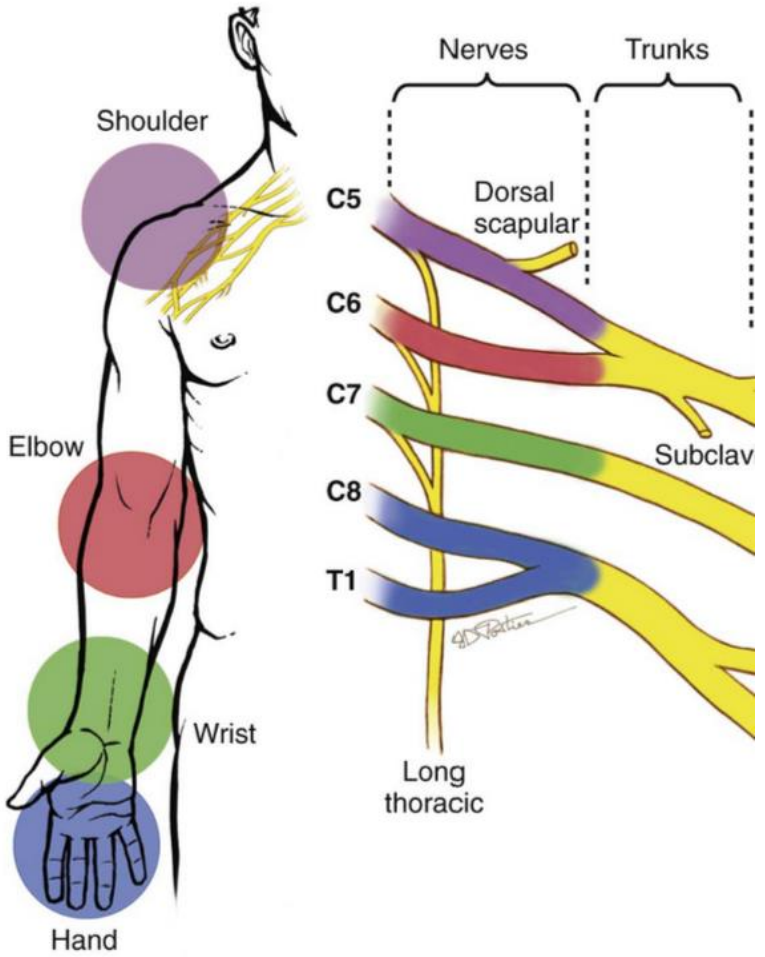
Mechanisms of Injury: Iatrogenic

- Spine Surgery
  - Cervical spine decompression
  - Scoliosis surgery
- Patient positioning
- Anesthesia Regional Blocks
- Robot-assisted thyroid surgery

1. Joiner ER, Andras LM, Skaggs DL. J Bone Joint Surg Am. 2013 Nov 6;95(21):e161
2. Guzman JZ, Baird EO, Fields AC, McAnany SJ, Qureshi SA, Hecht AC, Cho SK. Bone Joint J. 2014 Jul;96-B(7):950-5.

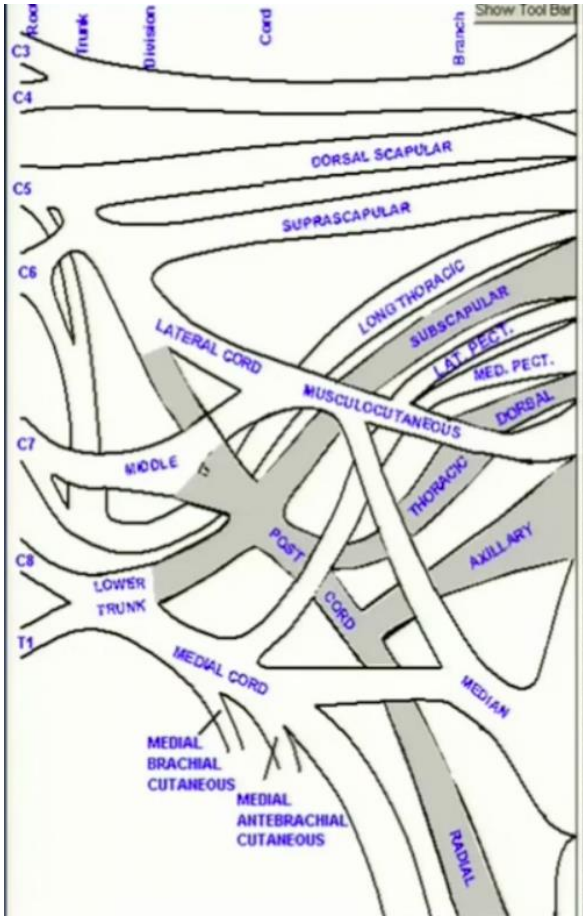
Common Patterns of Injury

- C5-6 injury: 15%
- C5-7 injury: 20-35%
- C8-T1: 10%
- Pan Plexus: 50-75%

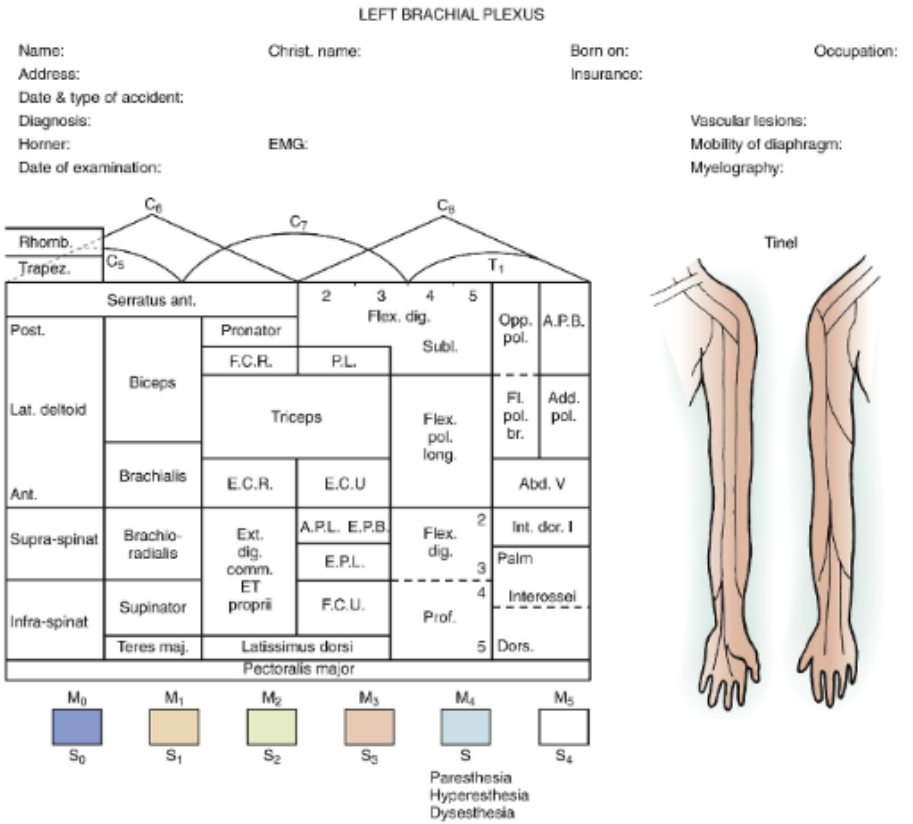


Brachial Plexus Injury: Evaluation

Framework



	Examiner
C3, C4, XI	Upper trapezius
C3, C4, XI	Middle trapezius
C3, C4, XI	Lower trapezius
C(3), C(4), C5	Levator scapulae
C4, C(5)	Rhomboids
C(5), C6	Supraspinatus
C(5), C6	Infrapinatus
C(5), C(6), C(7)	Serratus anterior
C5, C6	Teres major
C5, C6	Subscapularis
C5, C(6), C7	Clav. pect. major
C6, C(7), C(8), T1	Stern. pect. major
C6, C7, C8, T1	Pect. minor
C6, C(7), C8	Latissimus dorsi
C(5), C6	Biceps & Brachialis
C5, C6, C7	Coracobrachialis
C(5), C6	Deltoid anterior
C(5), C6	Deltoid middle
C(5), C6	Deltoid posterior
C5, C6	Teres minor
C7, C(8), T1	Pronator quadratus
C(6), C(7)	Pronator teres
C(6), C(7)	Flex. carpi rad.
C7, C(8), T1	Flex. dig. prof. II, III
C7, C(8), T1	Flex. dig. sup.
C7, C(8), T1	Palmaris longus
C7, C(8), T1	Flex. pol. long
C6, C7, C(8), T1	Flex. pol. brev. (long)
C6, C7, C(8), T1	Abd. pol. brev.
C(8), T(1)	Opponens pollicis
C8, T1	Lumbricales, 1, 2
C6, C(7), C8	Triceps
C(5), C6	Supinator
C(5), C6	Brachioradialis



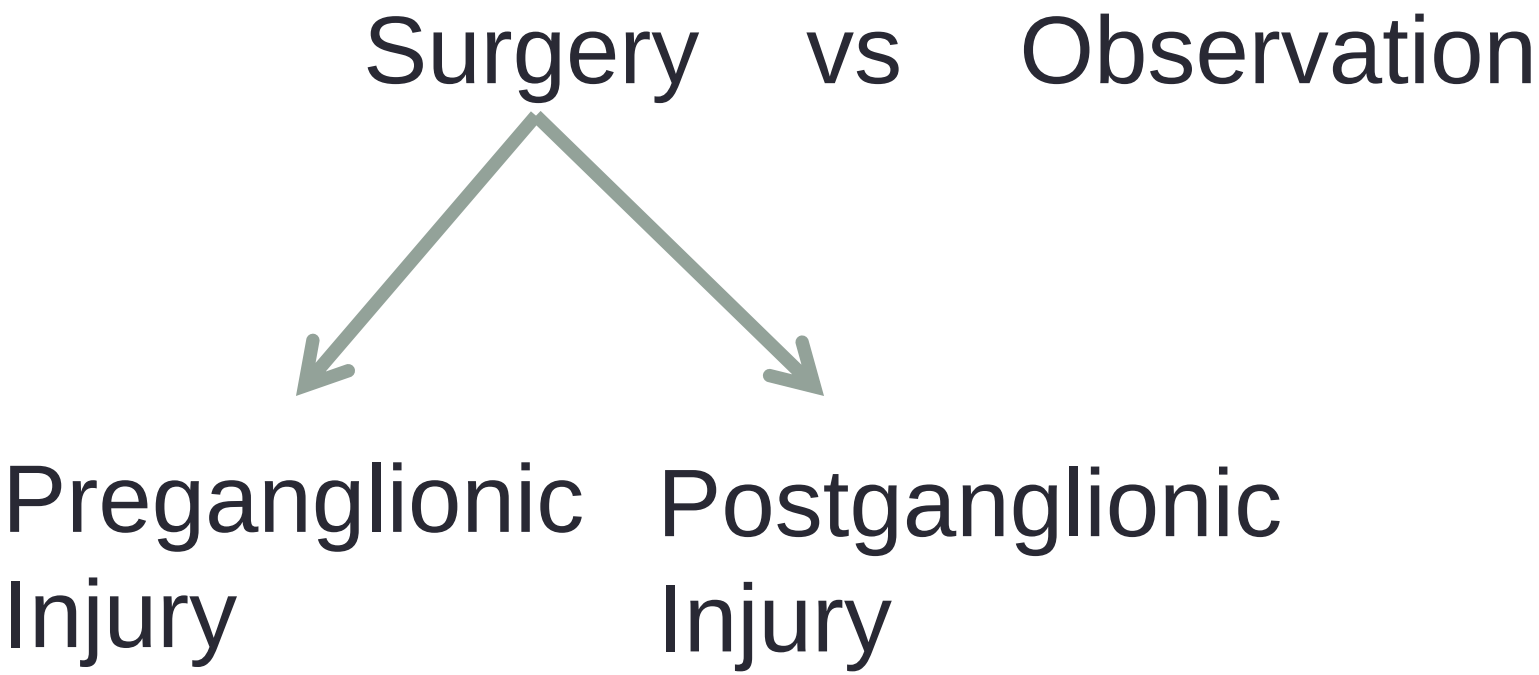
Evaluation

- Goals:

Surgery vs Observation

Evaluation

- Goals:

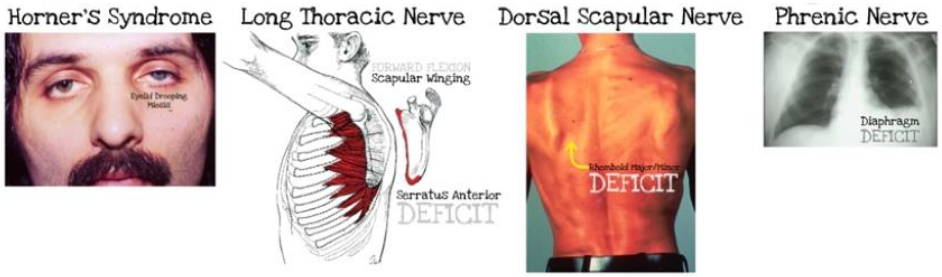


History

- Mechanism
  - High vs low energy
- Associated Injuries
  - Vascular
  - Scapula/rib fxrs
  - Spine injuries
  - Pneumothorax
  - Brain injury

Physical Exam

- Indicators of ***Preganglionic*** Lesions
  - Loss of rhomboid, serratus anterior function
  - Horner's syndrome
  - Absence of Tinel sign or tenderness
  - Atrophy of paraspinous muscles
  - Intact SNAP on NCS



Diagnostic Studies

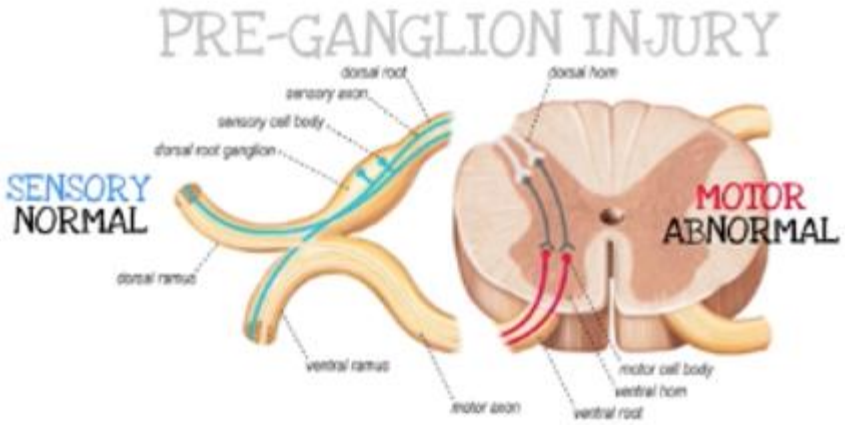
- XRs
  - CXR, C-spine, shoulder/scapula/clavicle
- CT myelography
  - Gold standard nerve root injury
  - 3-4 weeks after injury to allow meningocele to form
- MRI
  - Visualize injury distal to nerve roots
- EMG / Nerve Conduction Study (NCS)
  - Distinguishes pre and postganglionic

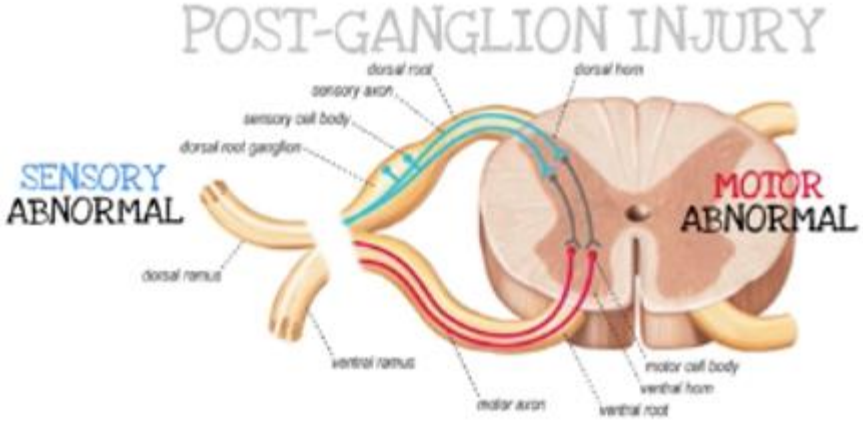
Electrodiagnositic studies

- Baseline exam at 3-4 weeks
- Serial exams to assess recovery
- Electromyography (EMG)
- Sensory Nerve Action Potentials (SNAPs)
- Motor: CMAP

Electrodiagnositic studies

- Pre-Ganglionic
  - CMAP: non-recordable
  - SNAP: normal
- Post-Ganglionic
  - CMAP: non-recordable
  - SNAP: non-recordable





Brachial Plexus Injury: Treatment Strategies

Indications for surgery

- Patients with no hope for spontaneous recovery
- Traction injuries/GSW with no evidence of recovery by 2-3 months

- Contraindications
  - Ongoing spontaneous clinical recovery
  - Delay >1 year
  - Unwilling/unrealistic pt
  - Isolated C8-T1 lesions

Timing of Surgery

- Primary
  - Immediate
    - Penetrating injury/laceration
    - Emergent vascular reconstruction
  - Delayed
    - Undetermined potential for spontaneous recovery

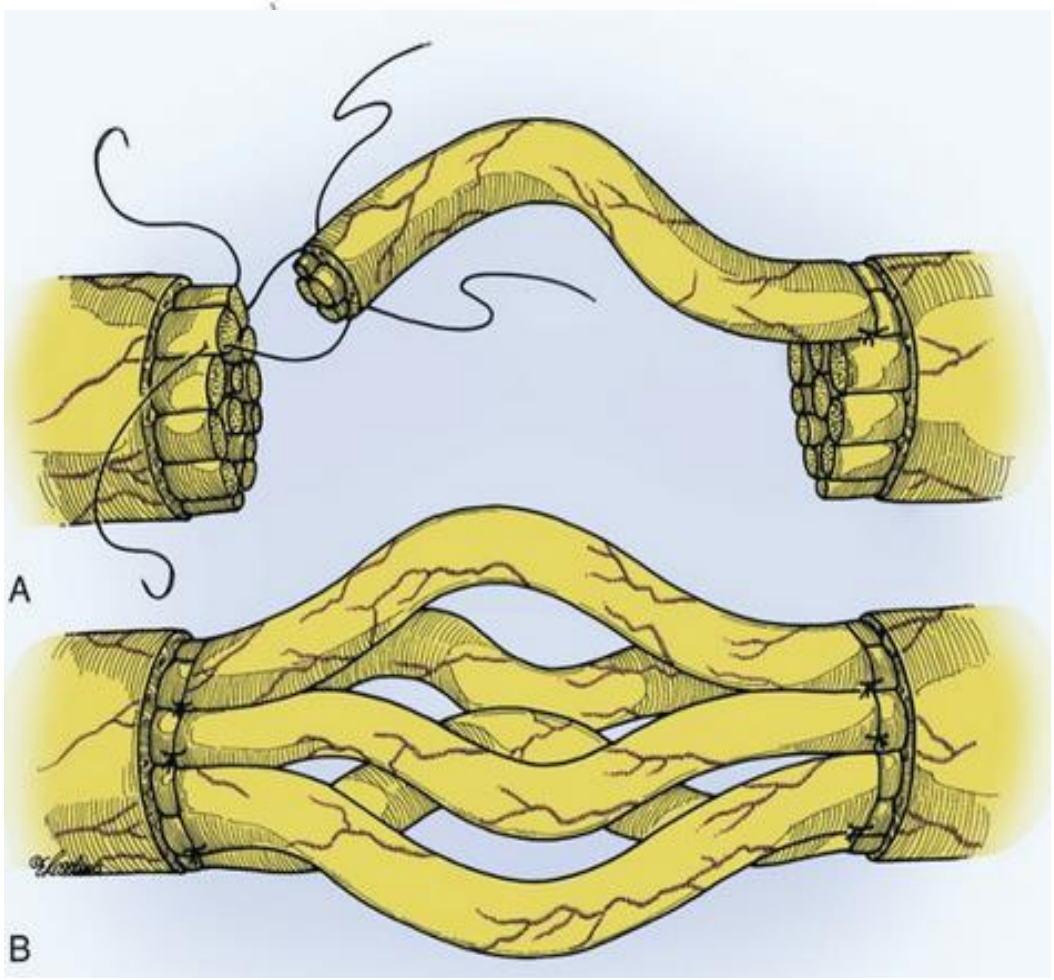
Priorities in Reconstruction

- Pan-plexus Injury
  - **Elbow flexion**
  - **Shoulder stability, abduction, external rotation**
  - Hand Sensation
  - Wrist/finger flexion
  - Wrist/finger extension
  - Intrinsics

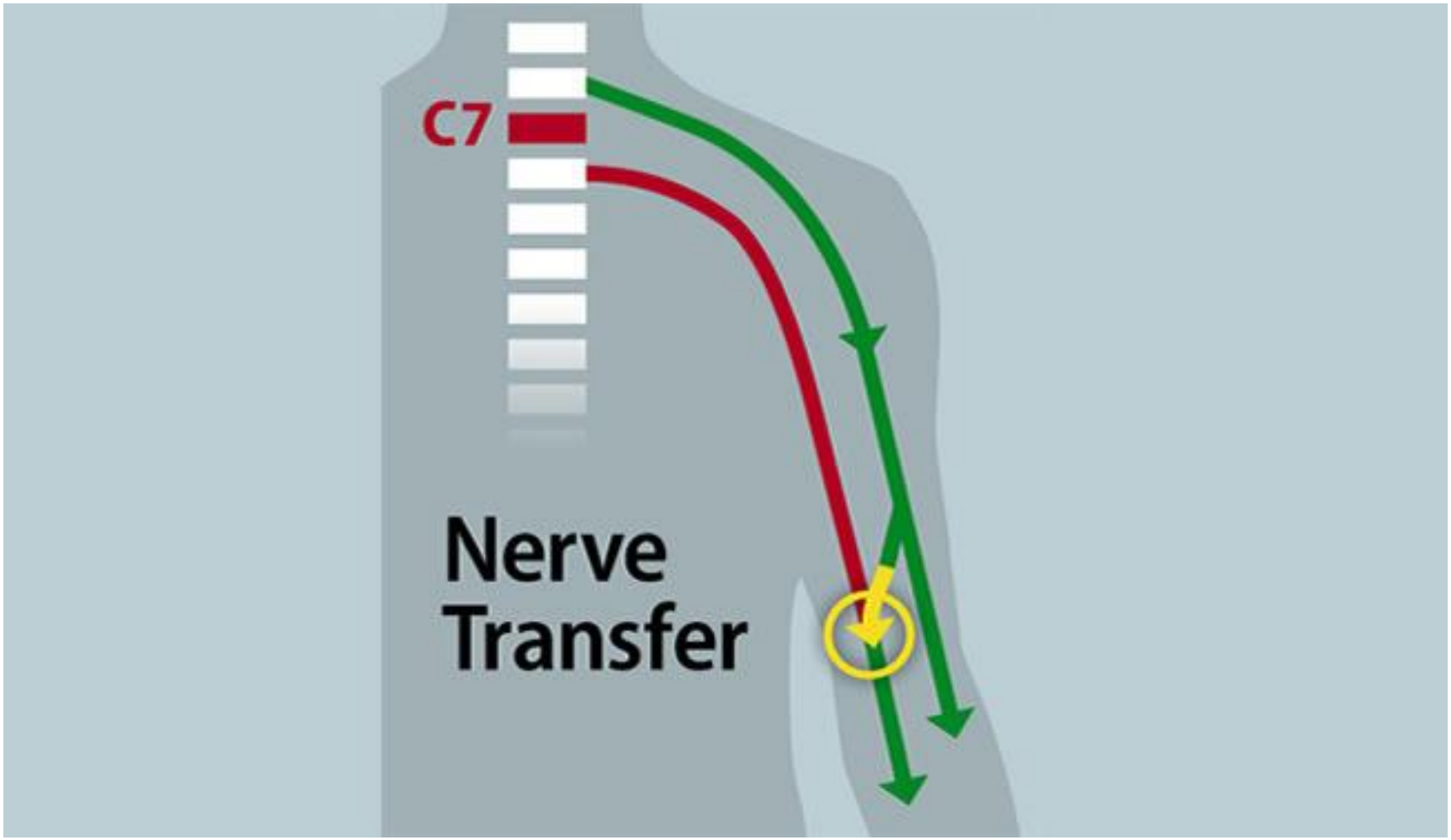
Methods of Repair: Traditional Reconstruction

- Neurolysis
- Direct coaptation
- Interpositional nerve grafting

- Vascularized nerve grafting
- Direct muscle neurotization

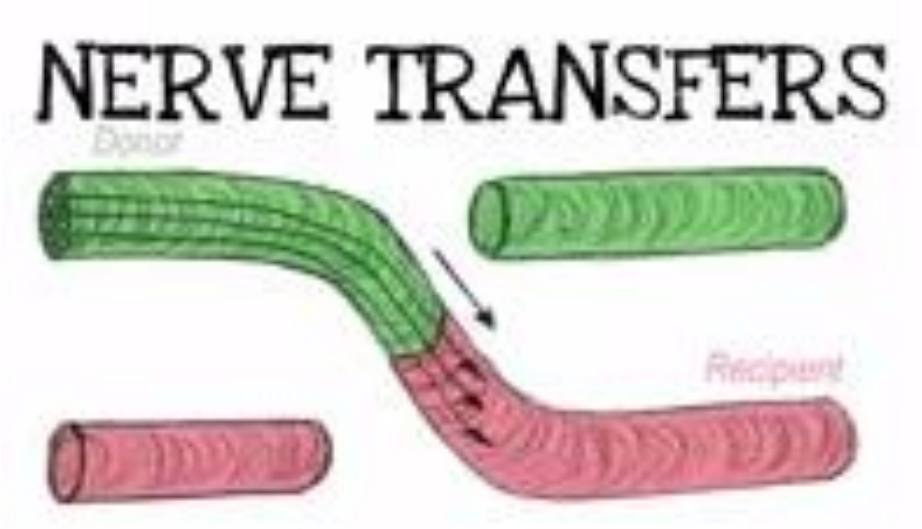


Methods of Repair: Nerve Transfers



Indications for Nerve Transfers

- Brachial plexus injuries for which there are no graftable proximal nerve or nerve root
- High proximal injuries that require a long time for regeneration
- Delay in time to reconstruction
- Large nerve gap requiring long graft



Nerve Transfers: The donor nerve

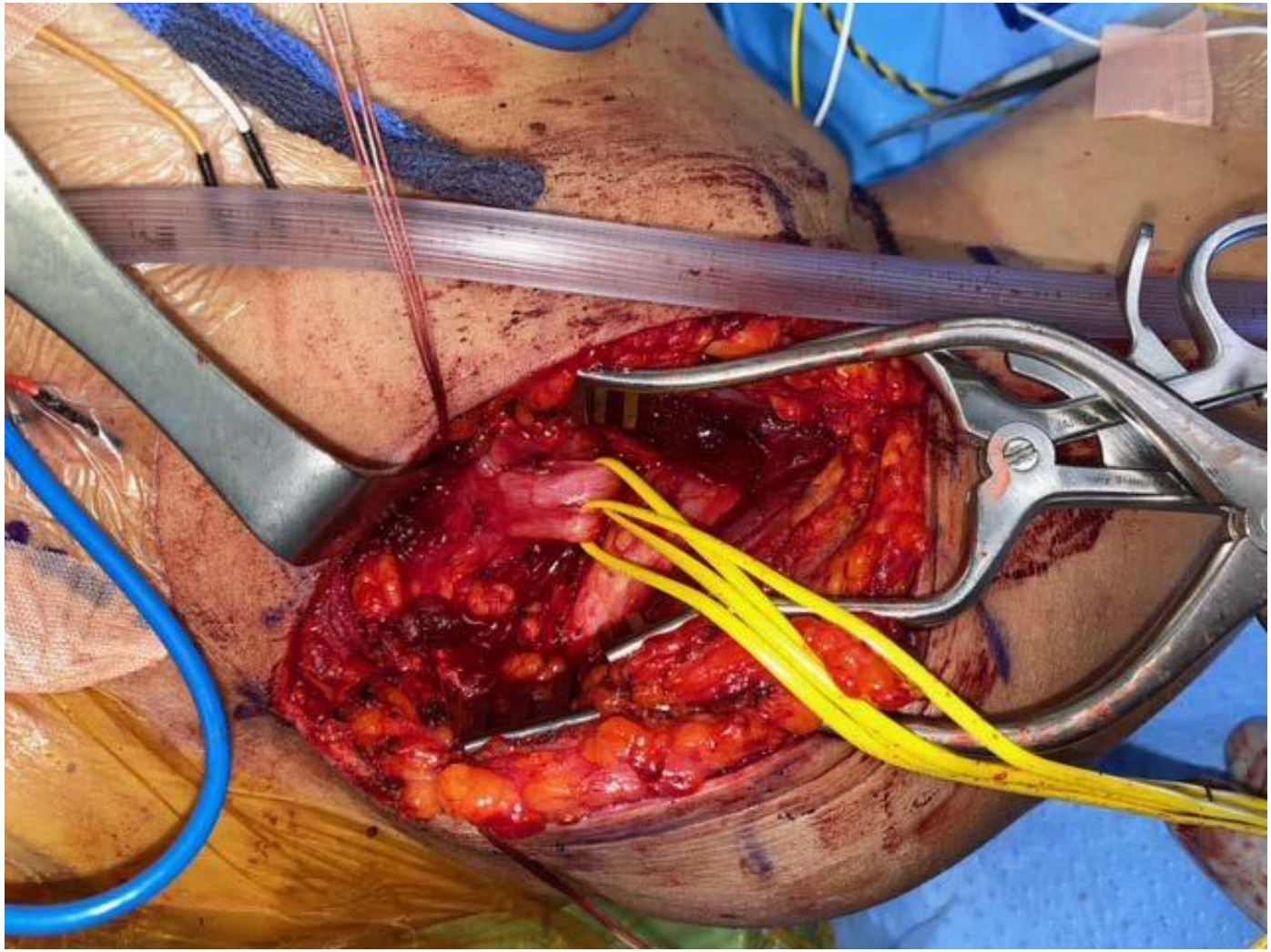
- Ideal qualities
  - Close to target muscle
  - Expendable
  - ‘Pure’ motor / sensory
  - Large number of axons
  - Donor function is synergistic to target muscle
- Common donor nerves
  - Spinal accessory nerve
  - Intercostal nerves
  - Contralateral C7
  - Medial pectoral nerve
  - Phrenic nerve
  - Ulnar nerve fascicle
  - Median nerve fascicle
  - Triceps branch
  - Distal AIN

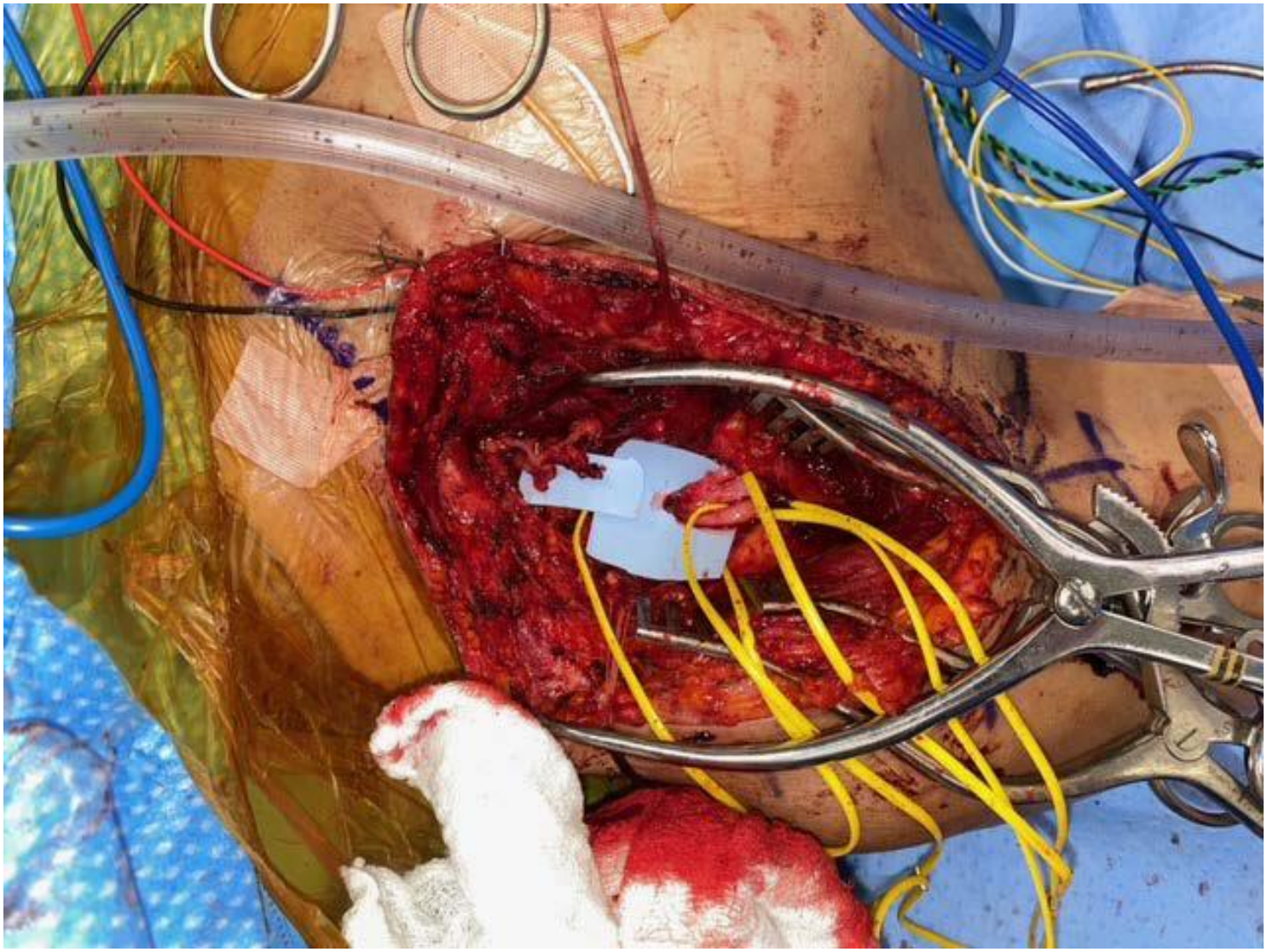
Case Example

- 48 y/o F, graphic designer, s/p resection of right chest wall 4.3cm liposarcoma
- Postop: RUE weakness (0/5 biceps/brachialis), numbness and pain to radial digits
- NCS: severe plexopathy, predominantly lateral cord
- EMG: +fasc, -MUAP to biceps, pec major, pronator teres
- +subclavian occlusion, failed attempted vascular thrombectomy

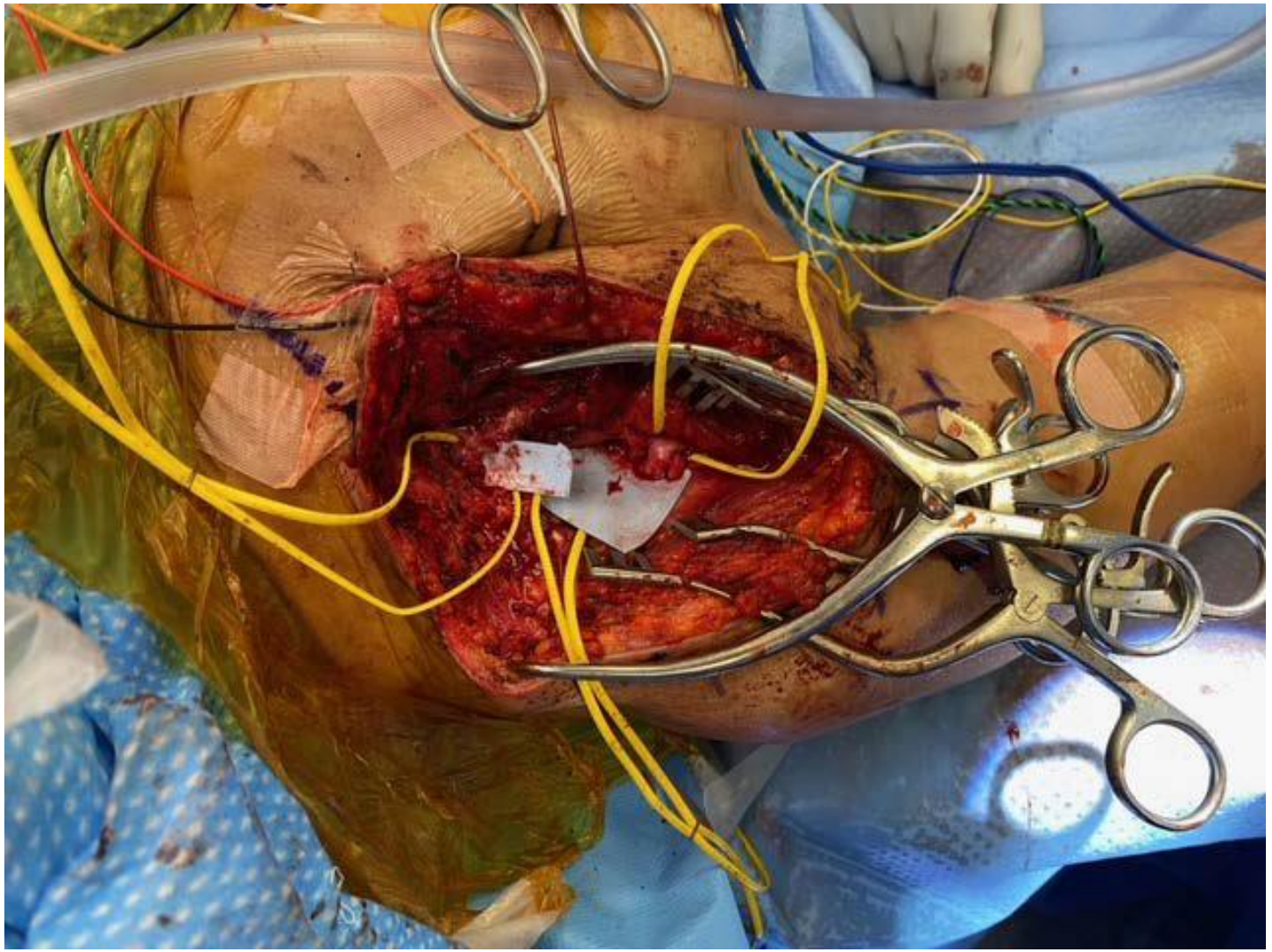
Isolated distal branches from lateral cord

Lateral cord transected proximally

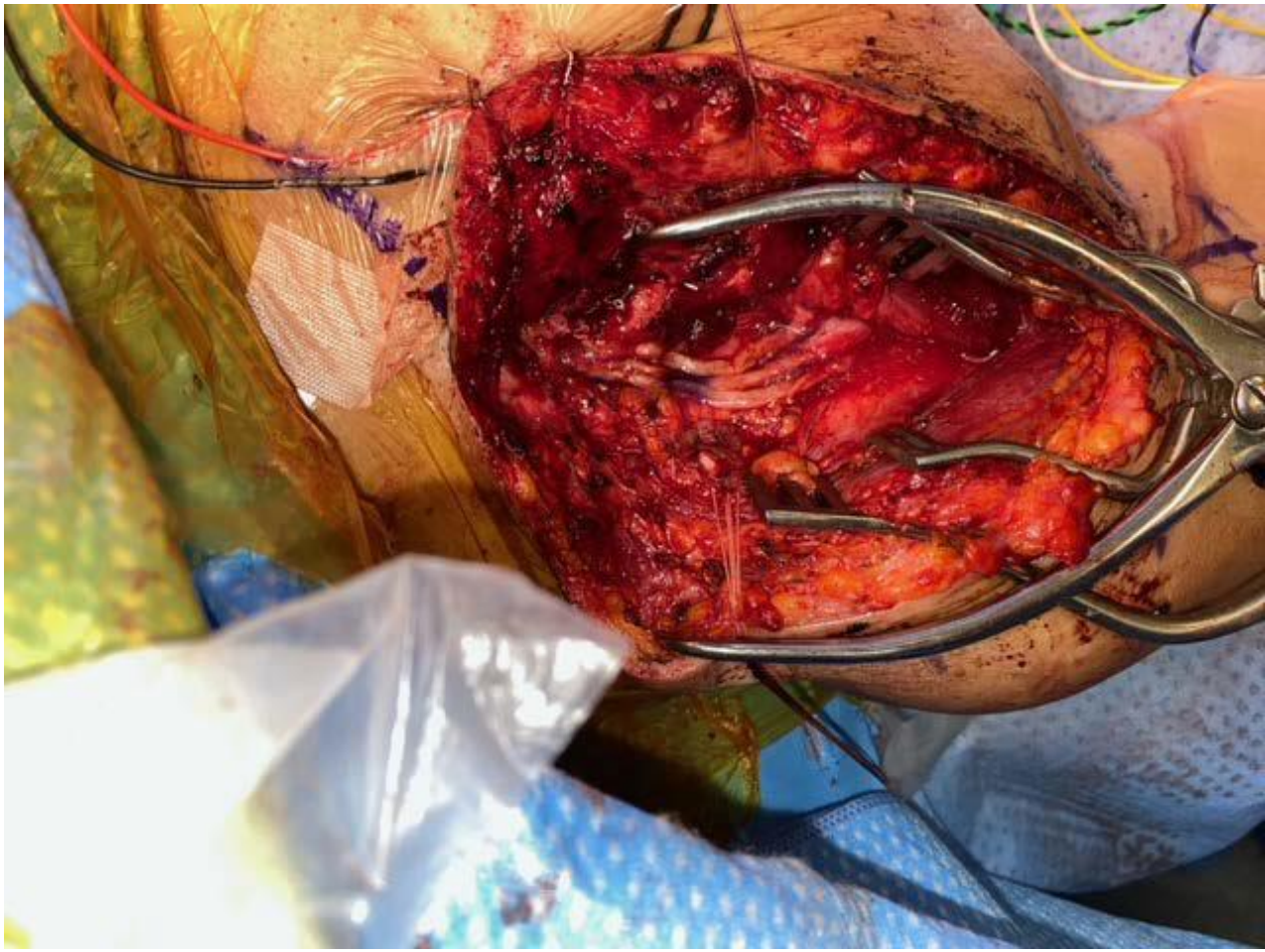




After debridement back to healthy nerve



- s/p sural cable graft from proximal lateral cord to
  - Musculocutaneous
  - LC contribution to median n
- Additional cable from proximal pectoral nerve to distal nerve branch to pec



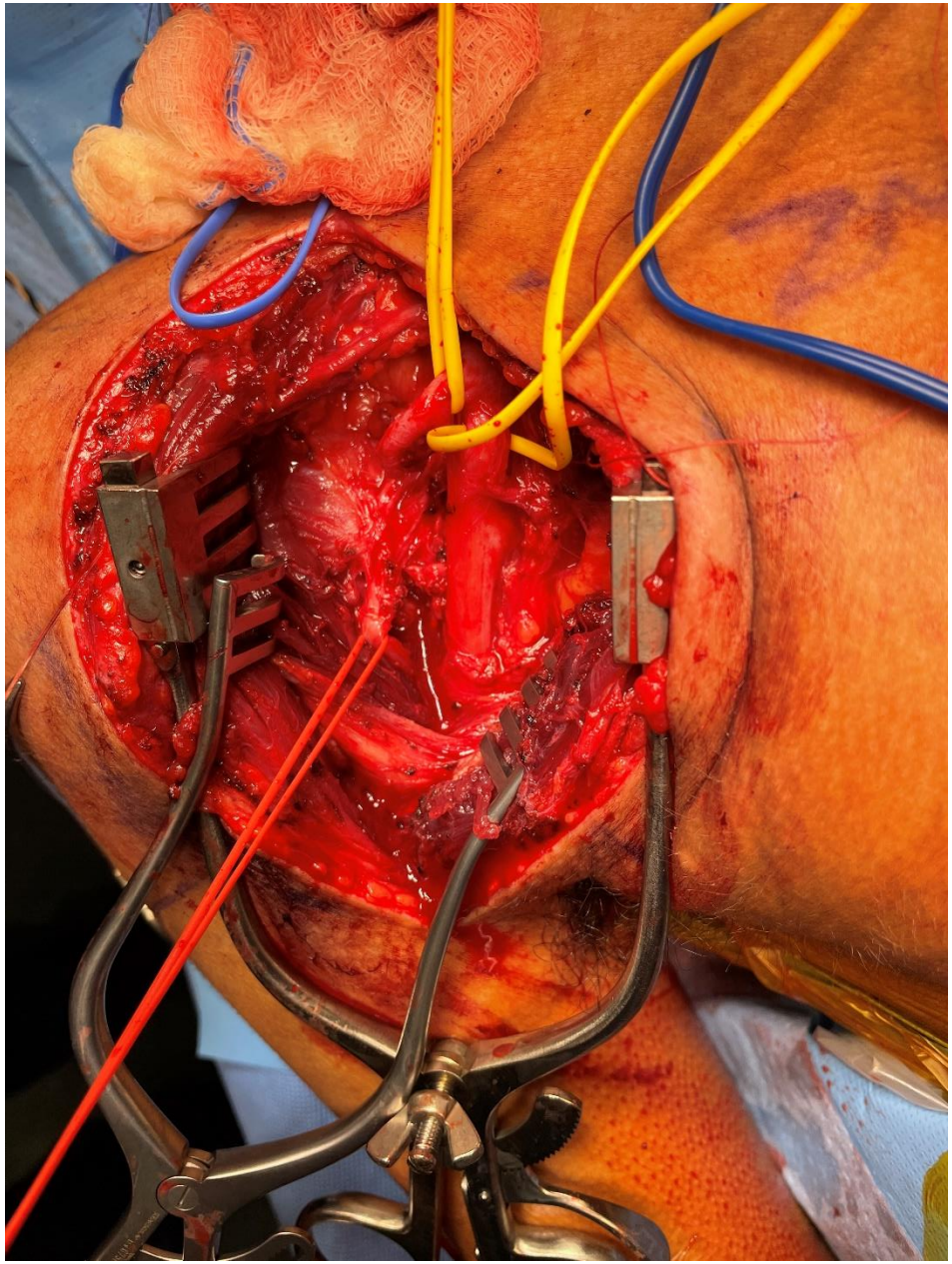
14 months postop

Case Example

- 19 y/o M, s/p thrown 78 ft from motorcycle
- Severe plexopathy; no recovery over 4 months

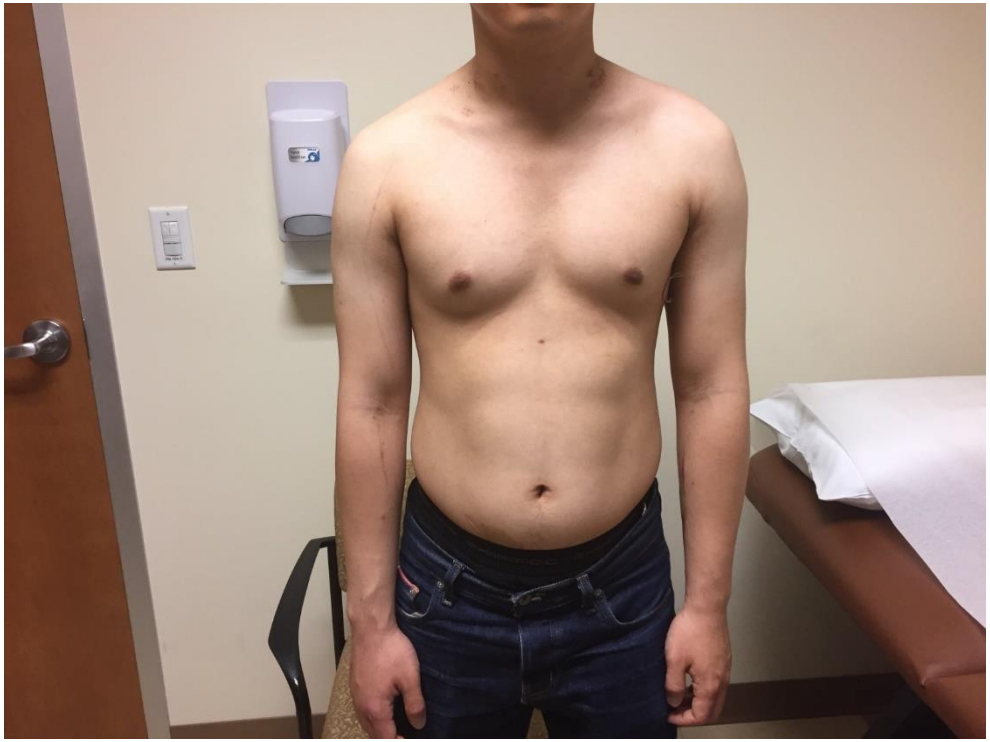
Exploration

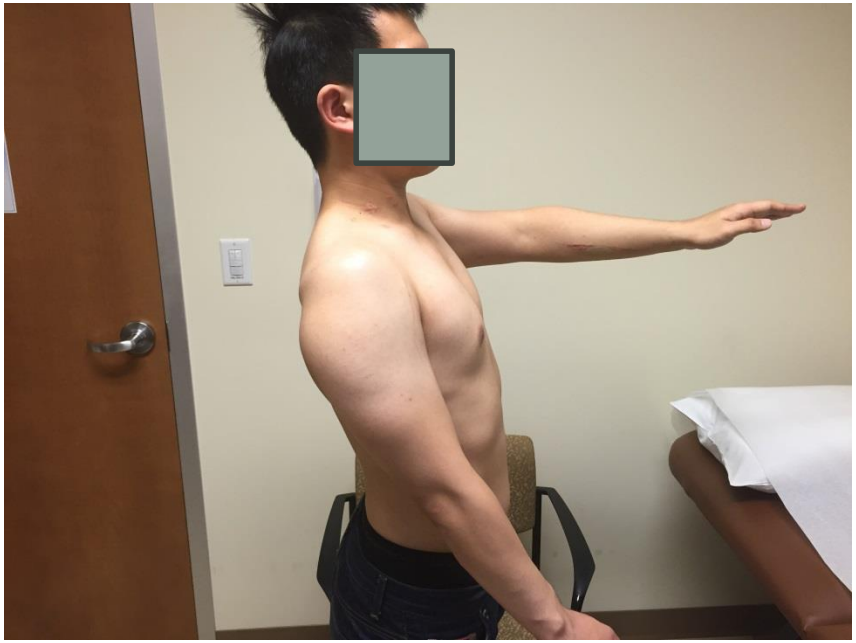
- Found upper trunk injury/avulsion
- Musculocutaneous nerve injury
- Performed 15cm cable graft from C5 to axillary x 2, C6 anterior to MCN, and C6 post to median n

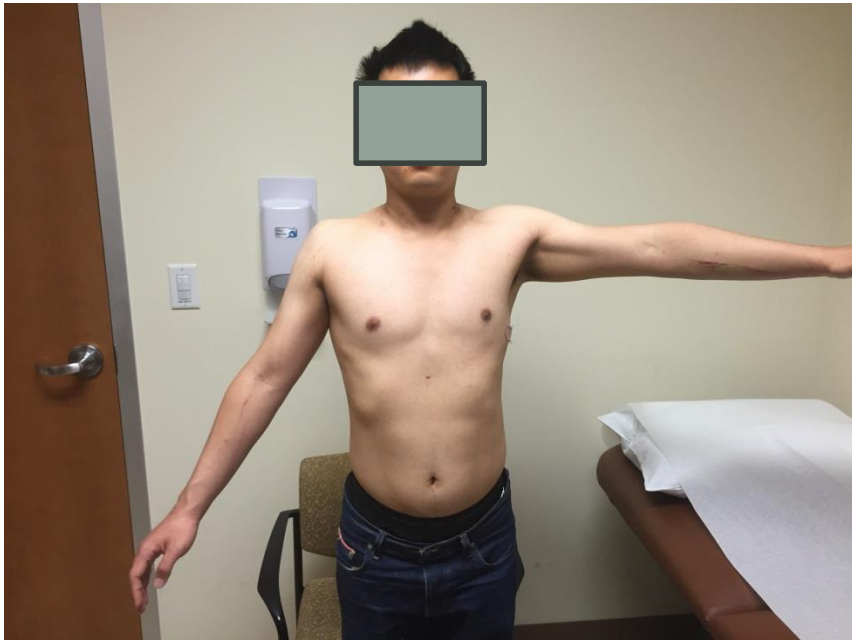


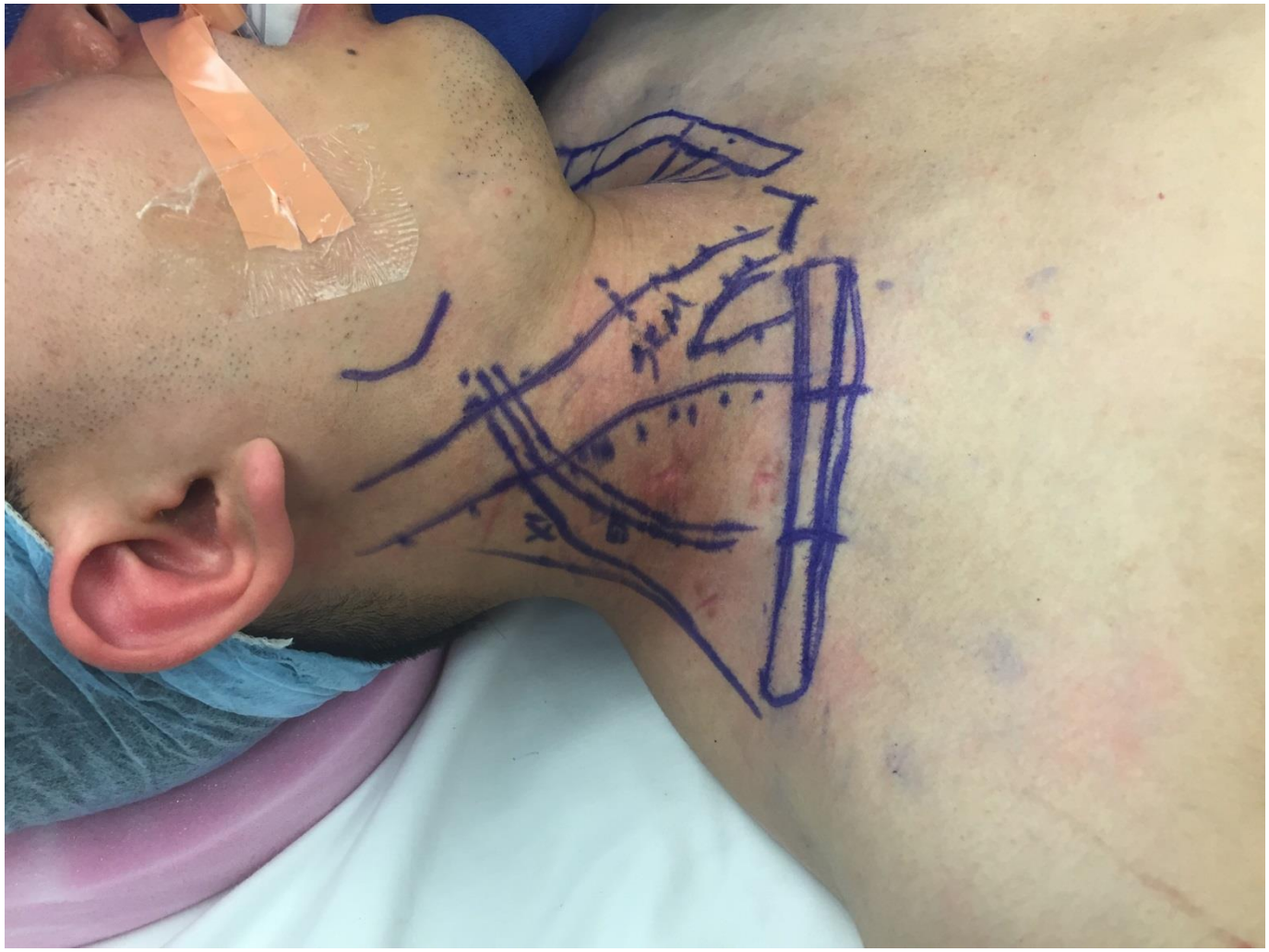
Example:

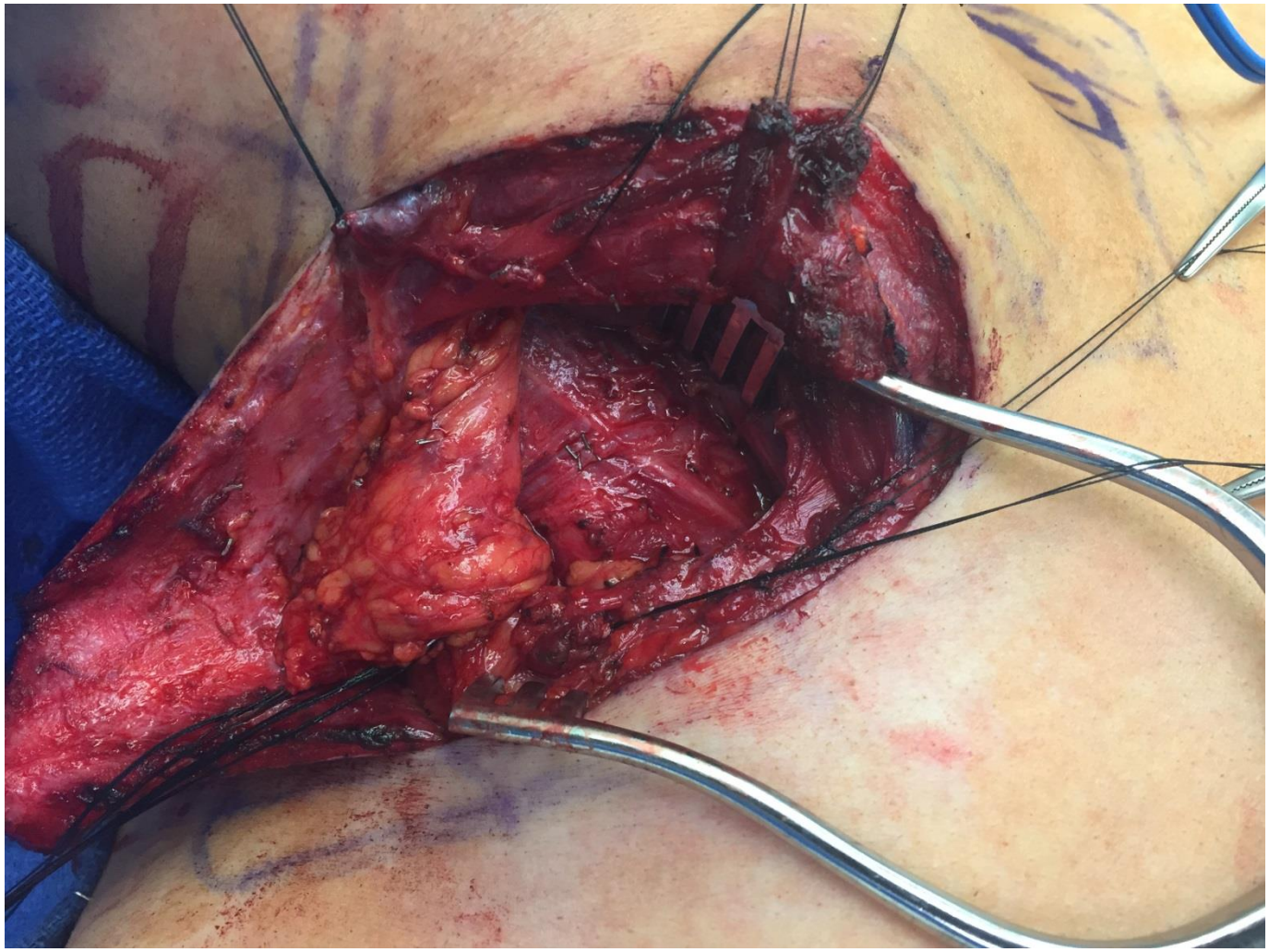
- 28 M
- b/l self-inflicted stab to neck

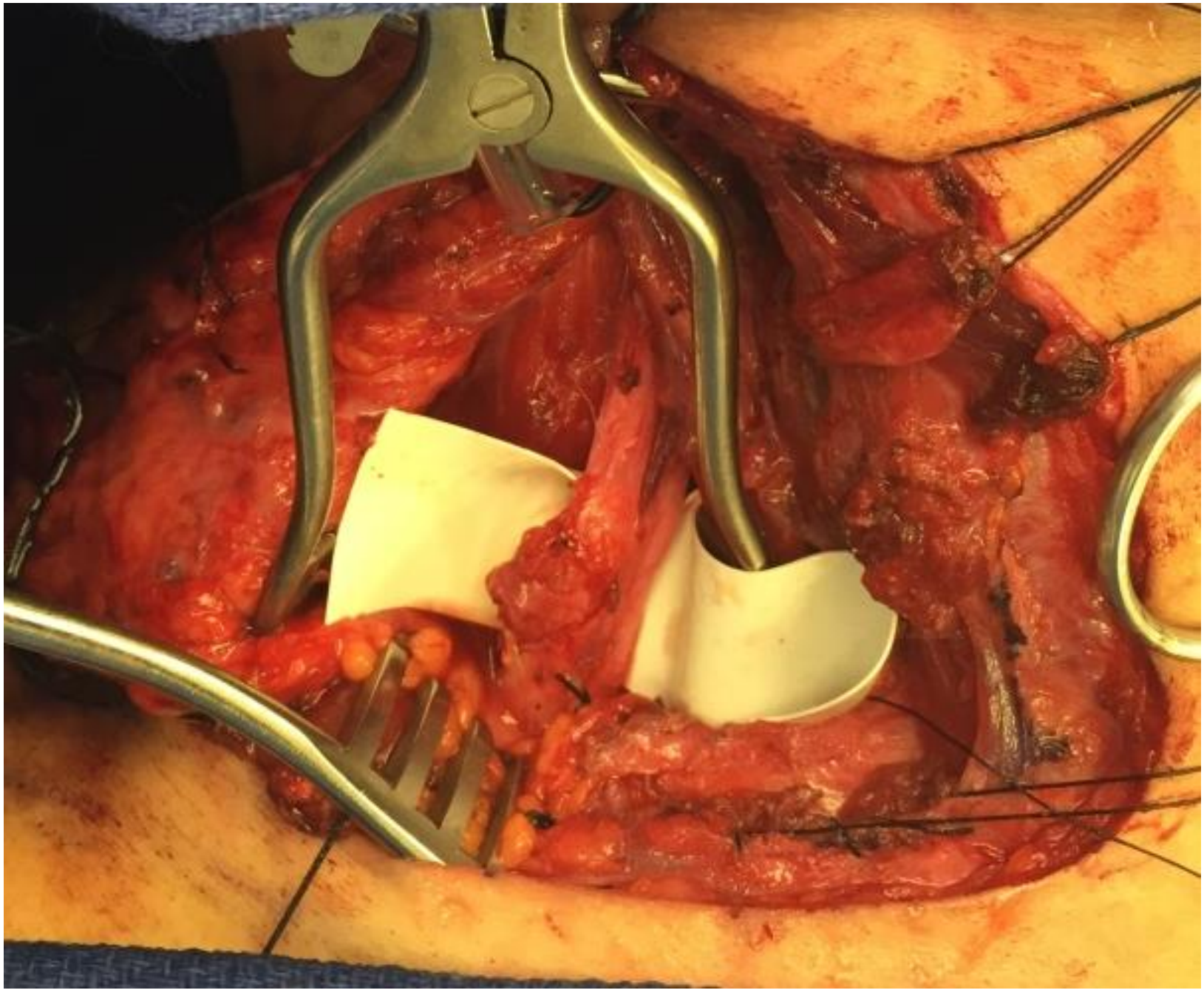


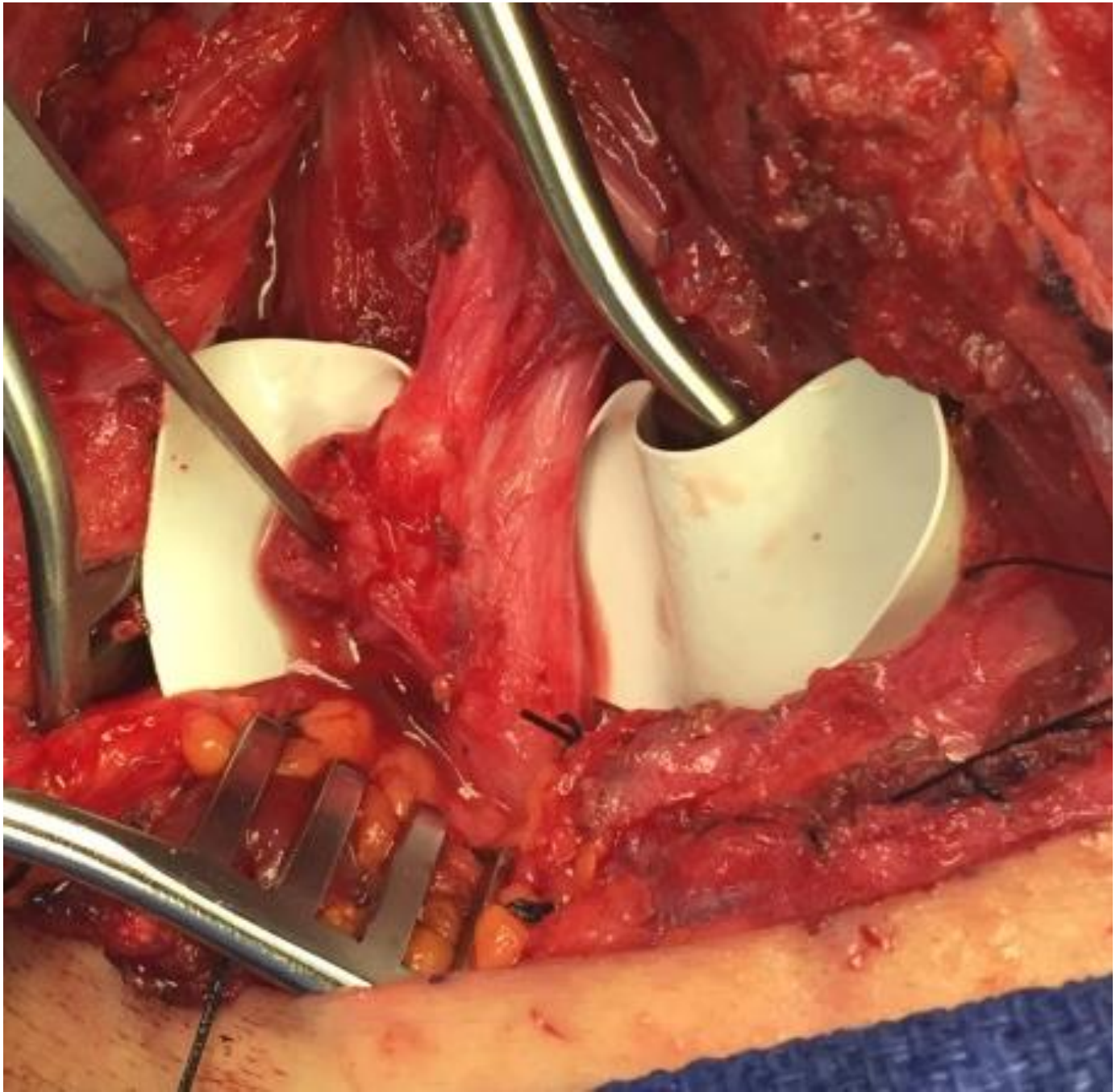


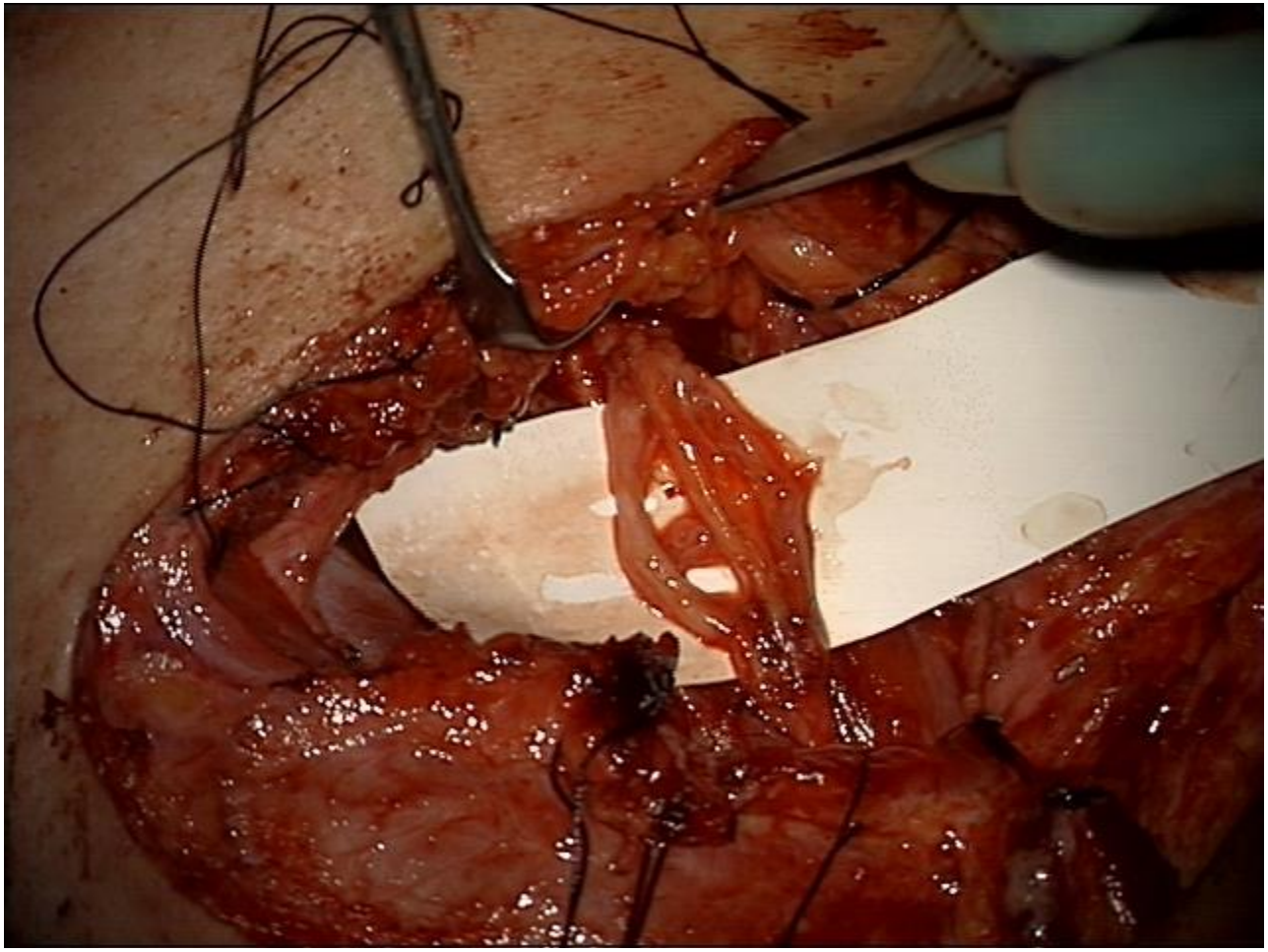


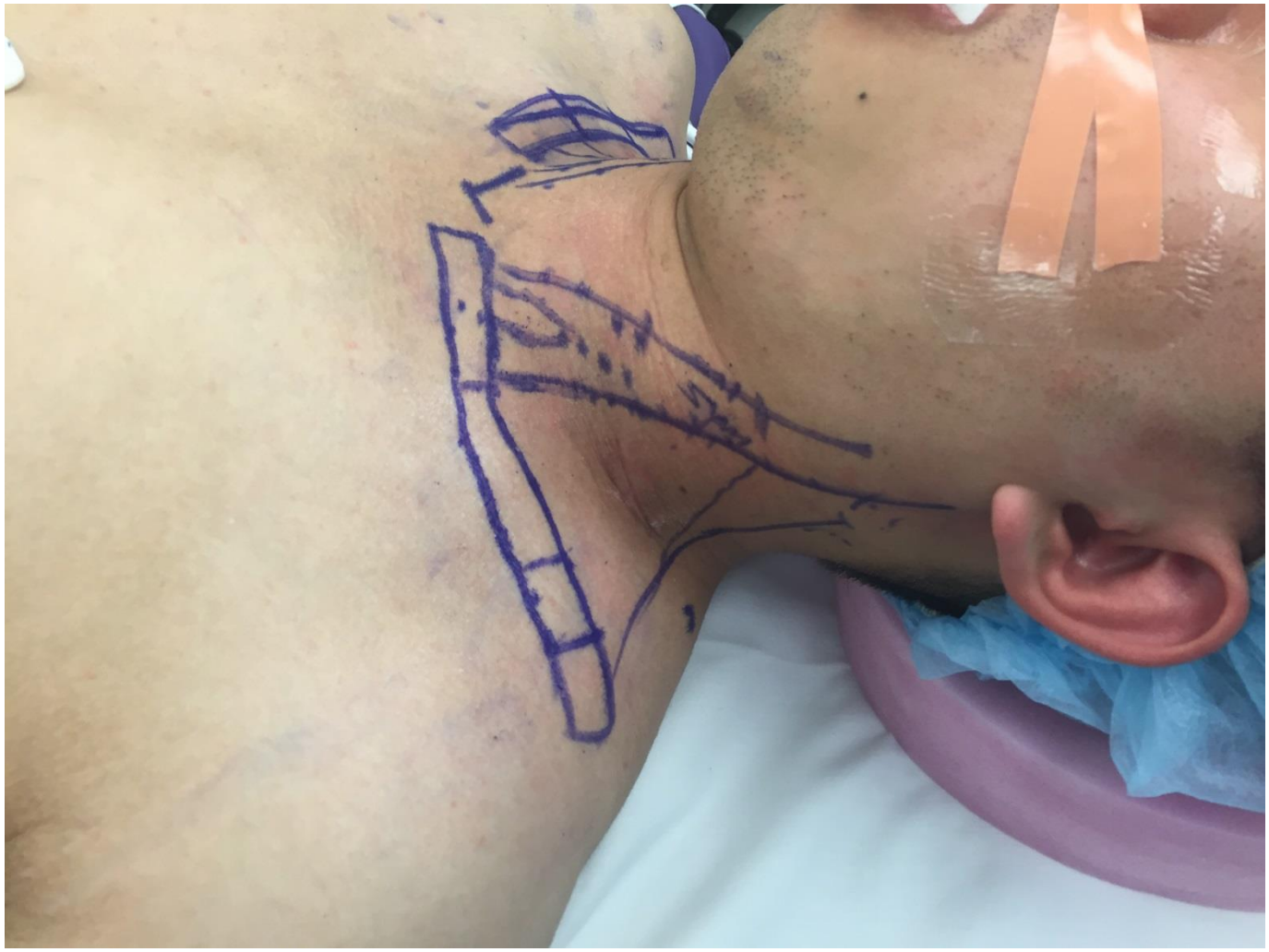


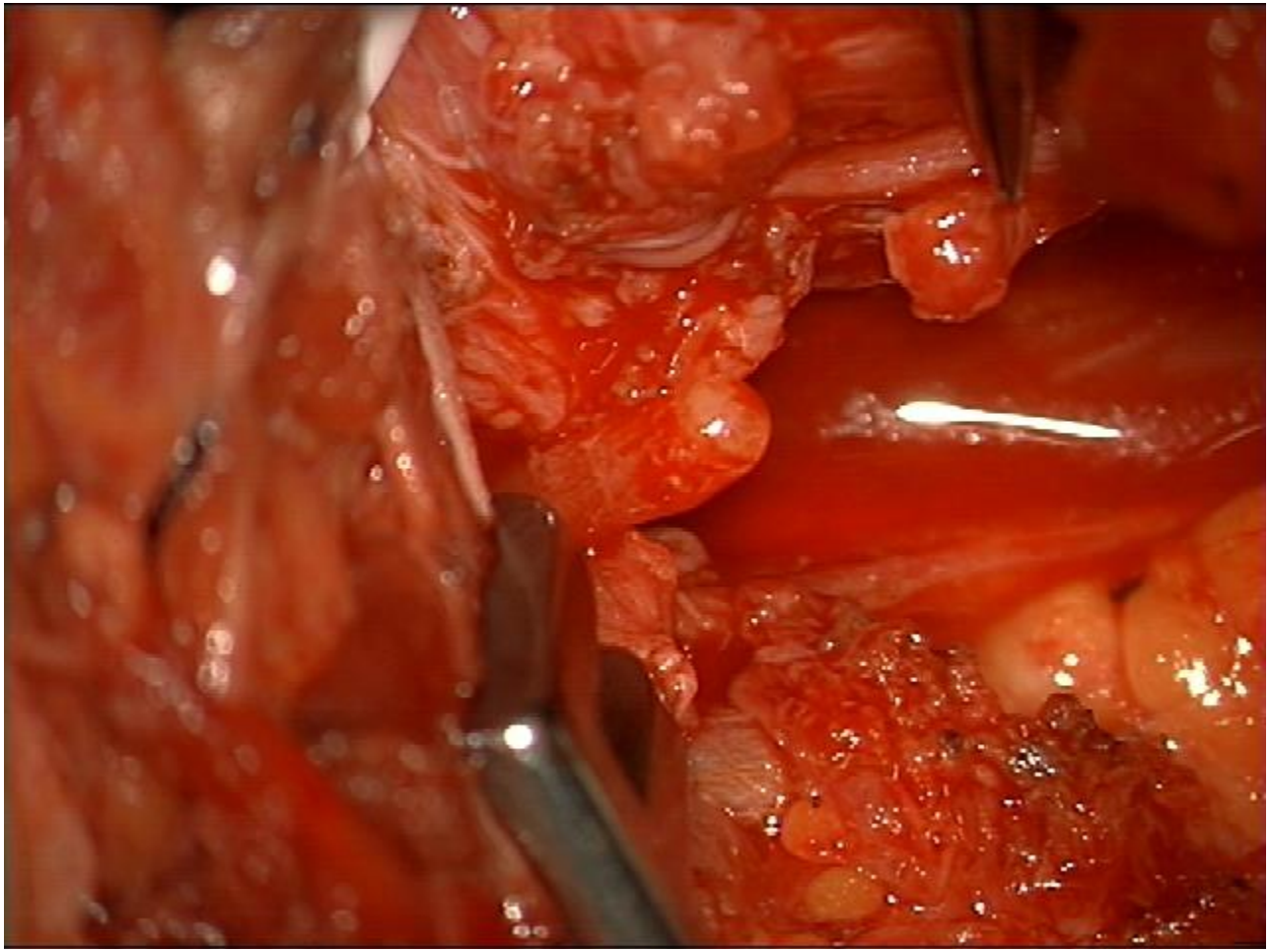


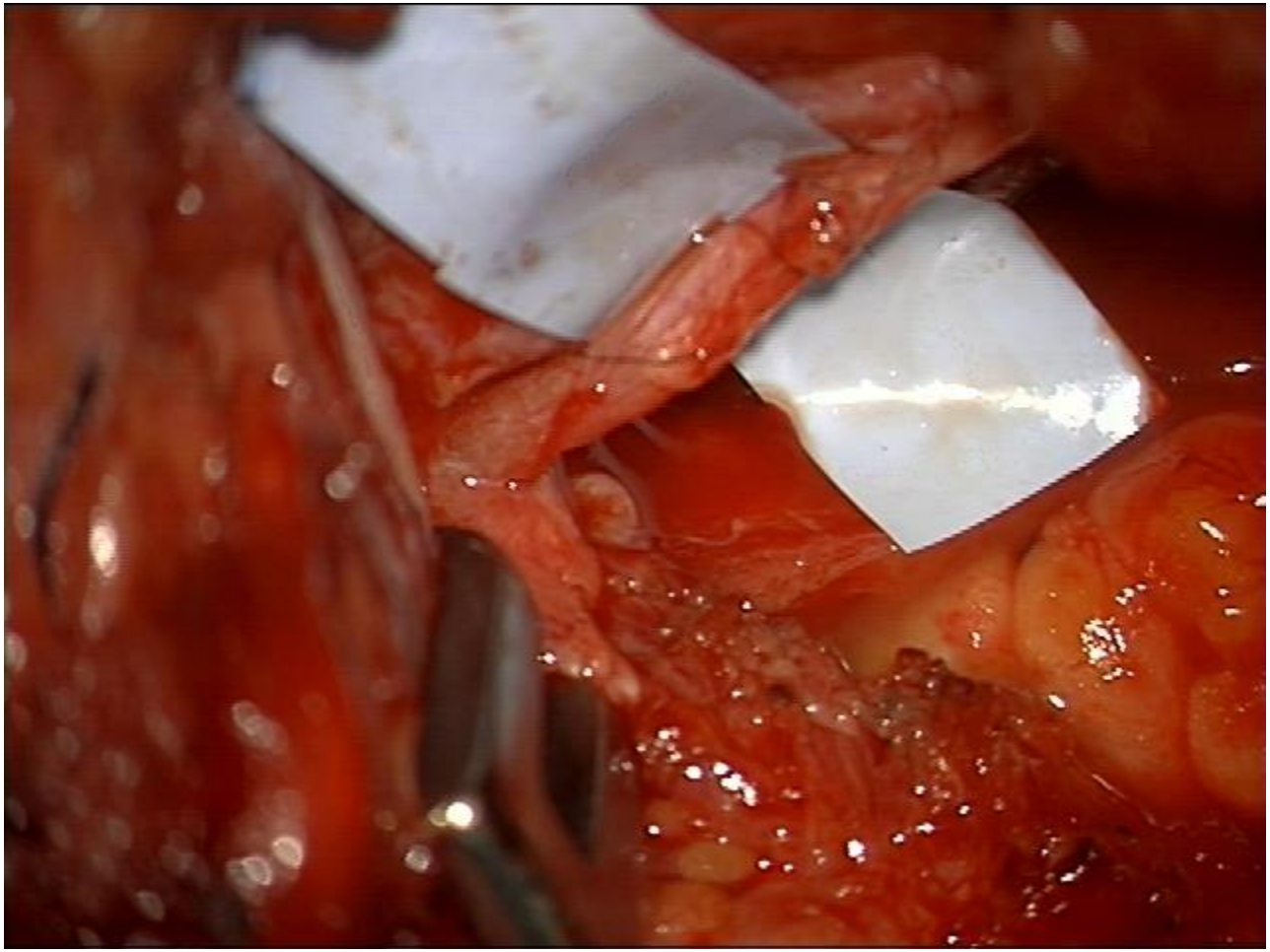




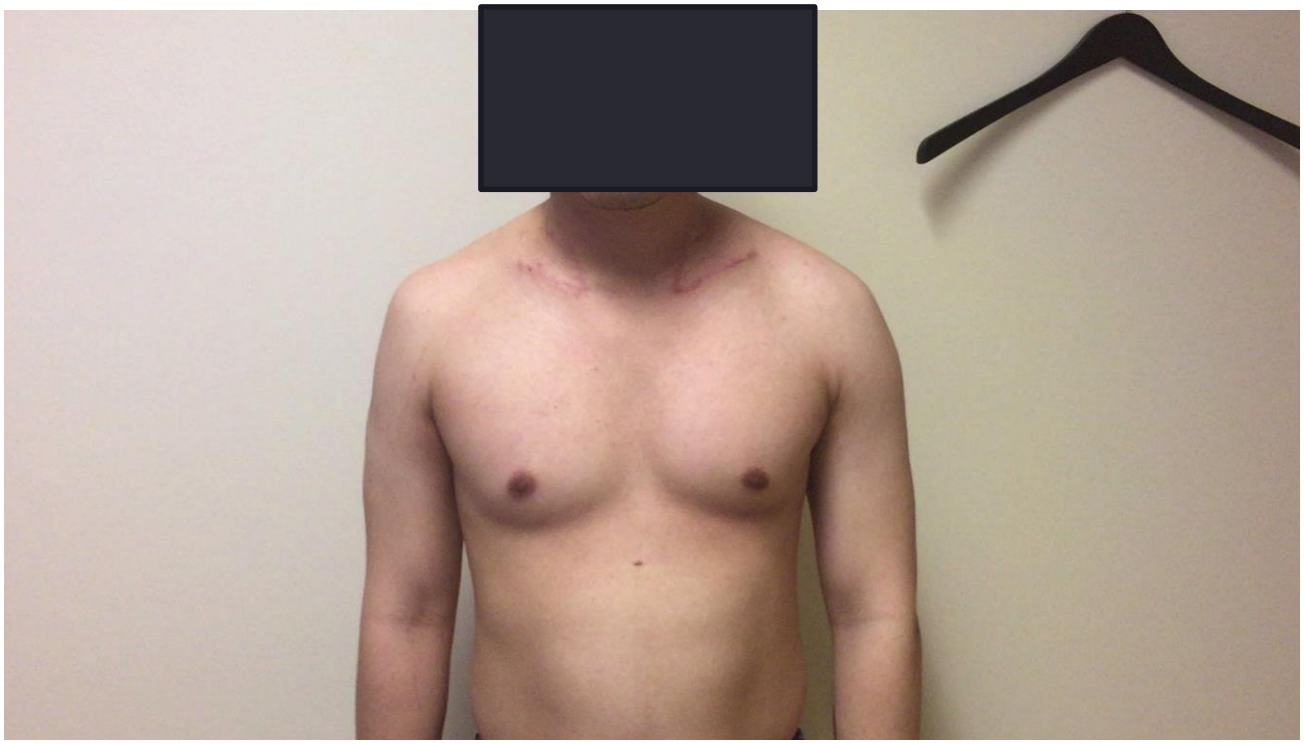




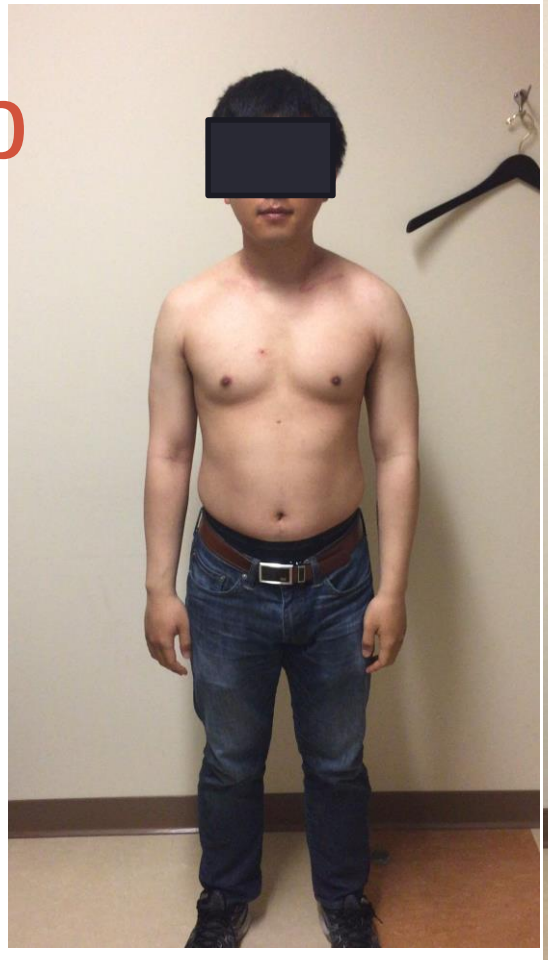




4 months postop



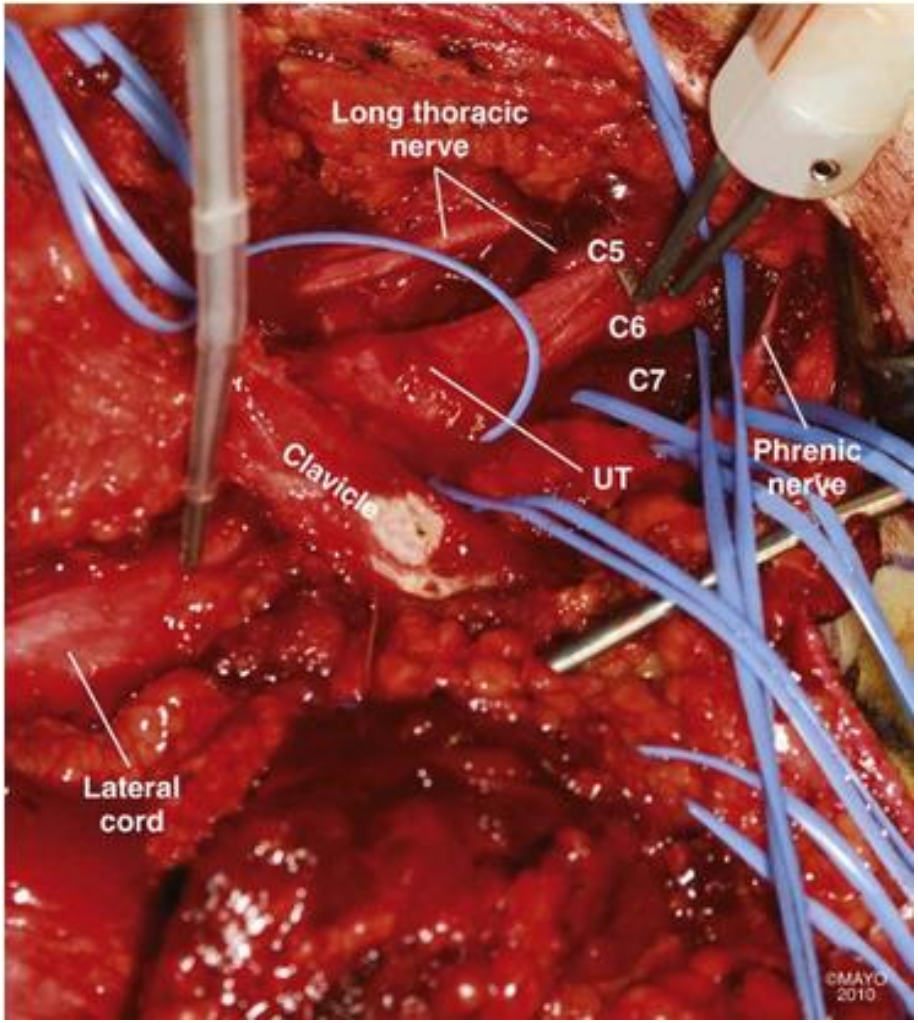
7 months postop



Intraoperative Assessment

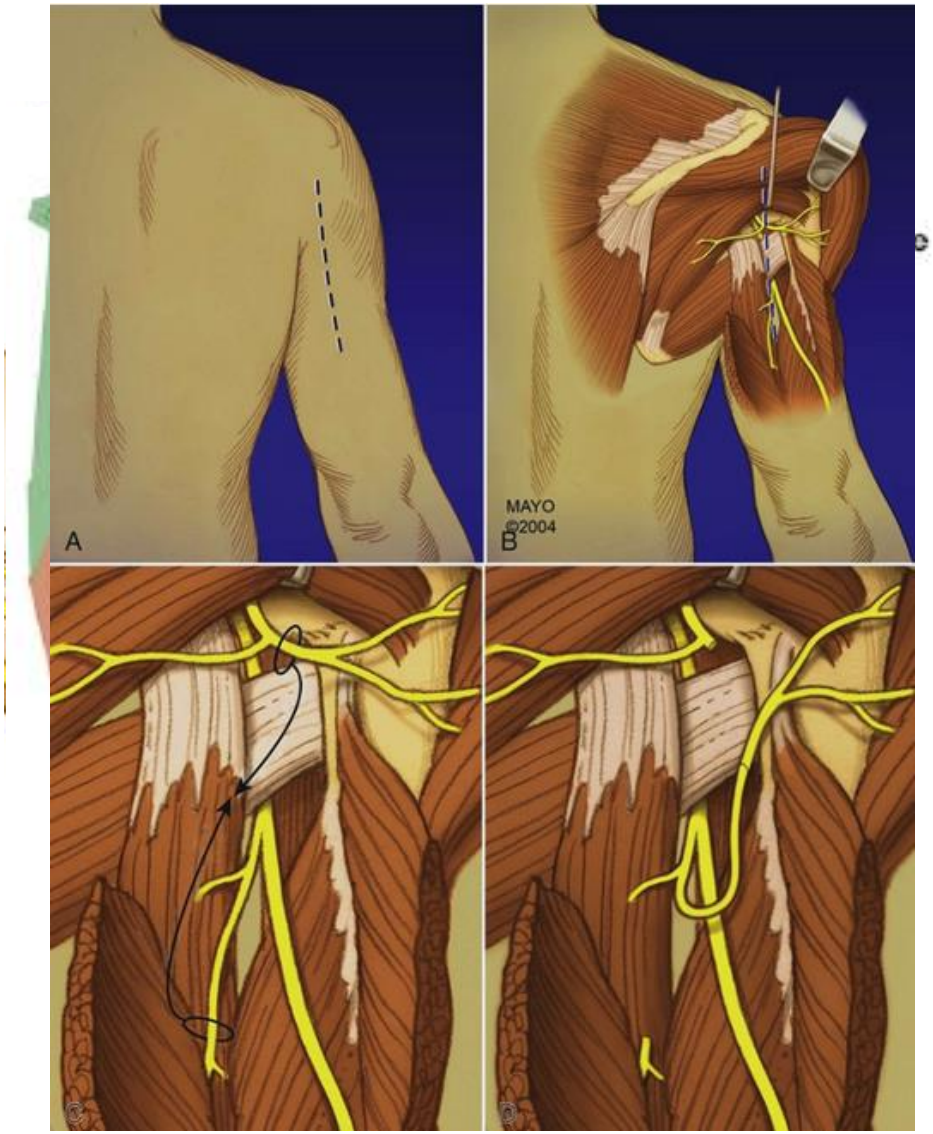
- Somatosensory Evoked Potentials (SSEPs)
- Motor Evoked Potentials (MEPs)
- Nerve Action Potentials (NAPs)

- Choline acetyltransferase activity (CAT)
- Frozen sections



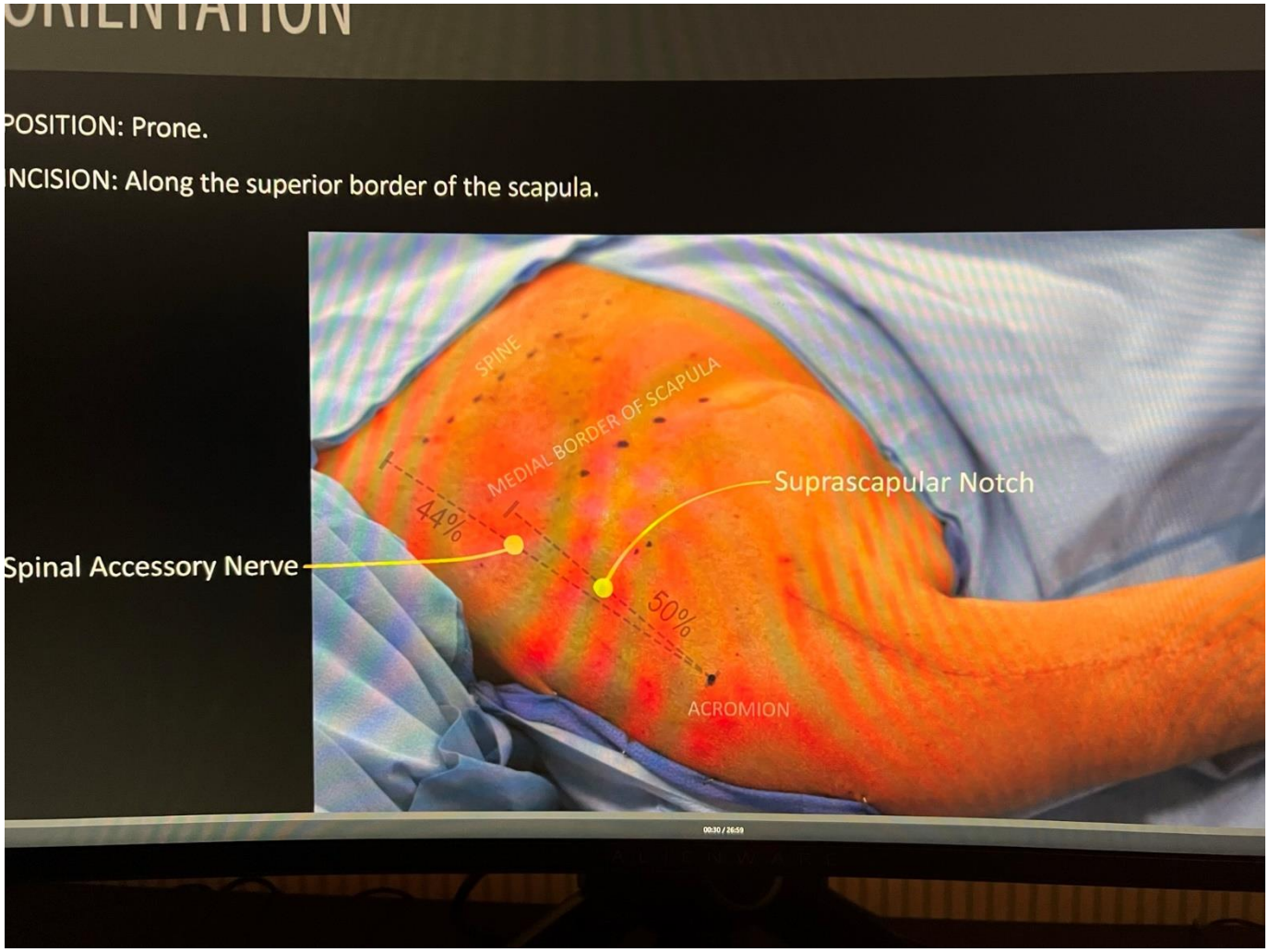
Strategies for specific injuries: C5-6

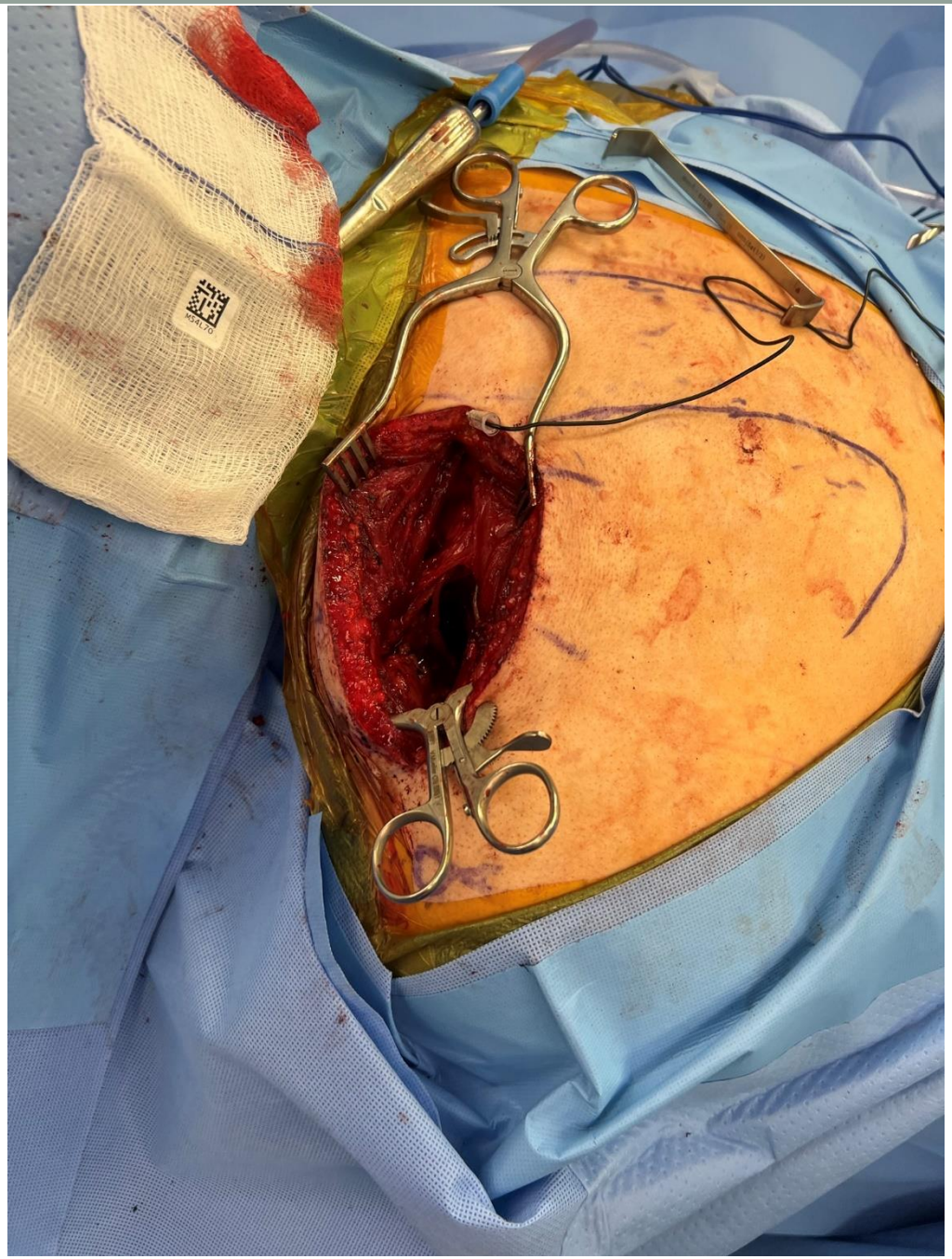
- Exploration
- Elbow flexion
  - Oberlin transfer
- Shoulder function
  - Graft from C5 stump if available
  - Cr XI to suprascapular transfer
  - Triceps branch to axillary nerve transfer

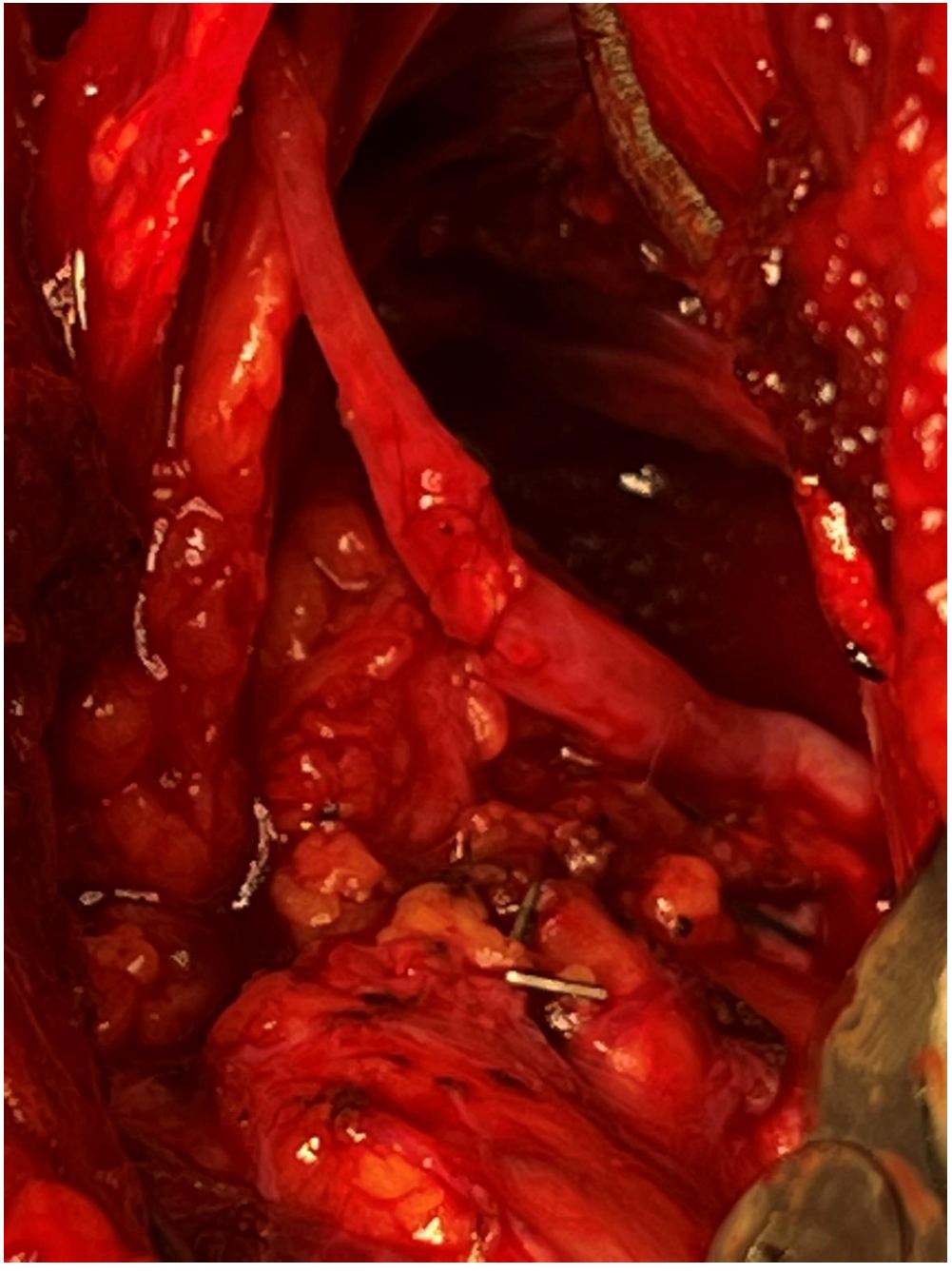


Case Example

- 25 M biker hit by car
- Underwent T4-11 spine fusion, ORIF clavicle L, mandible fxr repair at ZSFG
- Severe L plexopathy; 0/5 delt/bicep; 4/5 function distally
- Plexus explored; no targets for grafting


ORIENTATION
POSITION: Prone.
INCISION: Along the superior border of the scapula.
SPINE
MEDIAL BORDER OF SCAPULA
44%
50%
Suprascapular Notch
Spinal Accessory Nerve
ACROMION
00:30 / 26:59

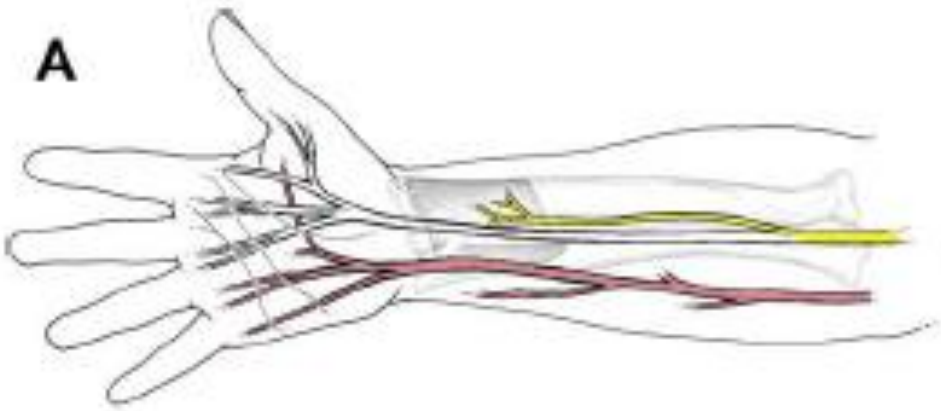


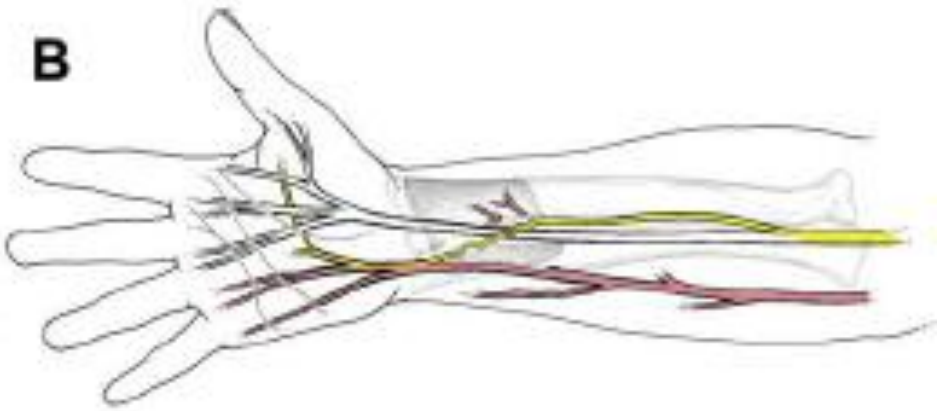


- One month later received received
  - Triceps to axillary nerve transfer
  - Double fascicular transfer LUE

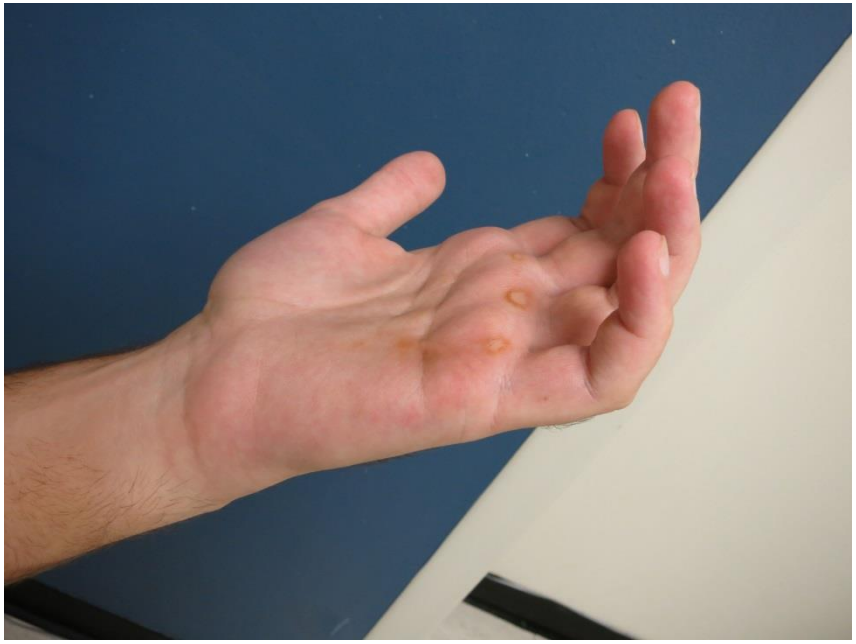
Strategies for specific injuries: C8-T1

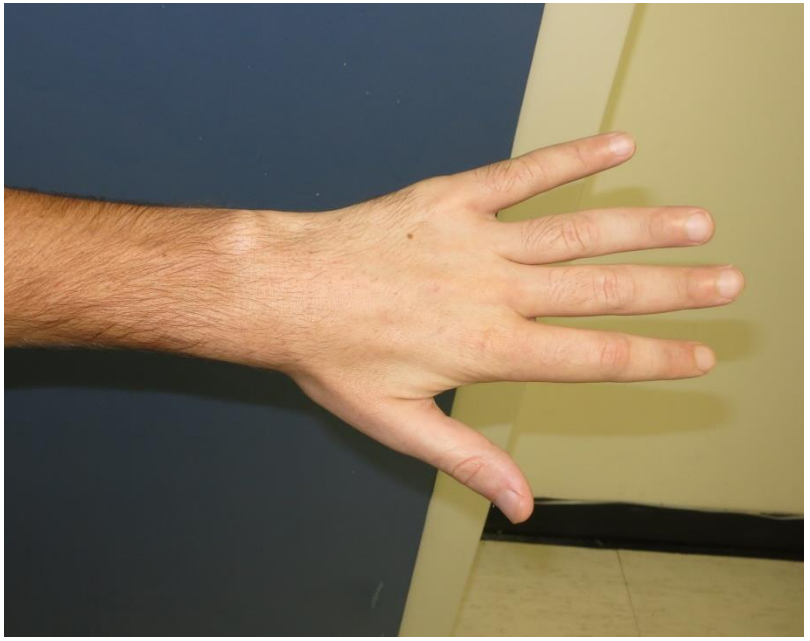
- Controversial
- Distal nerve transfers
- Early or delayed tendon transfers

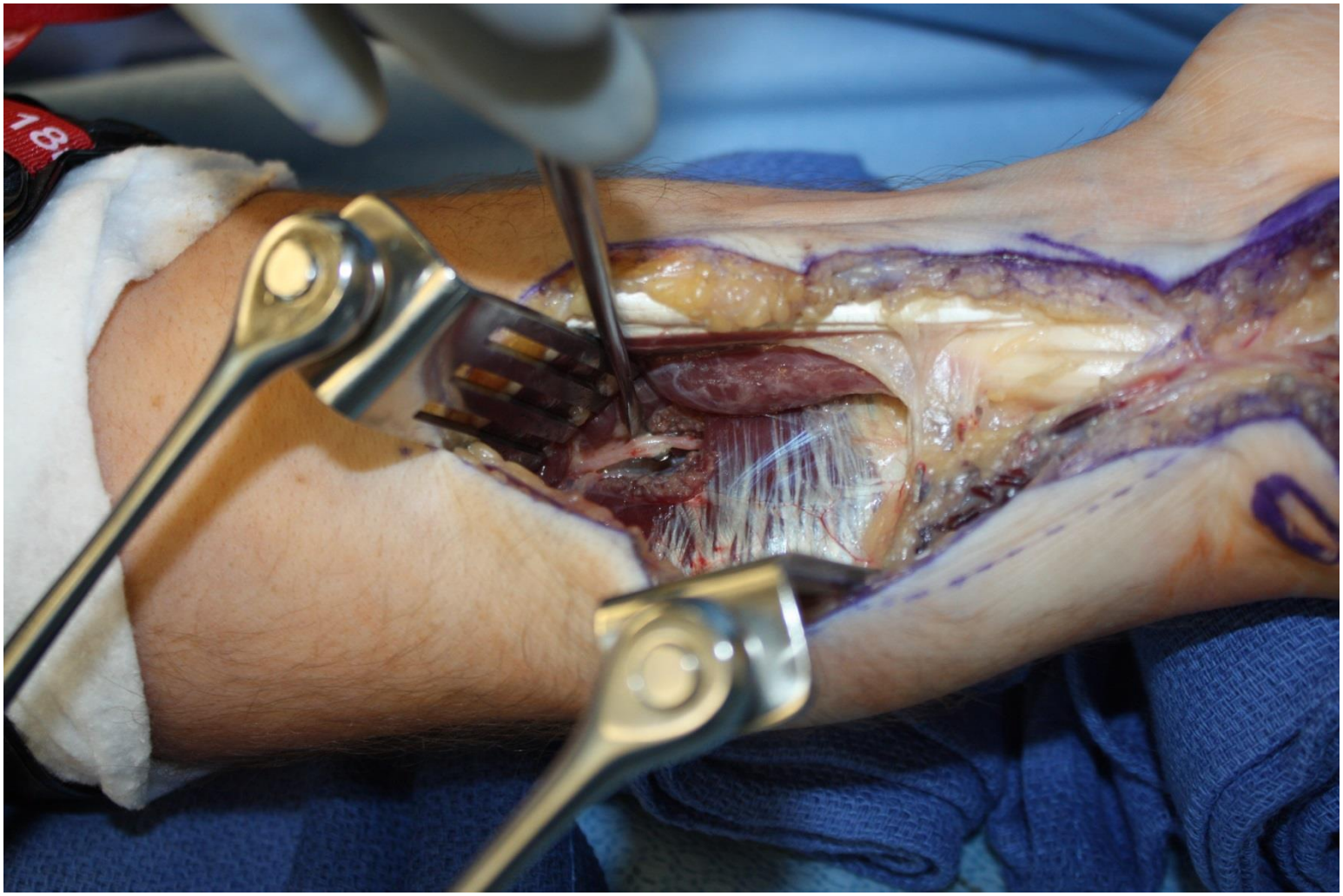


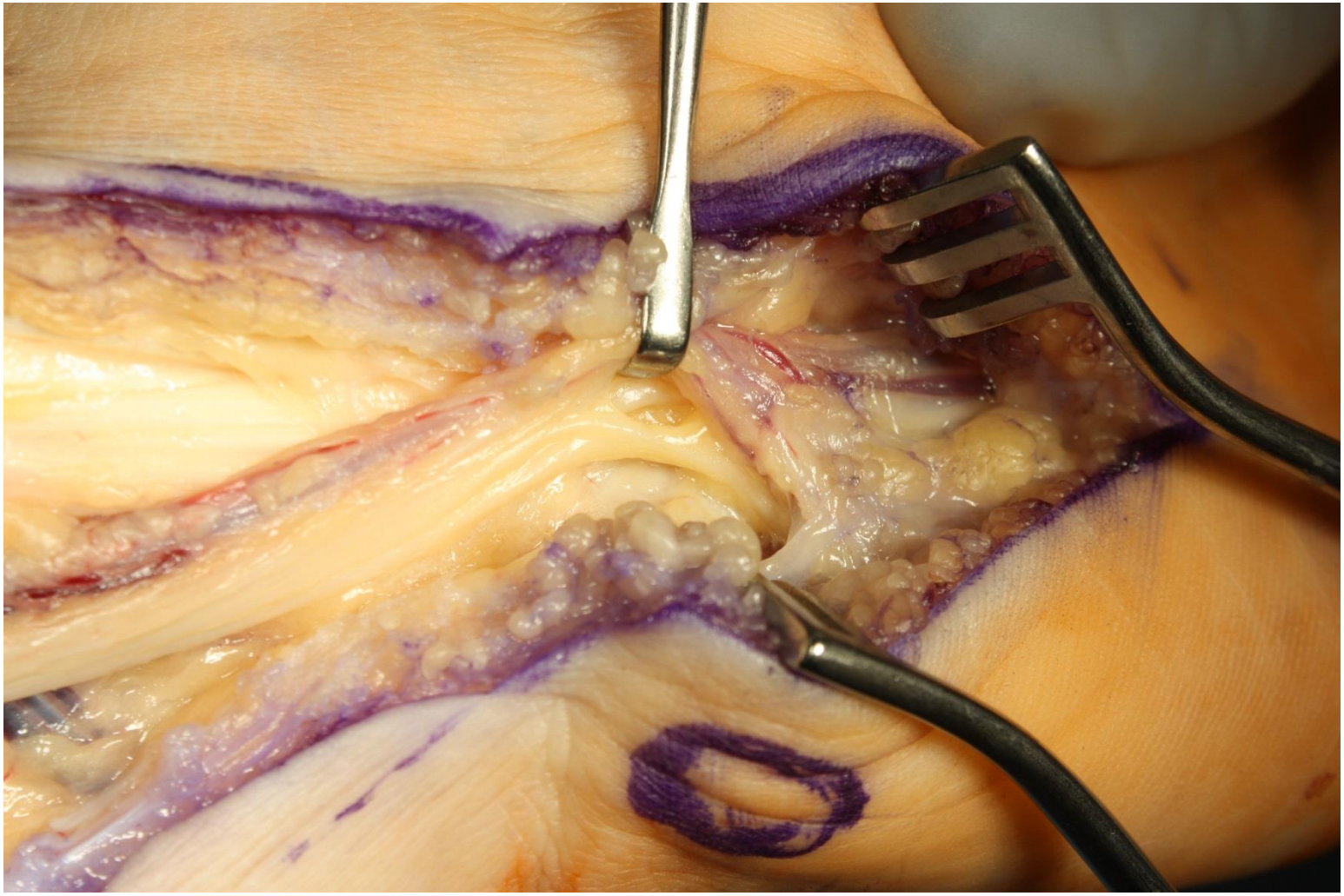


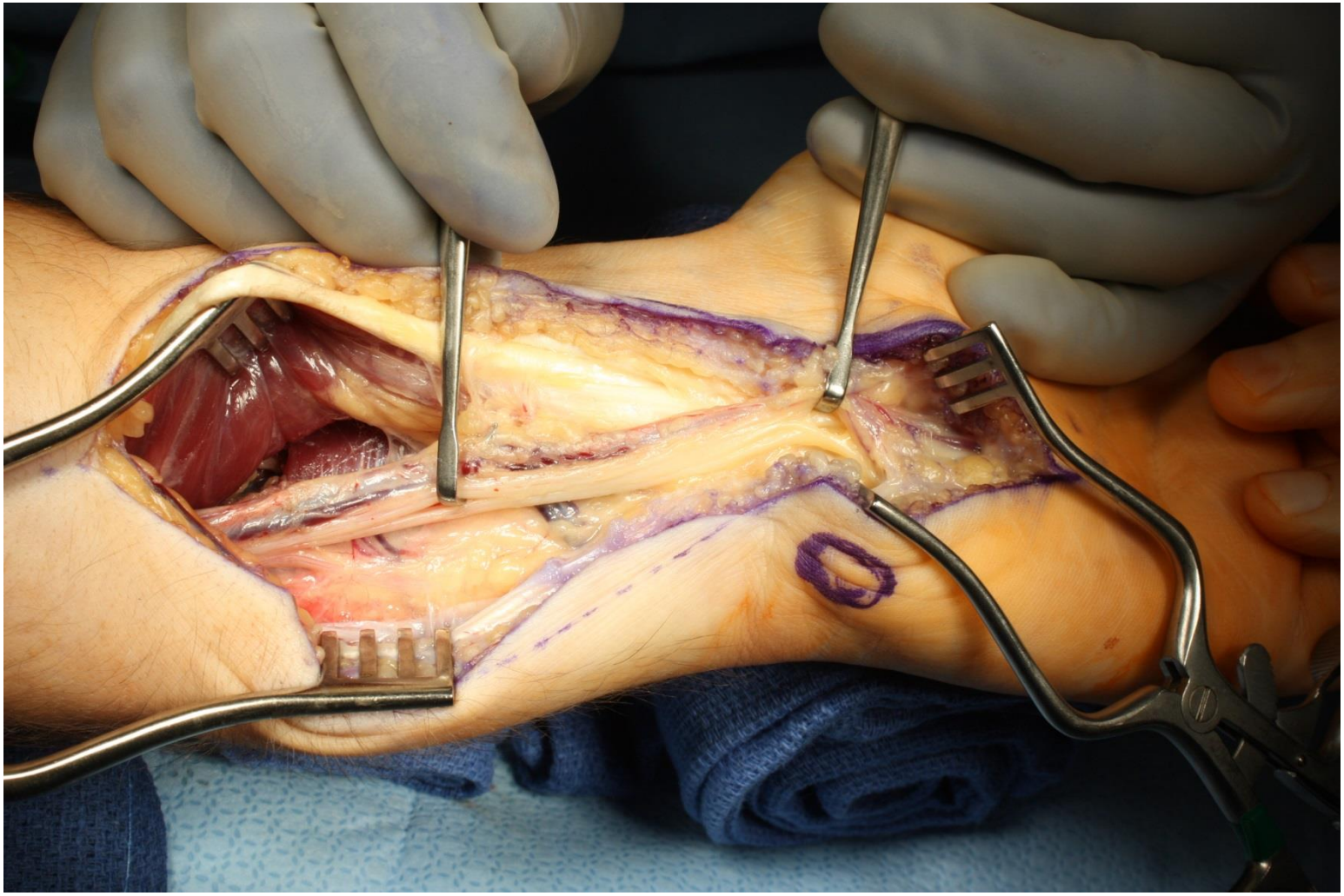
Example

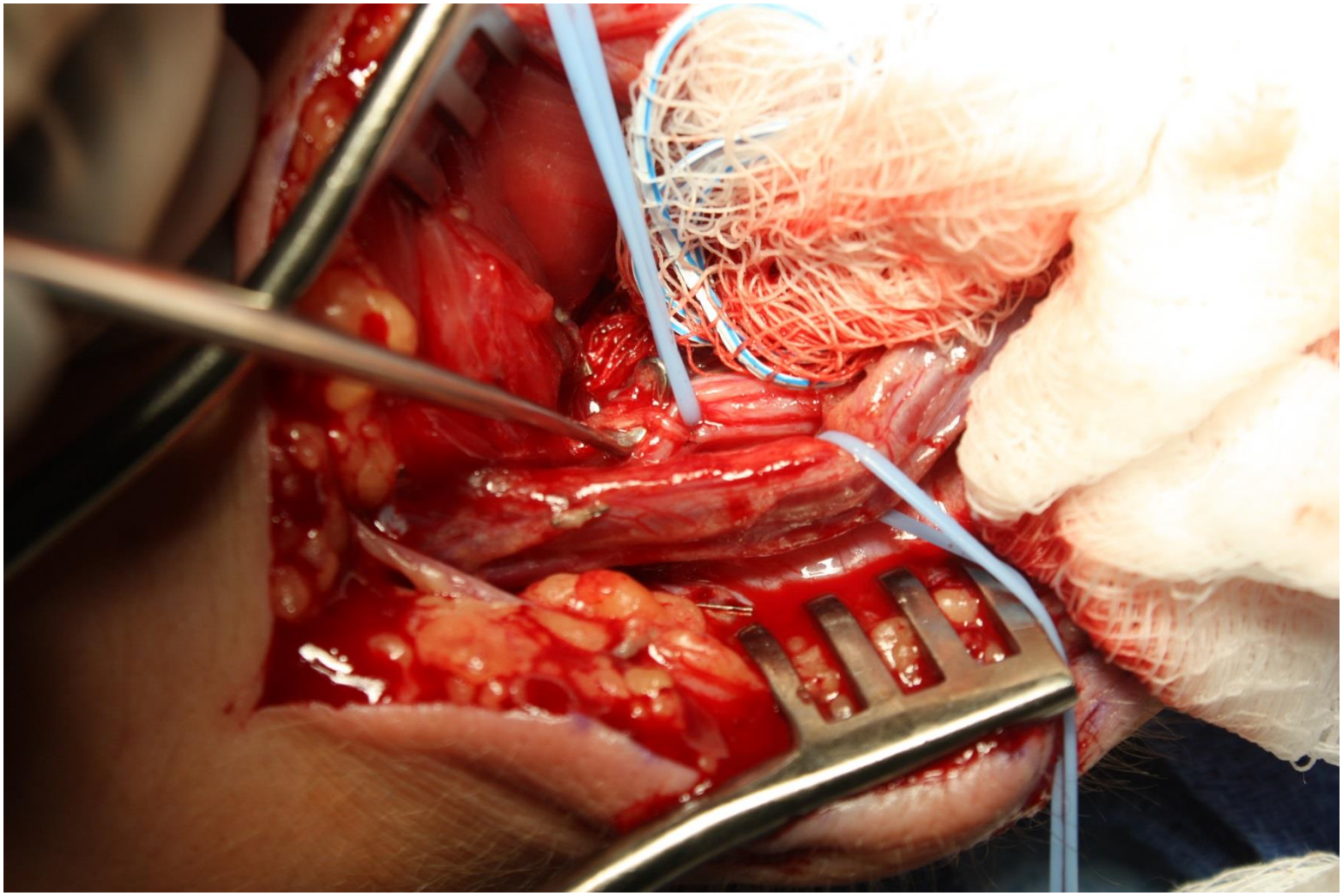






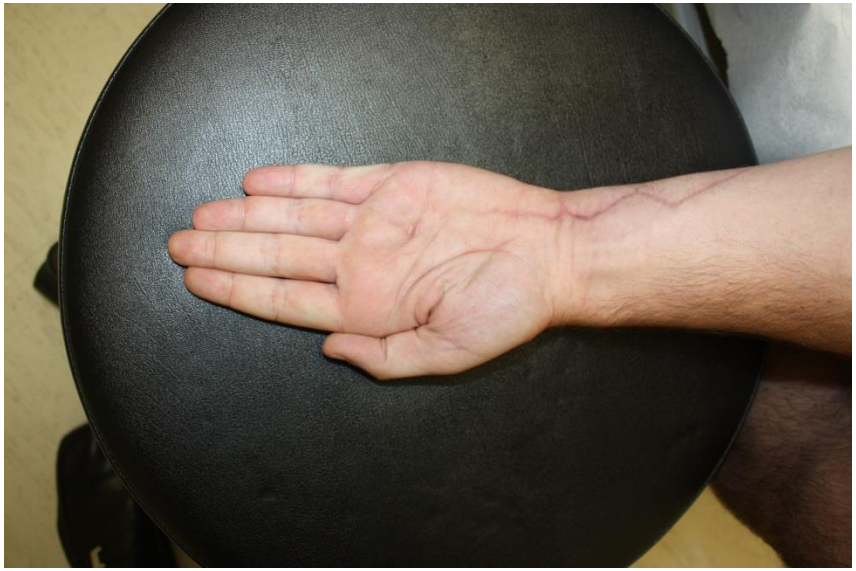


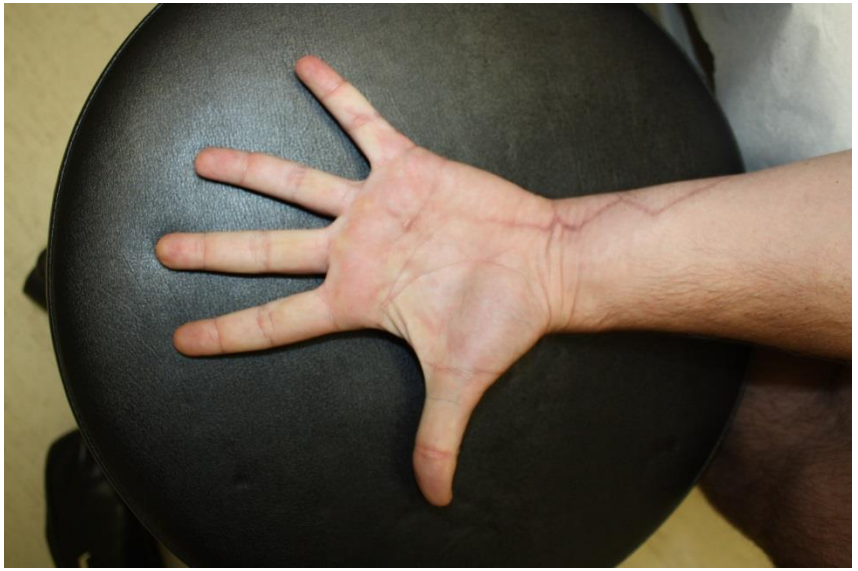


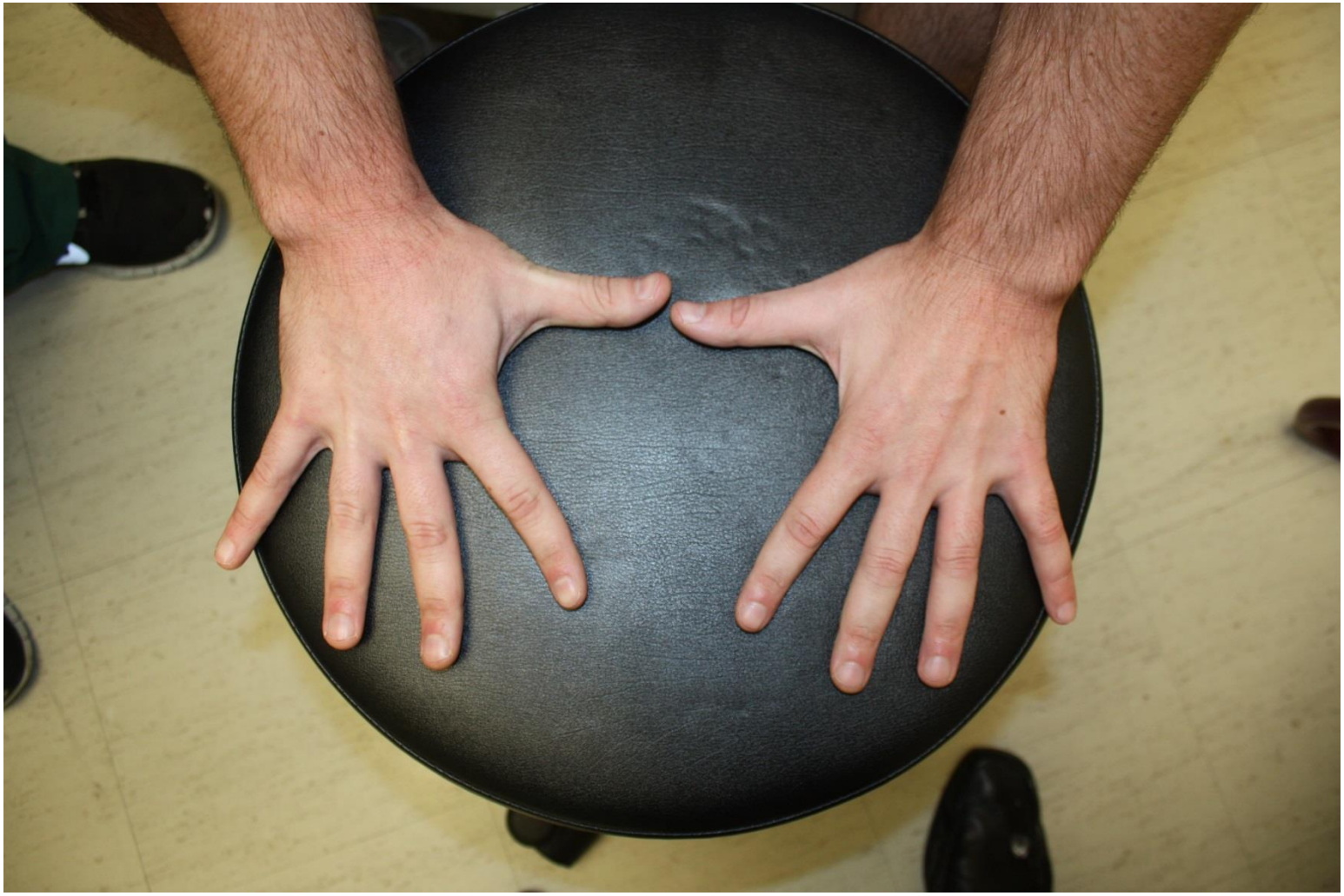


6 weeks postop

4 months postop







The Pan-Plexus Injury

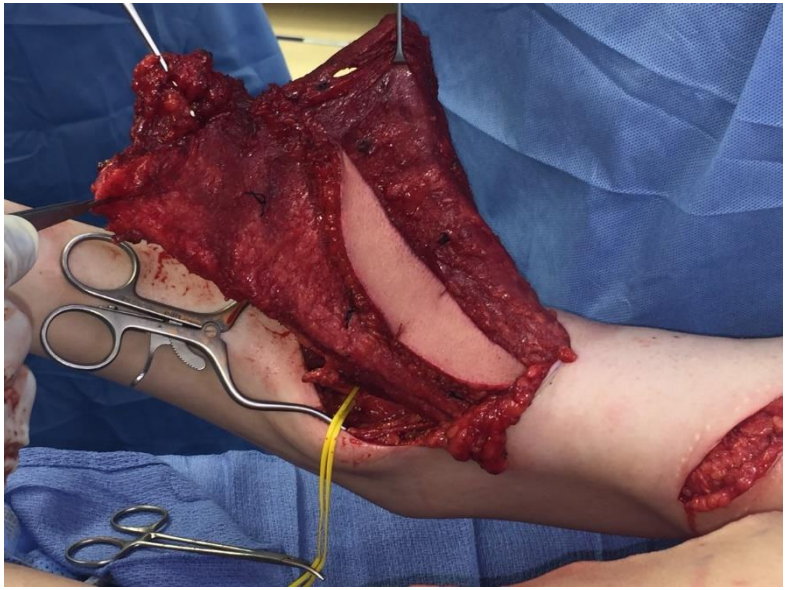
- Available donor nerve
  - Intact proximal stump
  - Intercostals
  - Spinal accessory
  - Phrenic nerve
  - Contralateral C7
- Elbow flexion
  - intercostal transfer to MC, +/- free functioning muscle transfer
- Shoulder stability, abduction, ext rotation
  - Cr. XI to SS
  - Secondary reconstruction options
    - Lower trapezius transfer

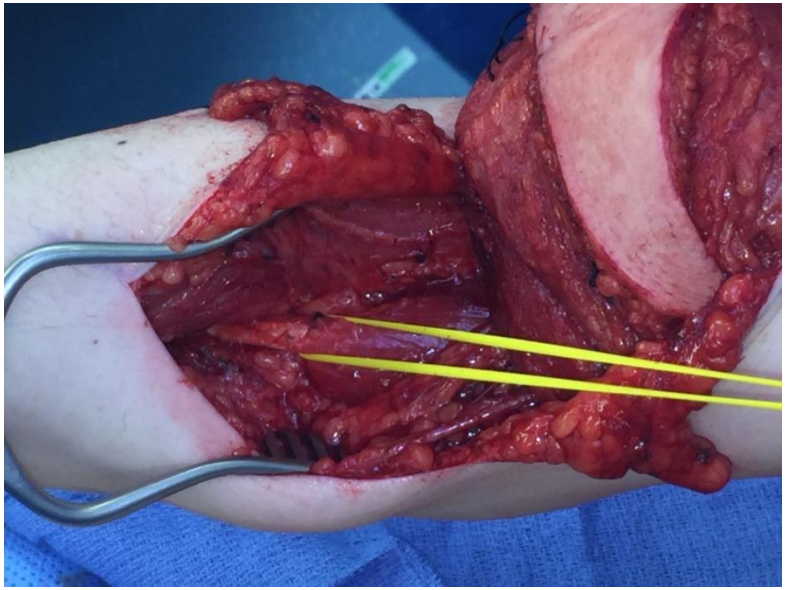
Options for secondary/late reconstruction

- Latissimus functional muscle transfer
- Free functioning muscle transfers (gracilis)
- Tendon transfers
- Steindler flexorplasty
- Pec major transfer
- Triceps transfer

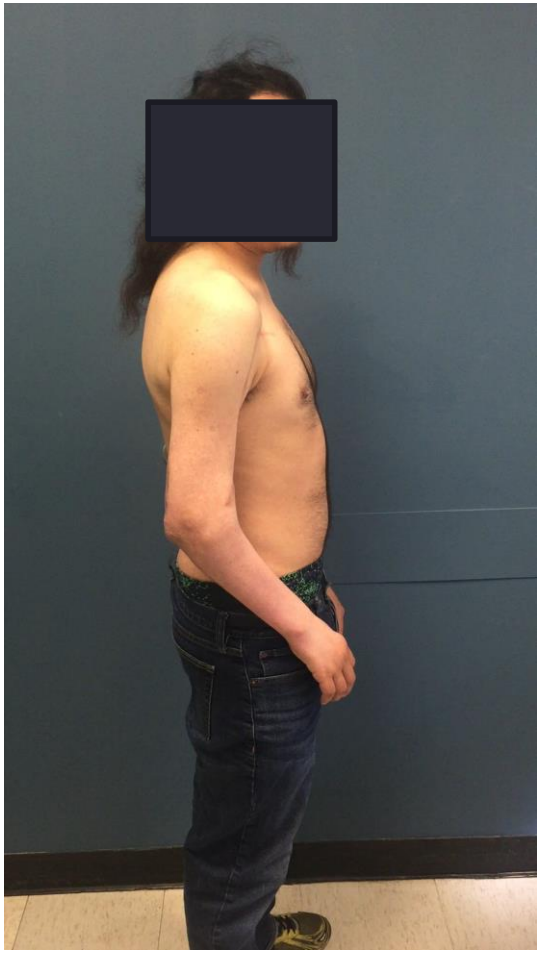
Long-standing Brachial Plexopathy

26 y/o M, s/p stab wound to right shoulder with vascular injury



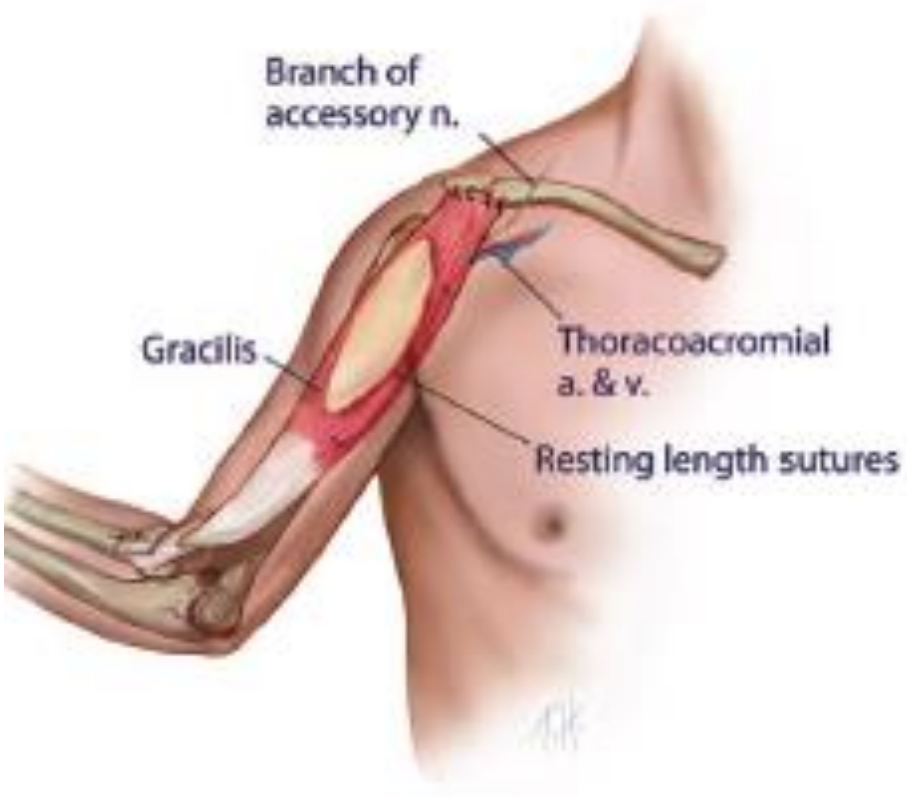


7 months postop



Functional Free Muscle Transfer

- Principles
  - Restore muscle resting length
  - Need full ROM of joint
  - Suitable soft tissue bed
  - Adequate antagonist muscle function
  - Need ‘pure’ donor motor nerve
  - Need healthy recipient vessels



Functional Free Muscle Transfer

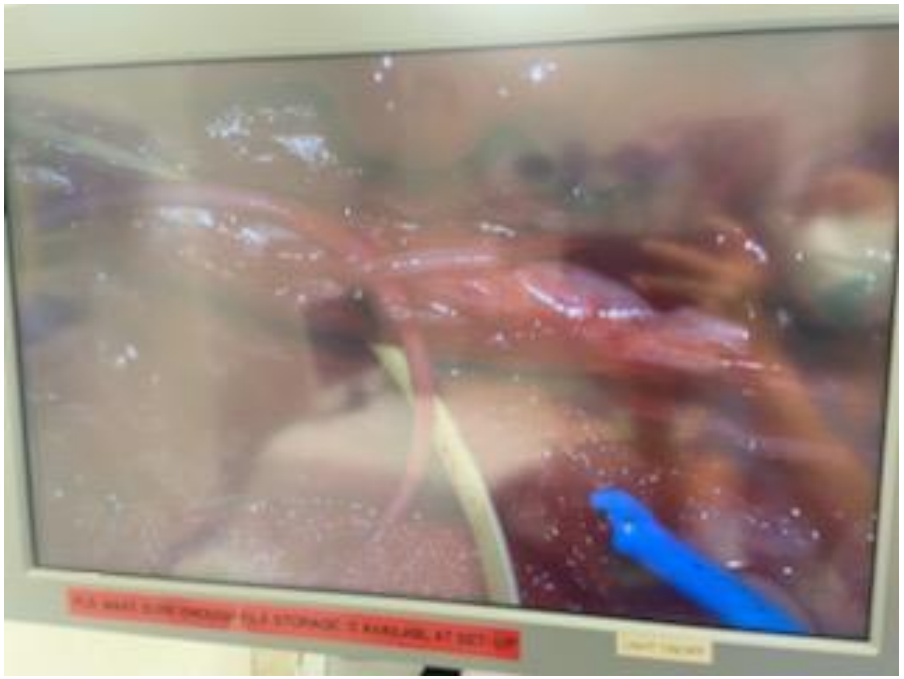
- Donor muscle
  - Adequate length/excursion
  - Sufficient force
  - Acceptable donor morbidity
  - Adequate fascia/tendon to secure

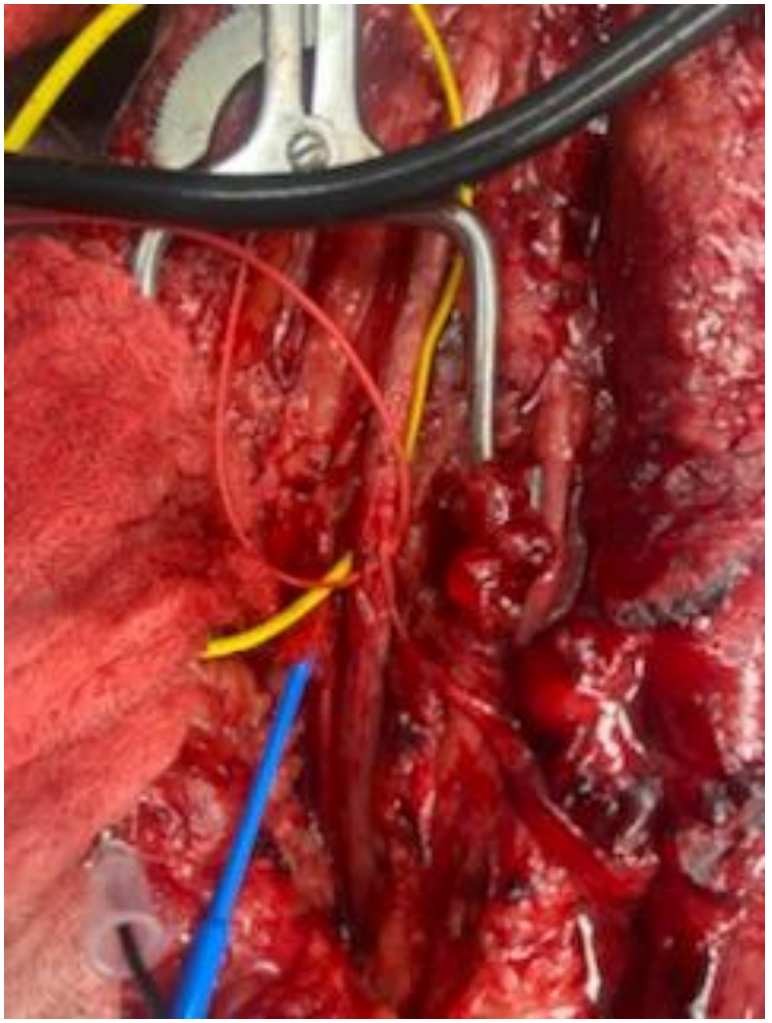
- **Gracilis**

- Latissimus
- Tensor fascia latae
- Rectus femoris
- Medial gastroc
- Serratus anterior
- Pec major

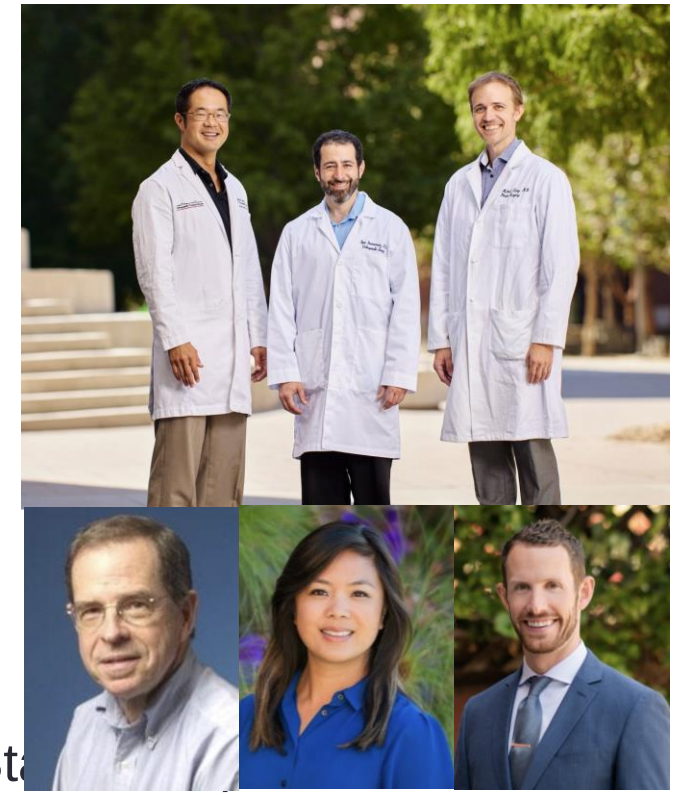
Case Example

- 36 y/o M with longstanding L BP injury (C5-7 root avulsion), 0/5 delt, elbow flex, extensors





- At 7 months postop, 1/5 strength, +detectable twitch to muscle



- Inter-disciplinary clinic
  - Ortho, Plastics, PM&R, Sports Medicine
- Team:
  - Dr Vincent R Hentz (Emeritus Professor, St
  - Dr Karina Del Rosario (PM&R)
  - Dr William Berrigan (Sports Medicine)
  - Dr Michael Terry (Plastic Surgery)
  - Dr Nicholas Lee (Orthopedic Surgery)
  - Dr Igor Immerman (Orthopedic Surgery)

- Same-day EMG
- Same-day US nerve eval and diagnostic blocks
- Peripheral nerve injury/pathology (UE/LE) – includes nerve pain
  - Repair, grafts, nerve transfers, tendon transfers, TMR, RPNI, etc
- UE function restoration in TBI, SCI, spasticity, motor neuropathies
  - Joint releases, fusions, muscle lengthening, hyperselective denervation

- UCSF Orthopedic Institute
  - Outpatient clinic
  - Radiology suite
  - Occupational Therapy
  - Orthotics and Prosthetics

https://peripheralnerve.ucsf.edu/

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  - **nicolas.lee@ucsf.edu or cell 213-760-6426**
  - **Michael.terry@ucsf.edu or cell 203-815-7323**

THANK YOU

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