

UNDERSTANDING THORACIC OUTLET SYNDROME

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California Orthopedic Association
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Thoracic Outlet Syndrome

- Definition

- Symptomatic compression of the neurovascular bundle at the thoracic outlet

Thoracic Outlet Syndrome

- **Criteria to Diagnose TOS:**
 1. Signs and symptoms consistent with TOS
 2. Compression of the neurovascular bundle at the thoracic outlet
 3. #1 is related to #2
 4. No other obvious explanation for #1

Types of Outlet Syndrome

- 1. Neurogenic
- 2. Venous
- 3. Arterial

Clinical history is very
important

KNOWLEDGE OF
ANATOMY
IS CRITICAL TO
UNDERSTANDING
THE CLINICAL HISTORY

Thoracic Outlet Syndrome

Anatomy

- Areas of Compression
 - Interscalene Triangle
 - Costoclavicular Space
 - Retro-Pectoralis Minor Space

Thoracic Outlet Syndrome

- Causes

- Osseous changes
- Soft tissue abnormalities
- Trauma
- Inflammation

Thoracic Outlet Syndrome

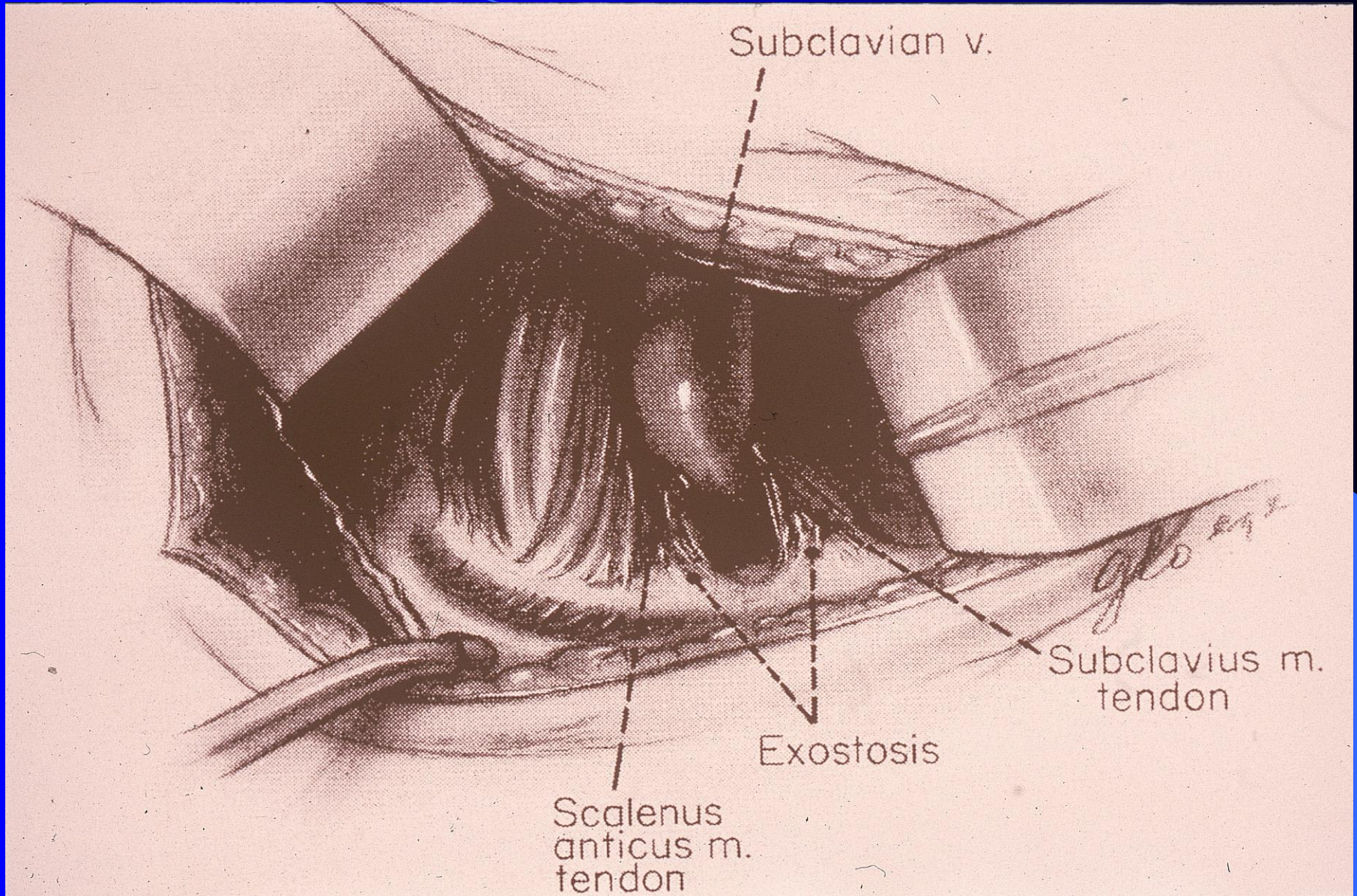
- Causes
 - Osseous Changes
 - Cervical ribs
 - Bifid clavicle
 - First rib abnormalities

Thoracic Outlet Syndrome

- Causes

- Soft Tissue Abnormalities

- Congenital bands and ligaments
- Congenital and acquired scalene muscle changes
- Shoulder girdle muscular changes



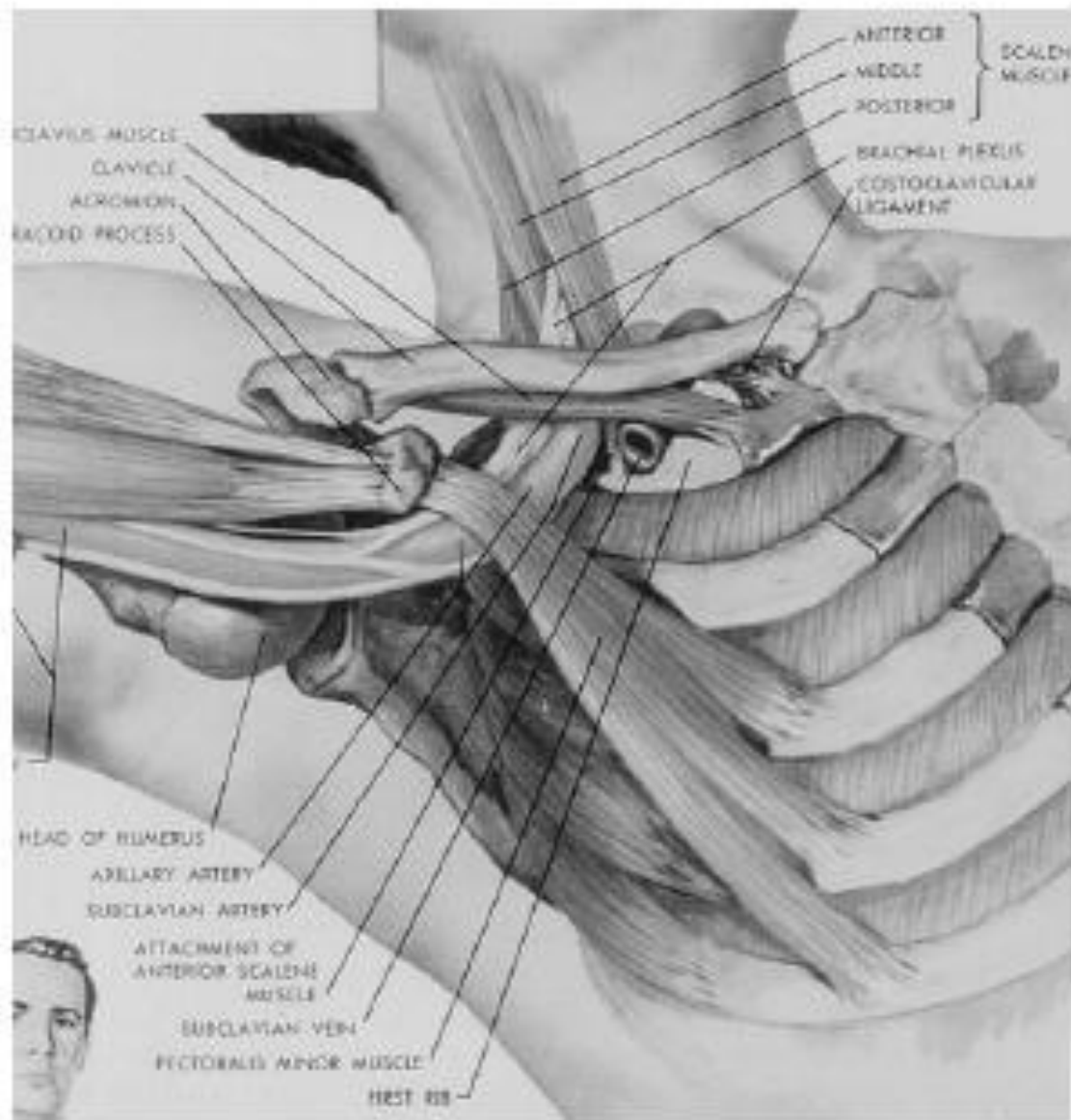
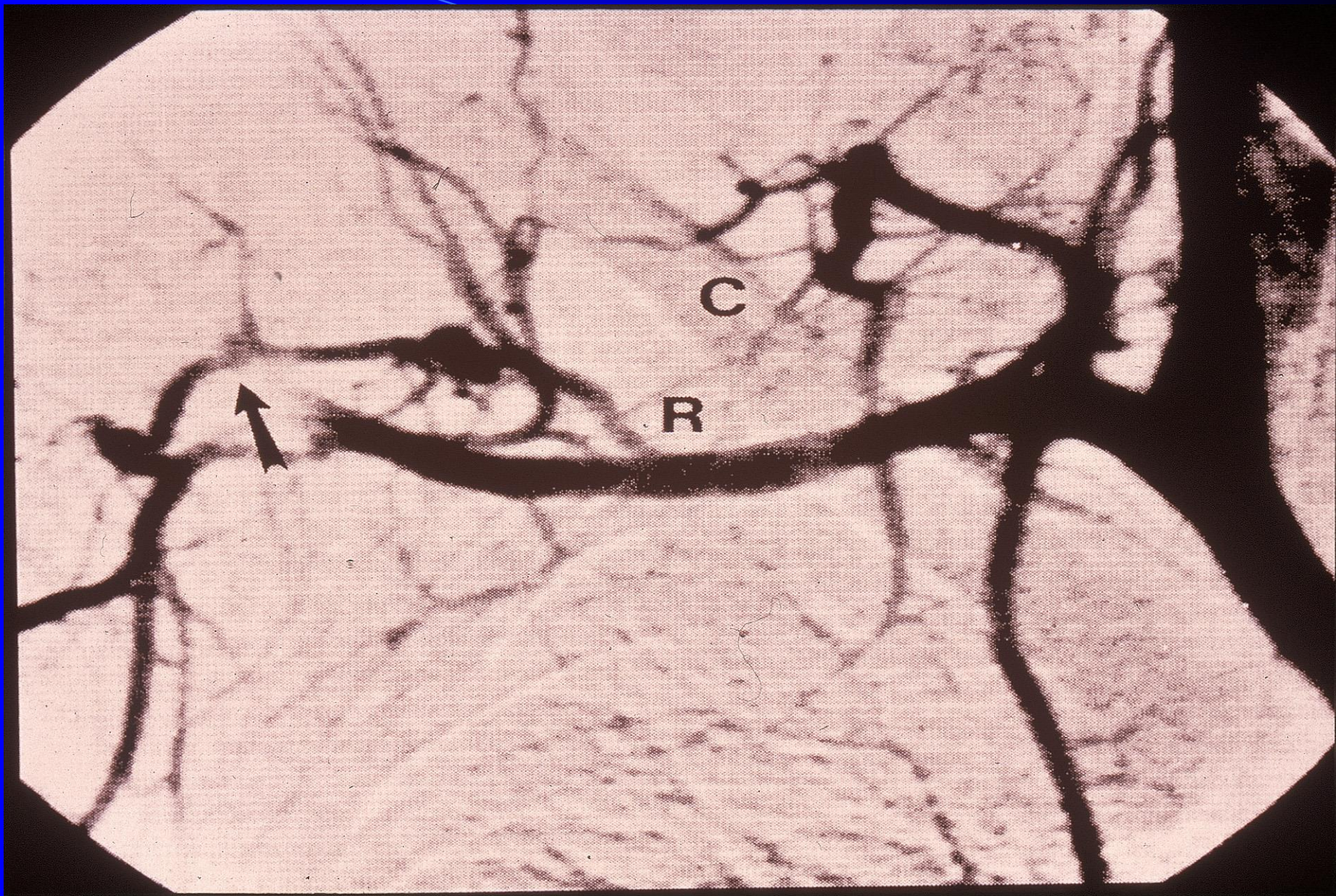
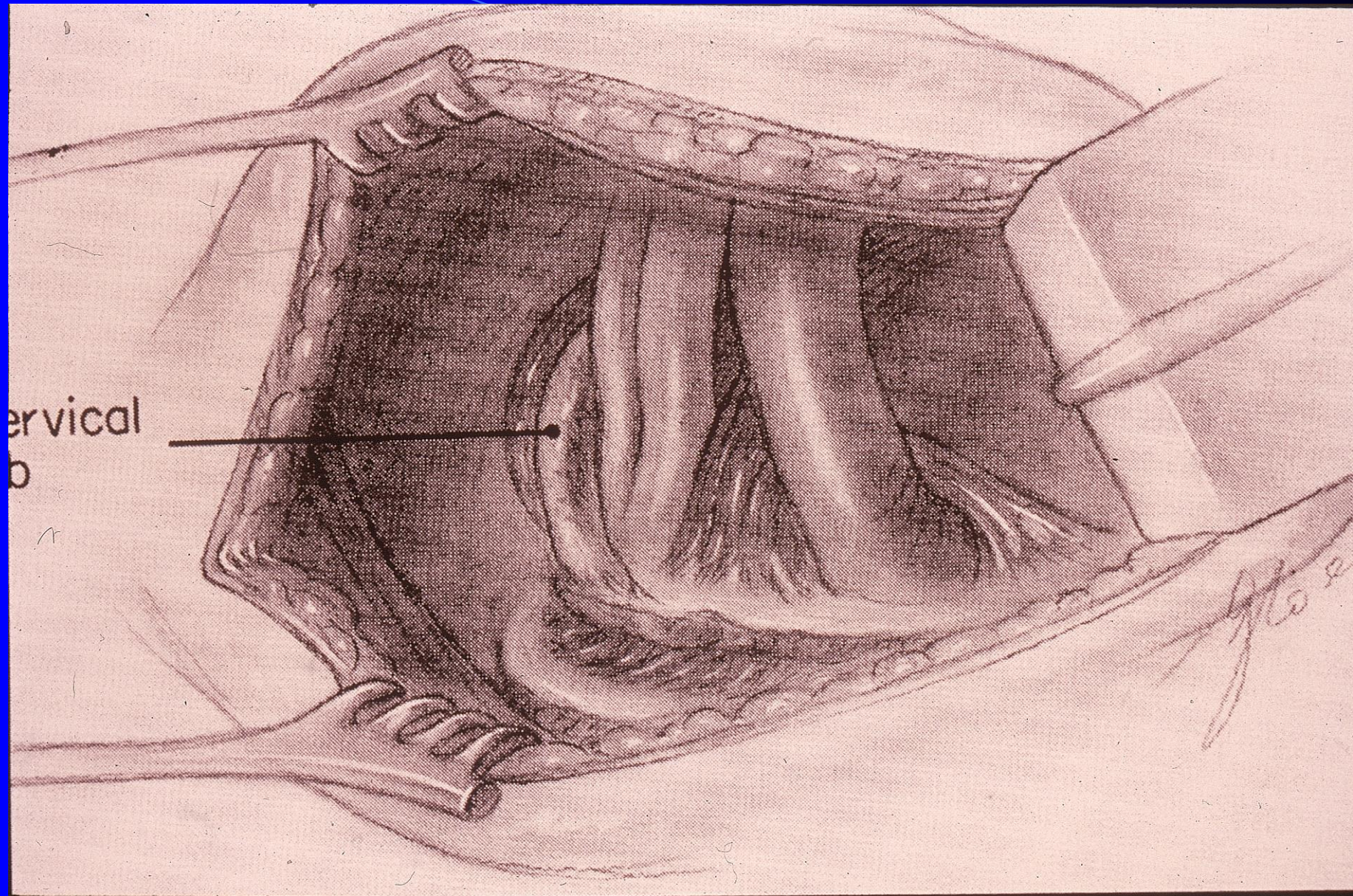
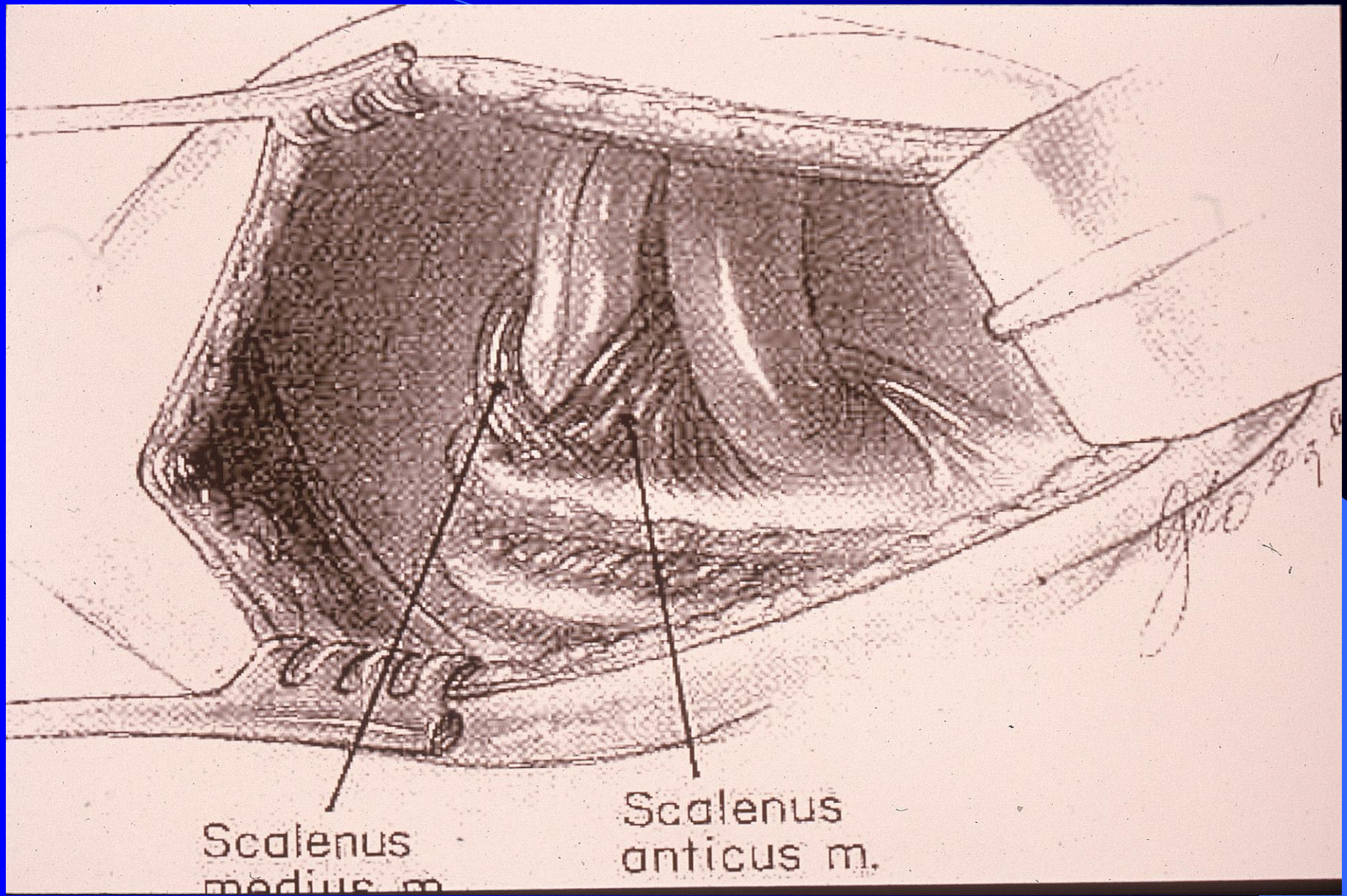


Fig 1. The axillary subclavian vein traverses a tunnel bound by the clavicle and subclavius muscle anteriorly, the scalenus anticus muscle laterally, the first rib posterior-inferiorly, and the costoclavicular ligament medially. (Courtesy Ciba; Frank Netter, MD, artist.)



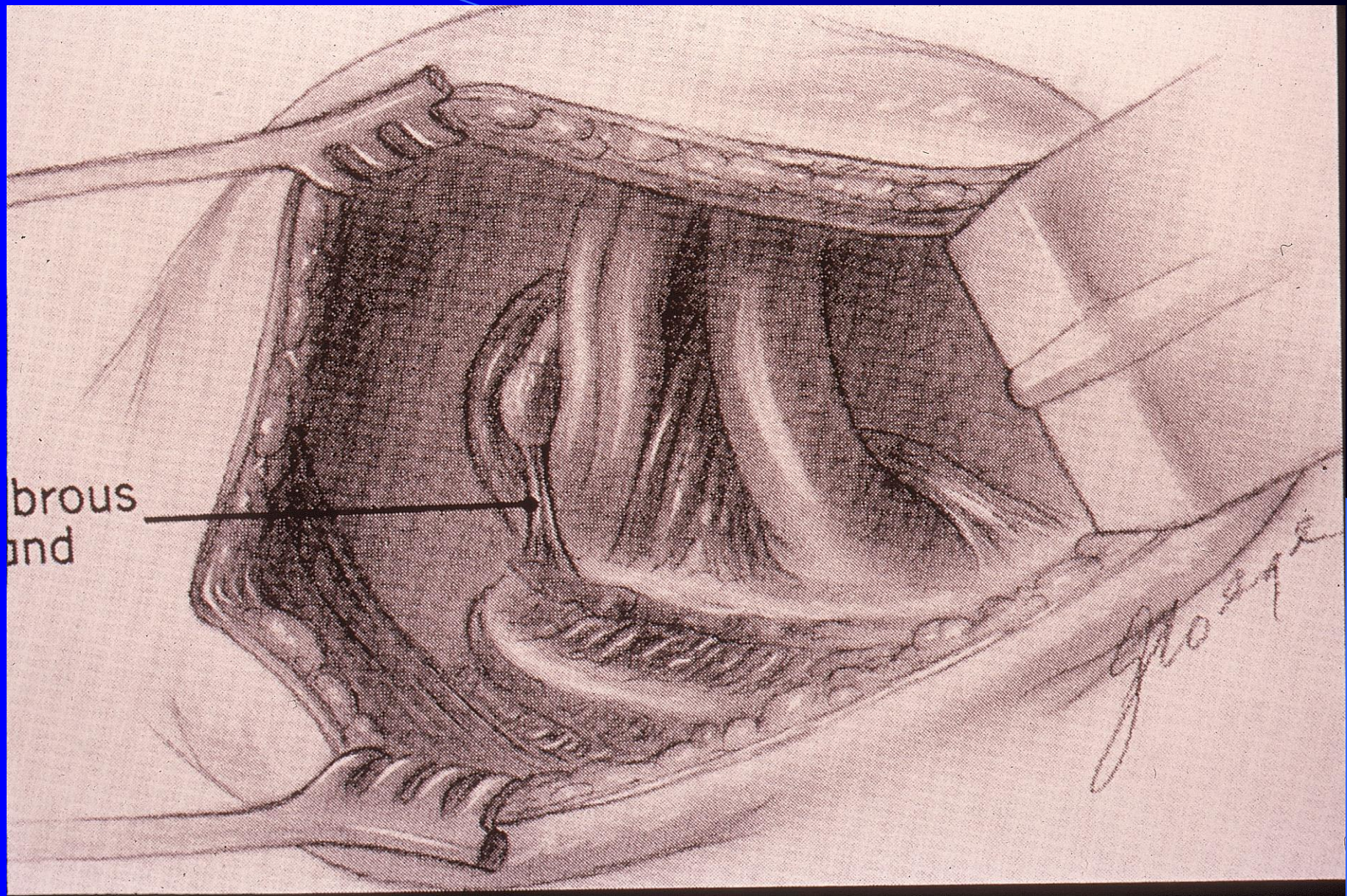


Cervical
o



Scalenus
medius m.

Scalenus
anticus m.



fibrous and

Gross

Thoracic Outlet Syndrome

- Causes

- Trauma (80% Incidence Reported)

- Neck

- Shoulder girdle

- Upper Extremity

- Inflammation

Thoracic Outlet Syndrome

- Incidence

0.3 % to 2% (Depending on Series)

- Most Common Age Range:

25 to 40 years

- Female to Male Ratio

4 to 1

Thoracic Outlet Syndrome

SYMPTOMS

- Neurogenic
 - Peripheral Nerves
 - Autonomic Nerves
- Venous
- Arterial

Thoracic Outlet Syndrome

- Neural symptoms

Peripheral

Pain

Paresthesias

Tingling

“pins and needles”

Motor

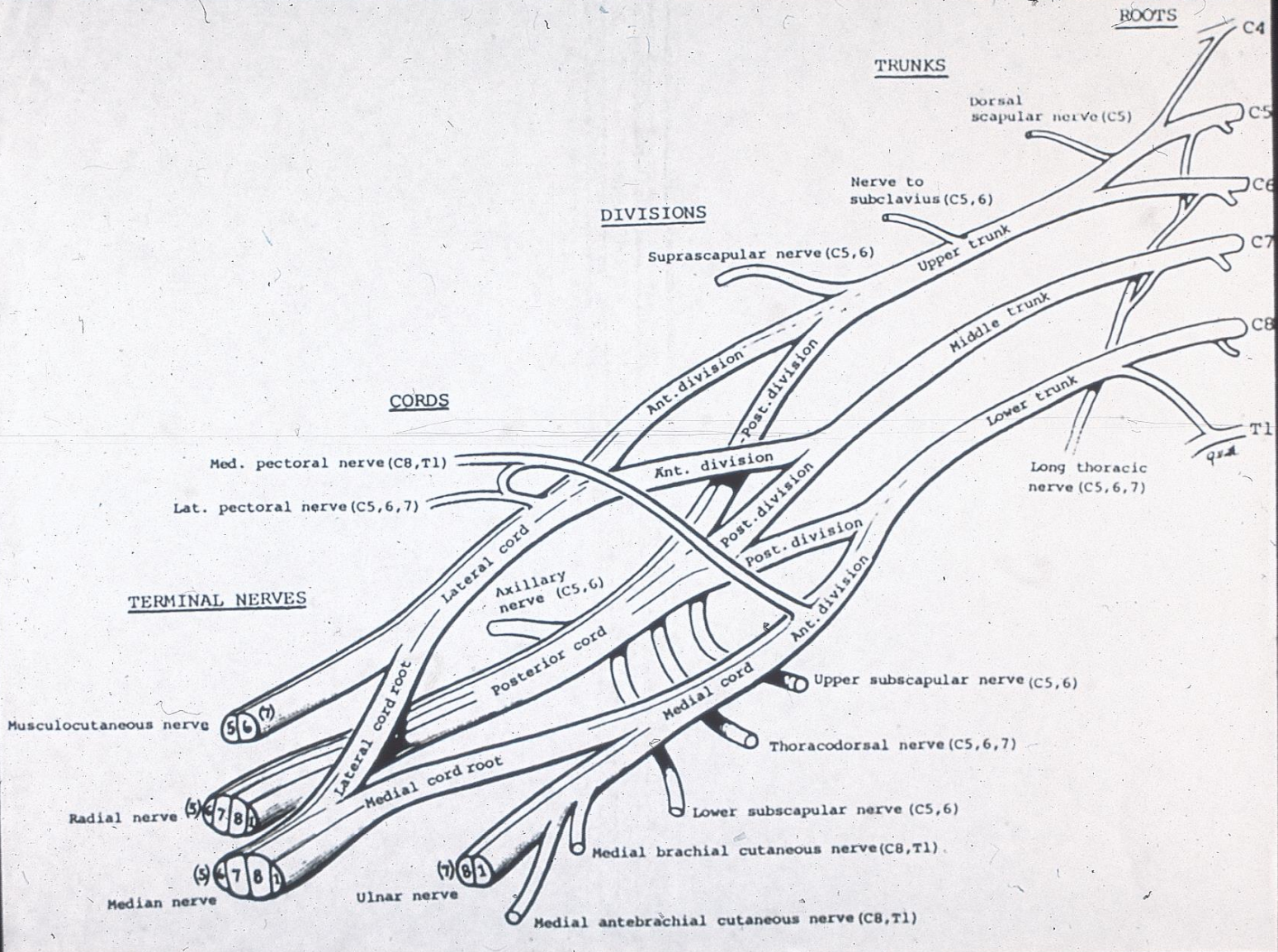
Weakness, Atrophy

Autonomic

Raynaud's

Temp Change

Color Changes



TOS - HAND ATROPHY



TOS - HAND ATROPHY

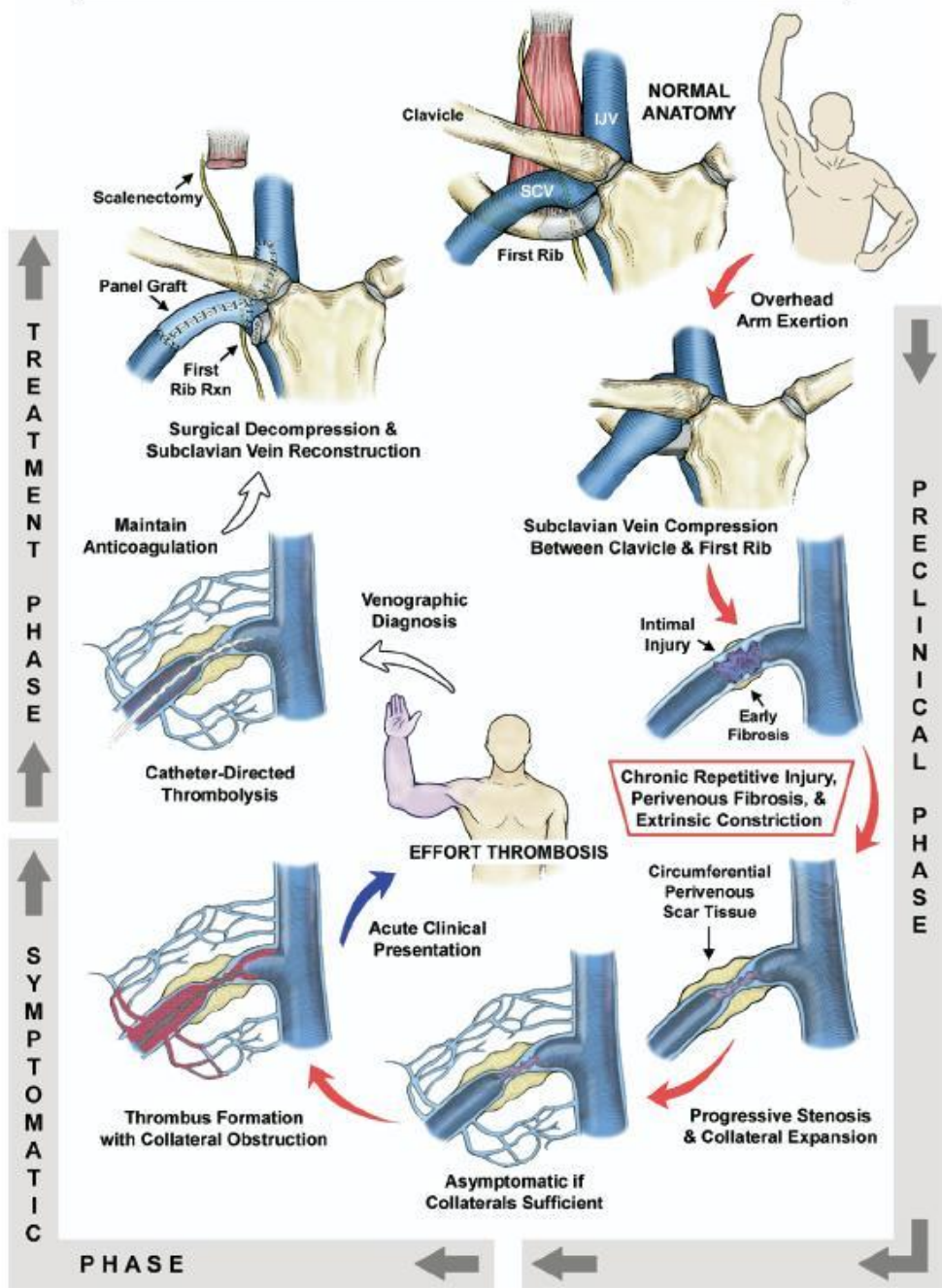




Thoracic Outlet Syndrome

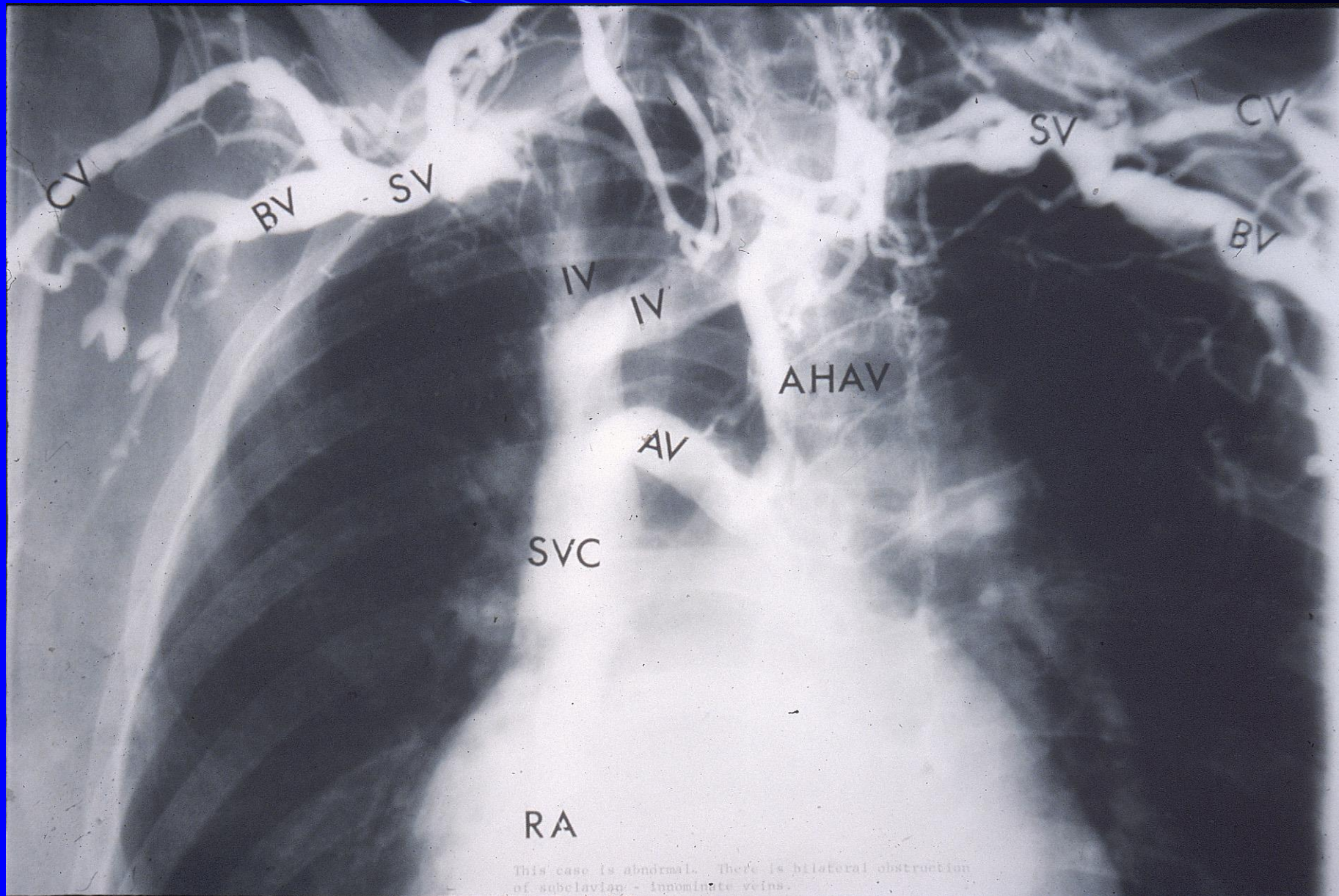
- Venous Symptoms
 - Pain
 - Edema
 - Venous distension
 - Cyanosis
 - Collaterals

Pathophysiology and Treatment of Subclavian Vein Effort Thrombosis



- Brandão LR, Williams S, Kahr WH, Ryan C, Temple M, Chan AK. Exercise-induced deep vein thrombosis of the upper extremity. 2. A case series in children. *Acta Haematol.* 2006;115(3-4):221-9.

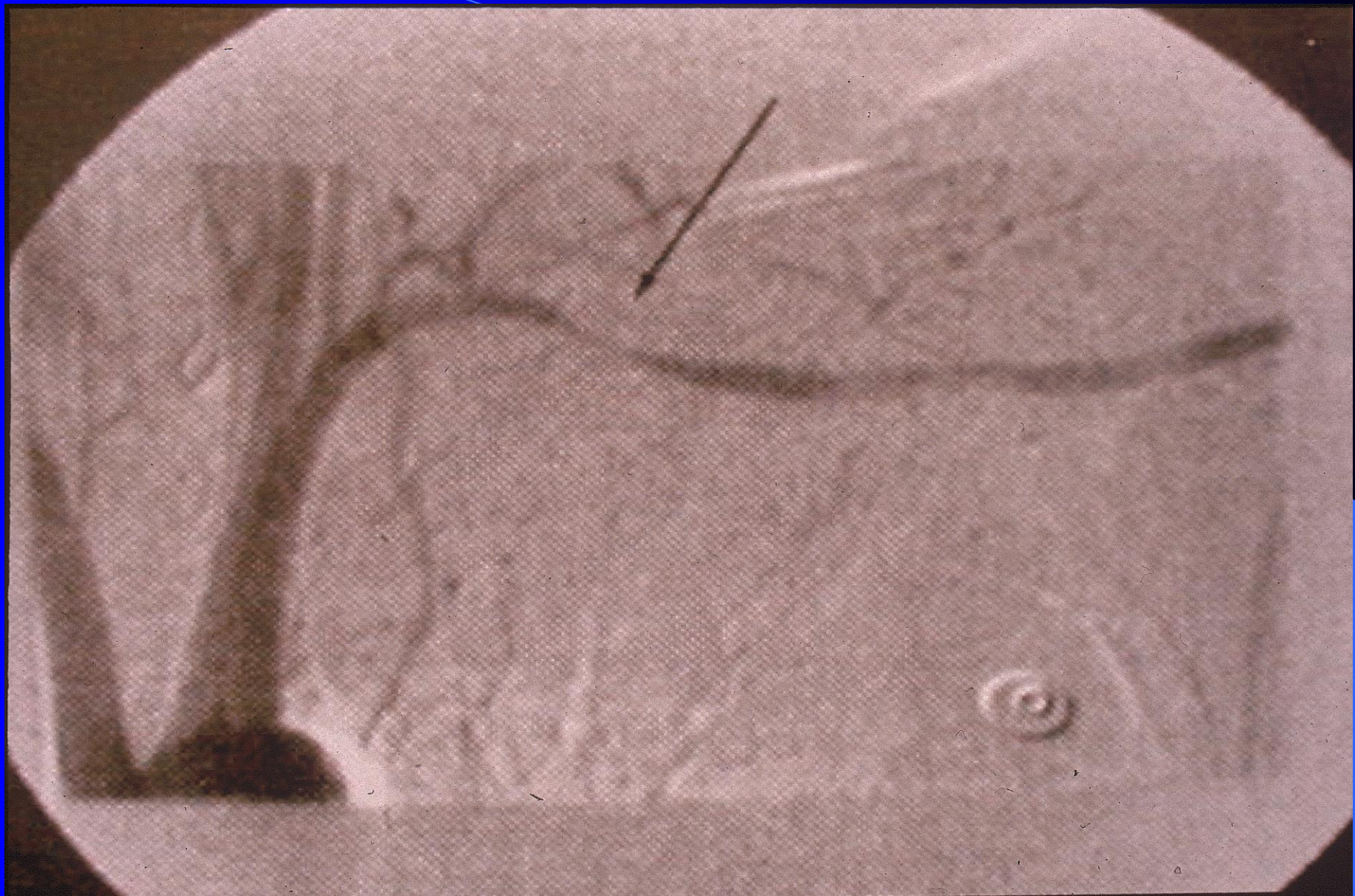
- Meier MA, Rubenfire M. Life-threatening acute and chronic thromboembolic pulmonary hypertension and subclavian vein thrombosis. Clin Cardiol. 2006 Mar;29(3):103-6.

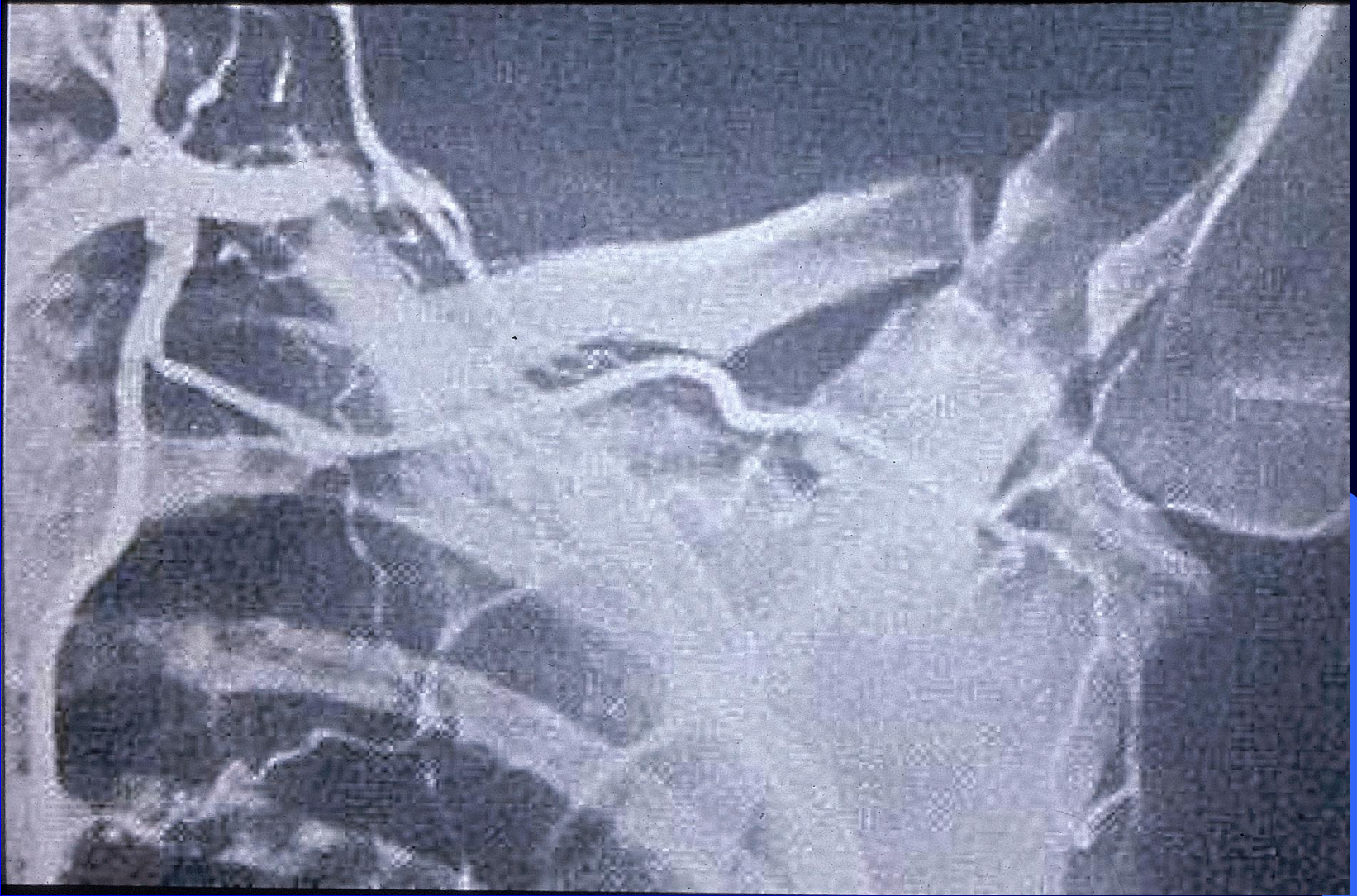


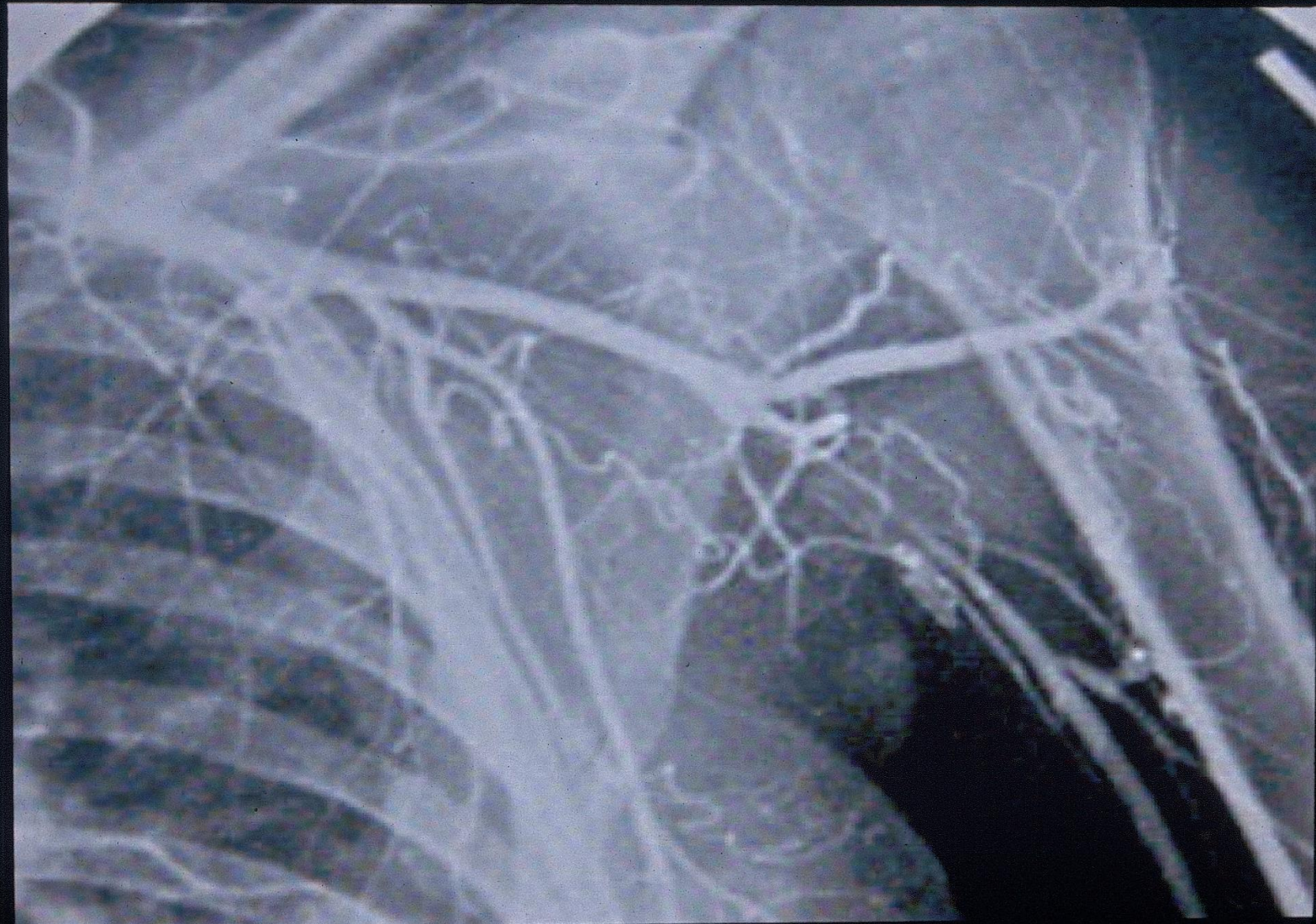
This case is abnormal. There is bilateral obstruction of subclavian - innominate veins.

Thoracic Outlet Syndrome

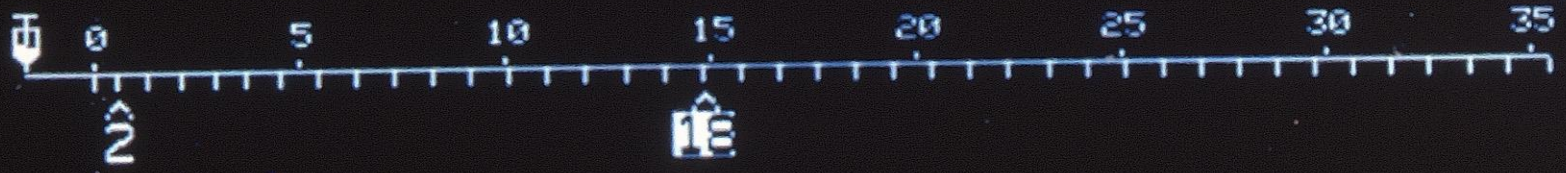
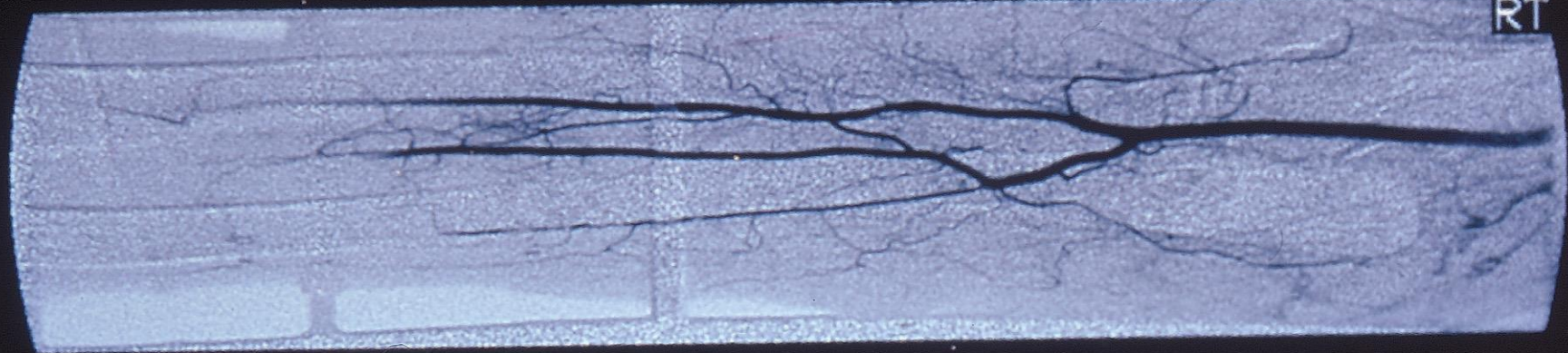
- Arterial Symptoms
 - Loss of pulse
 - Claudication
 - Thrombosis
 - Emboli
 - Necrosis





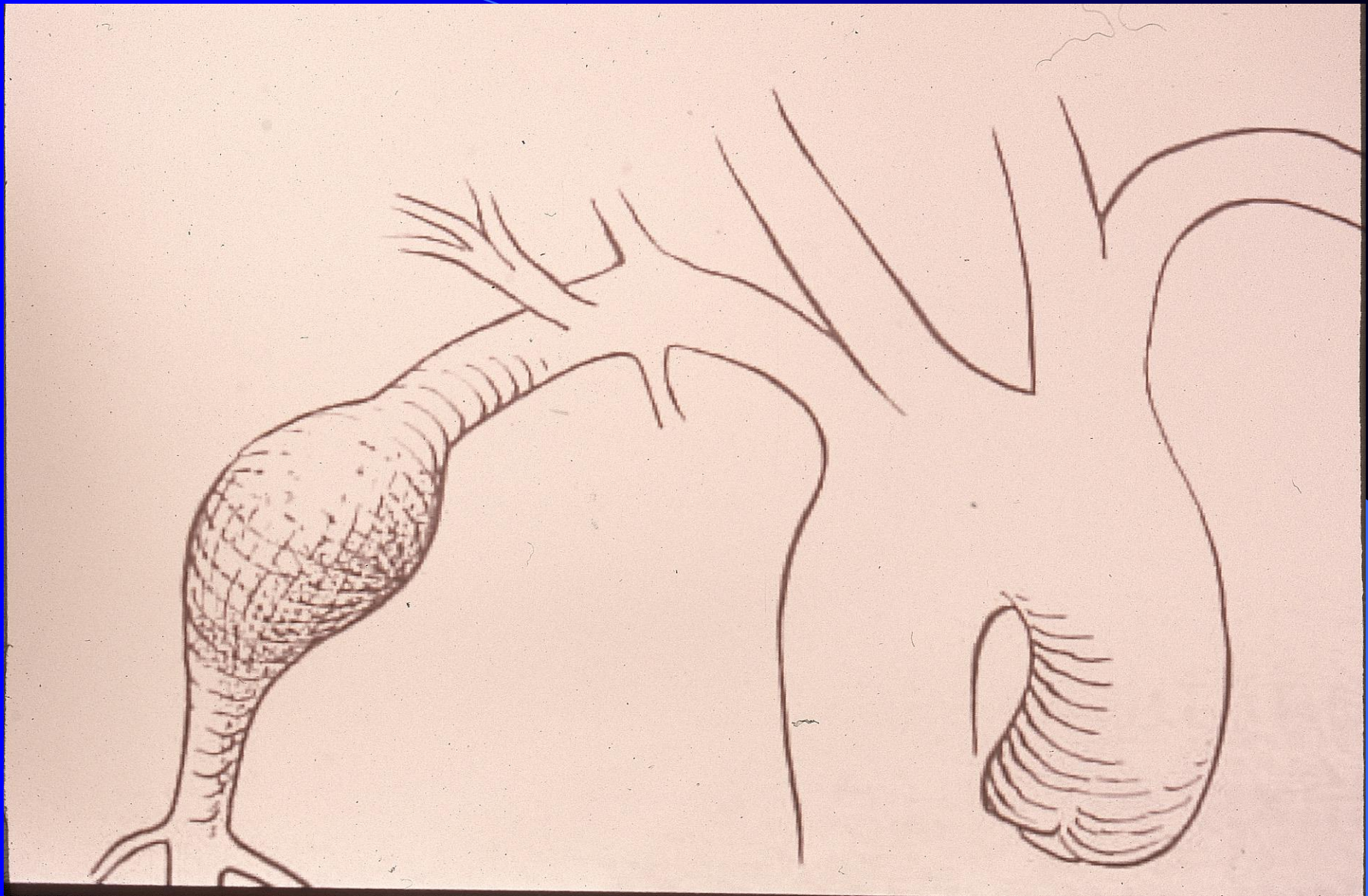


RT



0.0
0.1
3

TIME



Thoracic Outlet Syndrome

- 41% of Neurogenic TOS patients presented with headache as one of principal complaints
- 1.5% of all surgical TOS patients (43% of Arterial TOS patients) presented with Vertebrobasilar stroke
- 1-2% of patients presenting with TOS have underlying tumors at the thoracic outlet

Thoracic Outlet Syndrome

- Diagnosis

- Provocative Clinical Tests

- Adson's
 - Wright's Hyperabduction
 - EAST-Roos
 - AER

Thoracic Outlet Syndrome

- Arm abduction external rotation rotates the clavicle and subclavius muscle posteriorly and inferiorly

TOS - ROOS TEST



Thoracic Outlet Syndrome

- Diagnostic Imaging
 - MRI of the Brachial Plexus

Thoracic Outlet Syndrome

- MRI sequences include:

Coronal

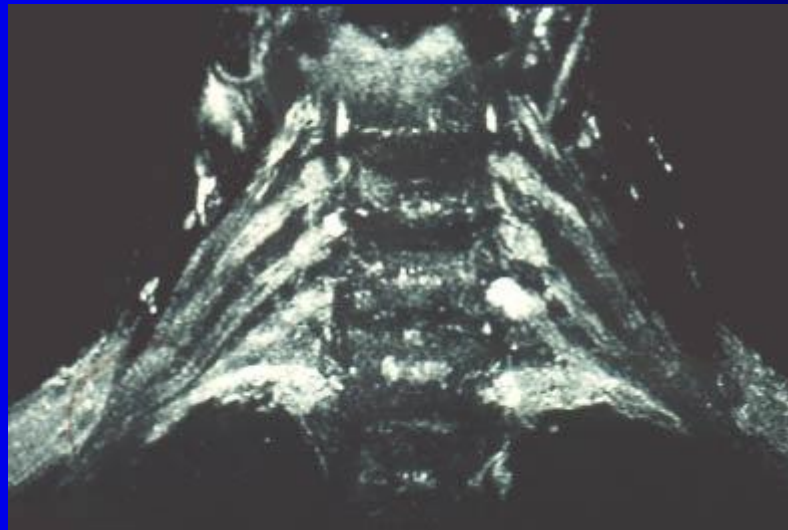
Sagittal

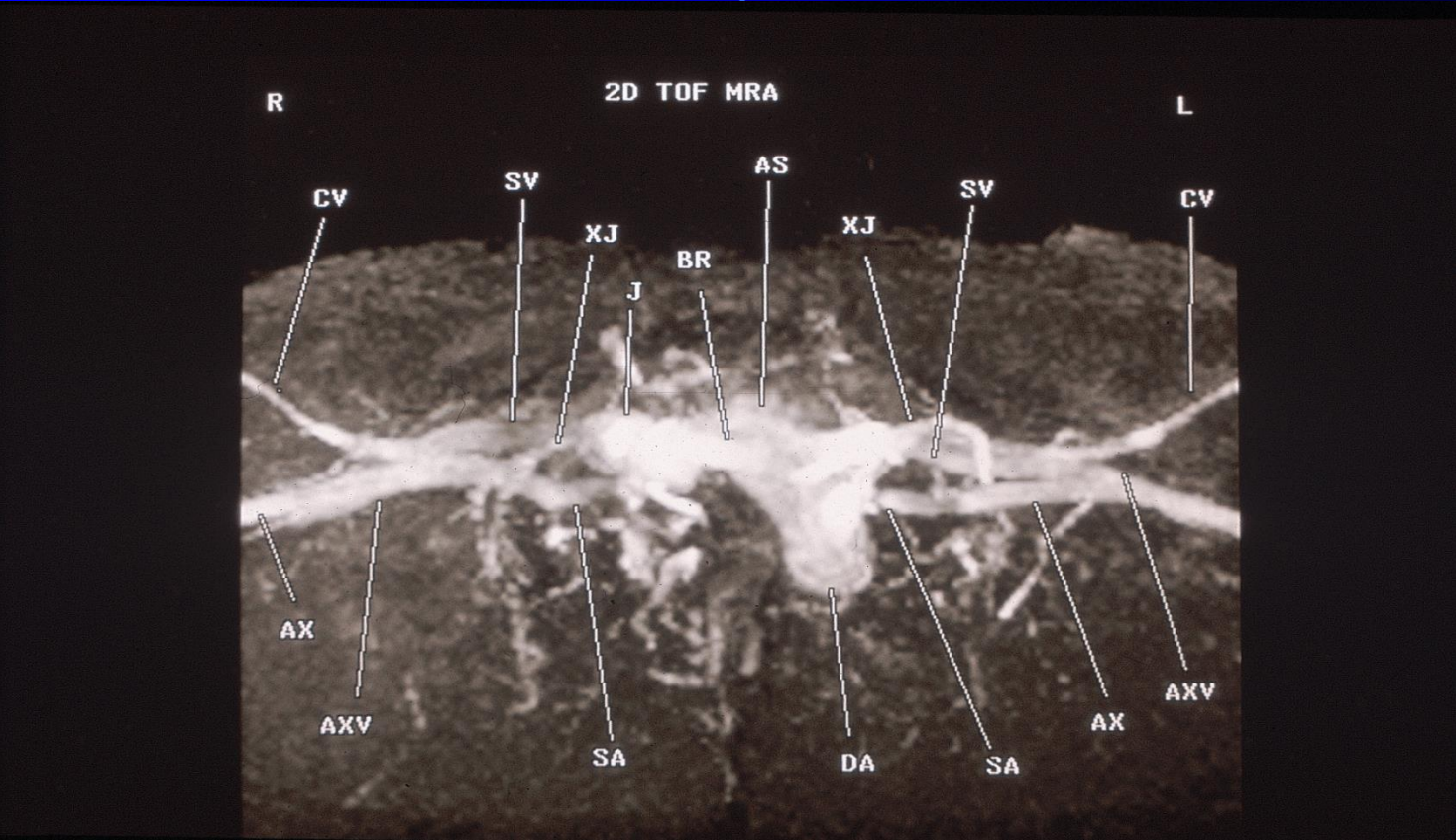
Transverse

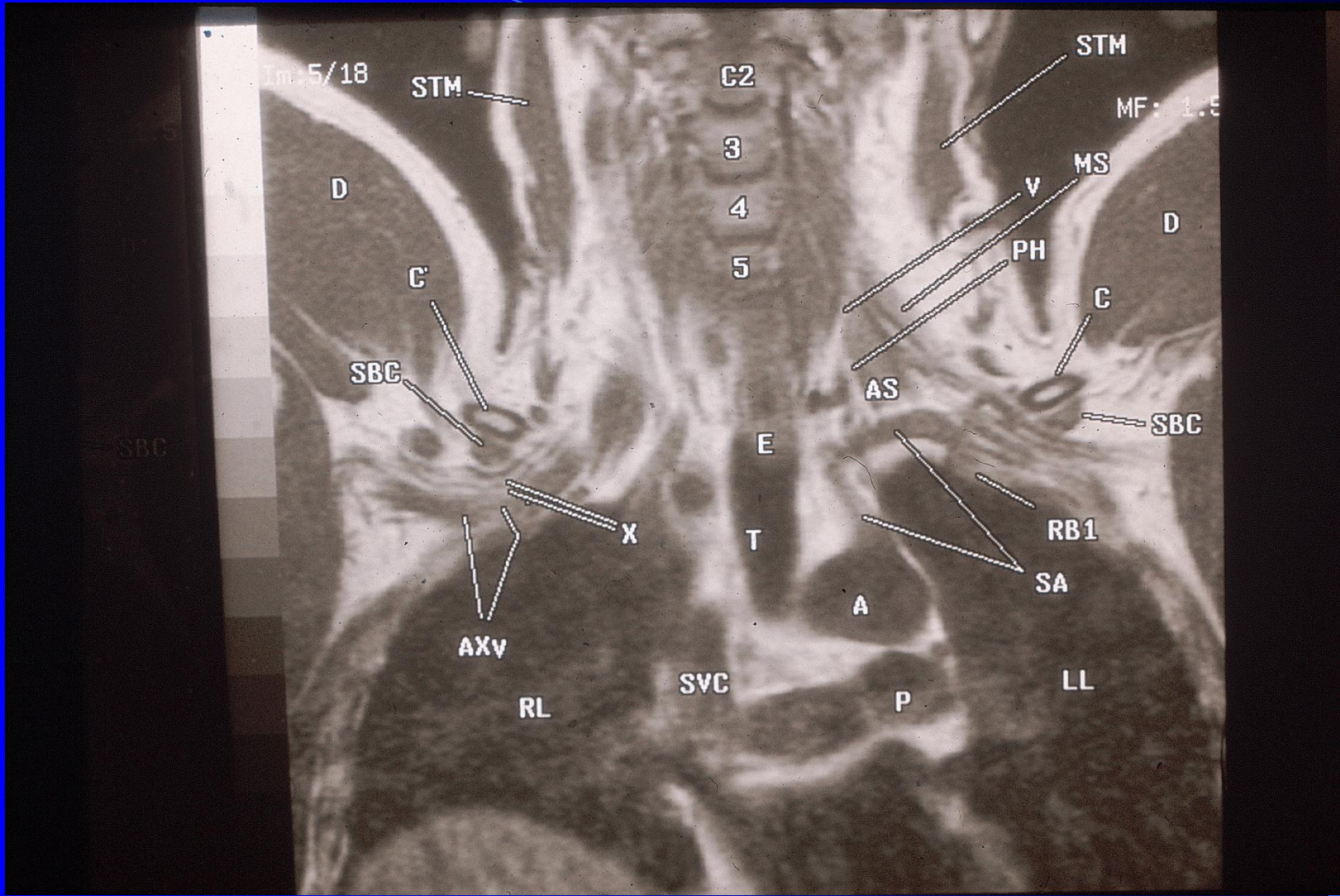
Transverse Oblique

Arm abduction, external rotation (arm overhead)

TOS - BRACHIAL PLEXUS

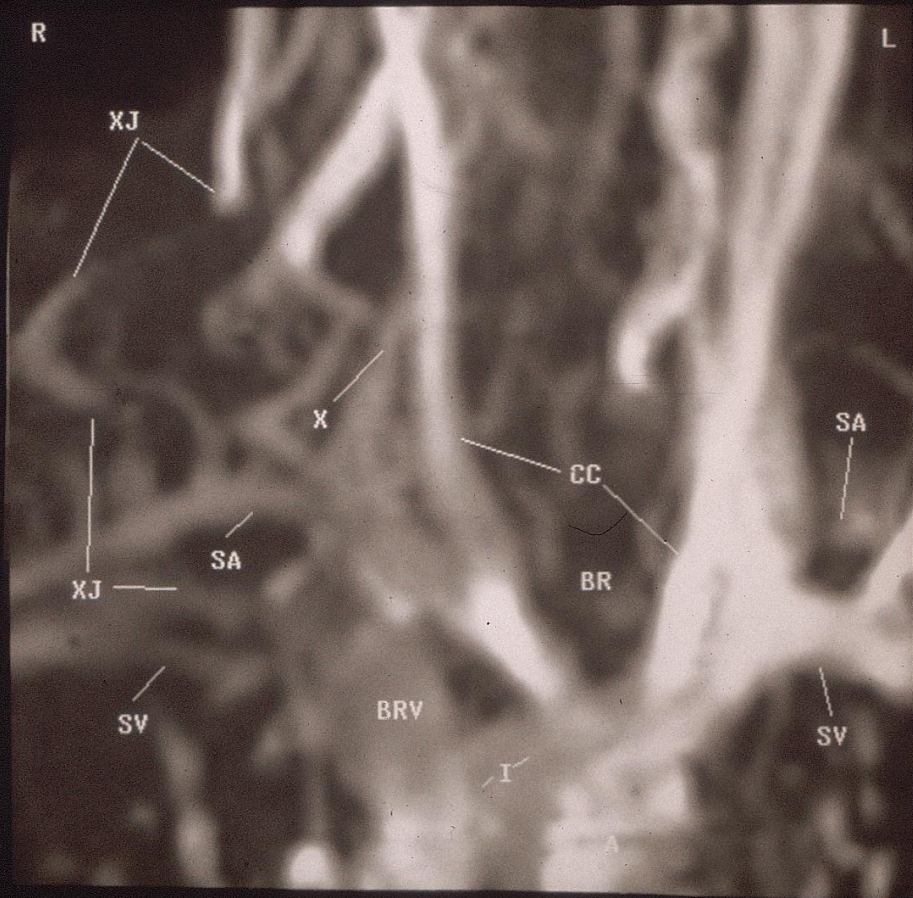






Thoracic Outlet Syndrome

- Impaired venous flow on MRI is demonstrated as increased or mixed signal intensities on T1-weighted images without the addition of contrast



Thoracic Outlet Syndrome

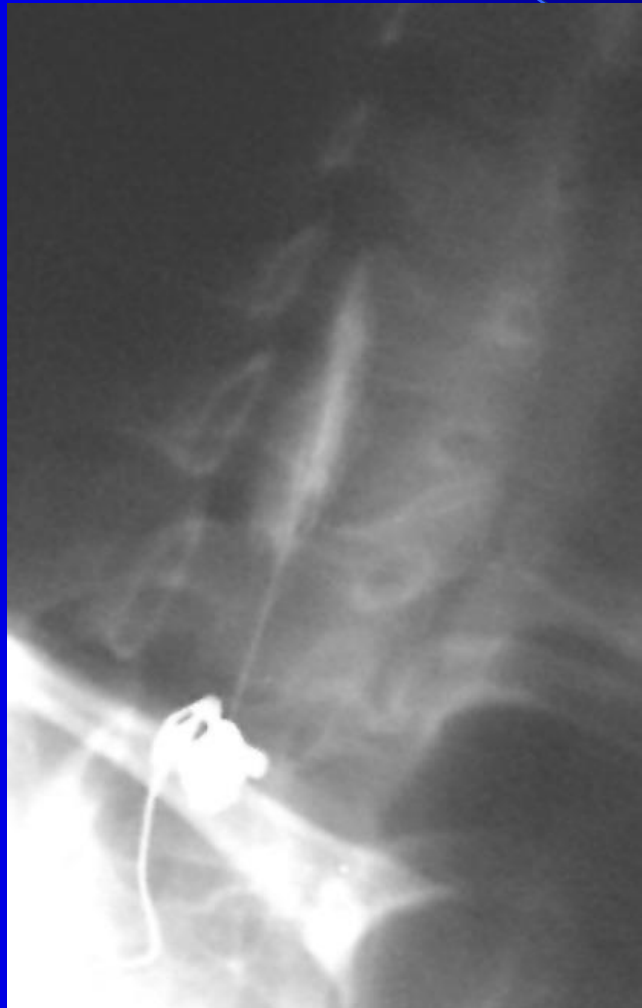
- Provocative Diagnosis Test
 - Scalene Block

S Jordan '99

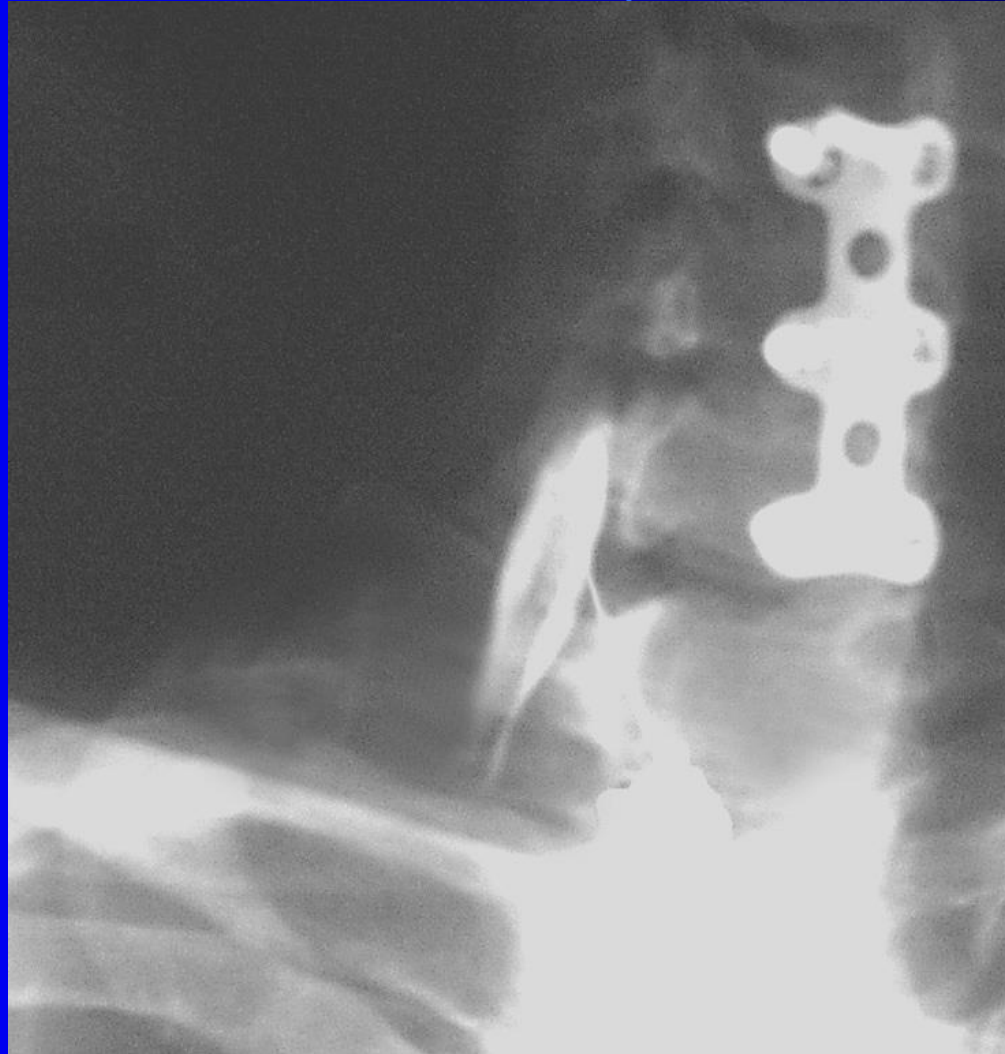
**ANTERIOR SCALENE
MUSCLE BLOCK**



TOS - SCALENE BLOCK



TOS - SCALENE INJECTION

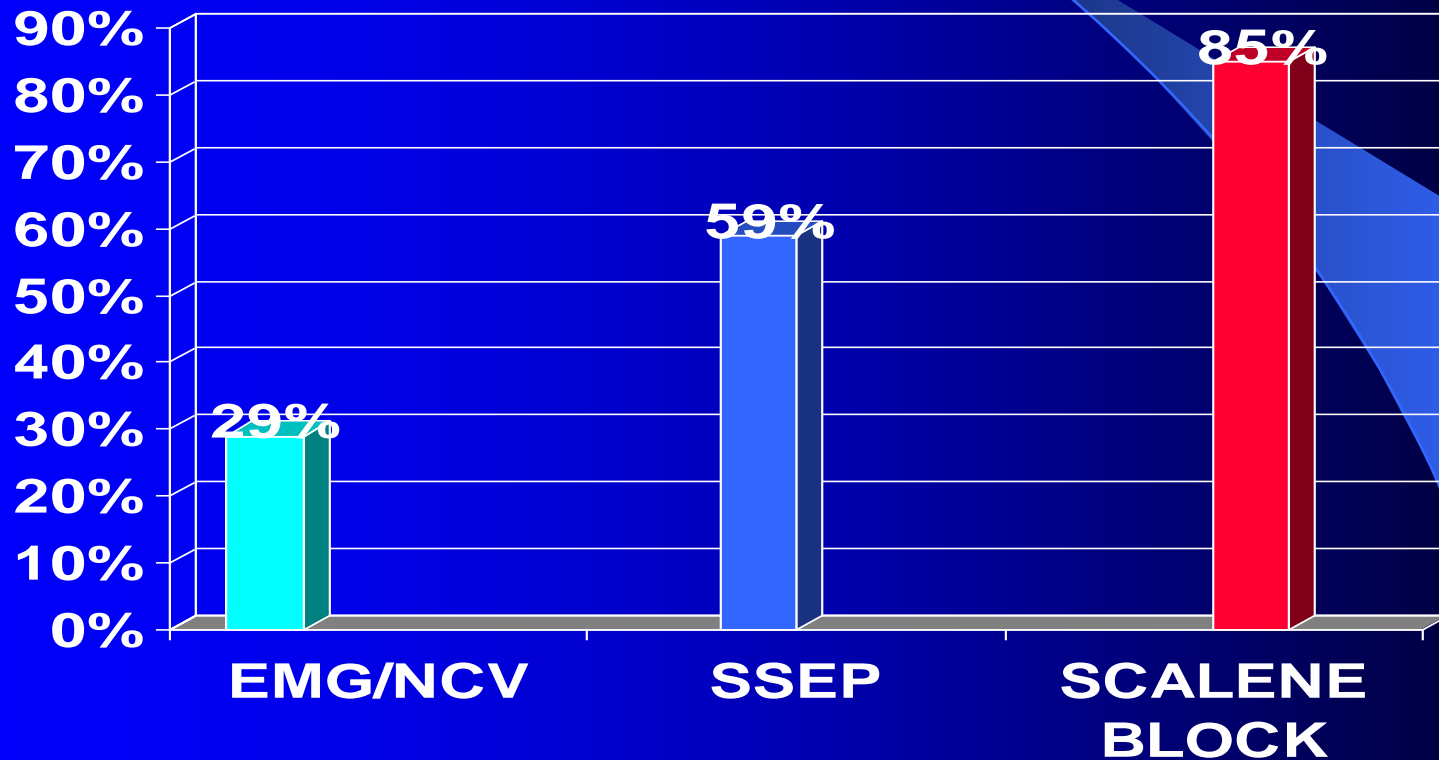


Thoracic Outlet Syndrome

– Electrophysiological Tests

- Electromyography
- Nerve Conduction Velocity
- Somatosensory Evoked Potential

Scalene Block More Sensitive than SSEP or EMG/NCV



Scalene Block Related to Surgical Outcome at 2 months

	Good Outcome	Poor Outcome
Positive Block	85%	15%
Negative Block	77%	23%

Scalene Block Related to Surgical Outcome at 6 months

	Good Outcome	Poor Outcome
Positive Block	72%	28%
Negative Block	50%	50%

A 4-point Criteria for N-TOS

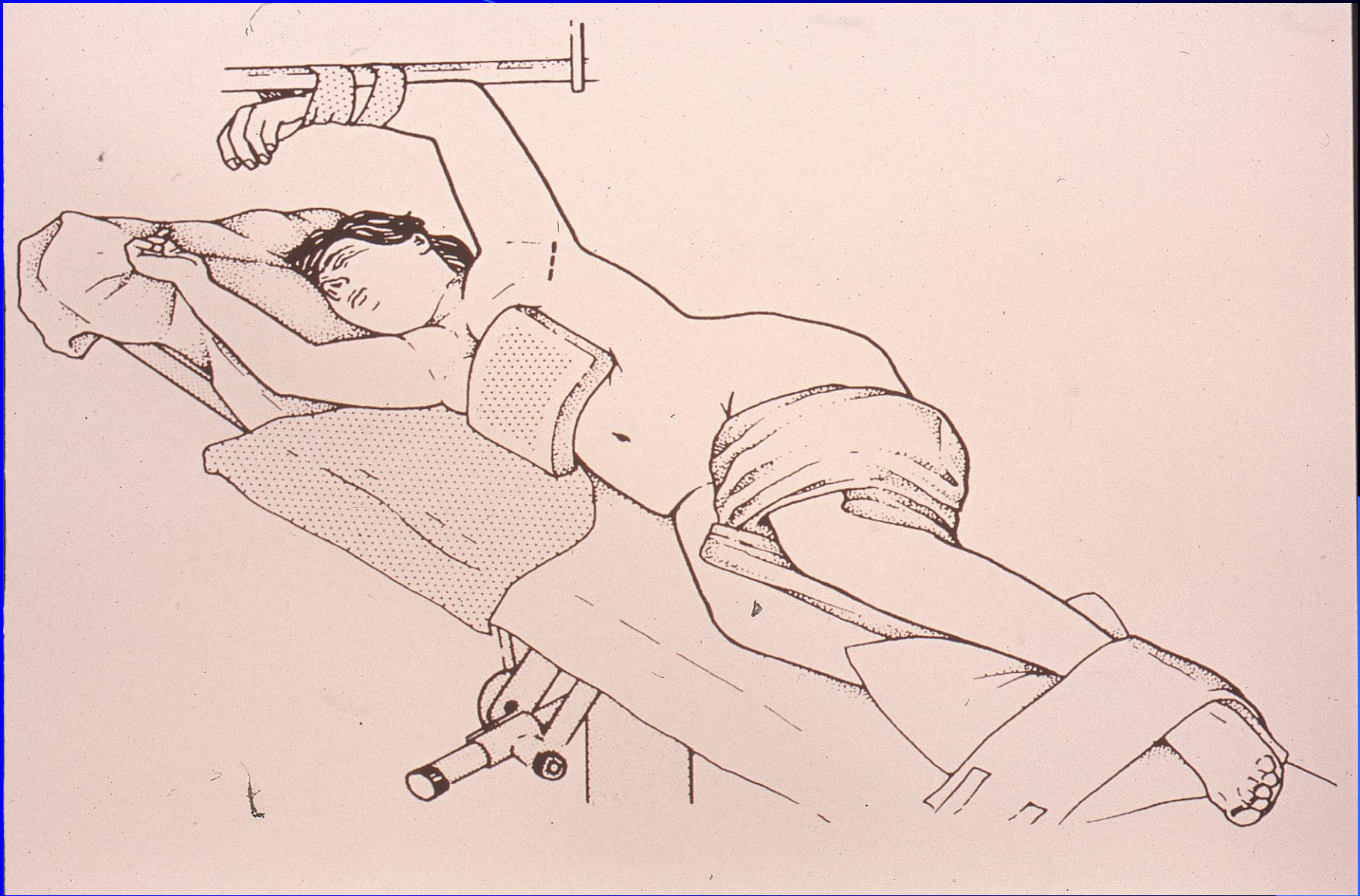
- (1) **Symptoms** consistent with N-TOS
- (2) **Evidence of compression** of the neurovascular bundle at thoracic outlet by physical exam and MRI
- (3) **Evidence of causal relationship** between (1) and (2) by **SMB**
- (4) **Absence of obvious other causes** for (1) by SSEP, MRI, CT

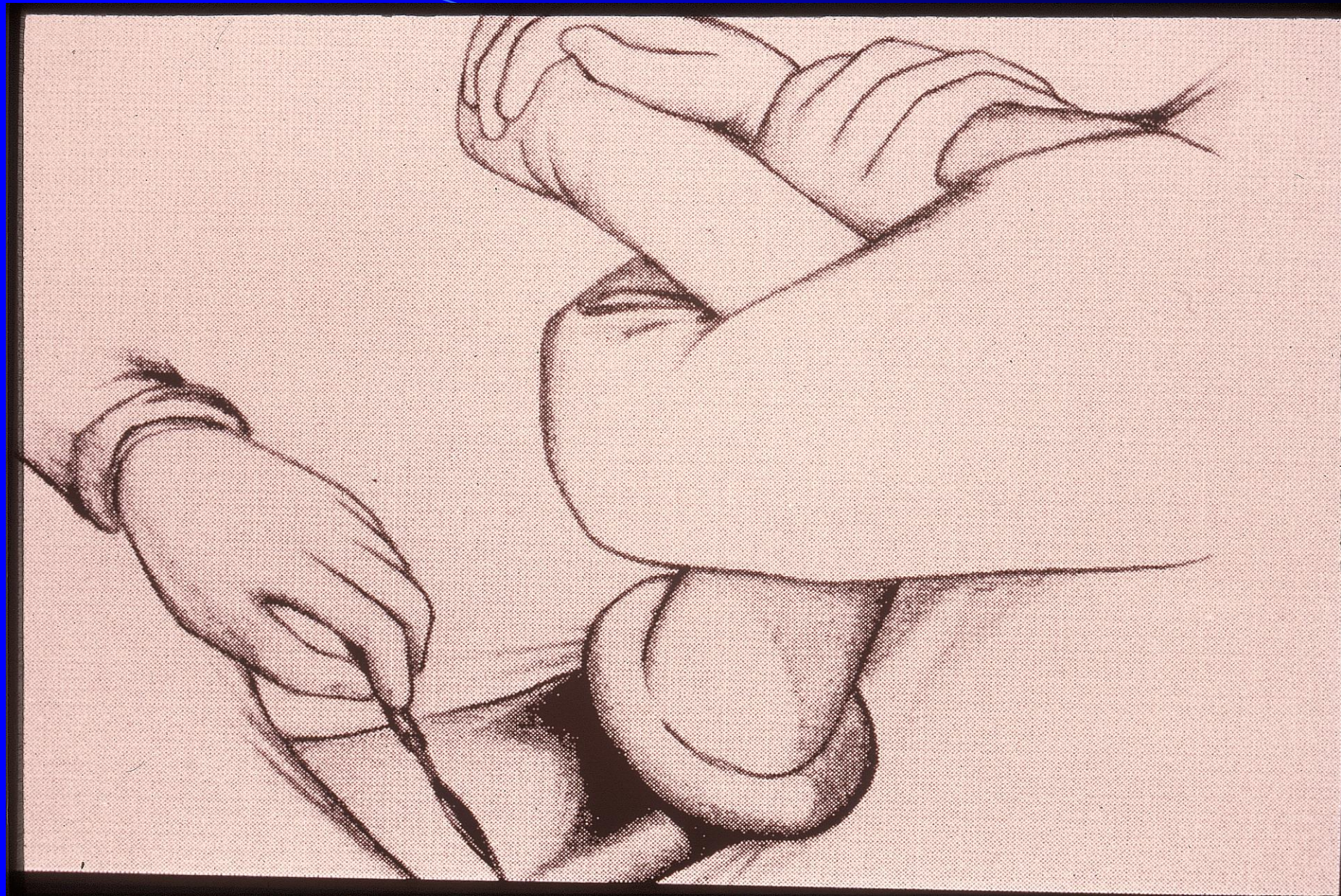
Thoracic Outlet Syndrome

- Treatment (Neurogenic)
 - Conservative / Medical
 - Pain medications
 - Migraine medications in TOS patients with migraines
 - Physical Therapy
 - Botox

Thoracic Outlet Syndrome

- Treatment (Neurogenic)
 - Surgical Management
 - Transaxillary first (and cervical) rib resection
 - Supraclavicular scalenectomy





3

Subclavian Artery

Anterior Scalene Muscle

T1 Root of
Brachial Plexus

Subclavian Vein

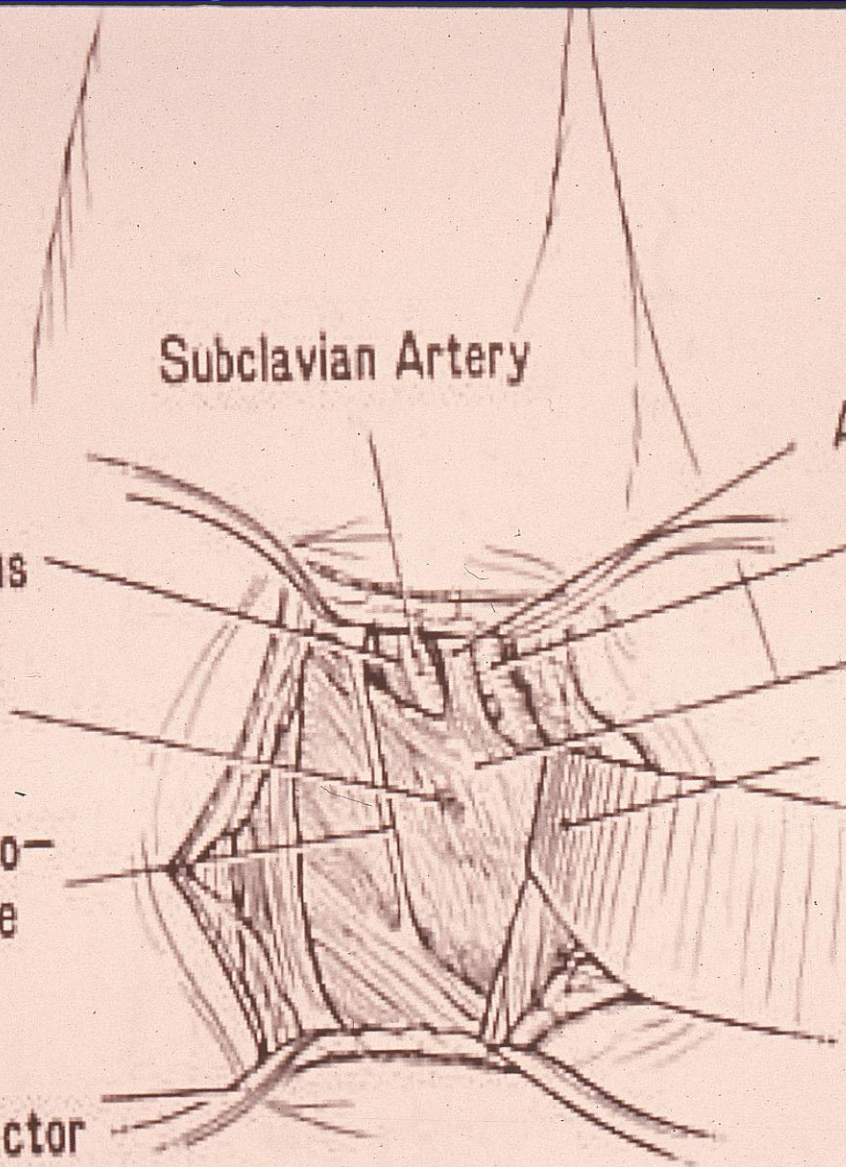
Superior Thoracic
Artery and Vein

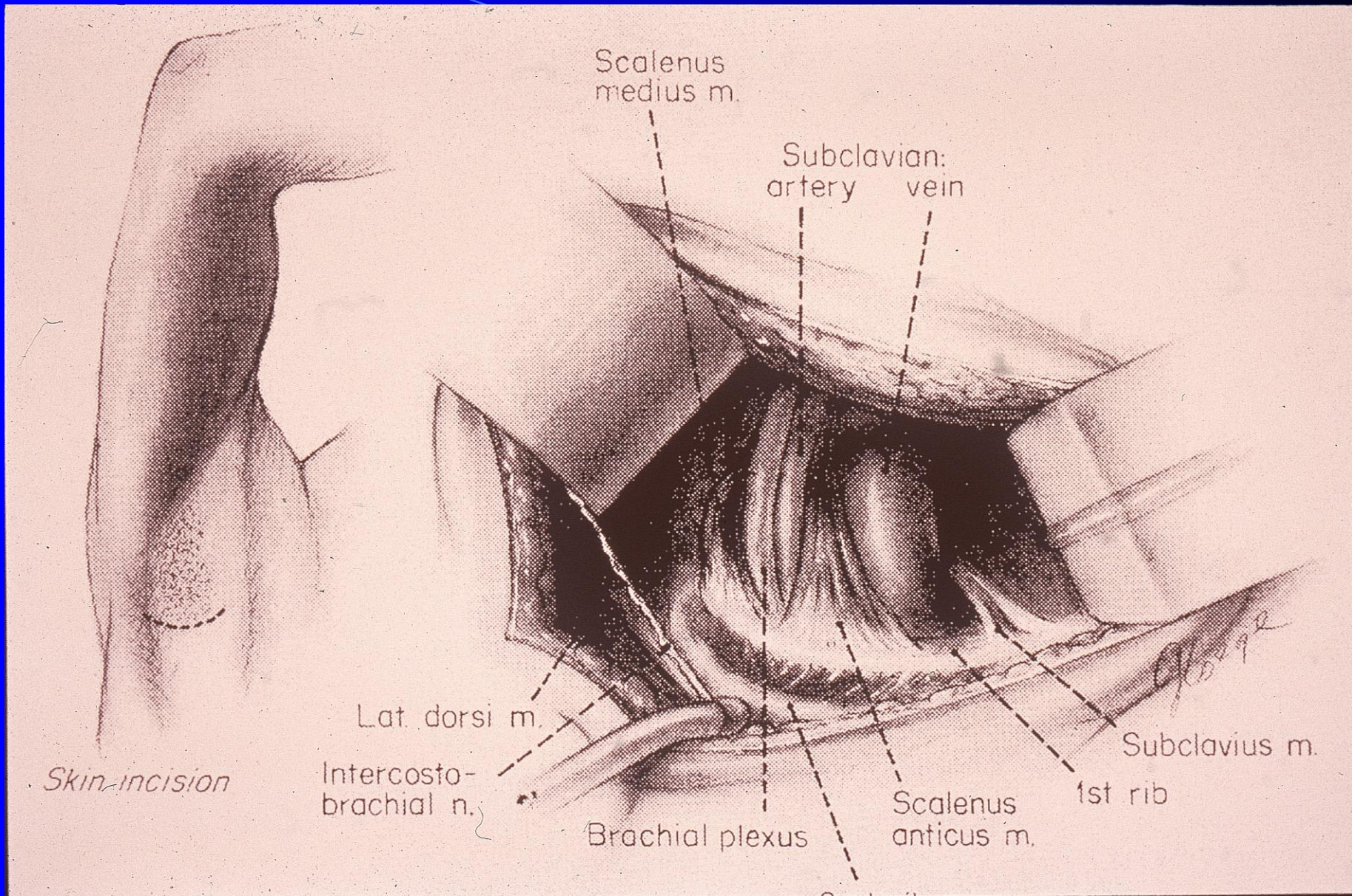
First Rib

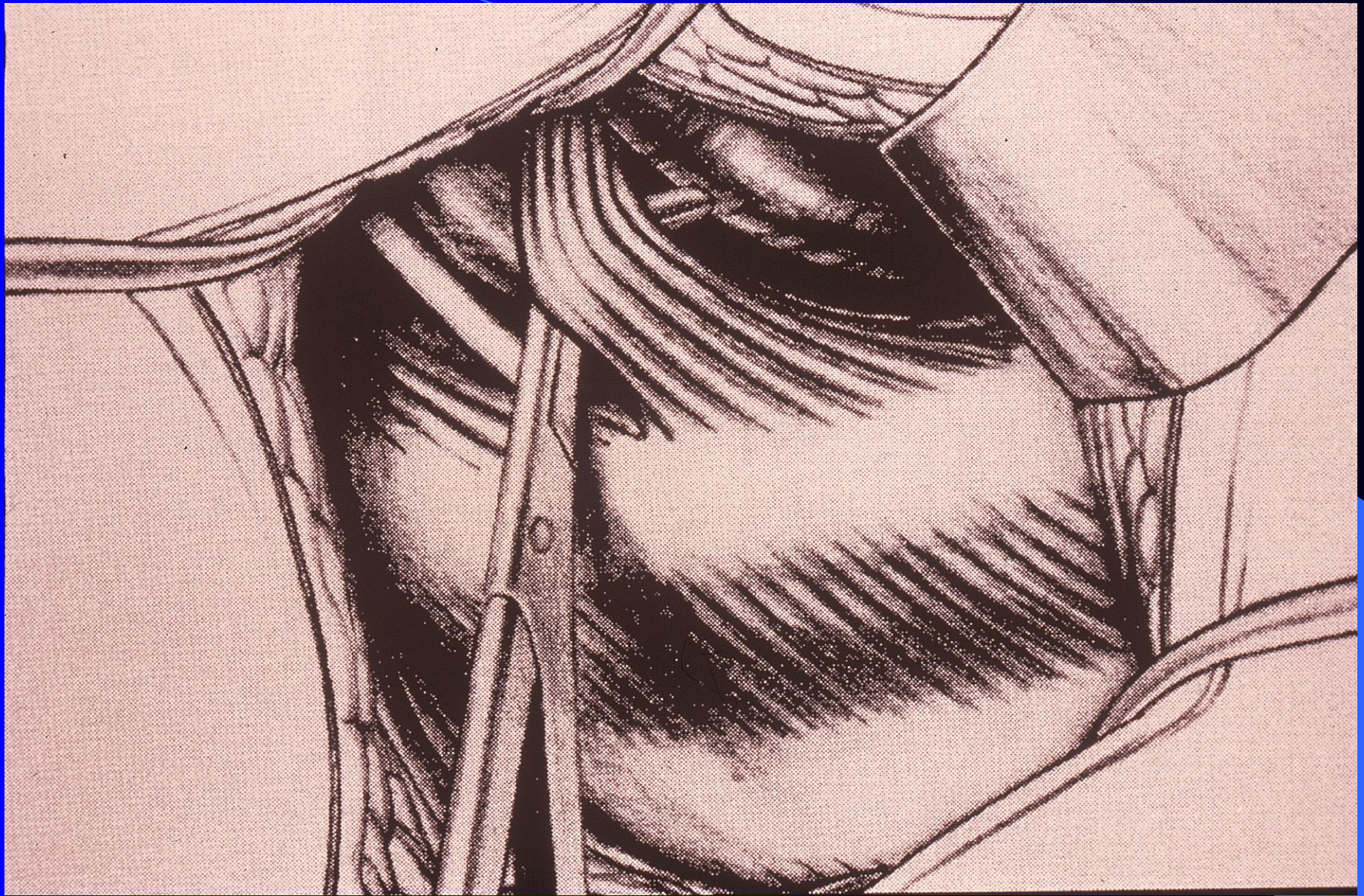
Intercostobrachio-
cutaneous Nerve

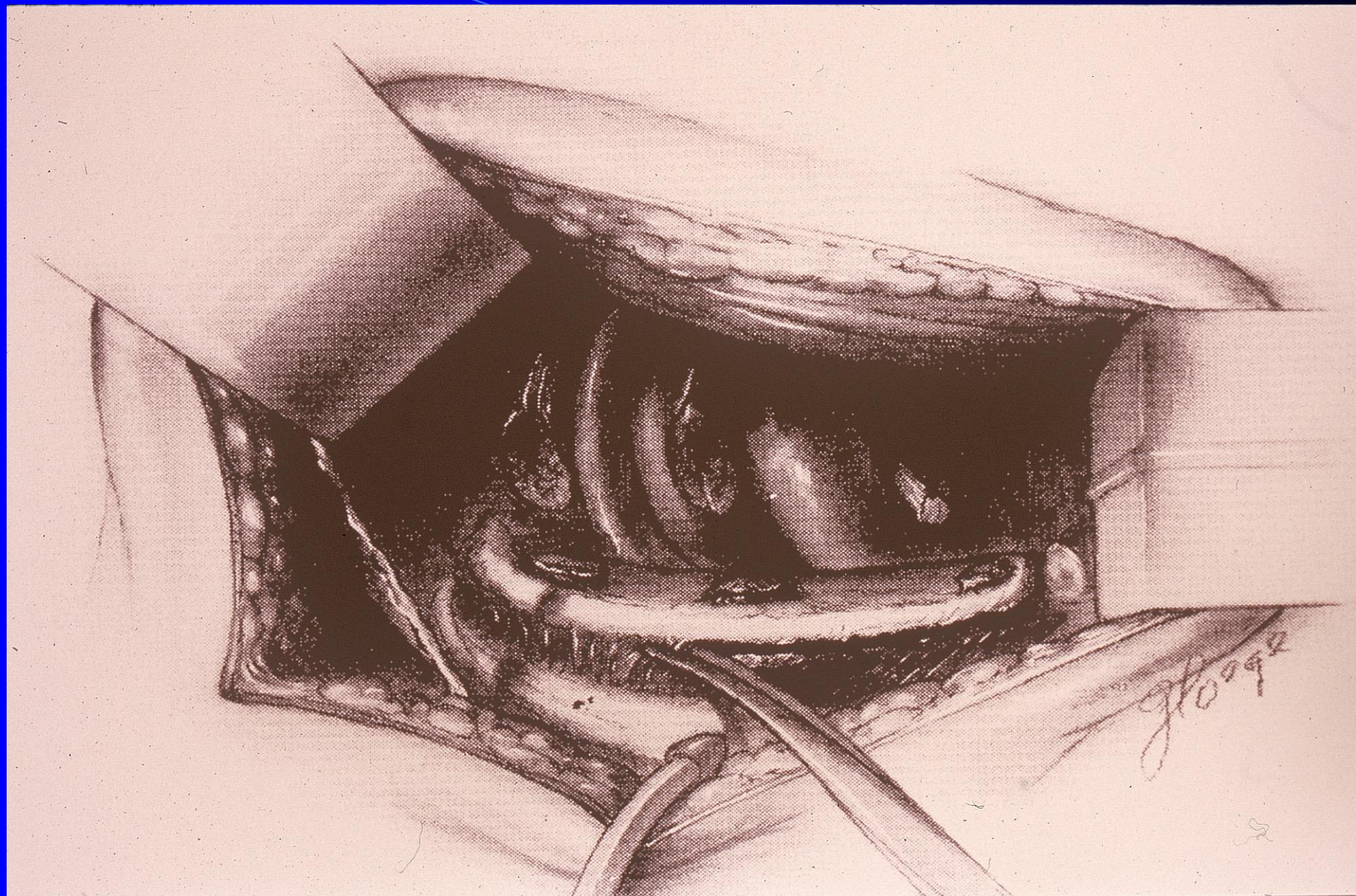
Heaney Retractor

Gelpi Retractor

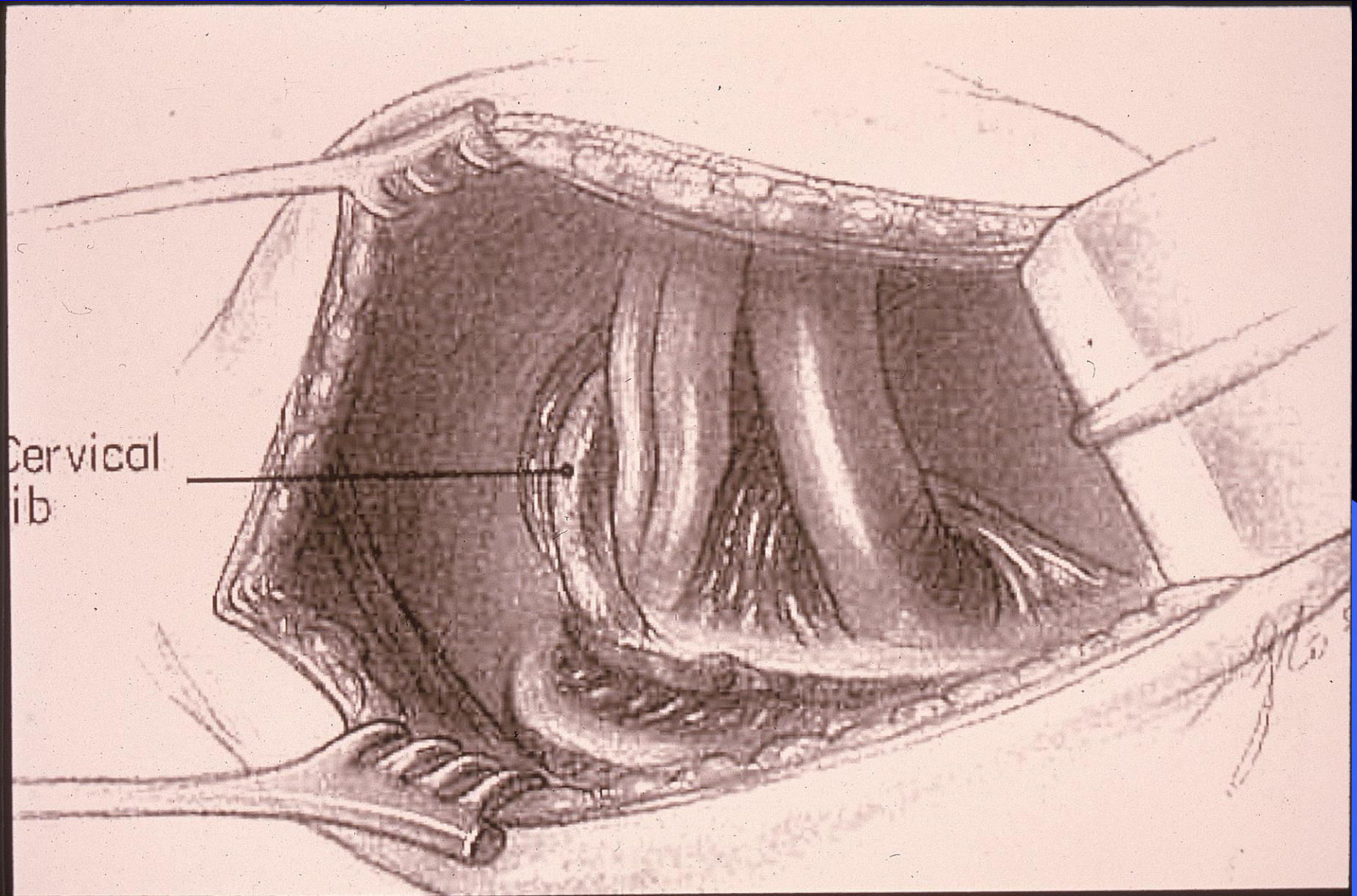


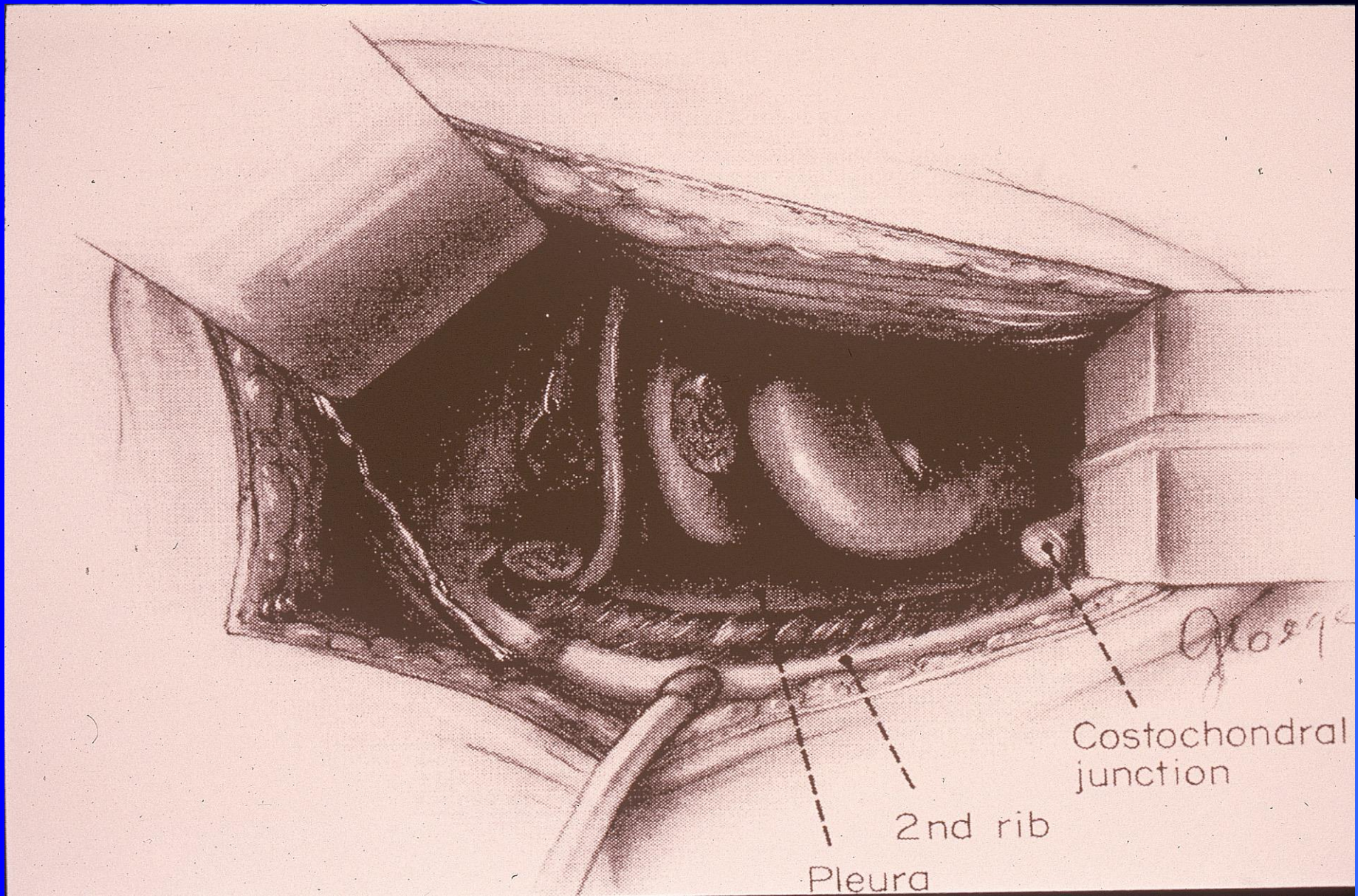






Cervical
rib



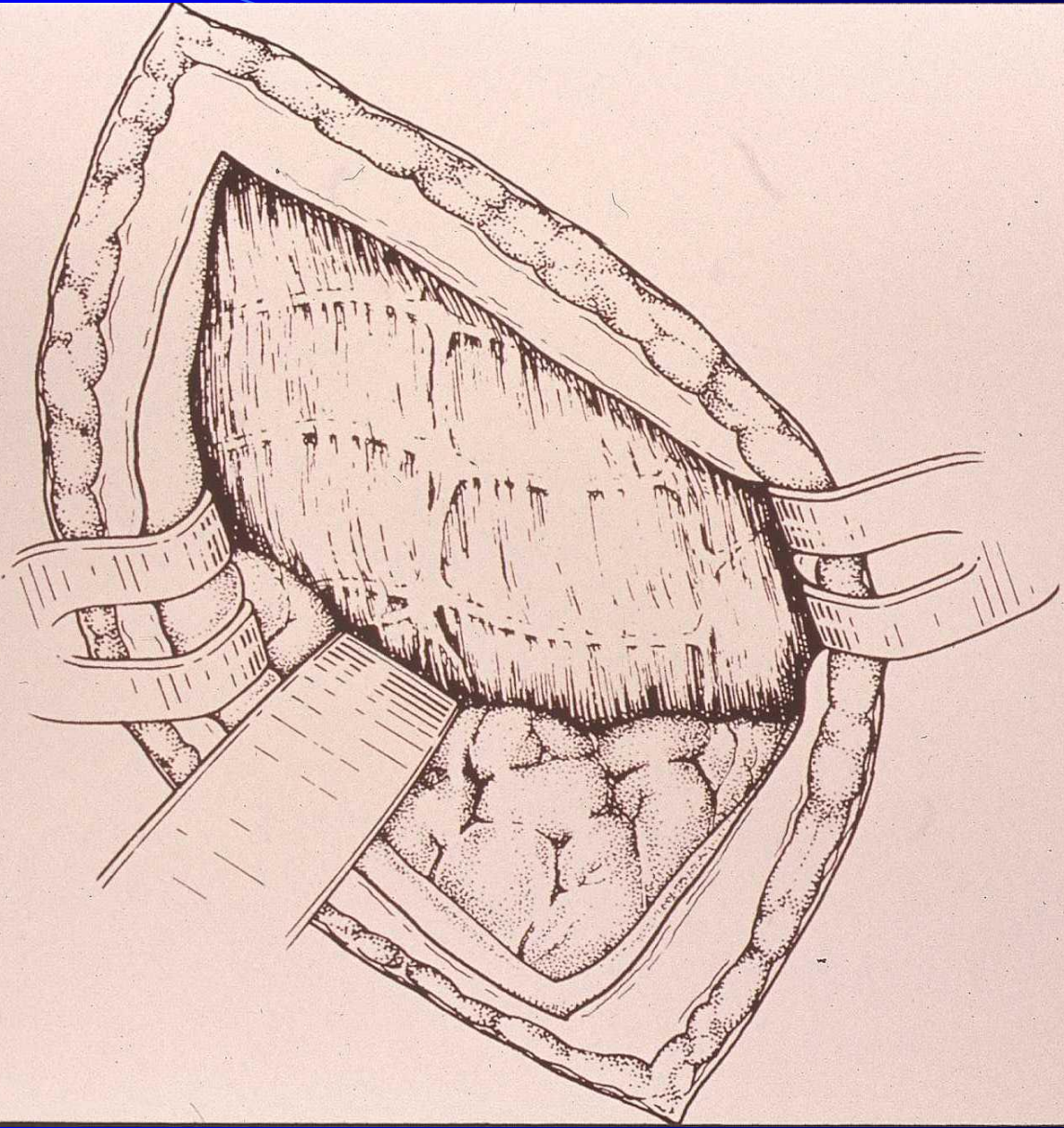


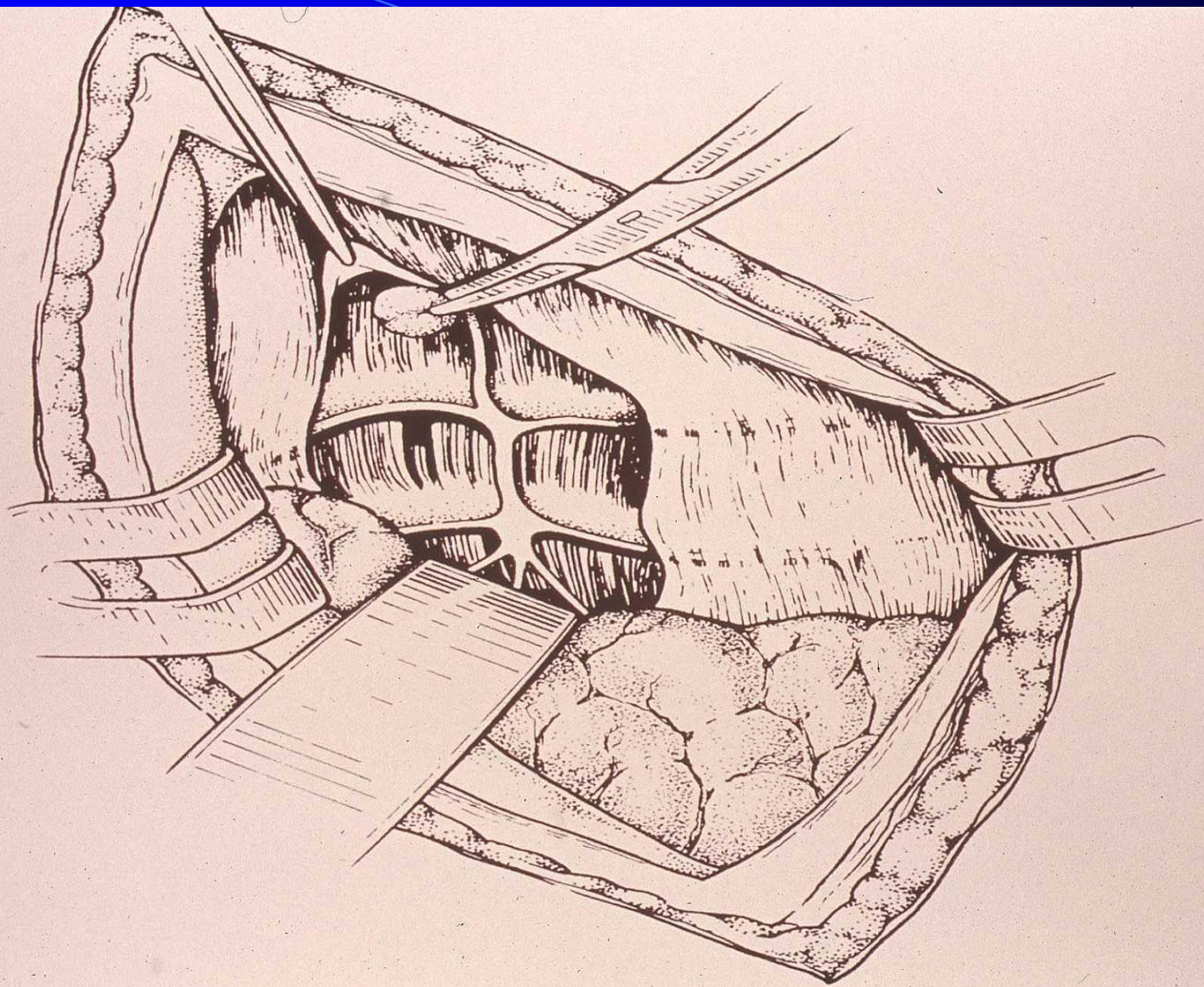
010298

Costochondral
junction

2nd rib

Pleura





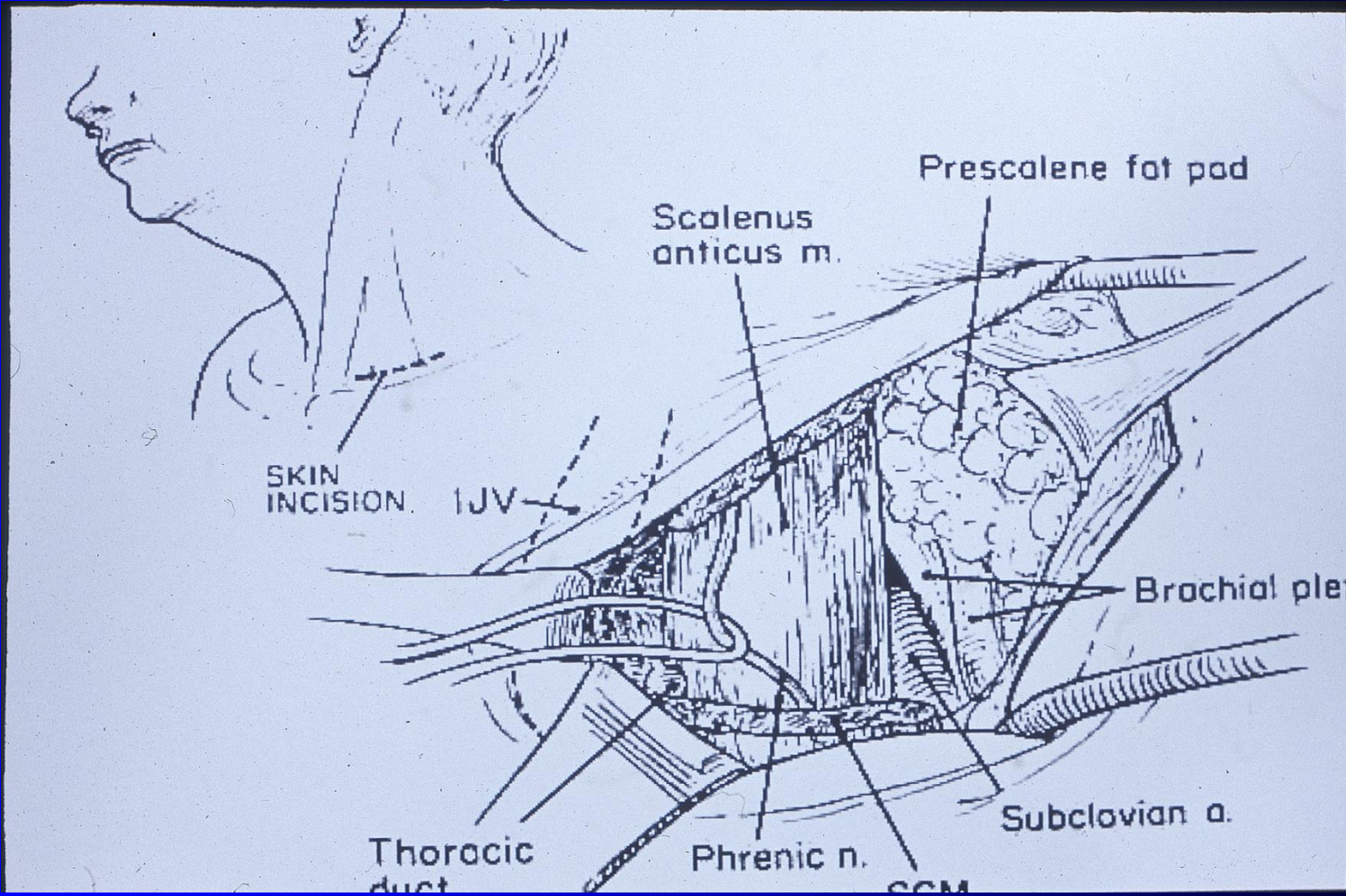
©1987 W. H. Webster

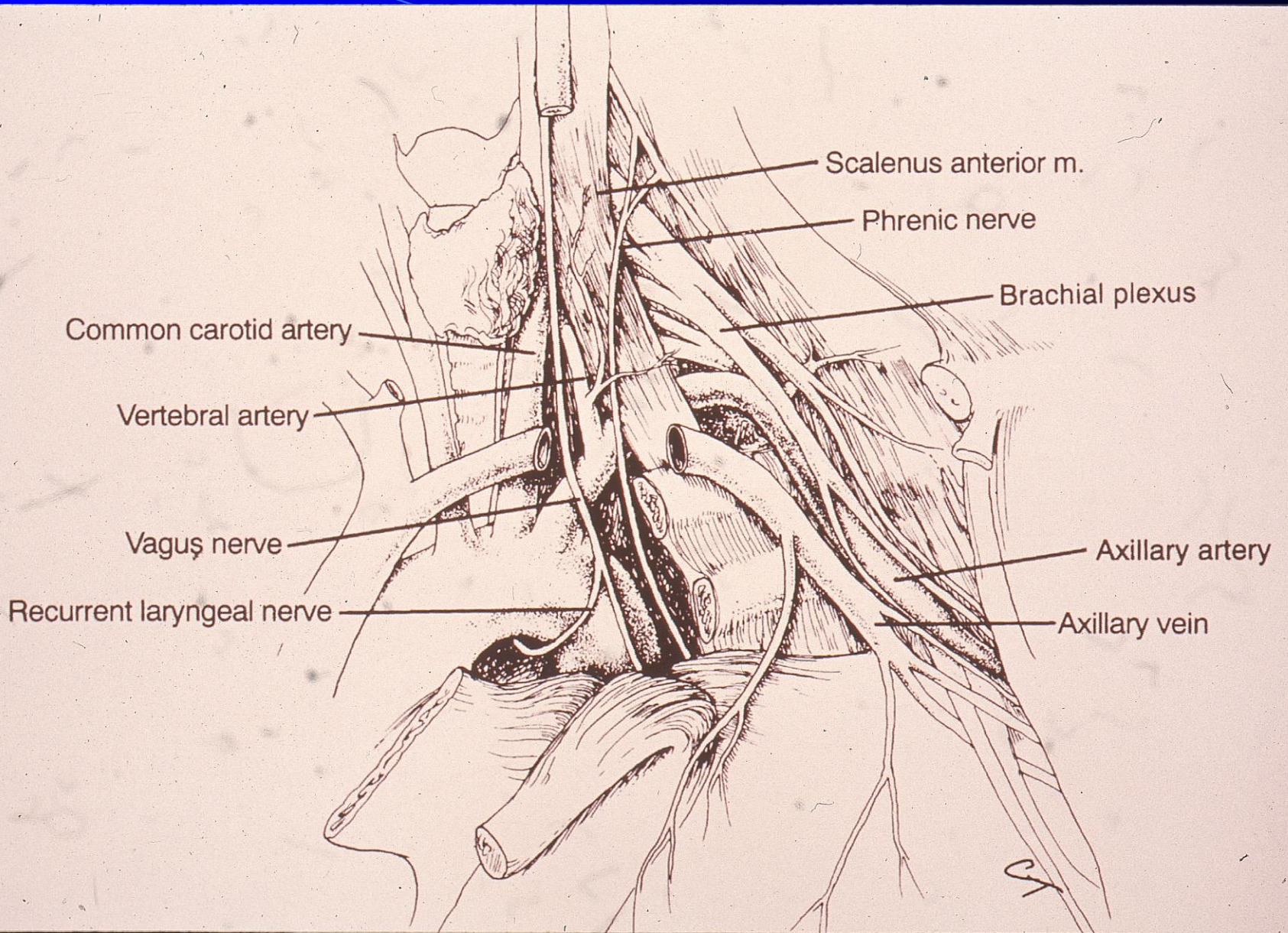


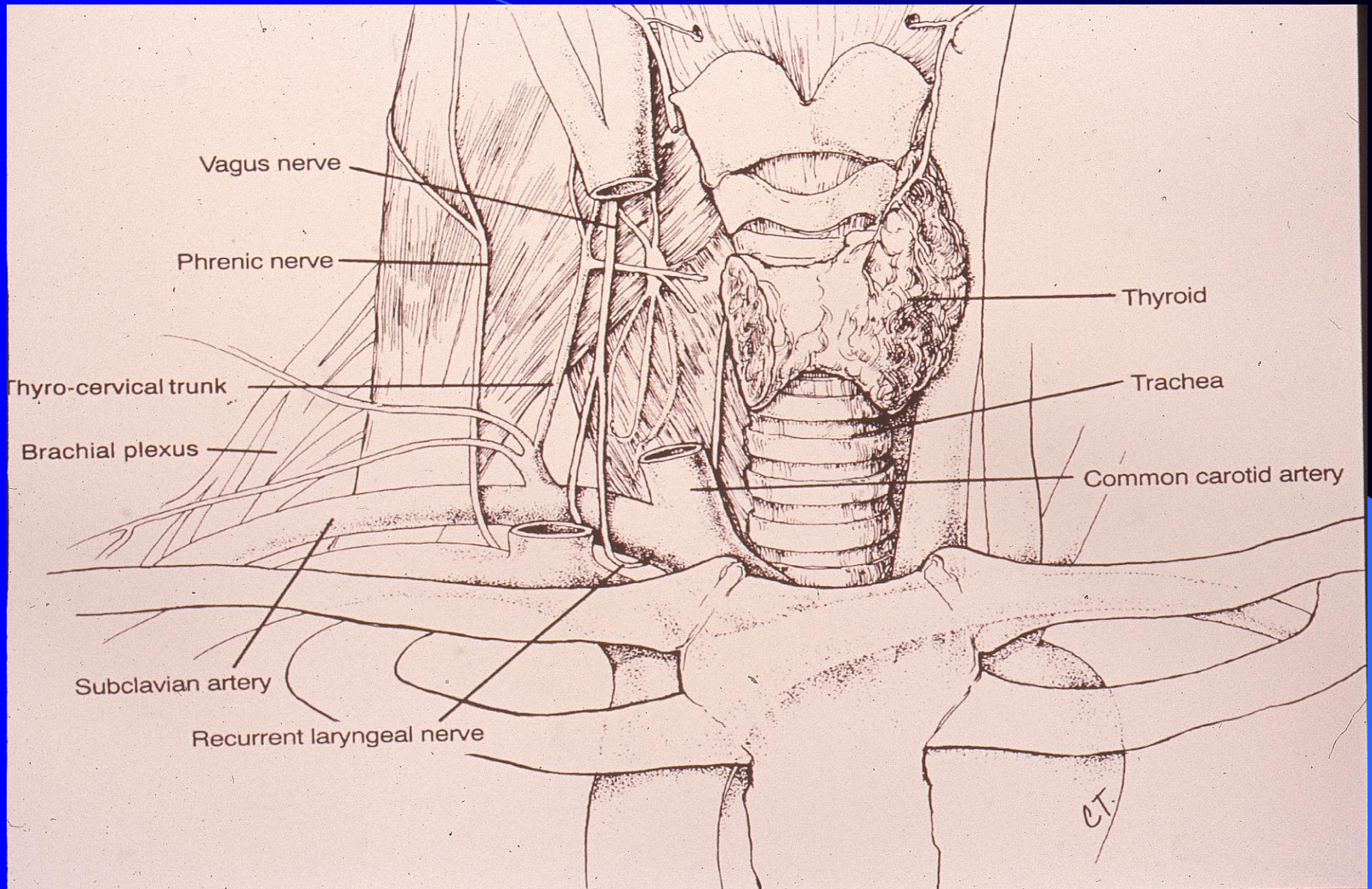
Sternal
head of sternocleidomasto
muscle

External jugular vein

Incision site for anterior scalenectomy





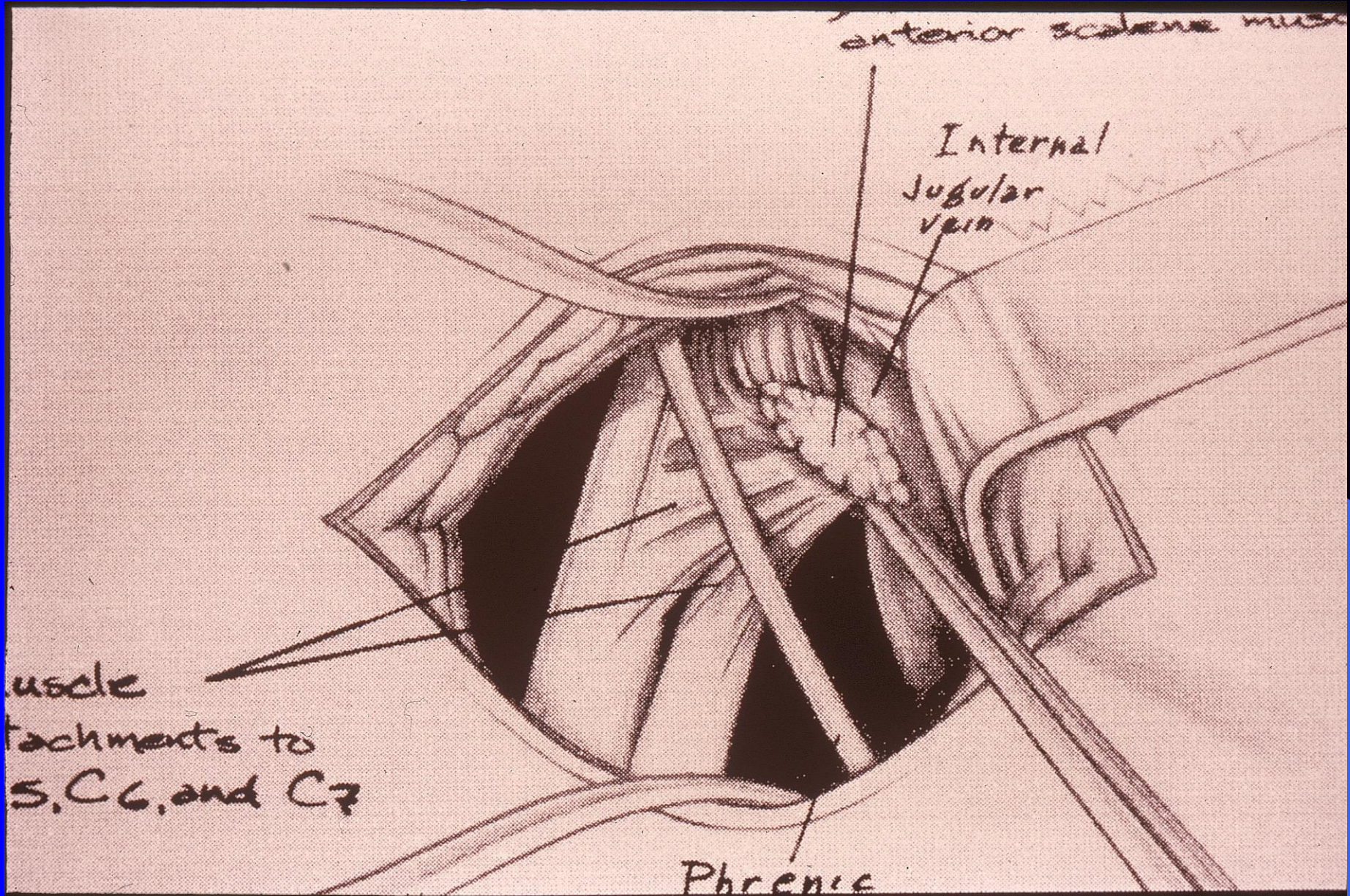


anterior scalene muscle

Internal
Jugular
vein

muscle
attachments to
S, C6, and C7

Phrenic



Material and Methods

- Study period: from 1994 to 2004
- 393 operative sides with N-TOS
 - **primary transaxillary first rib resection** and the lower part of scalenectomy
 - followed by **109 subsequent** upper part of **scalenectomy** with supraclavicular approach for persistent or recurrent symptoms.

Material and Methods

- Lost to follow-up: 11 (3%) operative sides
- 382 operative sides in 292 patients were analyzed.
 - mean age = 39 (range 15-80)
 - female:male = 4:1

Definition of Success

- The gold standard for N-TOS diagnosis
 - An operative success results at 2 months after surgery
- “*Success*” was defined as:
 - > 50% symptomatic improvement judged by the patient using a 10-point scale
 - Returning to preoperational work status

Results

- **No technical failures** and **no deaths** < 30 days after the operations
- The complication rate: **3%**.
 - Pneumothoraxes.....7
 - Injuries to the subclavian vein.....3
 - Injury to the long thoracic nerve.....1
 - Injury to the internal mammary artery
w/ a blood transfusion.....1
 - A suture granuloma.....1

Results

Diagnosis of N-TOS

(based on the operative results at 2 M)

- N-TOS.....321 (84.0%)
- Non N-TOS..... 61 (16.0%)

Results

	<i>Positive predictive value</i>	<i>Negative predictive value</i>	<i>Odds Ratio (95%CI)</i>
4-point Criteria	94.4% (234/248)	78.6% (44/56)	61.3 (26.6-141)
Physical Exam	85.3% (302/354)	34.6% (9/26)	3.1 (1.3-7.3)
MRI	85.4% (276/323)	31.6% (6/19)	2.7 (1.0-7.5)
SMB	86.7% (235/271)	66.7% (22/33)	13.1 (5.8-29.2)

Results of Transaxillary Approach to Neurogenic TOS

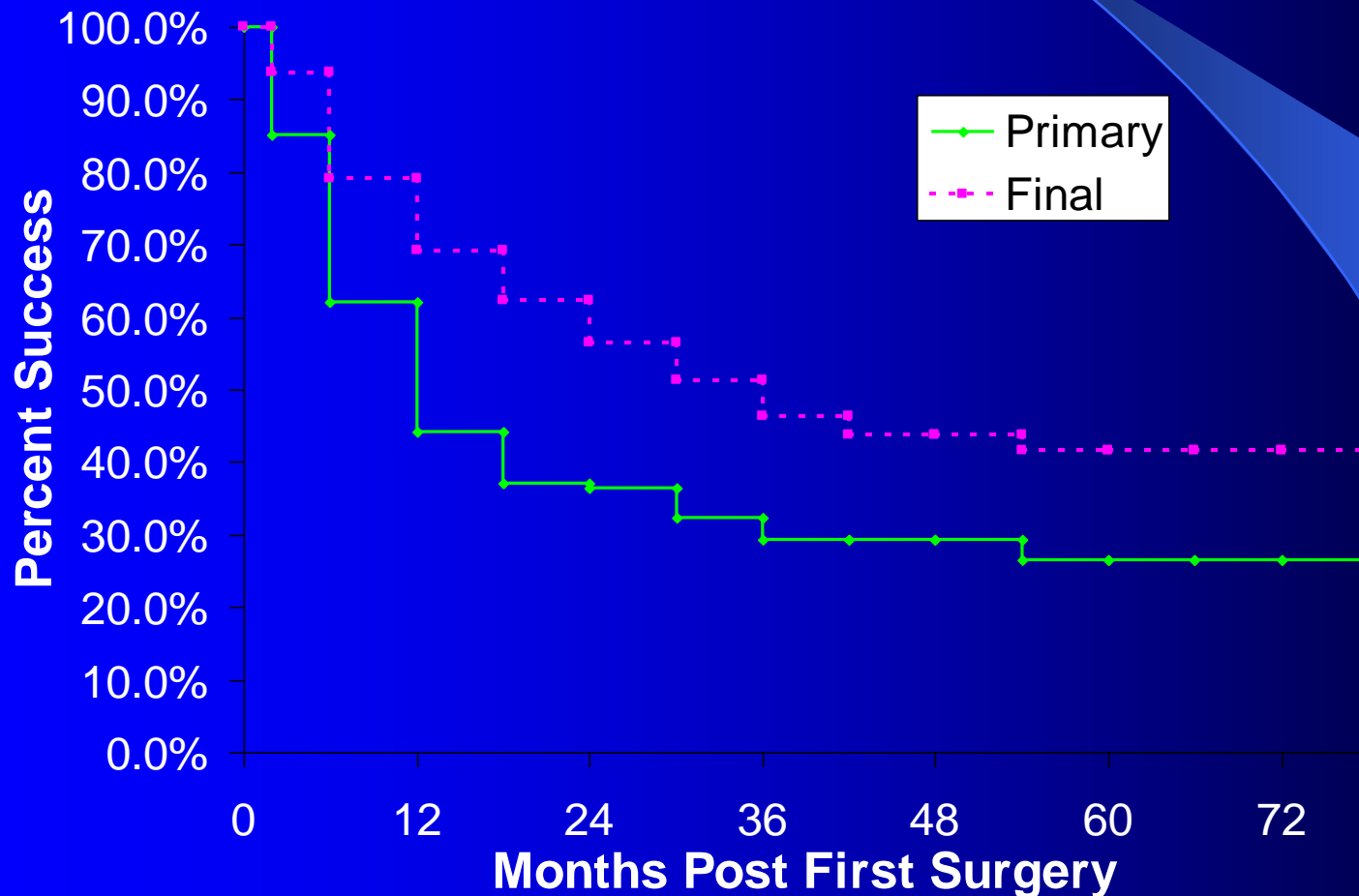
<u>Authors</u>	<u>Year</u>	<u>No. patients</u>	<u>Followup duration</u>	<u>Definition of Success</u>	<u>Success rate</u>
Sharp, Nowak, Zamani, et al	2001	27	2-108 mo (avg 48 mo)	Relief of most major symptoms	66%
Fulford, Baguneid, Ibrahim, et al	2001	61	2-96 mo (median 6 mo.)	Partial or complete improvement	91.5%
Franklin, Fulton-Kehoe, Bradley, et al	2000	158 worker's comp.	Avg 58 mo	Symptom improvement (worker-reported)	36.5%
Mingoli, Feldhaus, Farina, et al	1995	105	99 +/- 72 mo.	Mild residual symptoms w/ return to employment	81.4%
Sanders, Pearce	1989	111 surgeries	3-5 yrs 5-10 yrs	Improvement in some symptoms	73% 69%
Lindgren, Oksala.	1995	48	7-204 mo (avg 96 mo)	asymptomatic	43%
Altobelli, Haas, Kudo, Ahn	2004	185	2-76 mo (avg 26 mo)	50% improvement of symptoms	61%

Results of Supraclavicular Approach to Neurogenic TOS

<u>Authors</u>	<u>Year</u>	<u>No. patients</u>	<u>Followup duration</u>	<u>Definition of Success</u>	<u>Success rate</u>
Axelrod, Proctor, Greenfield, et al	2001	167	Avg 10.4 mos	Progress (Good/average)	67%
		89	Avg 47 mos	Symptoms improved	66%
Sanders, Pearce	1989	278 surgeries	3-5 yrs 5-10 yrs	Improvement in some symptoms	70% 69%

Actuarial Life-Table Analysis

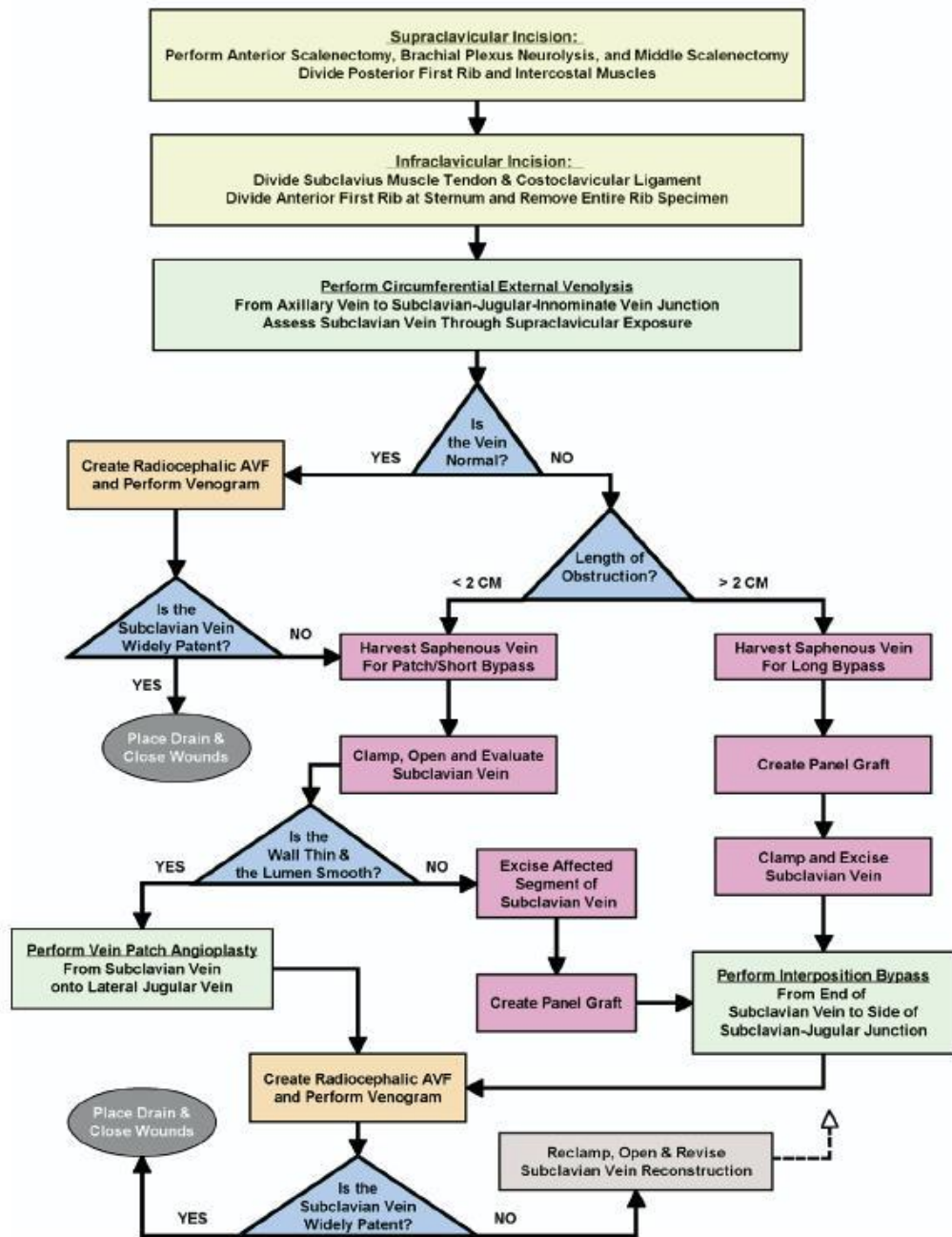
Primary Outcome Vs. Final Outcome
N=254





MANAGEMENT OF VENOUS TOS

Current Algorithm for the Operative Management of Venous TOS



Proximal Axillary

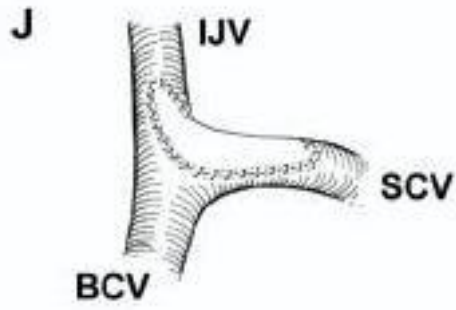


Subclavian

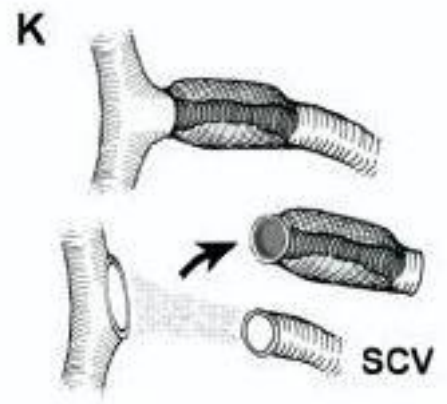


Management of Paget-Schroetter

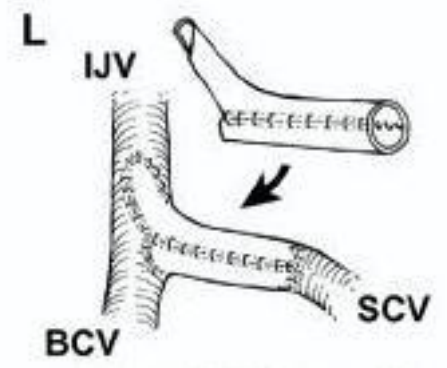
Author	Reference	N	Thrombolysis	Surgery	Success Rate	Complication rate
Molina JE, Hunter DW, Dietz CA	Vasc Surg. 2007 Feb;45(2):328-34.	97	Yes	Early	97/97 (100%)	1 bleeding complication, 2 pleural tear, 2 lymphocele
Kreienberg PB et al	J Vasc Surg. 2001 Feb;33(2 Suppl):S100-5.	23	Yes	Early	23/23 (100%)	3 wound hematoma, 1 subpleural hematoma, 2 transient brachial plexopathy
Urschel HC, Razzuk MA	Ann Thorac Surg. 2000 Jun;69(6):1663-8; discussion 1668-9.	294	Yes	Early	212/235 (90%)	None stated
Melby SJ et al.	Vasc Surg. 2008 Apr;47(4):809-820; discussion 821. Epub 2008 Feb 14.	32	Yes	Delayed	32/32 (100%)	2 hemothorax, 2 wound hematoma or lymph leak
Adelman MA et al.	Ann Vasc Surg. 1997 Mar;11(2):149-54.	10	Yes	Delayed	10/10 (100%)	None
Kunkel JM, Machleder HI	Arch Surg. 1989 Oct;124(10):1153- 7; discussion 1157- 8.	17	Yes	Delayed	17/17 (100%)	None



Vein Patch Angioplasty



Segmental Excision of Obstructed Portion of Subclavian Vein



Interposition Bypass with Saphenous Vein Panel Graft

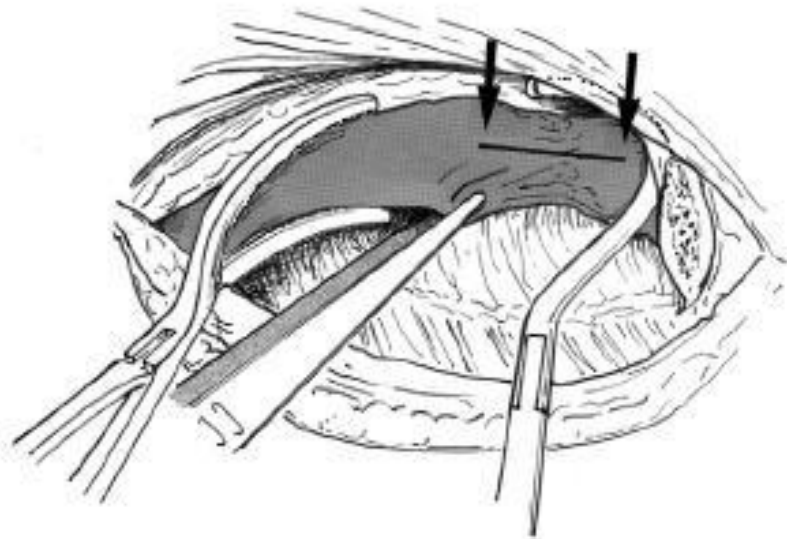


Fig 2. With the subclavian vein freed and fully mobilized, an incision (*arrows*) is placed across the stricture, extending medially into the normal innominate vein.



Fig 3. All of the organized fibrotic material causing the obstruction is removed before placement of the venous patch.

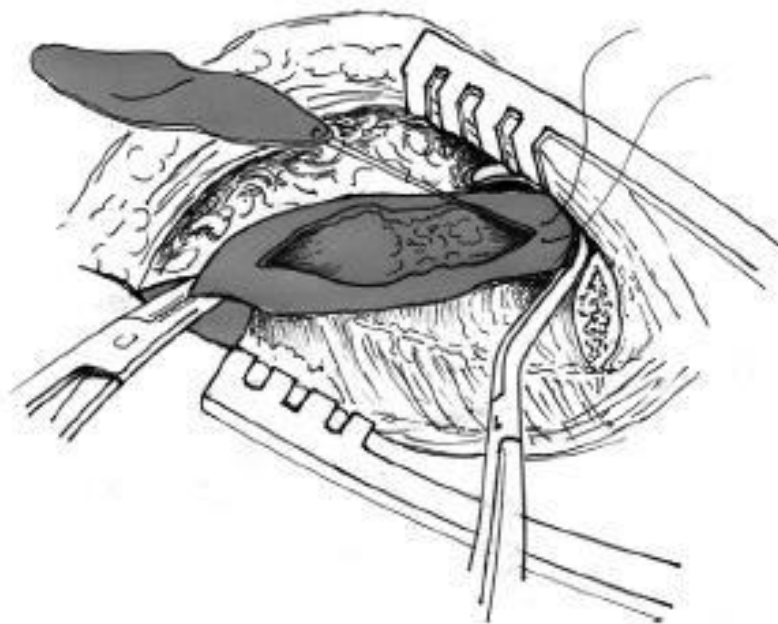


Fig 4. The saphenous vein patch is laid over the strictured segment of the vein.

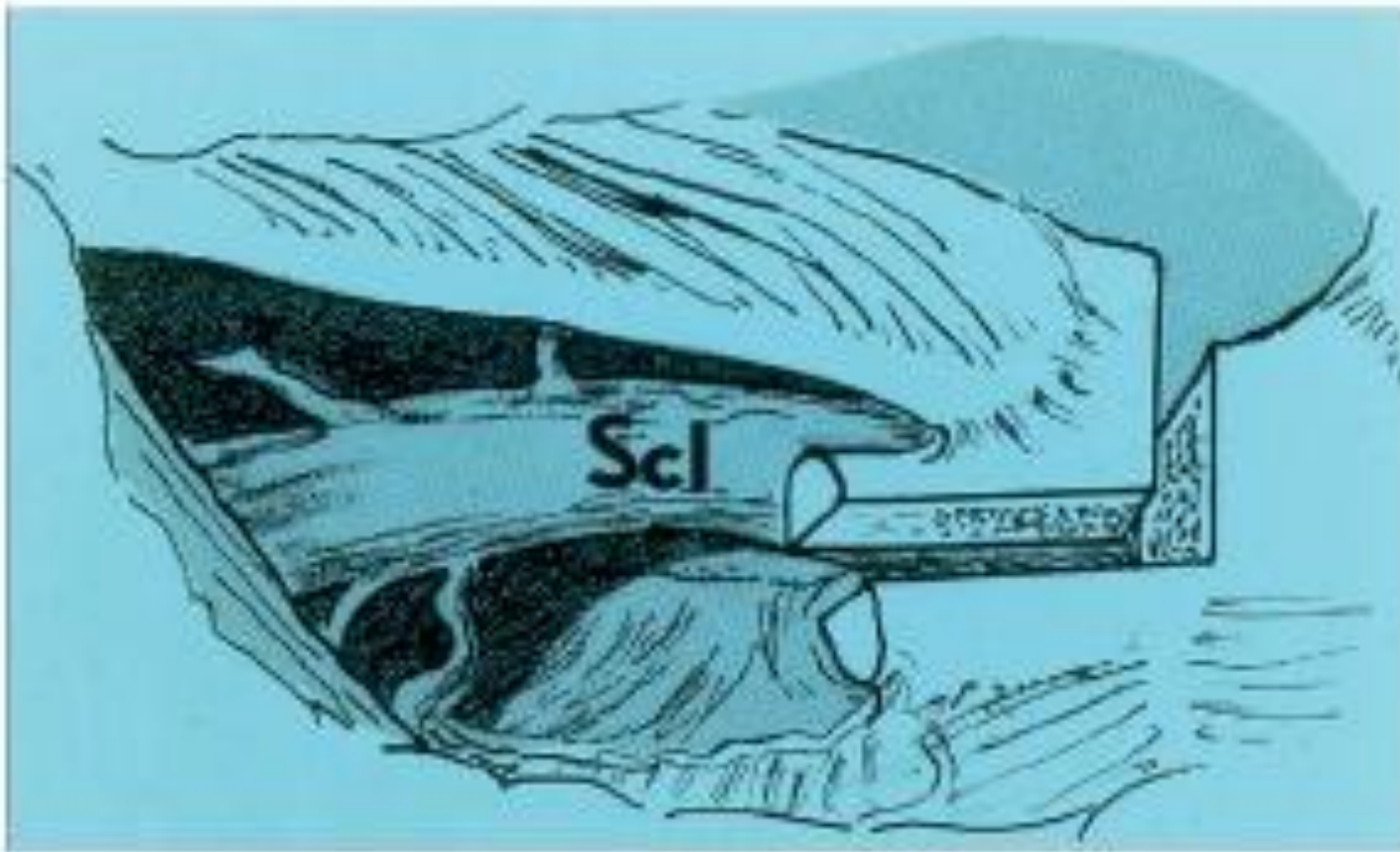
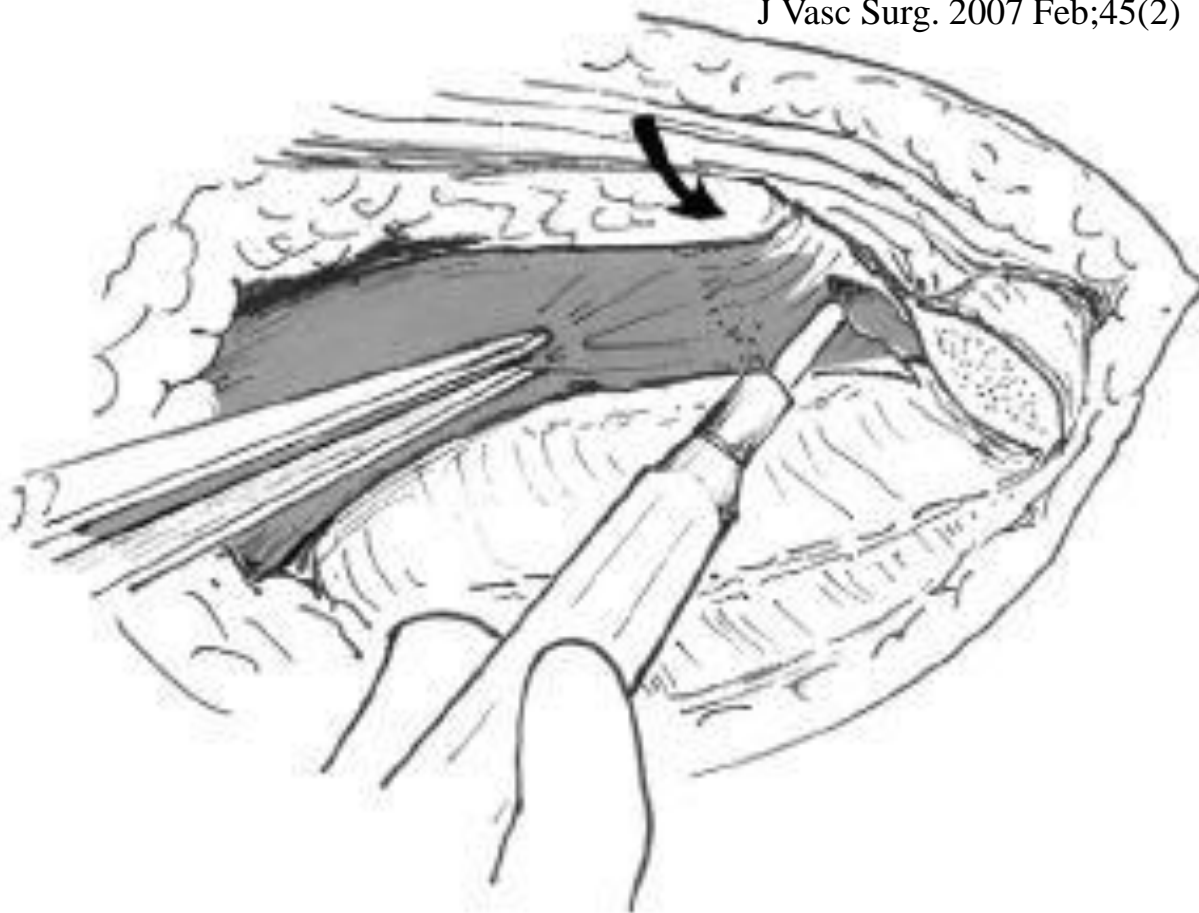


Fig 5. Drawing shows the transmanubrial extension of the subclavicular incision to the center of the sternum and vertically up to the sternal notch. This exposes the entire subclavian (*Scl*) and innominate vein without a need to remove or divide the clavicle.



THE KEY

Fig 6. The key to success is the complete mobilization of the subclavian vein, detaching it anteriorly from the sternum (*arrow*) until the vein is easily exposed in the operative field, allowing sufficient margin for placement of the medial clamp between the site of the stricture and normal innominate vein.

Venogram

Before Angioplasty



After Angioplasty



Treatment of Arterial TOS

- 1. Anticoagulation
- 2. Thrombolysis/Thrombectomy
- 3. Surgical Decompression
- 4. Pectoralis Minor Muscle Release
- 5. Sympathectomy
- 6. Arterial Reconstruction

Percutaneous Transluminal Venous Angioplasty for Thoracic Outlet Syndrome

Jones, Lauren E.; Richmond, Jasmine L.;
Feldtman, Robert W.; Ahn, Samuel S.
Texas Surgical Society 2018
Houston, TX
April 7th, 2018



DFW Vascular

Background

- In 2014, Ahn *et al.* demonstrated that **internal jugular vein (IJ) stenosis is common in TOS patients**
 - Also showed **subclavian vein stenosis is common**
 - Concluded that **treatment of IJ and subclavian stenosis could benefit TOS patients**

Ahn SS, Miller TJ, Chen SW, Chen JF. Internal Jugular vein Stenosis is common in patients presenting with Neurogenic Thoracic outlet syndrome. *Annals of vascular surgery*, 2014;28(4), pp.946-950.

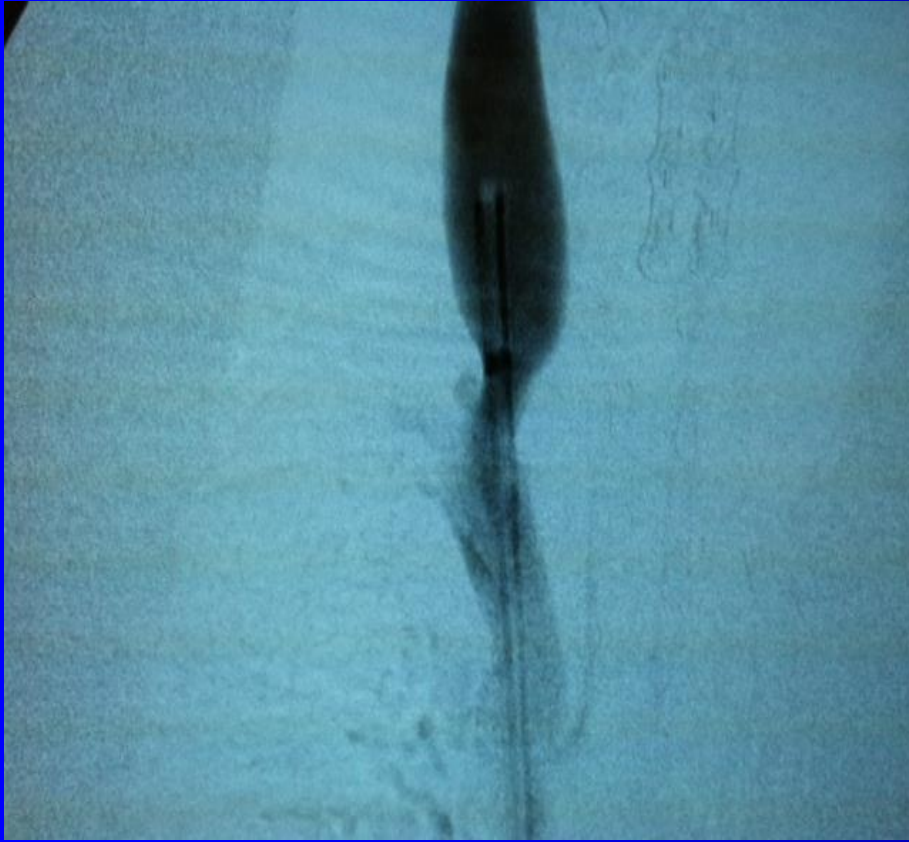
Medium



Low



High Grade Stenosis (Significant)



Medium Stenosis with Collaterals (Significant)



Patients Temporarily Benefit from IJ Ballooning



AHN Sign

A- Abduct the arm

H- Head turned

N- Neck vein distention

This patient presented with classic neurogenic symptoms, but was positive for non-thrombotic venous TOS





Introduction

- We postulate that **percutaneous transluminal angioplasty (PTA)** of the **subclavian** and/or **internal jugular** vein may benefit patients with TOS
 - Improves symptoms
 - May reduce need for open surgical decompression



Protocol

- **Physical therapy first**
- **Venography if physical therapy fails**
- **PTA of internal jugular & subclavian veins if stenosis found on venography**



Methods

- Retrospective chart review of all patients with symptoms of TOS from 2010-2016



Symptoms of TOS

- Headaches
- Neck pain
- Extremity pain
- Extremity numbness & tingling
- Extremity coldness
- Extremity swelling and/or engorged veins
- Embolic lesions
- Dizziness
- Unsteady gait



Diagnostic Categories of TOS

- Neurogenic: 456 (96.4%)
- Venous/DVT: 14 (3.0%)
- Arterial: 3 (0.6%)



Study Protocol

January 2010- July 2016

Patients with TOS Symptoms
N=503

All sent to physical therapy (PT)

Symptoms improved with PT
N=282

Symptoms did not improve with
PT
N=221

Continued treatment with home PT

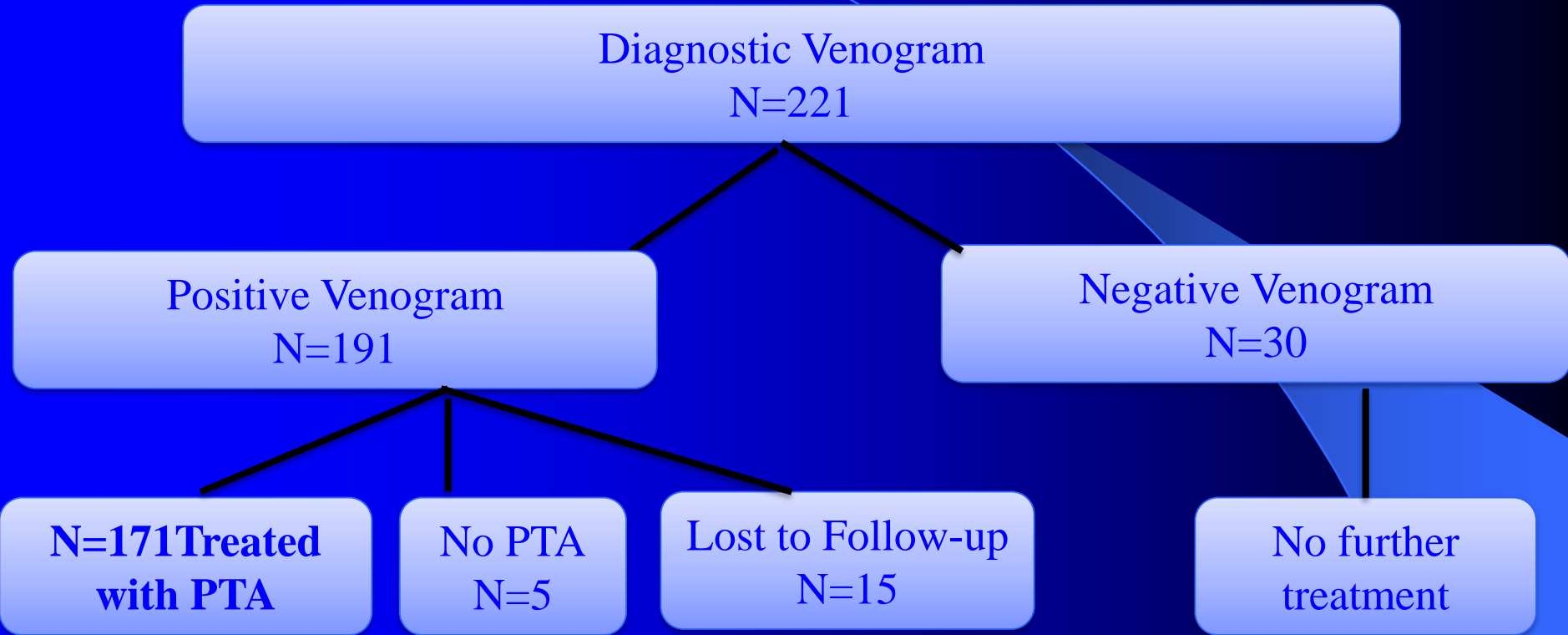
Diagnostic Venogram



DFW Vascular

Study Protocol

January 2010- July 2016



Demographics

171 subjects underwent PTA

- 76.6% female
- Median ASA
Classification: ASA II

Comorbidities	N	%
DM	20	4.6
HTN	89	20.4
COPD	20	4.9
CAD	13	3.0
ESRD	1	0.3



Technique

- Puncture Right GSV with ultrasound guidance
- 7 French sheath
- IV Heparin, 75units/kg
- Venogram
- IVUS since January 2016
- PTA with 10 or 12mm balloon
- Manual compression with sandbag and supine for 1 hour then discharge home



Results

- 63.7% reported significant improvement*

*Defined as $\geq 50\%$ improvement of symptoms

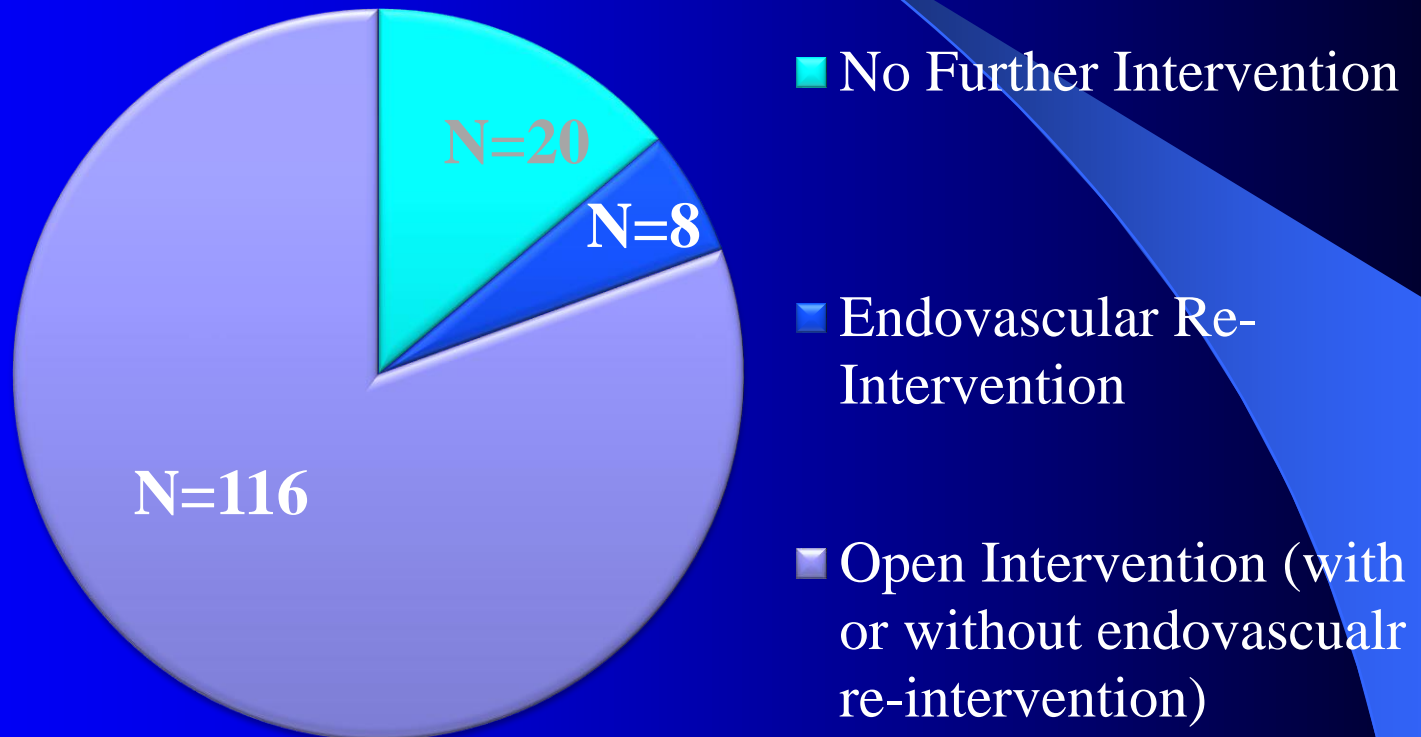
- 36.3% reported no improvement

Cohort Treated with PTA: Improvement Interval

Improvement Interval	N	%
No improvement	144	36.3
Short term (1-6 days)	33	8.3
Intermediate (7-89 days)	106	26.7
Long term (>90 days)	114	28.7

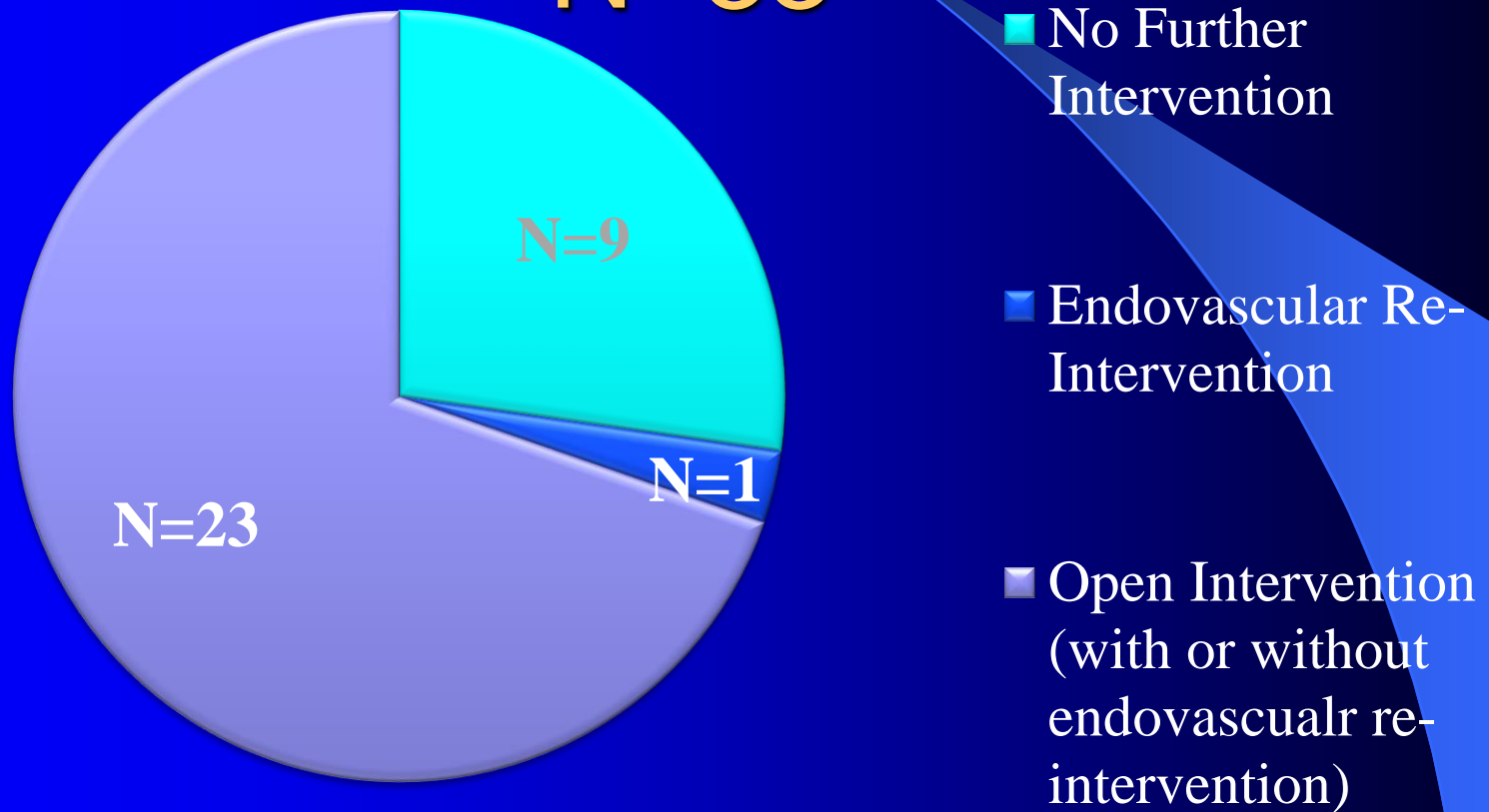


PTA Results: No Improvement N=144

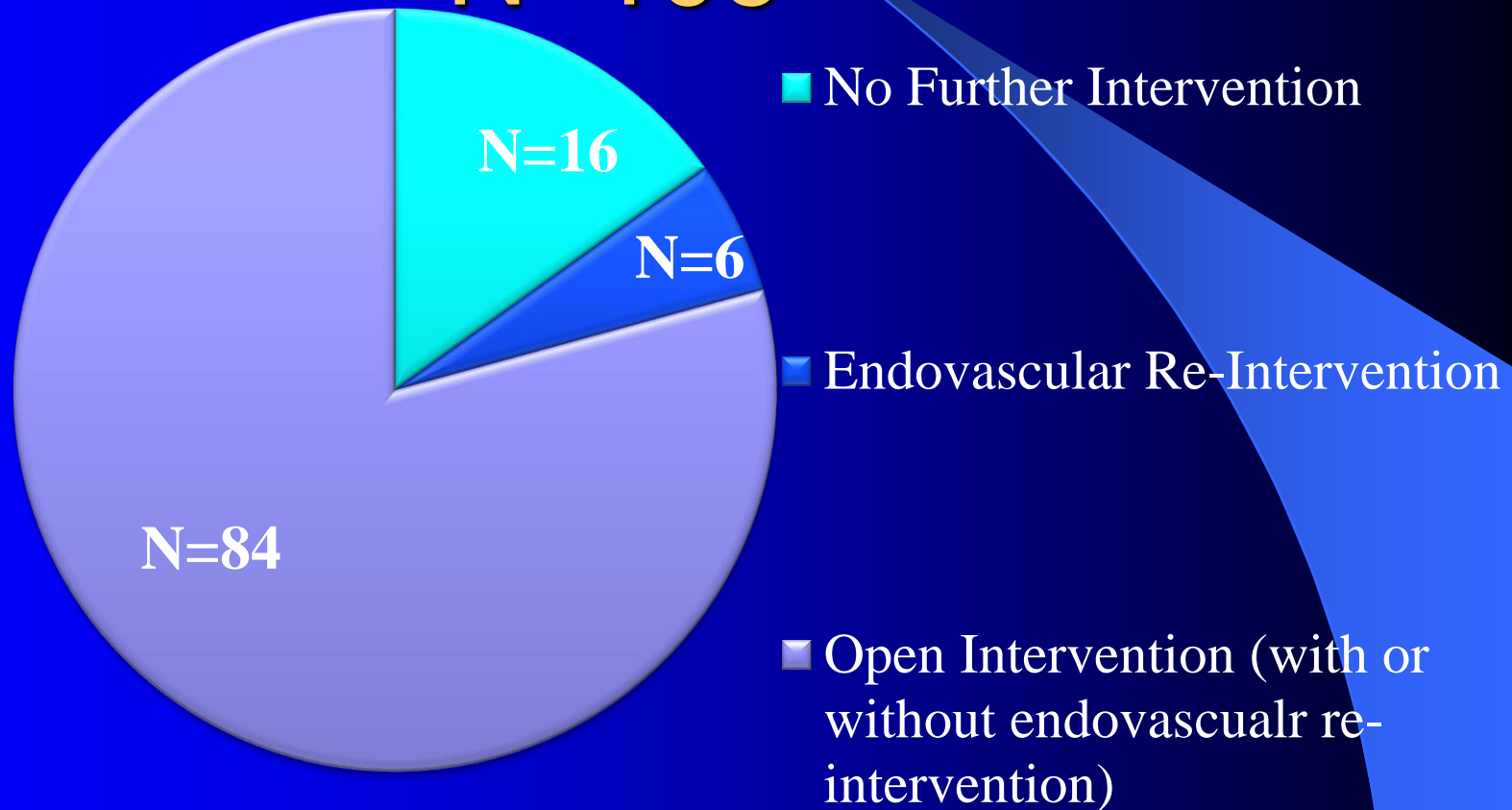


PTA Results: Short Term Improvement

N=33

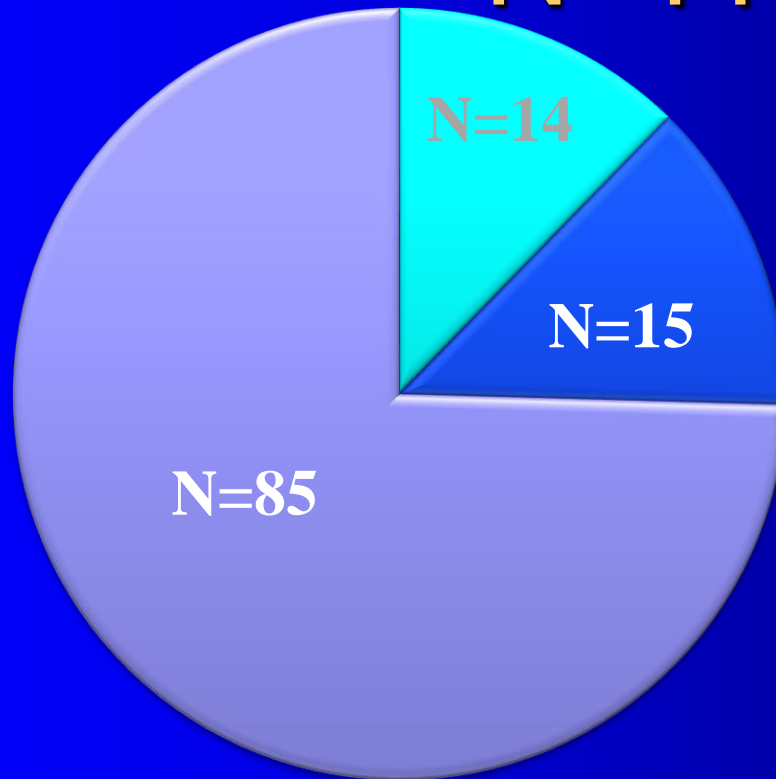


PTA Results: Intermediate Improvement N=106



PTA Results: Long Term Improvement

N=114



■ No Further Intervention

■ Endovascular Re-Intervention

■ Open Intervention (with or without endovascular re-intervention)



DFW Vascular

Complications

N=171

- **PTA- 1 (0.5%)**: ruptured balloon that required cut-down. Patient was discharged home same day with no prolonged recovery
- **Open- 1**: infected seroma at JP drain site



Summary

- 58 of 171 patients who had PTA **required no further intervention** (33.9%)
- 113 required **subsequent treatment** (66.1%)
 - 13 had only endovascular re-intervention (7.6%)
 - 100 had eventual open intervention (58.5%)
- 41.5% of patients treated with PTA **avoided open surgery**



Summary, cont.

- 52.5% of patients who had venogram **avoided open surgery**
- Overall, 79.1% of all TOS patients **avoided open surgery**



Conclusion

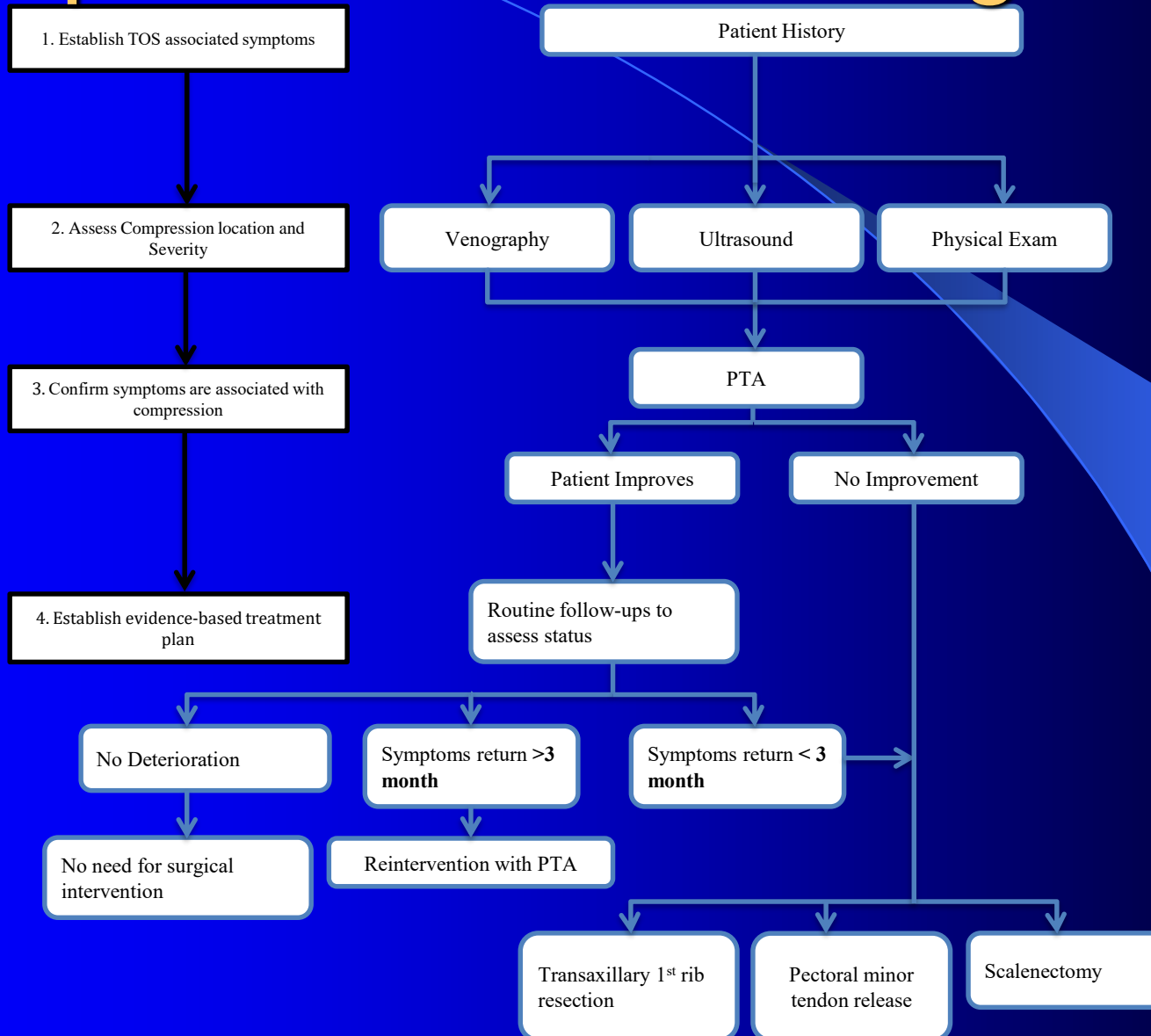
- **Diagnostic venogram and PTA are safe and effective in diagnosis and treatment of TOS**
- PTA benefits patients
 - Less invasive
 - Less traumatic
 - Improves symptoms
 - Avoided need for invasive surgery in majority of patients



New Concepts in TOS

- Most patients with classic symptoms of neurogenic TOS have a venous component
- These patients will benefit from angioplasty
- Update to classification of TOS
 1. Neurogenic
 2. Arterial
 3. Venous
 4. Non-thrombotic venous TOS

Proposed Treatment Algorithm

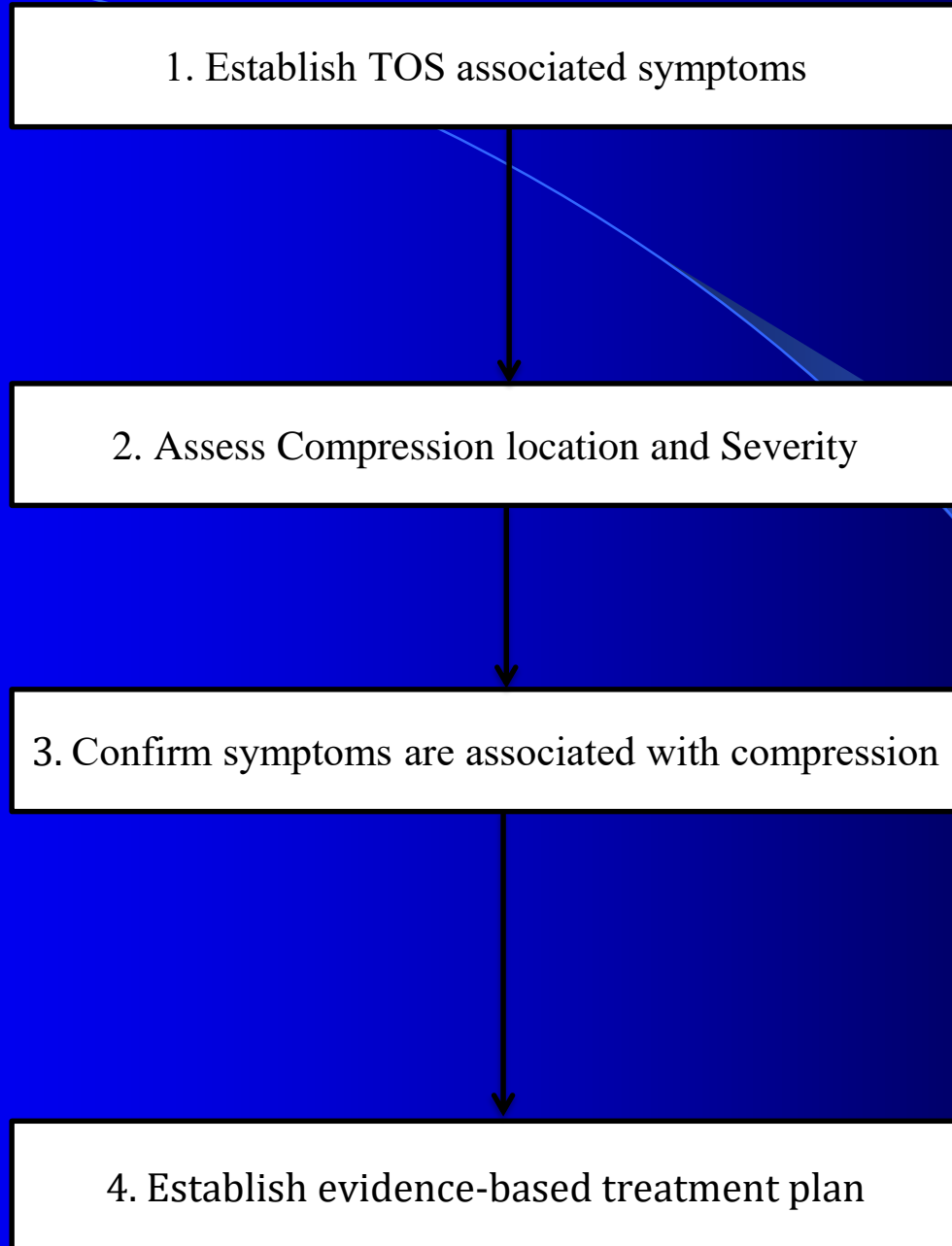


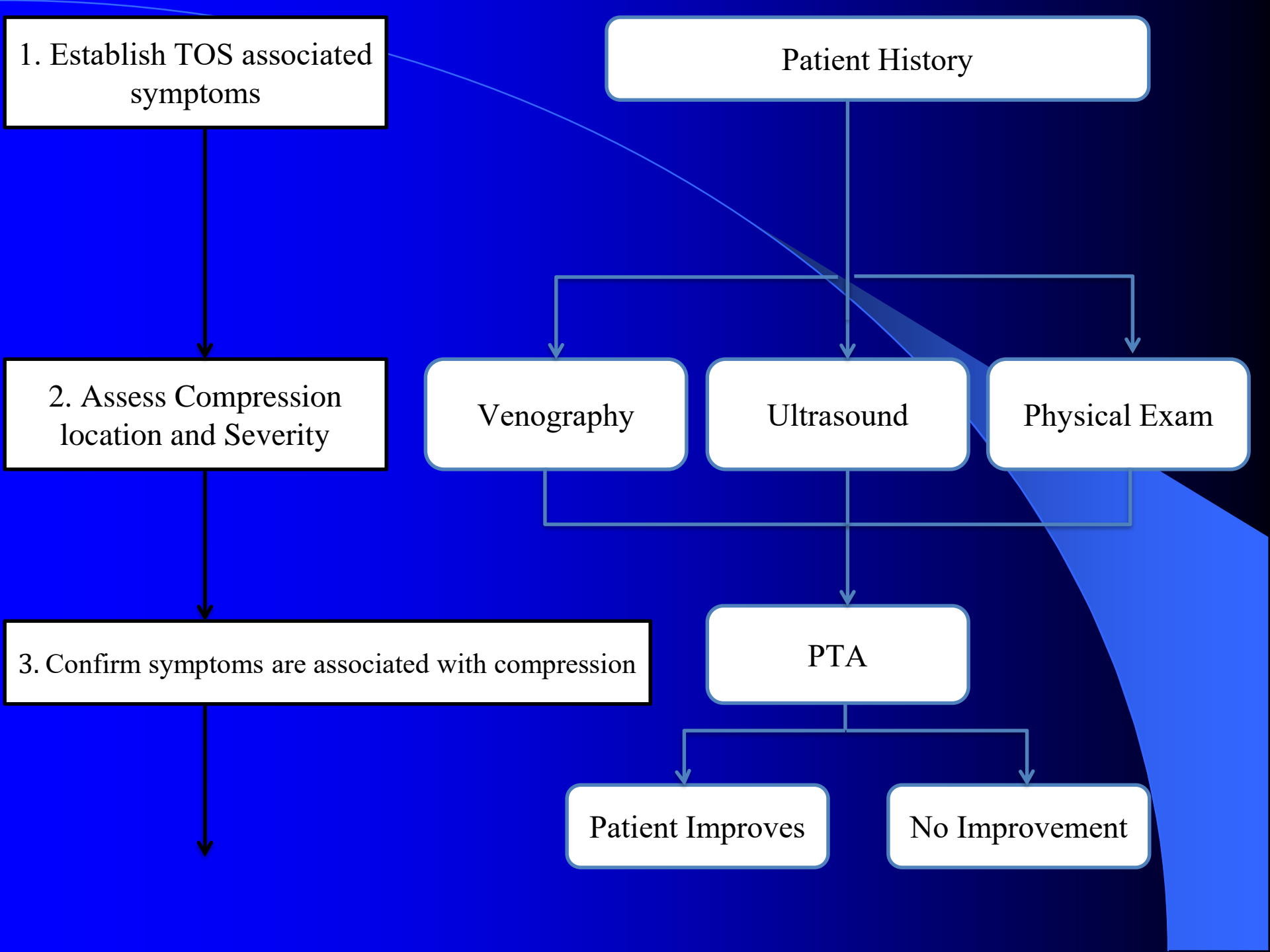
1. Establish TOS associated symptoms

2. Assess Compression location and Severity

3. Confirm symptoms are associated with compression

4. Establish evidence-based treatment plan





1. Establish TOS associated symptoms

Patient History

2. Assess Compression location and Severity

Venography

Ultrasound

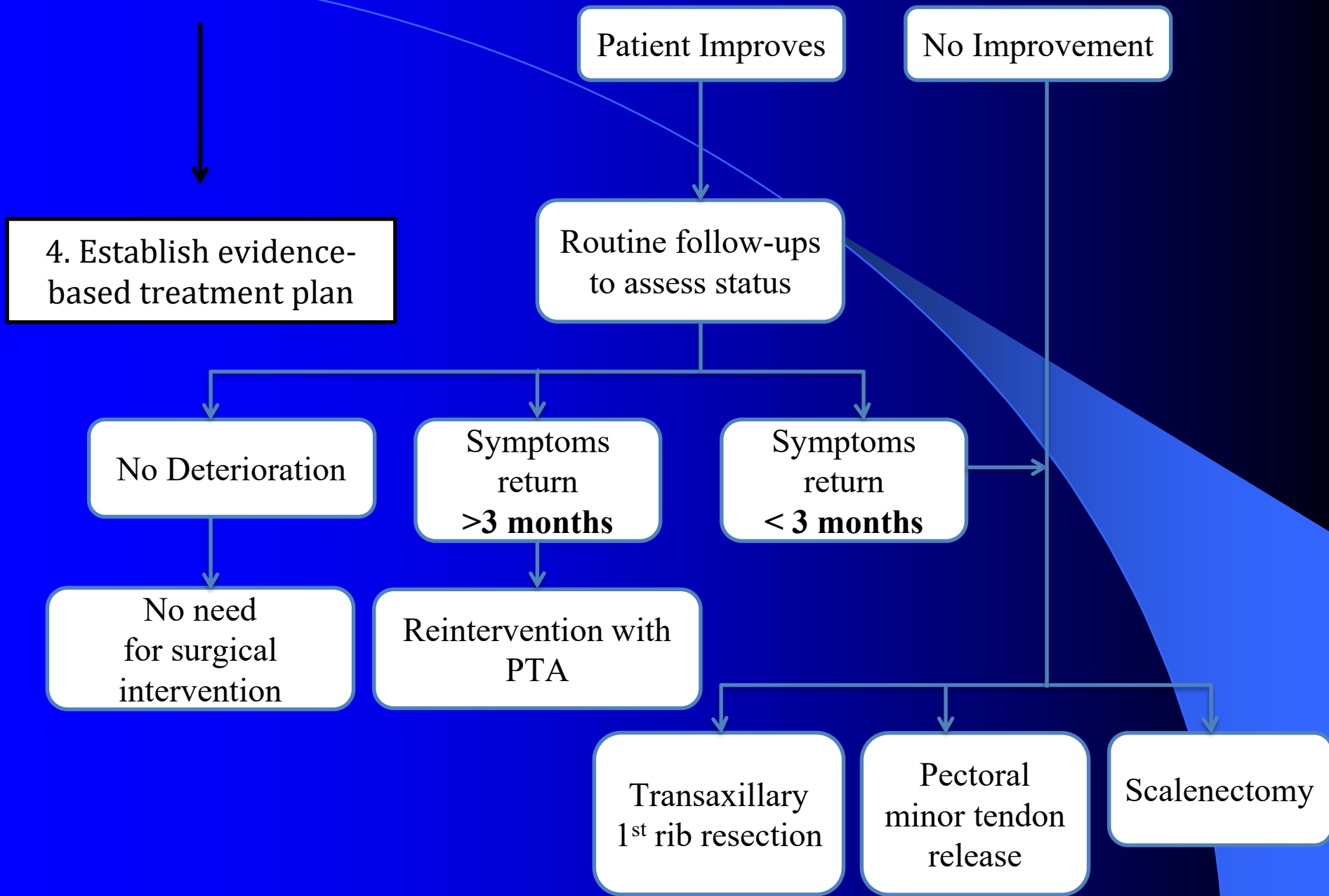
Physical Exam

3. Confirm symptoms are associated with compression

PTA

Patient Improves

No Improvement



Thoracic Outlet Syndrome Summary

- A complex disorder
- Multiple etiologies
- Varied presentations
- Multiple treatment options with varied results
- Long-term follow-up needed
- Most classic neurogenic TOS have a non-thrombotic venous component