Basics of ultrasound guided regional anesthesia?

Luc Sermeus, MD, PhD St. Luc University Hospital Catholic University of Louvain Brussels Belgium



Theoretical background and practical applications



- General considerations
- Define: 0
 - attenuation, Doppler
 - Image optimization
 - Image interpretation
 - Needle insertion and injection

Objectives

• Ultrasound generation, frequency, wavelength,

Peripheral Nerve Stimulator

Ultrasound guided regional anesthesia

Evolution

Peripheral Nerve Stimulator

<u>Current intensity</u>

- For localizing the nerve:
 - between 0.5 and 2 mA
- - between 0.3 and 0.5 mA

For avoiding intraneural needle positioning:

PNB with Peripheral Nerve Stimulator

Several disadvantages

Blind technique (anatomic variations?)

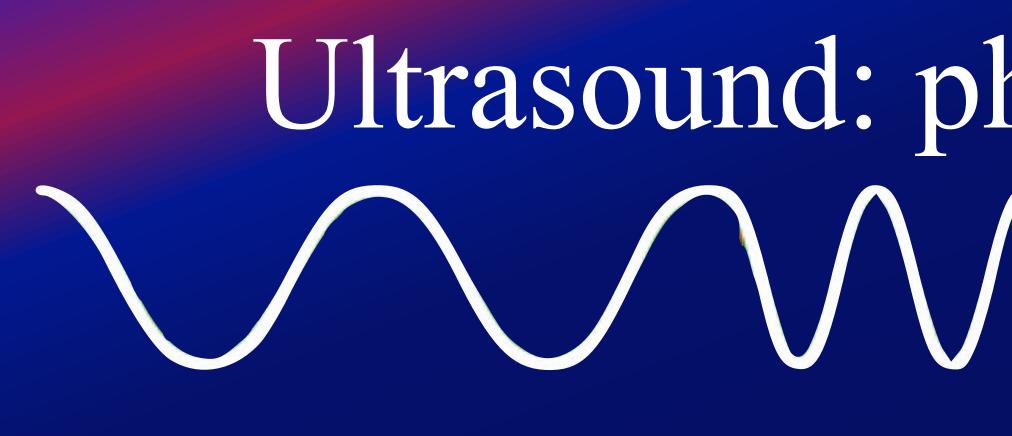
Dependent of normal functioning nerves

Large volumes of LA (risk of LAST)

- Landmark technique
- Several disadvantages
 - Blind technique (anatomic variations)
 - Dependent of normal functioning nerves
 - Large volumes of LA (risk of LAST)

PNB with Ultrasound

ULTRASOUND





16

Infrasound < 20 Hz



Ultrasound: physical definition

20 000

Audible sound <

Ultrasound >20,000Hz

The American Society of Regional Anesthesia and Pain Medicine and the European Society of Regional Anaesthesia and Pain Therapy Joint Committee Recommendations for Education and Training in Ultrasound-Guided Regional Anesthesia

Brian D. Sites, MD,* Vincent W. Chan, MD,† Joseph M. Neal, MD,‡ Robert Weller, MD,§ Thomas Grau, MD, PhD,// Zbigniew J. Koscielniak-Nielsen, MD, PhD,¶ and Giorgio Ivani, MD#

Reg Anesth and Pain Med. 34,1, Jan-Feb 2009

Reg Anesth Pain Med. 2010 35(2 Suppl):S74-80.

Knowledge of anatomy (and sonoanatomy)

The base



REMENBER!!

Anatomy varies and we are not all experts

Andreas Vesalius (Brussels 1514-Zakinthos 1564) De humani corporis fabrica libri septem





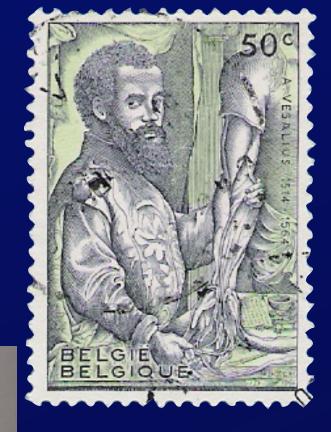
ANDREAE VESALII BRVXELLENSIS, DE HVMANI CORPO-V X E L L E TU STUD, E L I BER PRIMVS, IIS QVAE uniuerfum corpus fuffinent ac fuffulciunt, quibus qomnia ftabiliuntur & adnafcuntur dedicatus,

QVID OS, QVIS QVE IPSIVS VSVS & differentia. Caput I.



CAETERARVM hominispartium eft durifsi Ofination m, & aridifsimu, maxime's terreftre & frigidum, ique præter folos dentes expers. Huius temperamenti fummus rerum opifex Deus Oßium usus. neritò efformauit, corpori uniuerío fur ti inftar fubijciendam. Name nibus, & in tentorijs pali, & in nauibus il cum coftis præftant, id in hominis faum præbet substantia. Offium siquidem Opideffert is nomine tanquam corporisfulcra pro-Alia reliquis partibus ueluti propugnacula, Isimice ualli & muri à natura obijcit

admodum caluaria, uertebrarum ípinæ, & transuersi earundem proceffus, pectoris os, costæ; Alia quorundam offium artículis præficiuntur, ne illi plus fatis laxe moueantur, autin nimium acutos inclinentur angulos. Huius nanque beneficij occalione, olsicula effinguntur, felami feminis magnitudini à diffectionis profetforibus comparata, quorum quædam fecundo pollicis manus internodio, & quatuor reliquoru digitorum primis internodijs, & primis etiam internodijs quinque digitorum pedis coarticulantur. Dentes porrò incidendis & con fringendis & atterendis moliendis e cibis priuatim conducunt, perinde ac duo auditus infru menti ofsicula peculiari ulu audiendi officio famulantur. Verum cuiulgo offis primarium mu nus, fingulorum ofsium Caput fufius oftendet, quandoquidem in præfentia abunde eft, gene-ratim ofsium ulum recenfere : quo(ut femel dicam) hæc fulcrorum modo uniuerfam corporis molem fustentant, & ijs omnia adnascuntur & firmantur, & ab ijldem suspenduntur, aded fanèut ex ofsium ufu aut officio, non alia qu'am modò ferè diximus, defumi polsit differe In magnitudine uerò offa uariant, quòd nonnulla quidem fint grandia, utfemur, tibiz os, hu Difermicà merus, & offa facri offis lateribus utrinqué connexa:nonnulla autemparua existant, ut bra-chialis offa, dentes, & ofsícula que fefamo affimilantur. Alia ruríus ampla funt, ut offa facri of forma. chiais otta, dentes, & otsicula quæ felamo affimilantur. Alia rurlus ampla funt, ut offafacriol-fis lateribus coarctata, fcapulæ, facrum os, uerticis offa, frontis & occipitij. Alia angufta & gra cilia & longa, ut fibula, radius, ulna, & cum alijs multis coftæ. Porro fatius erit omnes diffe rentias, quas à forma petere integrum effer (cum innumeræ occurrant) ad priuatas ofsium defcriptiones referuare. Arduum quippe effer, ofsibus nondum enarratis alfequi, quæ nam horum fint alperatut ea quæ lapidea in caluariæ bafi uocabinus, quòd præruptærupi fimi-lia uideantur. item quæ læuia fint, ut uerticis offa, frontis os, pectoris os, deinde quæ triangu-lum referare ut fcapulæ t % quad henerulærum entratis affe. % area entre forcier obtineant. A forma lum referant, ut lcapulæ: & quadrangulum, ut uerticis offa; & quæ cunei specieris os. deinde quæ triangu-lum referant, ut lcapulæ: & quadrangulum, ut uerticis offa; & quæ cunei specieri obtineant, ut capitis os, à cuneo opluedolis dictum: & quæ iugis afsimilentur, ut lovjuara Græcis, iuga-lia autem nostris appellata: & quæ f nostrum imitentur, ut clauiculæ: & quæ enfiseffigieri oftendant, ut pectoris os ; inluper quæ / figuram referant, ut ut ut dia vecque os ; & quæ ra dij quo latiores cordulæ texuntur figuram exprimant, ut cubit os radij nomine donatum: & quæ cubo tefferæ ép comparamus, ut pedis os à cubi imagine luged dis nuncupatum ; & quæ cumbri imagine ut ser dia ser d cymbæ imagini accedant, ut pedis os à cymba Græcis oxagadolis appellatum : & quæmolæ, feuto & patellæ fimilia dicantur, ut os genu articulo præpofitum : ad hæc quæ totius Italiæ circunferiptionem leuiter proponant, ut femur:& quæ fibulam repræfentent, ut tenuius in ti bia os fibula appellatum : & quæ coccygis feu cuculi auis roftro comparentur, ut facto off fup pofitum os qua danse politum os, quod coccyx nuncupatur : dein quæ incudis uel molaris dentis effigiem quodam modo reprælenter, ut minus organi auditus ofsiculum:& quæ malleum, ut grant A organi



UGRA: 10 Tasks

- Visualize key landmarks structures:
 Blood vessels, bone, fascia, muscles
- 2. Identify nerves or plexus in SAX
- 3. Confirm normal anatomy or recognize variations
- 4. Plan for needle approach to avoid unnecessary trauma
- 5. Follow the needle under real-time visualization

UGRA: 10 Tasks

- 6. Consider a second confirmation technique
- 7. Hydrolocalisation
- 8. Follow the correct spread of local anesthetic
- injection characteristics

10.Maintain aseptic technique with respect to US equipment

9. Maintain safety guidelines: resuscitation equipment, aspiration, test dosing, monitoring, patient response,

Toxicity Chlorhexidine

Anaesthesia. 2014 Nov;69(11):1279-86. doi: 10.1111/anae.12844. Epub 2014 Sep 3.

Safety guideline: skin antisepsis for central neuraxial blockade.

Association of Anaesthetists of Great Britain and Ireland, Obstetric Anaesthetists' Association; Regional Anaesthesia UK; Association of Paediatric Anaesthetists of Great Britain and Ireland, Campbell JP, Plaat F, <u>Checketts MR, Bogod D, Tighe S, Moriarty A, Koerner R.</u>

... and PNB

A 0.5% concentration of chlorhexidine in alcohol should be used for skin antisepsis prior to performing a CNB.

The anaesthetist must be meticulous in taking measures to prevent chlorhexidine from reaching the CSF:

a. Chlorhexidine should be	b. The
kept well away from the	allowe
drugs and equipment to be	skin is
used for CNB. Antiseptic	punct

e solution must be red to dry before the s palpated or tured. c. The operator should check his/her gloves for contamination with chlorhexidine. If there is

Levels of difficulties

- - Patient-related factors like obesity
- Blocks near vital structures
- Small nerves
- Catheter-based techniques

• Deep blocks: degradation of US and needle image

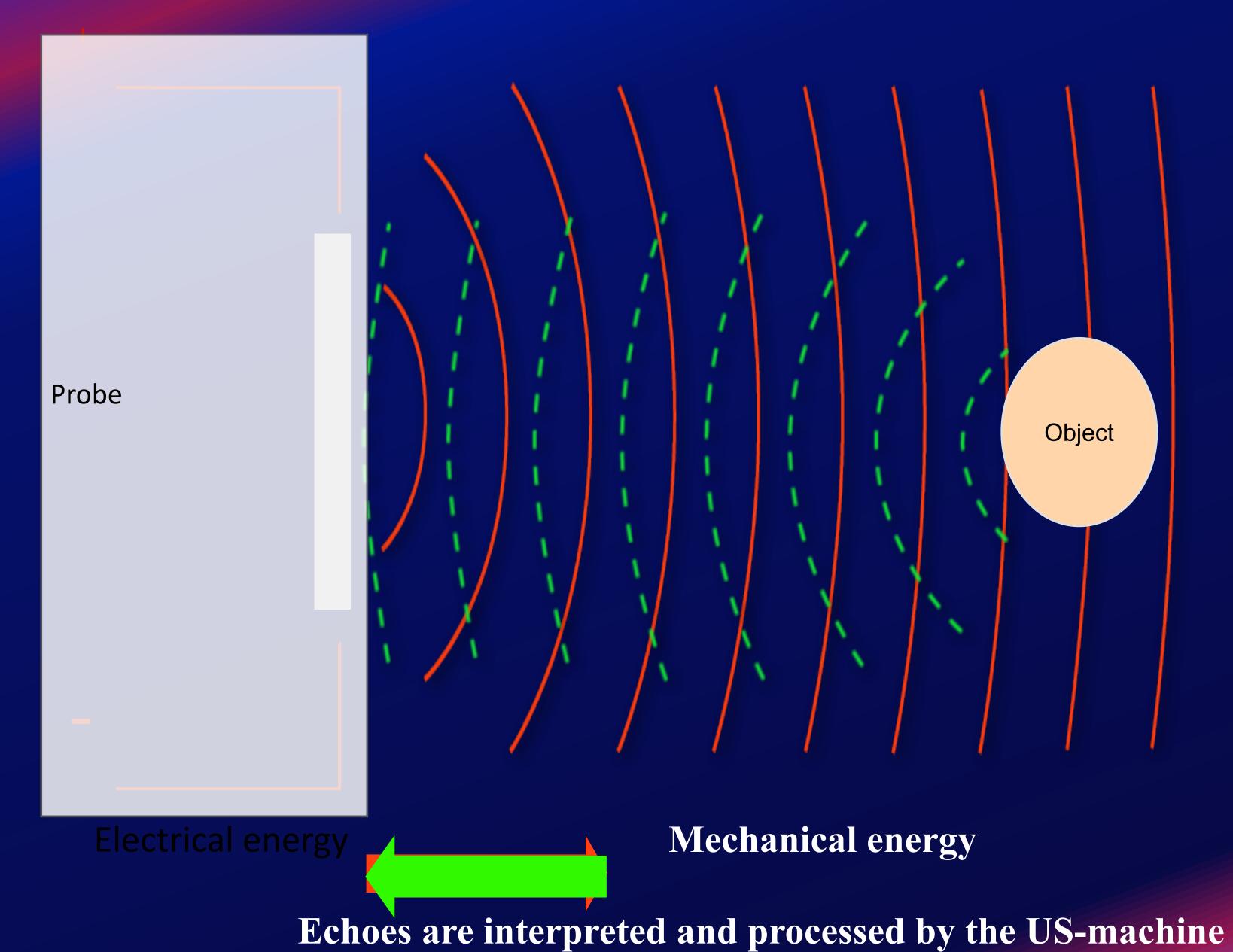
TABLE 2. Skill Sets Associated With Proficiency

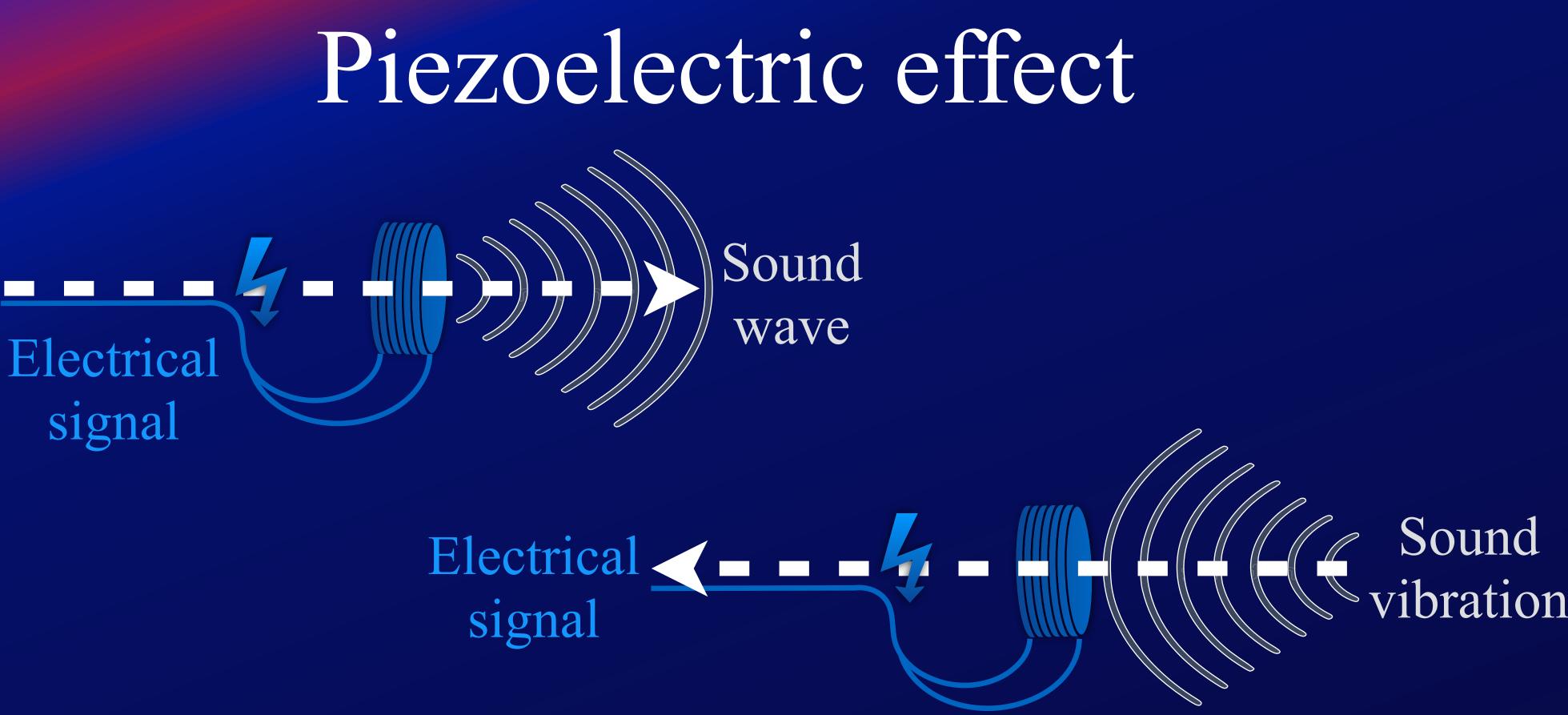
Understanding Ultrasound Image Generation and Device Operations	Image Optimization (Non–Device Related)	Image Interpretation	Needle Insertion and Injection
Understanding basic technical principles of image generation	Learn the importance of transducer pressure	Identify nerves	Learn the in-plane technique, maximizing needle visualization
Selection of the appropriate transducer	Learn the importance of transducer alignment	Identify muscles and fascia	Learn the out-of-plane technique
Selection of the appropriate depth and focus settings	Learn the importance of transducer rotation	Identify blood vessels, distinguish artery from vein	Learn the benefits and limitations of both techniques
Understanding and appropriate use of both time gain compensation and overall gain	Learn the importance of transducer tilting	Identify bone and pleura	Learn to recognize intramuscular needle location
Understanding and application of color Doppler		Identify common acoustic artifacts	Learn to recognize correct and incorrect local anesthetic spread
Archiving images		Identify common anatomic artifacts (pitfall errors)	Conduct proper ergonomics
Follow ASRA-ESRA standardization for screen orientation to the patient		Identify vascularity associated with needle trajectory	Minimize unintentional transducer movement
		•	Identify intraneuronal needle location

Skills

US machine and probes







Piezoelectric element

- deforms when subject to a voltage, creating a sound wave ightarrow
- produces a voltage when deformed by a sound wave
- is sender and receiver

• Pulsed beam

- Sends waves 1% of time
- Receives 99% of time
- Beam profile
 - 3D approx. 1 mm thick
- Image produced is "2D"
 - Tomographic slice



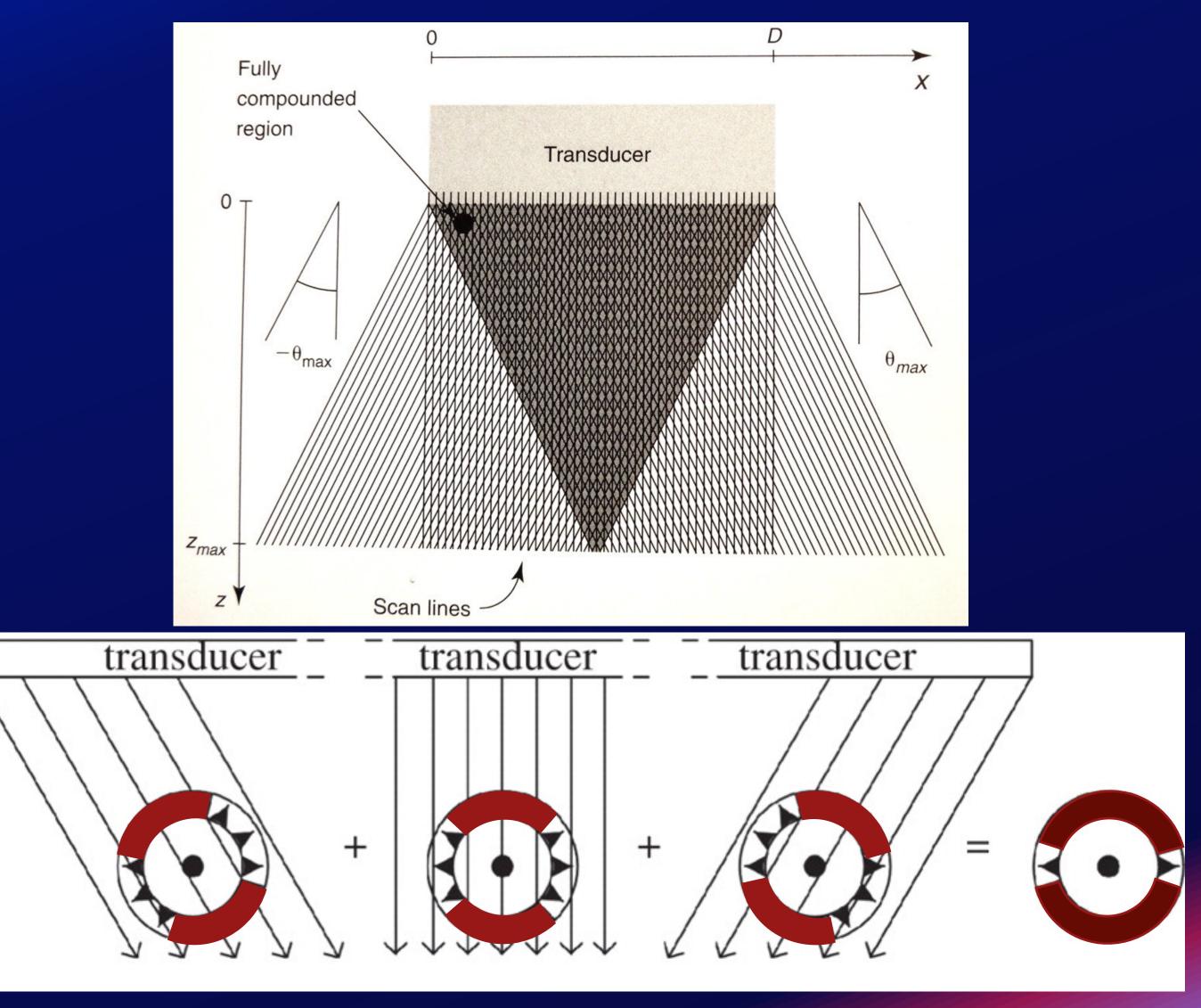
Bandwidth

- termed bandwidth
- Medical US: 2-20MHz

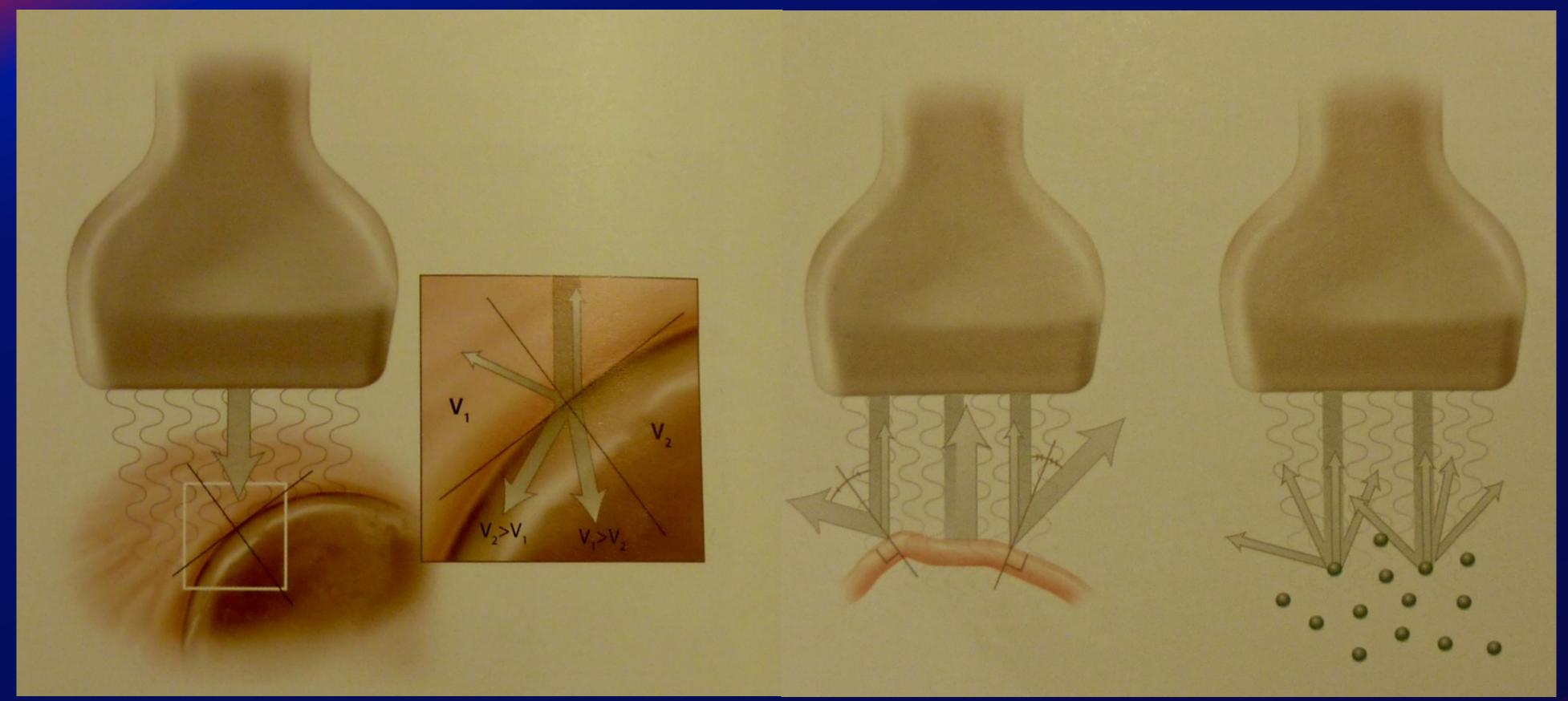
• All US-transducers contain a range of frequencies,



Spatial compound imaging





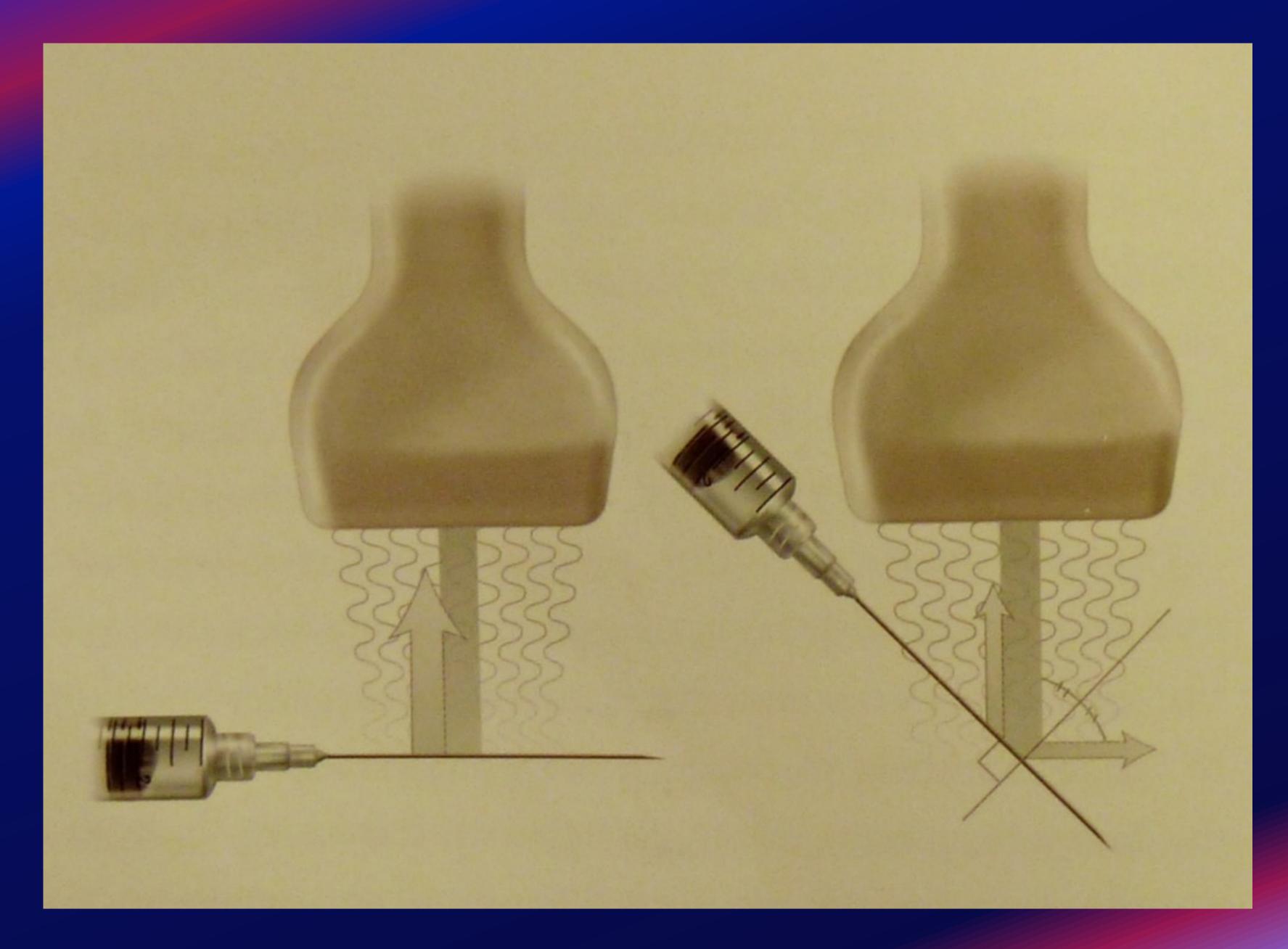


Absorption Refraction Reflection

Image generation

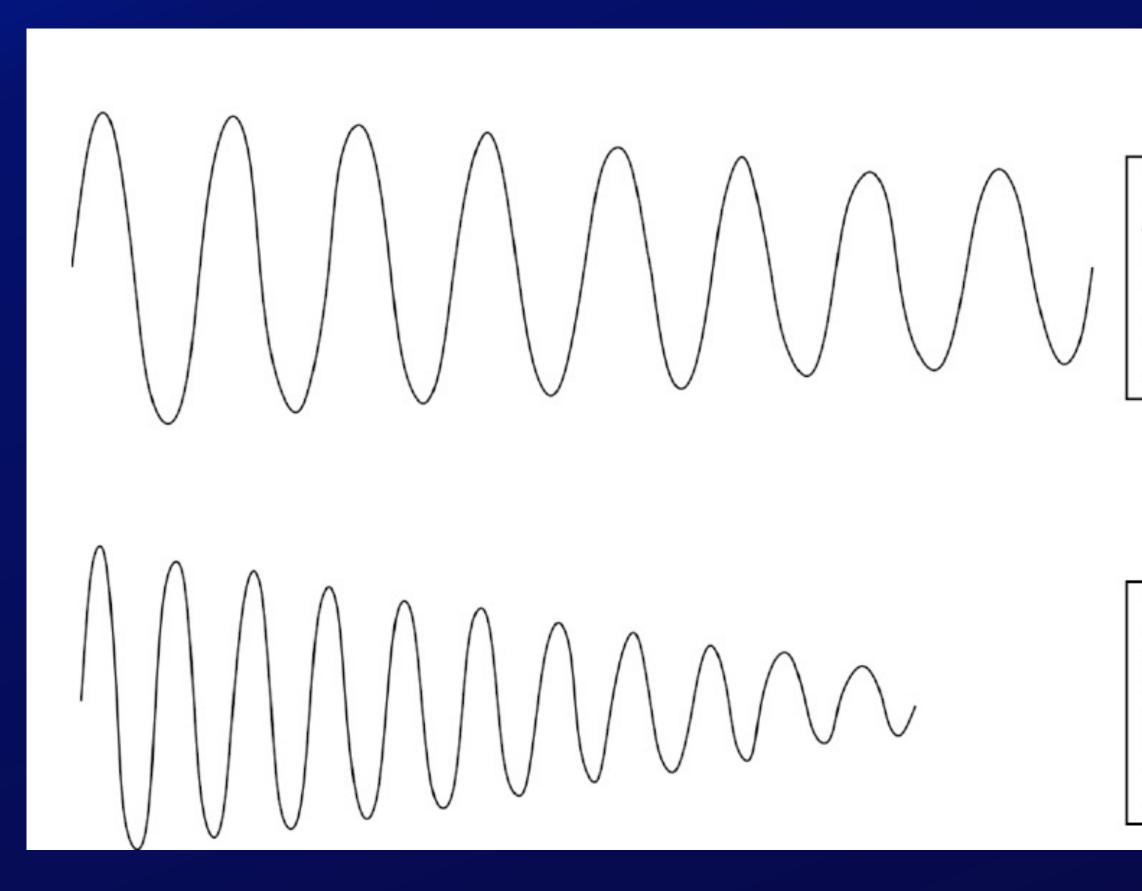
Reflection Refraction Scattering Refraction

usrabook.com



usrabook.com

Penetrance - Resolution Frequency





Worse resolution Less attenuation Deeper penetration

High-frequency ultrasound

Better resolution Greater attenuation Less penetration

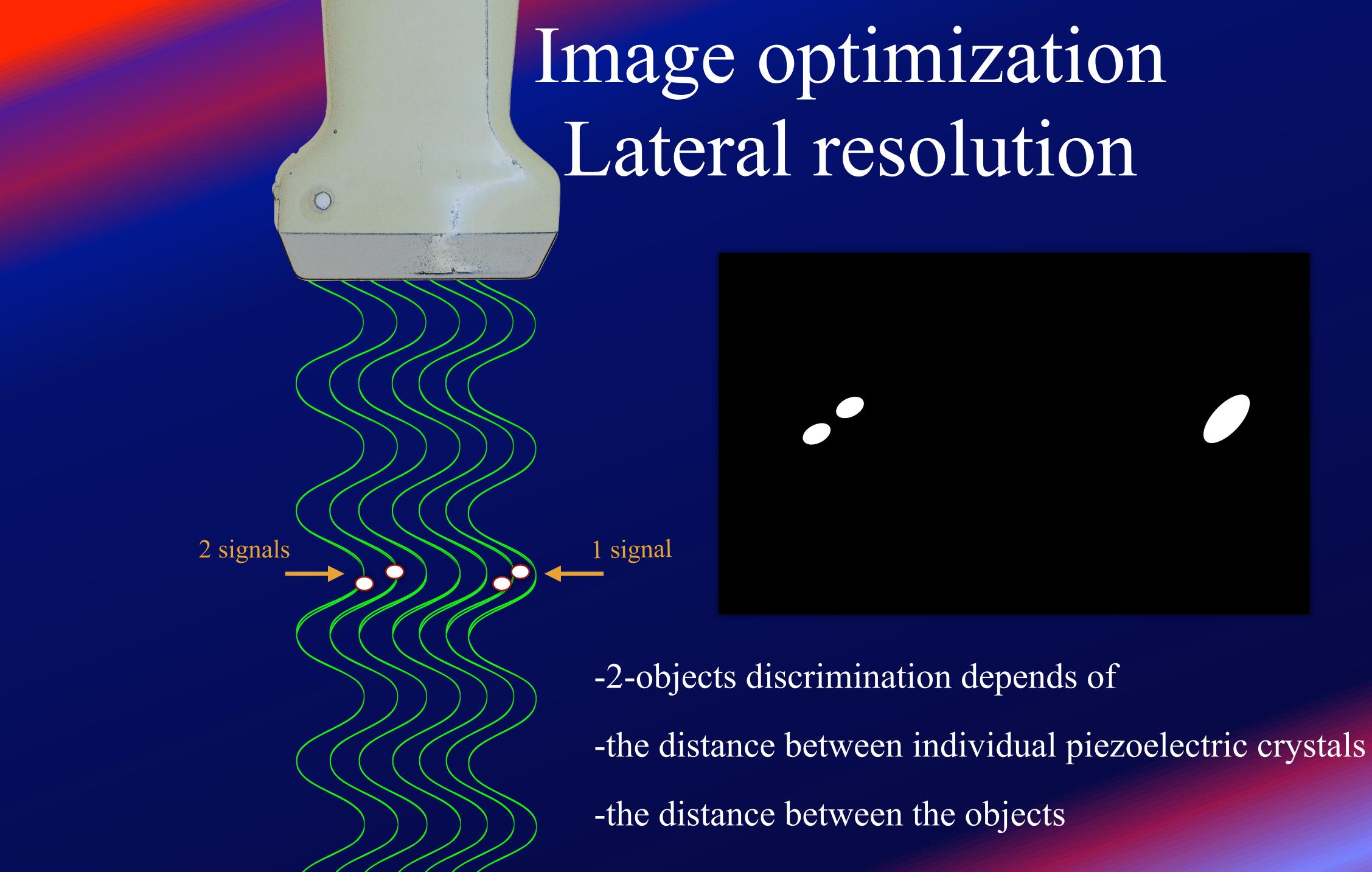
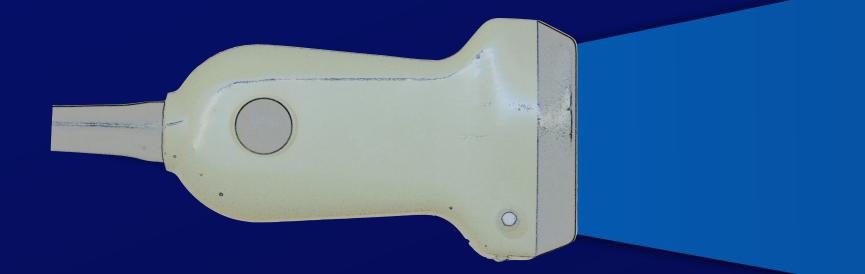


Image optimization - Focus







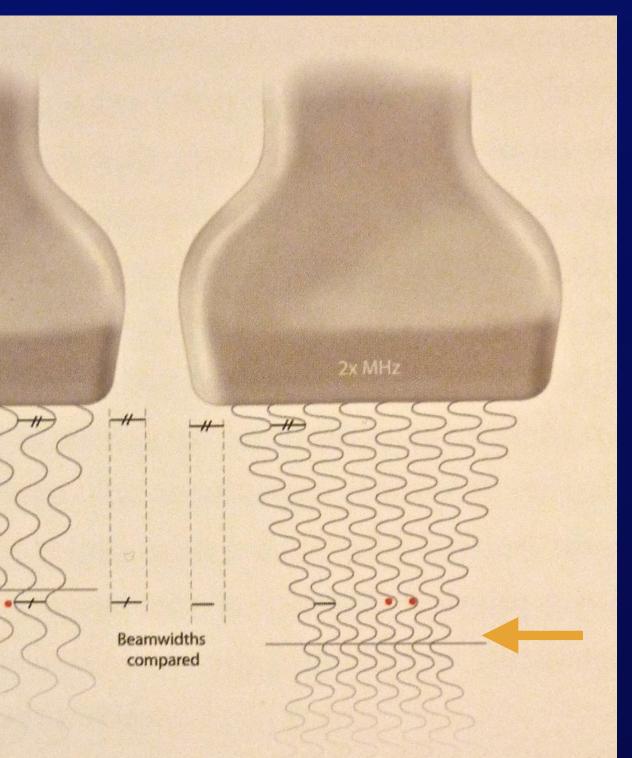
Ideal US-beam

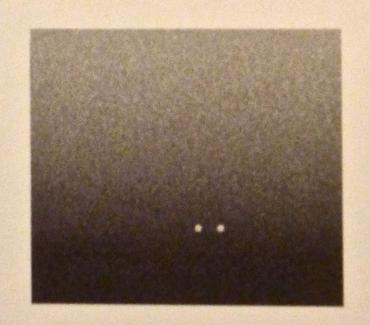
Unfocused US-beam

Focused US-beam

Image optimization Electronic Focus

= improved axial resolution





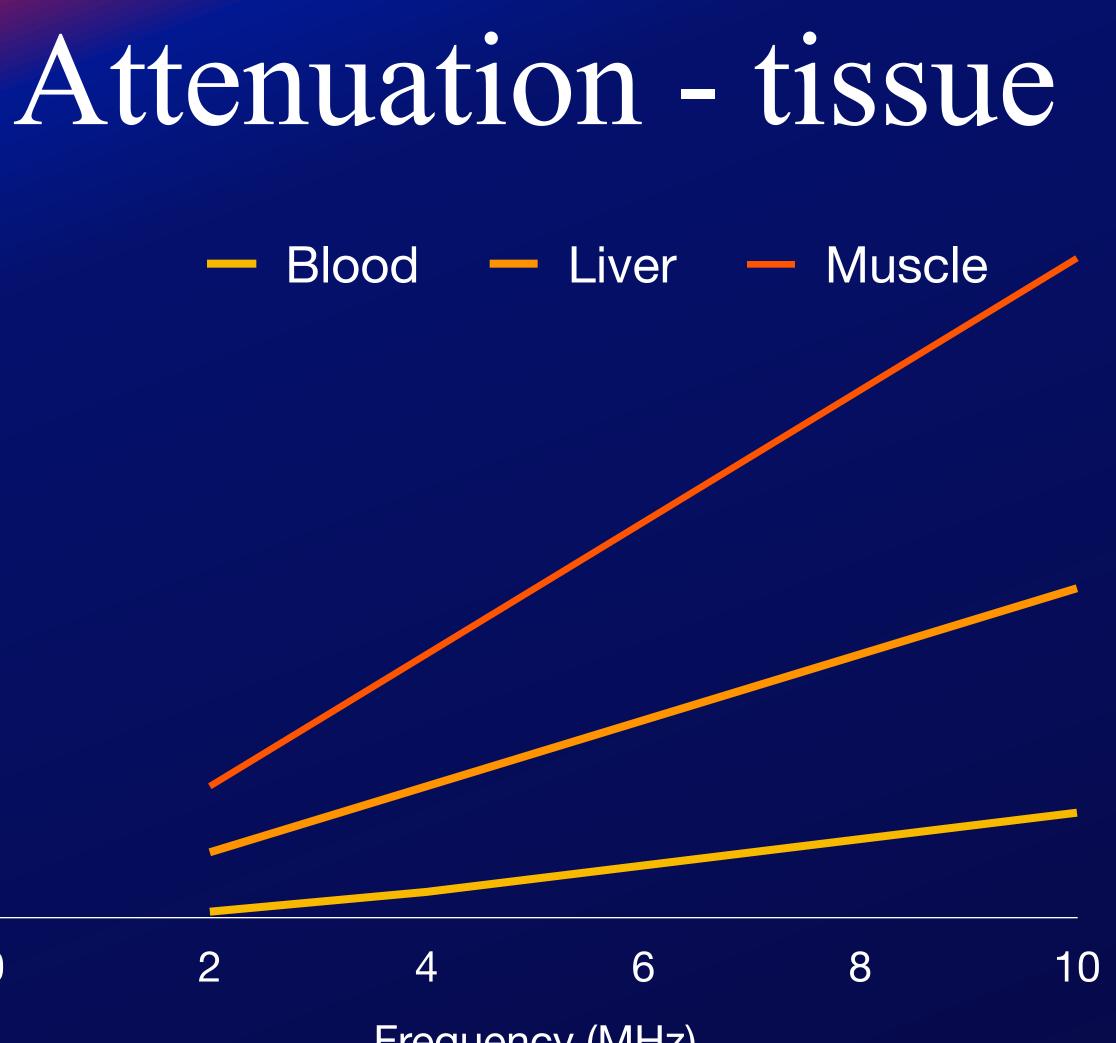
Focus

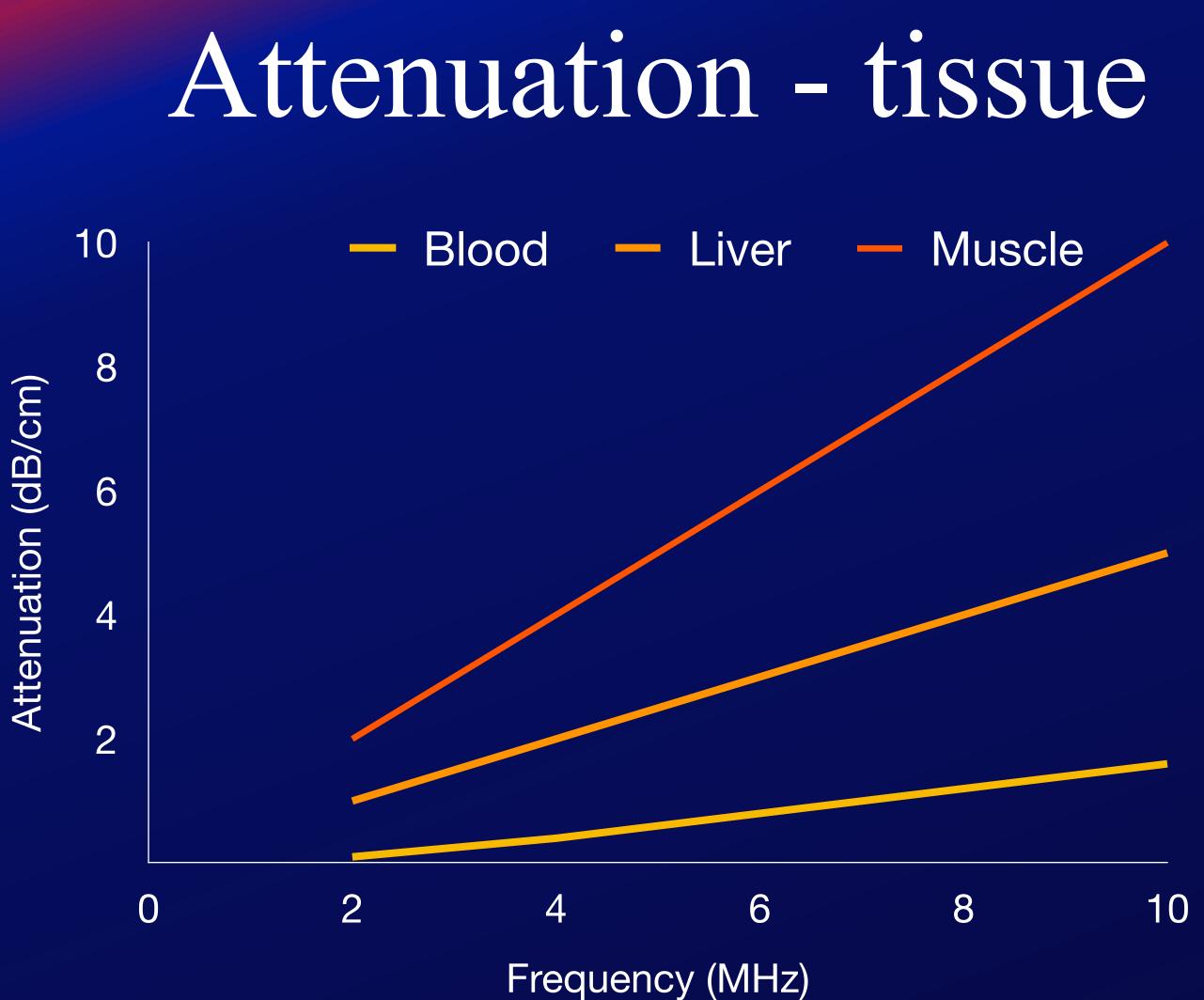
usrabook.com



- Definition: the reduction in power & intensity as sound travels through a medium
- Higher frequencies attenuate, or are adsorbed, faster than lower frequencies

Attenuation





Higher frequency = more attenuation More attenuation = less penetration

Ultrasound Pulse Velocity = determined by the material

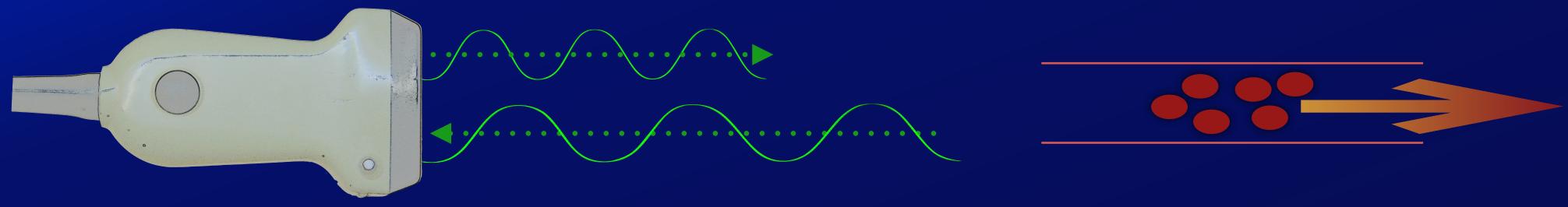


Average for soft tissue 1540 m/s

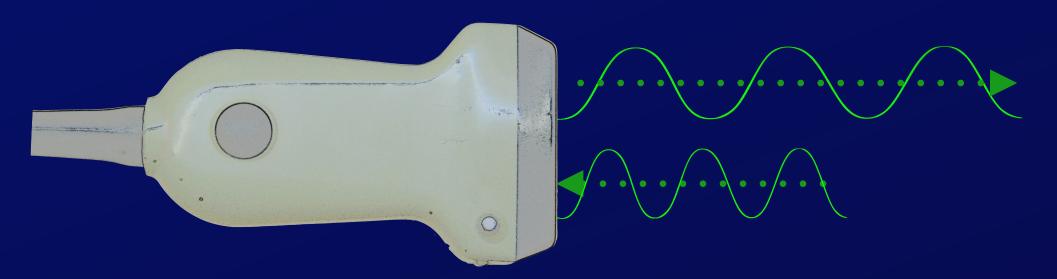
Velocity in medium

Material	Velocity (m/sec)
Fat	1460
Water	1480
Soft tissue (average)	1540
Bone	4080

Vessel recognition Color Doppler



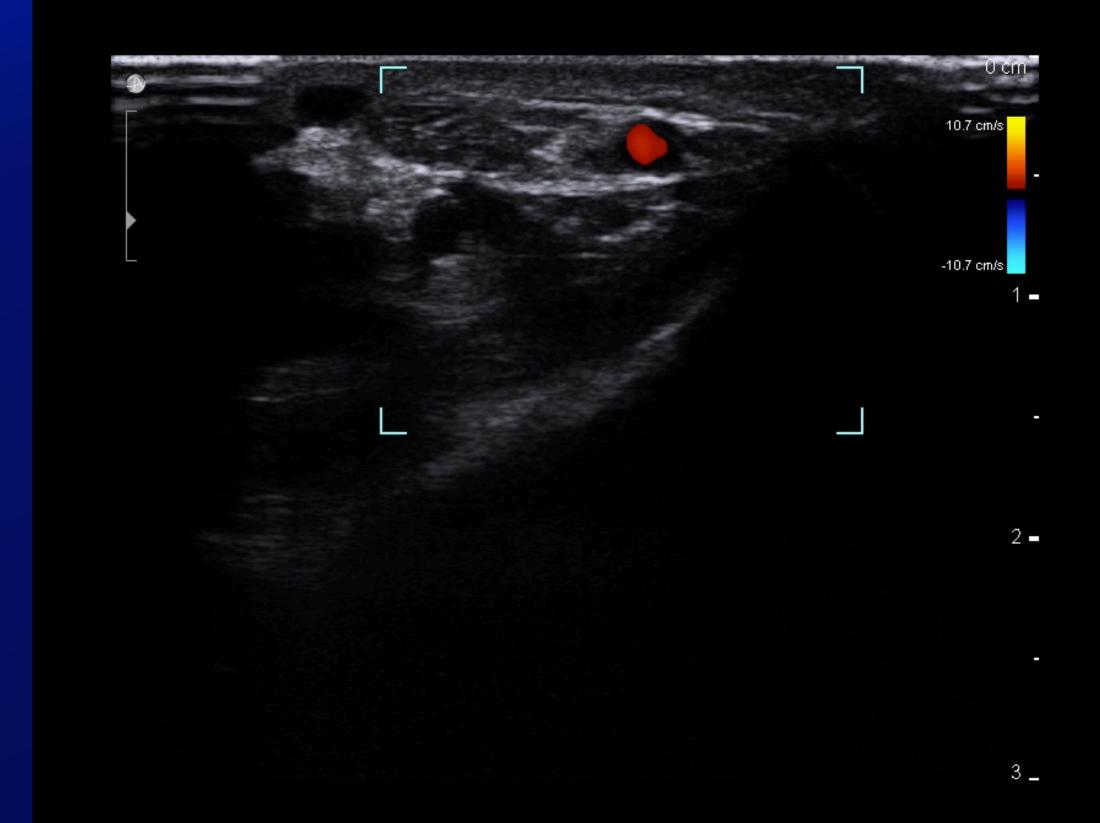
Returning signal: lower frequency

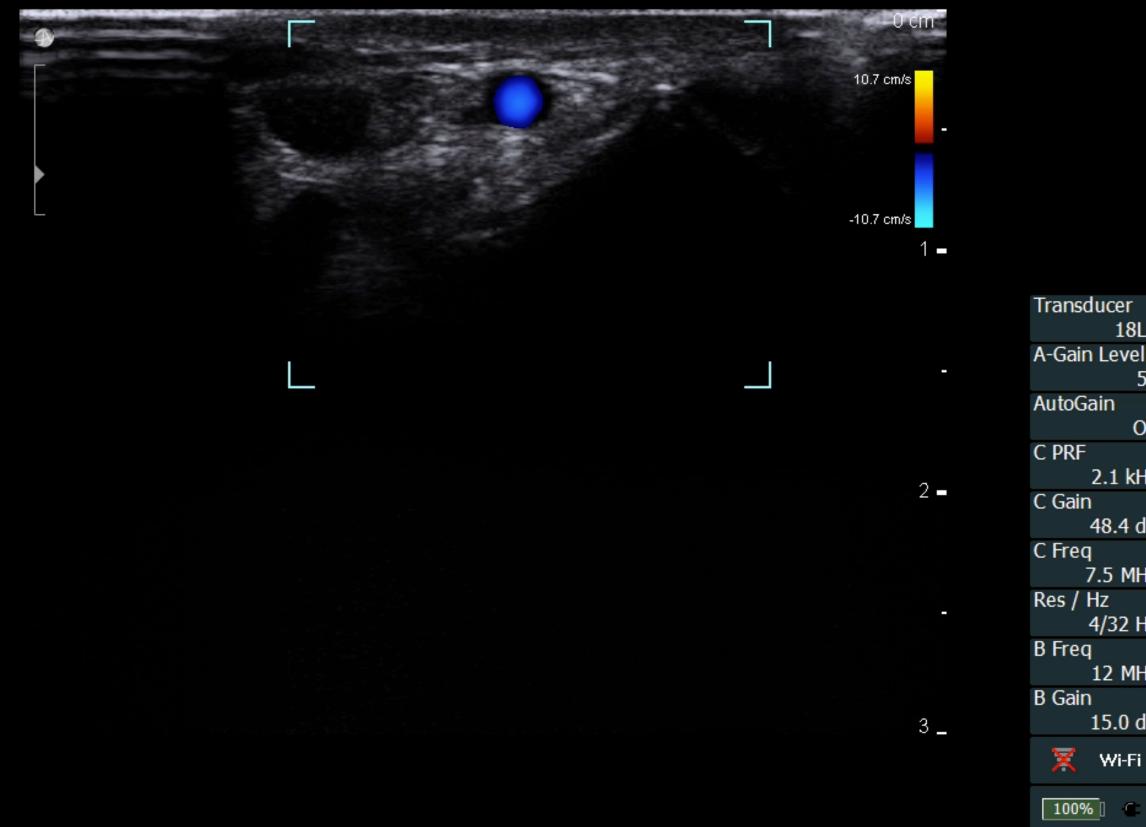


Returning signal: higher frequency



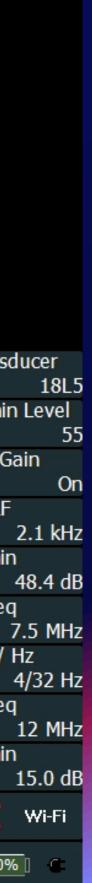
Vessel recognition Color Doppler





MI: 1.50<1.50 TIS: 0.6<2.0

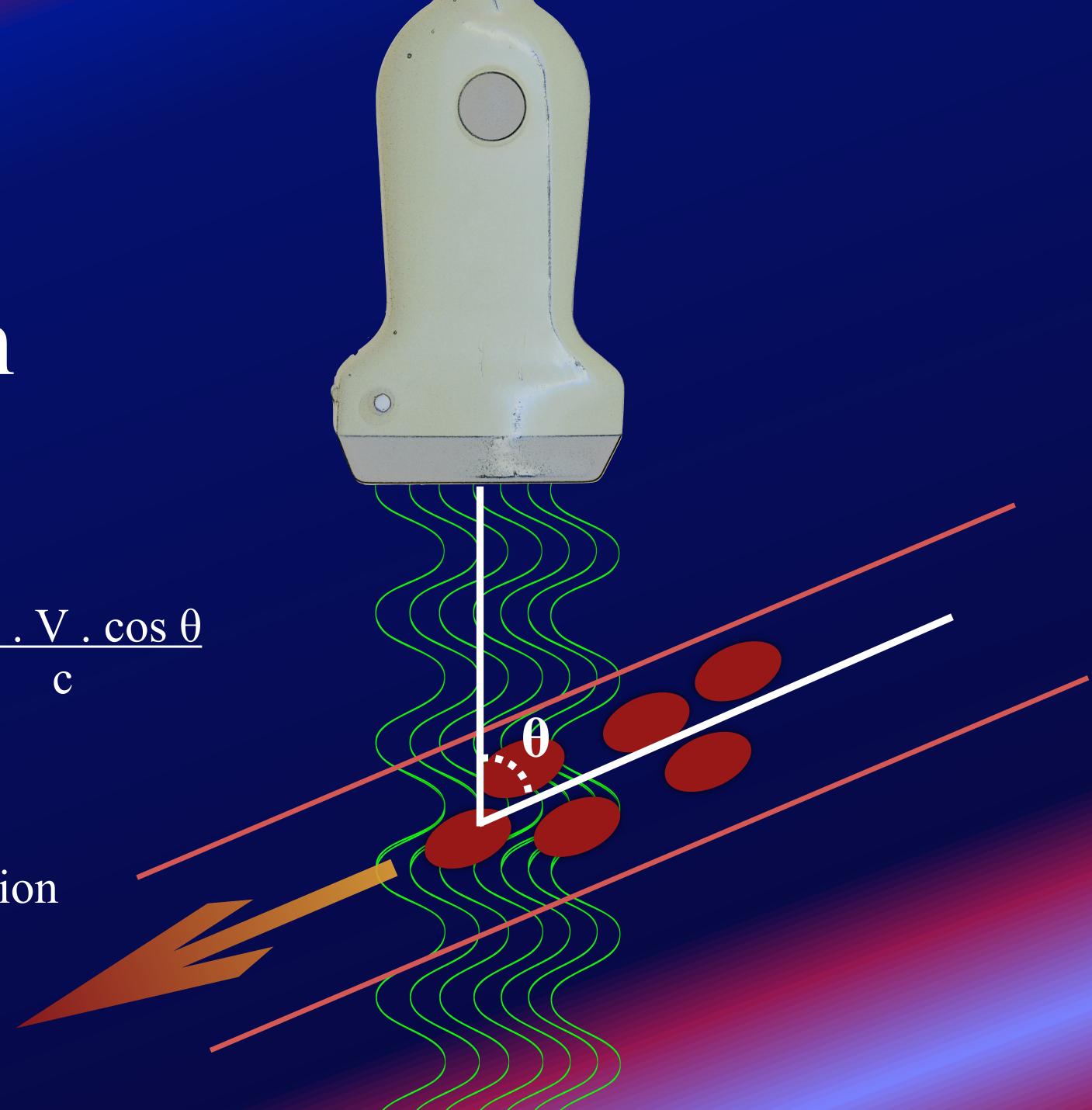
X



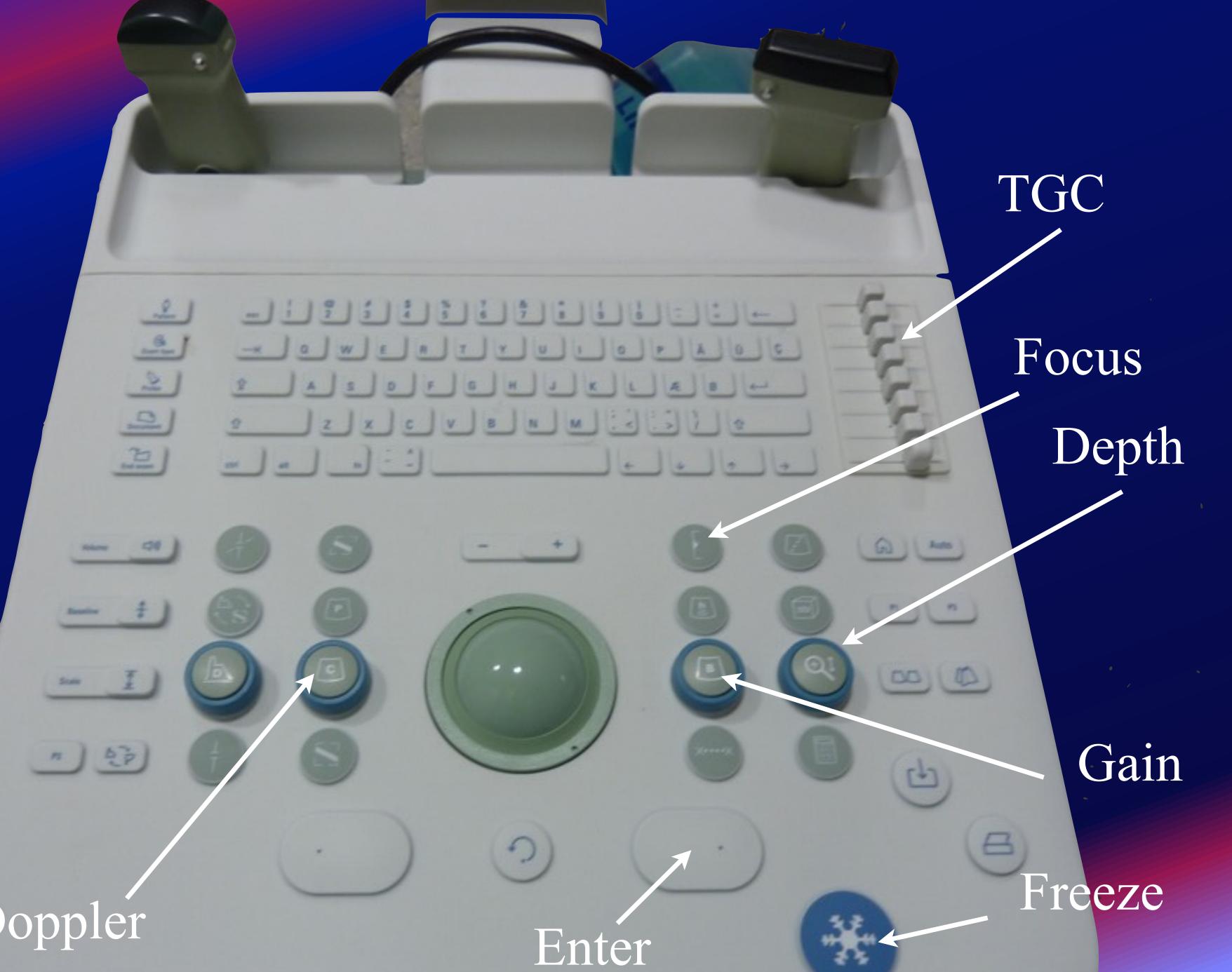
Doppler and Angulation

Doppler frequency (fd) = $2 \cdot \text{ft} \cdot \text{V} \cdot \cos \theta$

θ = angle of incidence
 between
 US-beam and flow-direction



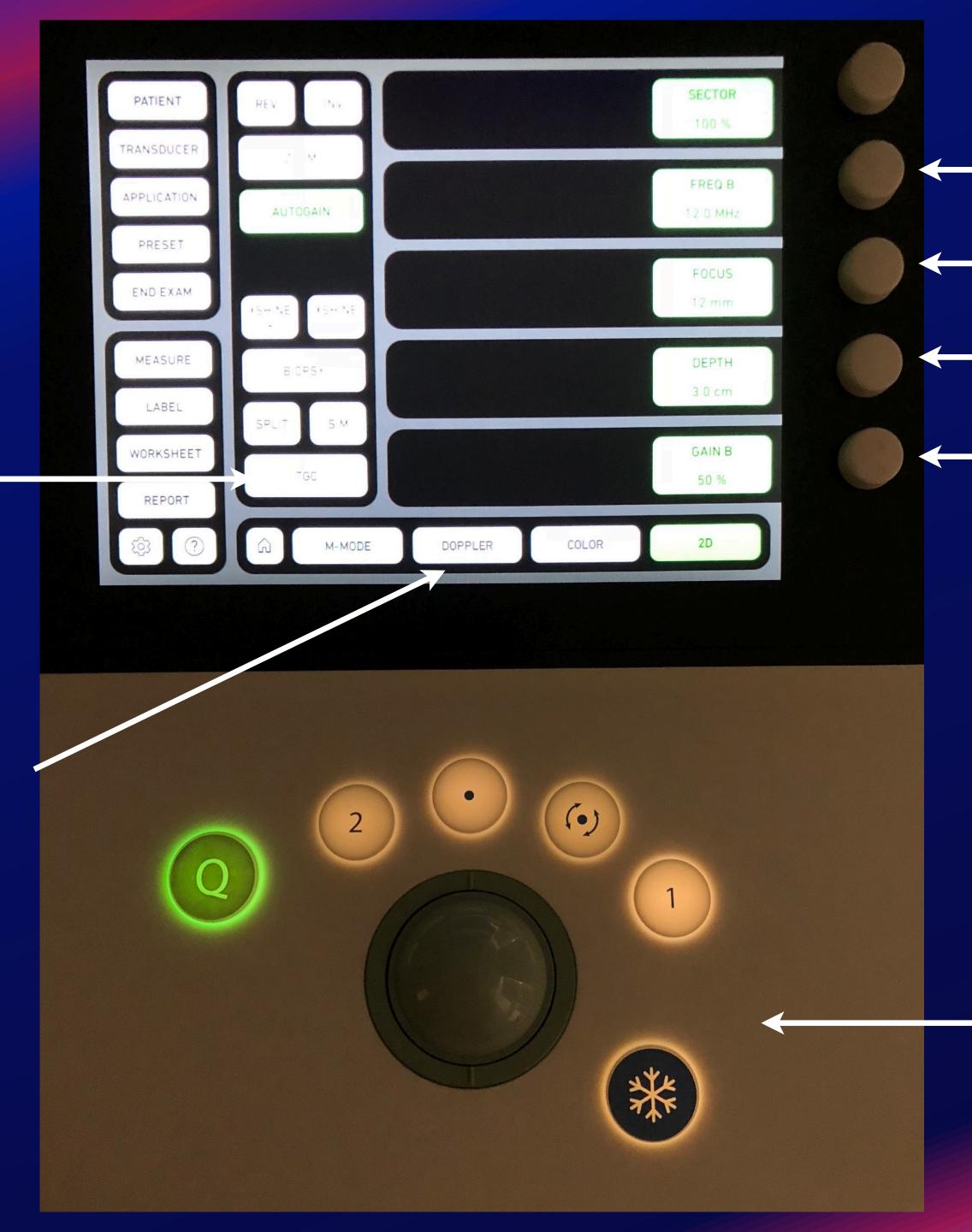




Doppler

TGC

Doppler



Frequency Focus Depth Gain



= gray scale optimization by modulation

of the returned US-signals

Anechoic = black Hypo-echoic = grey Hyper-echoic = white

1. Gain



2 -

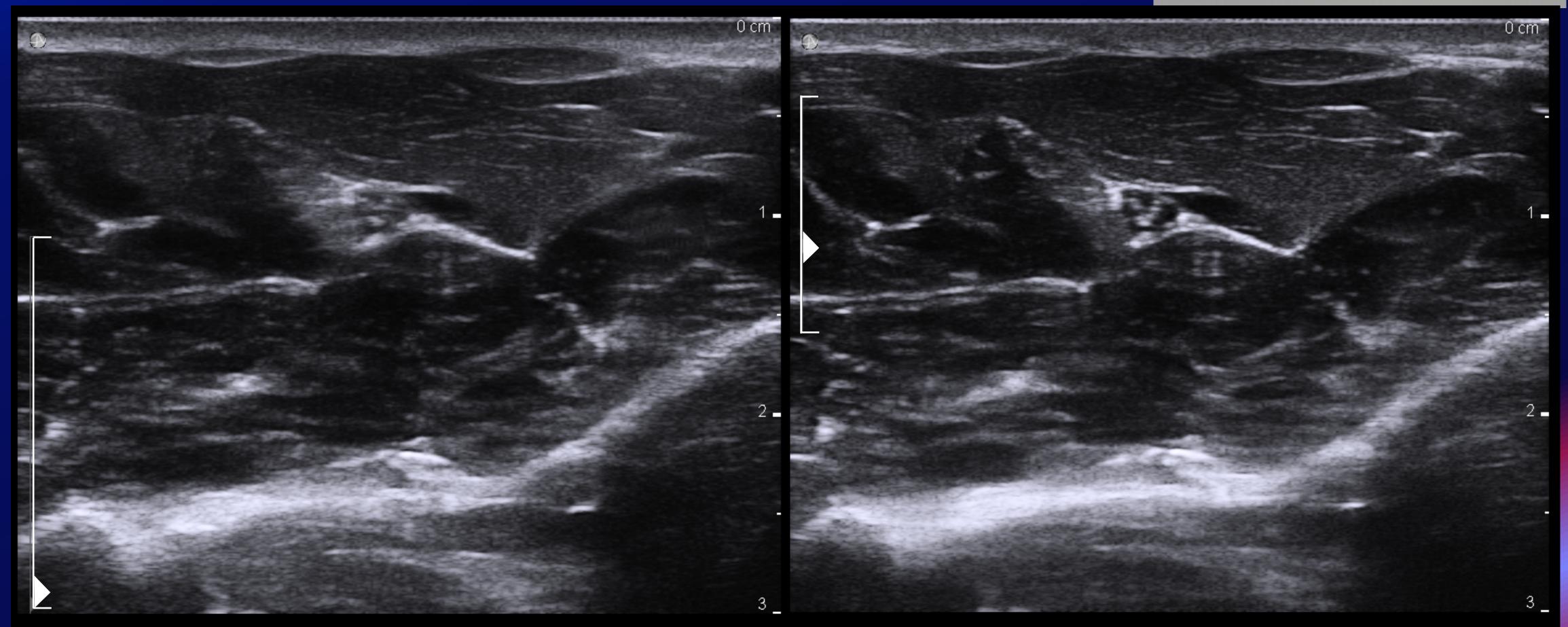
0 cm

1/65 Hz 18 MH 22 %

3:28

0.59<1.50 TIS: 0.1<2.0

2. Focal zone





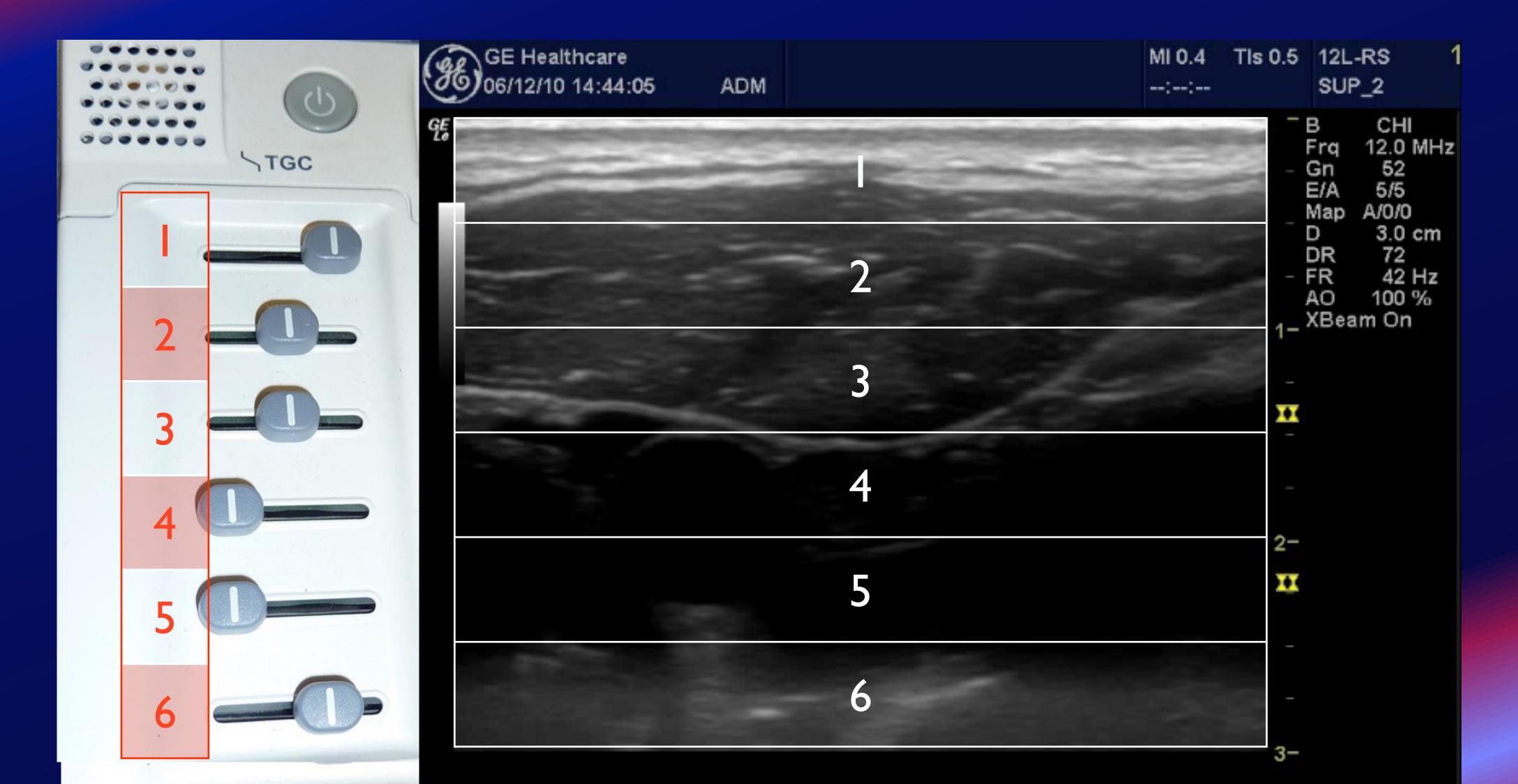
3. Time Gain Compensation

- depth of travel
- attenuation
- Must be adjusted manually

• The gain curve expected a certain attenuation with

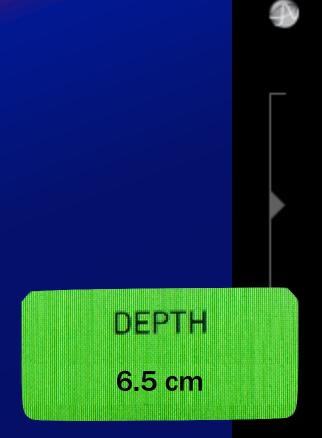
Operator controlled adjustment to compensate for the

3. Time Gain Compensation



4. Depth

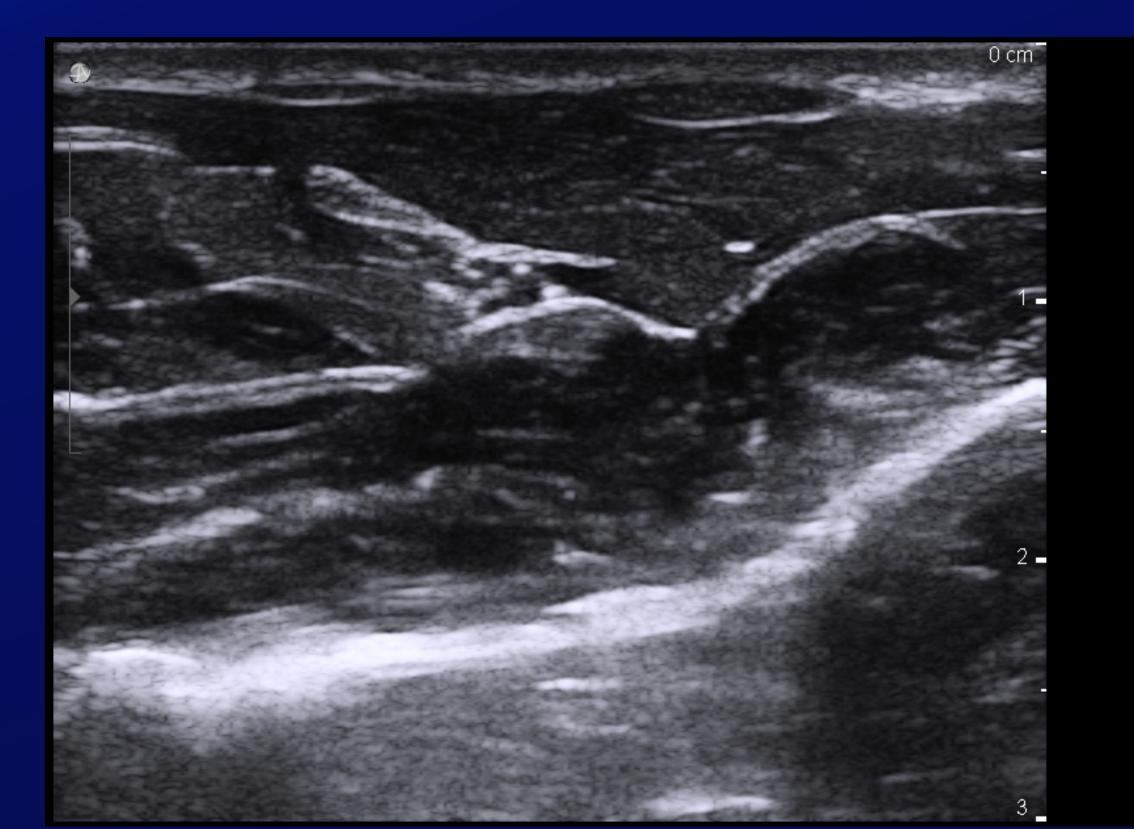
0 cm

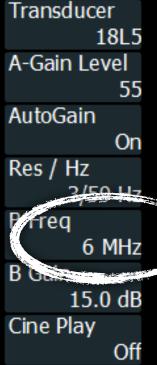


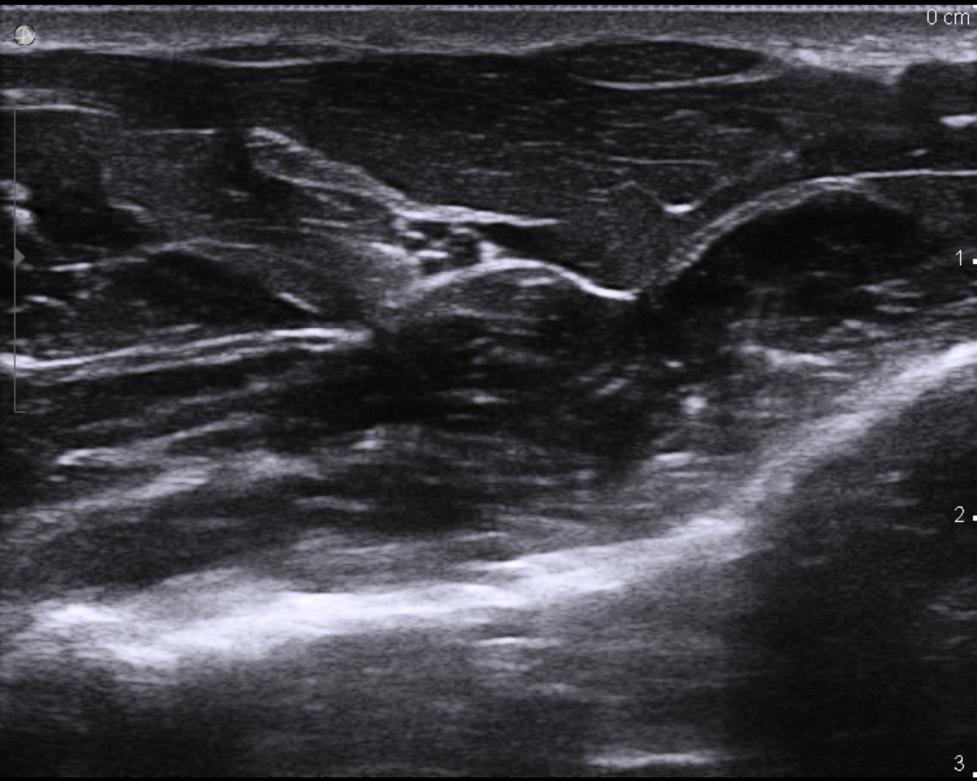
2 -3 🗕 Increasing the depth: Narrowed image to keep proportions Reduced lateral resolution Reduced axial resolution

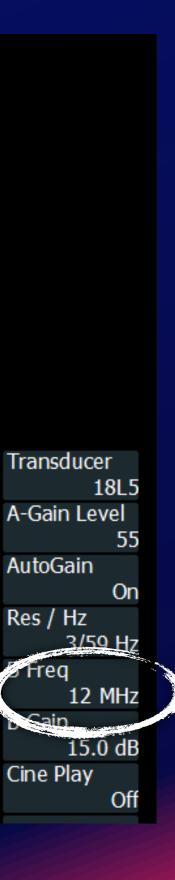
5. Frequency

The highest possible frequency related to the depth of the target







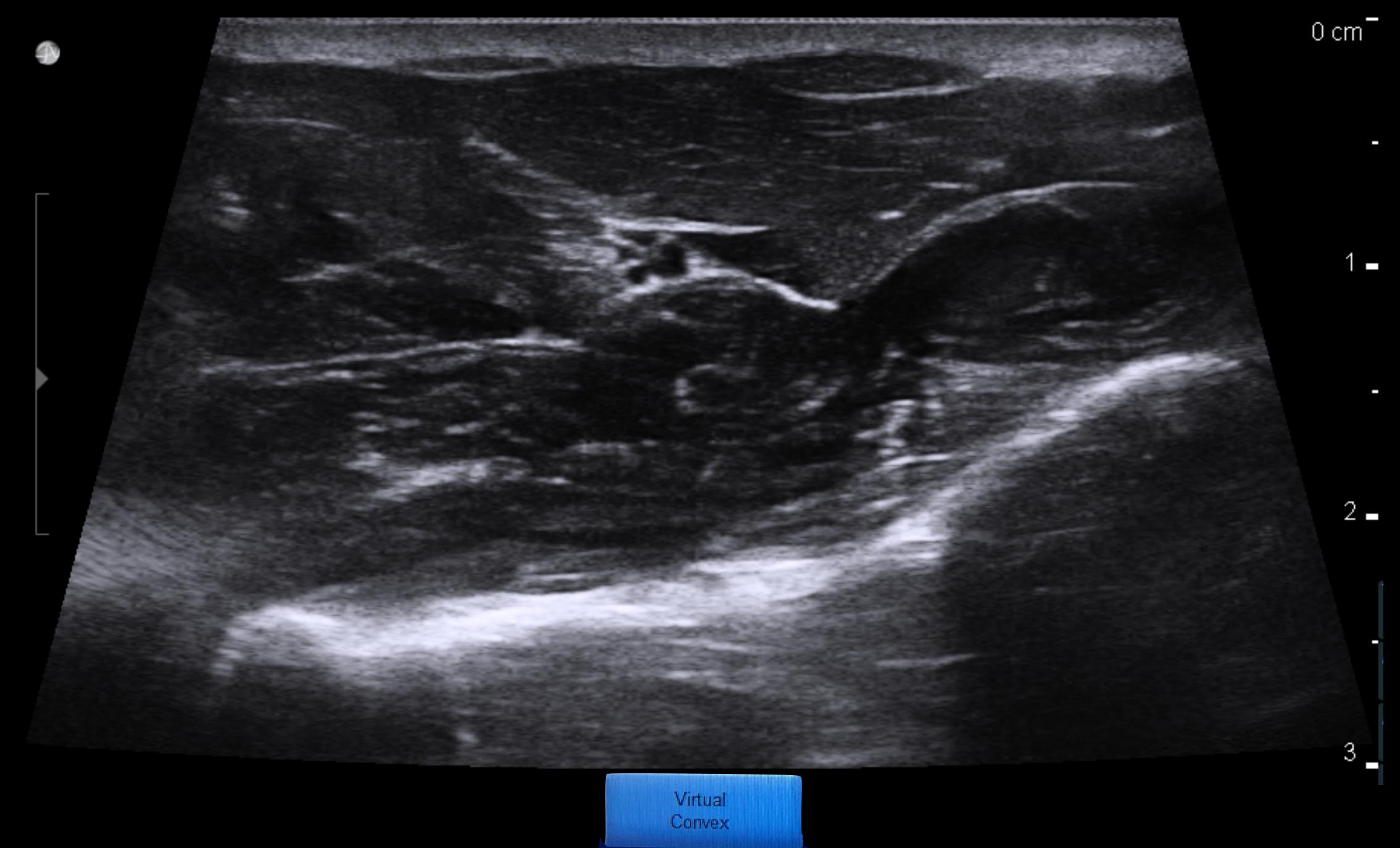


US-machine & Settings

- Choose transducer according to blocks' and patient's characteristics
- Position your target in the centre of the screen
- Set focal zones just above and below the target to optimize lateral image resolution
- Adjust TGC and gain to get the optimal view/contrast
- Adjust frequency to optimize penetrance & axial resolution
- US machine: be careful & keep clean

6. Machine dependent knobs





Skills

TABLE 2. Skill Sets Associated With Proficiency

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Follow ASRA-ESRA standardization for screen orientation to the patient

Image Optimizati (Non–Device Relat

Learn the importance of transducer press

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Learn the importance of transducer tiltin

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	dentify common anatomic artifacts (pitfall errors)	Conduct proper ergonomics
	dentify vascularity associated with needle trajectory	Minimize unintentional transducer movement
	•	Identify intraneuronal needle location

The Role of a Preprocedure Systematic **Sonographic Survey in Ultrasound-Guided Regional Anesthesia**

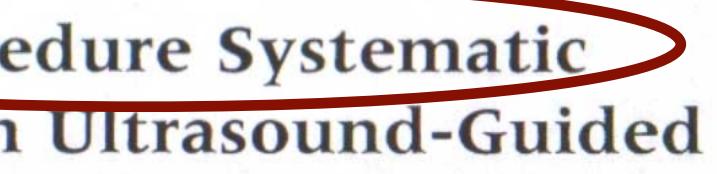
Baskar P. Manickam, M.D., F.R.C.A., Anahi Perlas, M.D., F.R.C.P.C., Vincent W. S. Chan, M.D., F.R.C.P.C., and Richard Brull, M.D., F.R.C.P.C.

Direct visualization of anatomical structures

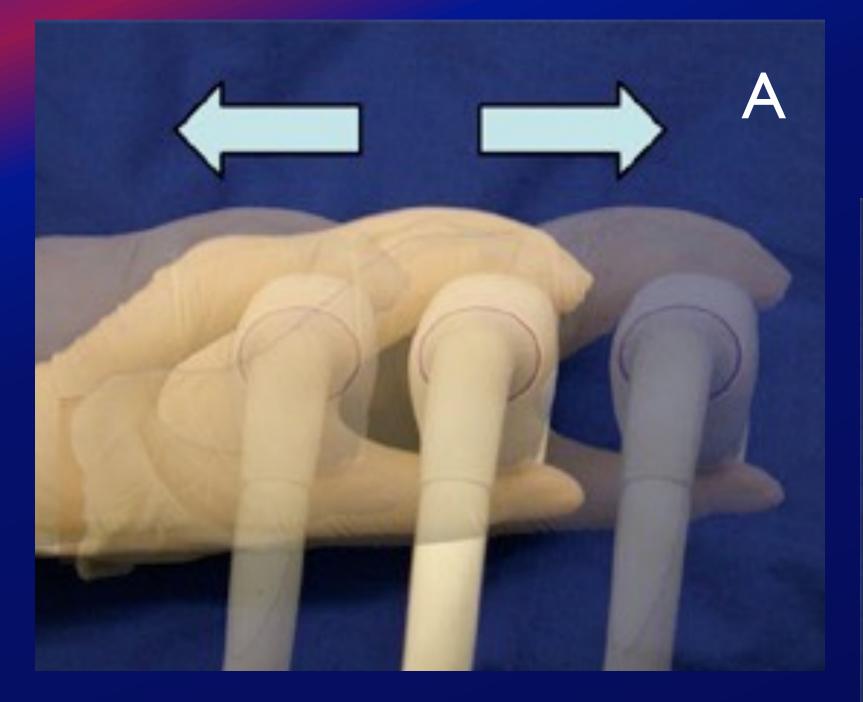
Dynamic tracing for confirmation / or not of anatomy

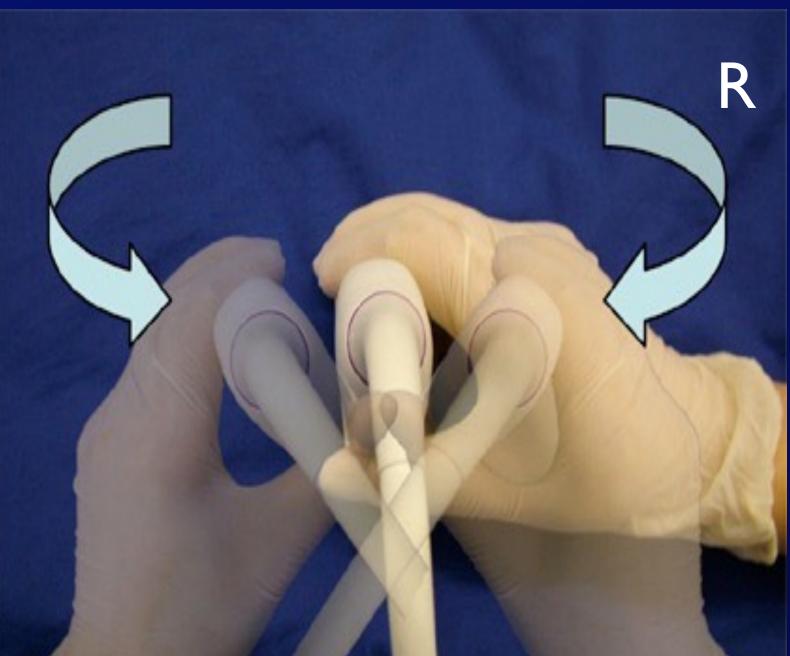
Doppler assessment of vascular structures

Different anatomical site evaluation for ease of block performance

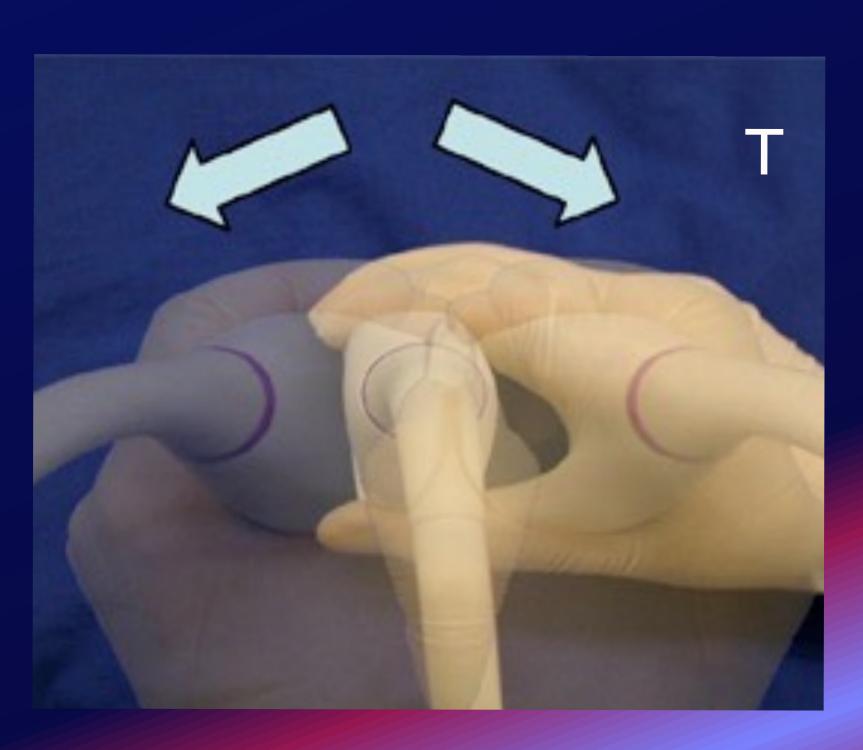


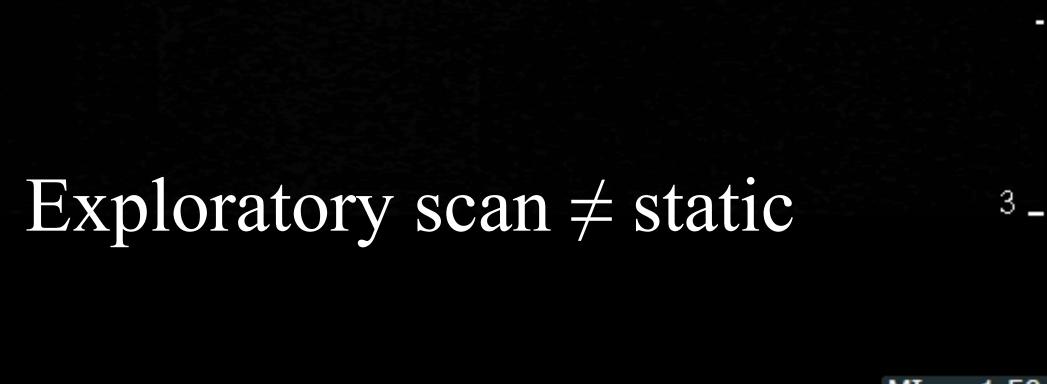
Exploratory Scan





Alignment Rotation Tilting Compression





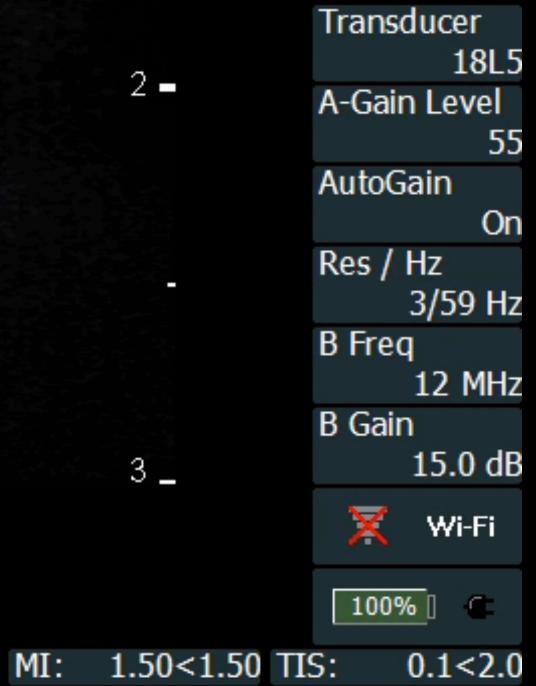
Transducer 18L5 A-Gain Level 55 AutoGain On Res / Hz 3/59 Hz B Freq 12 MHz B Gain 15.0 dB 🔀 🛛 Wi-Fi 100% 🛛 🗲 MI: 1.50<1.50 TIS: 0.1<2.0

0 cm

1 -

2 -





1 -2 -

0 cm

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STI S

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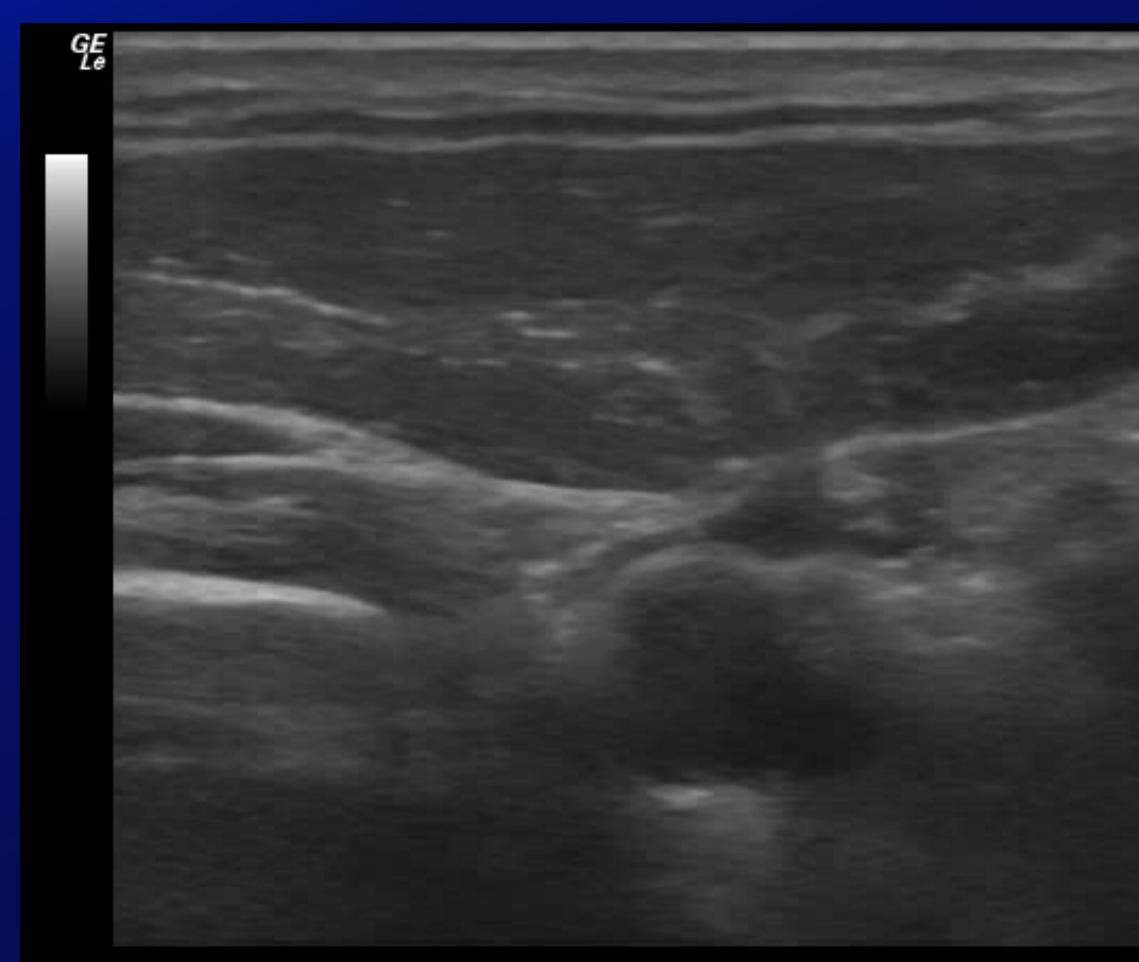
tion ated)	Image Interpretation	Needle Insertion and Injection			
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	Identify common anatomic artifacts (pitfall errors)	Conduct proper ergonomics			
	Identify vascularity associated with needle trajectory	Minimize unintentional transducer movement			
	•	Identify intraneuronal needle location			



• Not a "true" representation of the tissue imaged • Artifacts to characterize tissue (medical diagnostic)



Acoustic enhancement



Artifacts

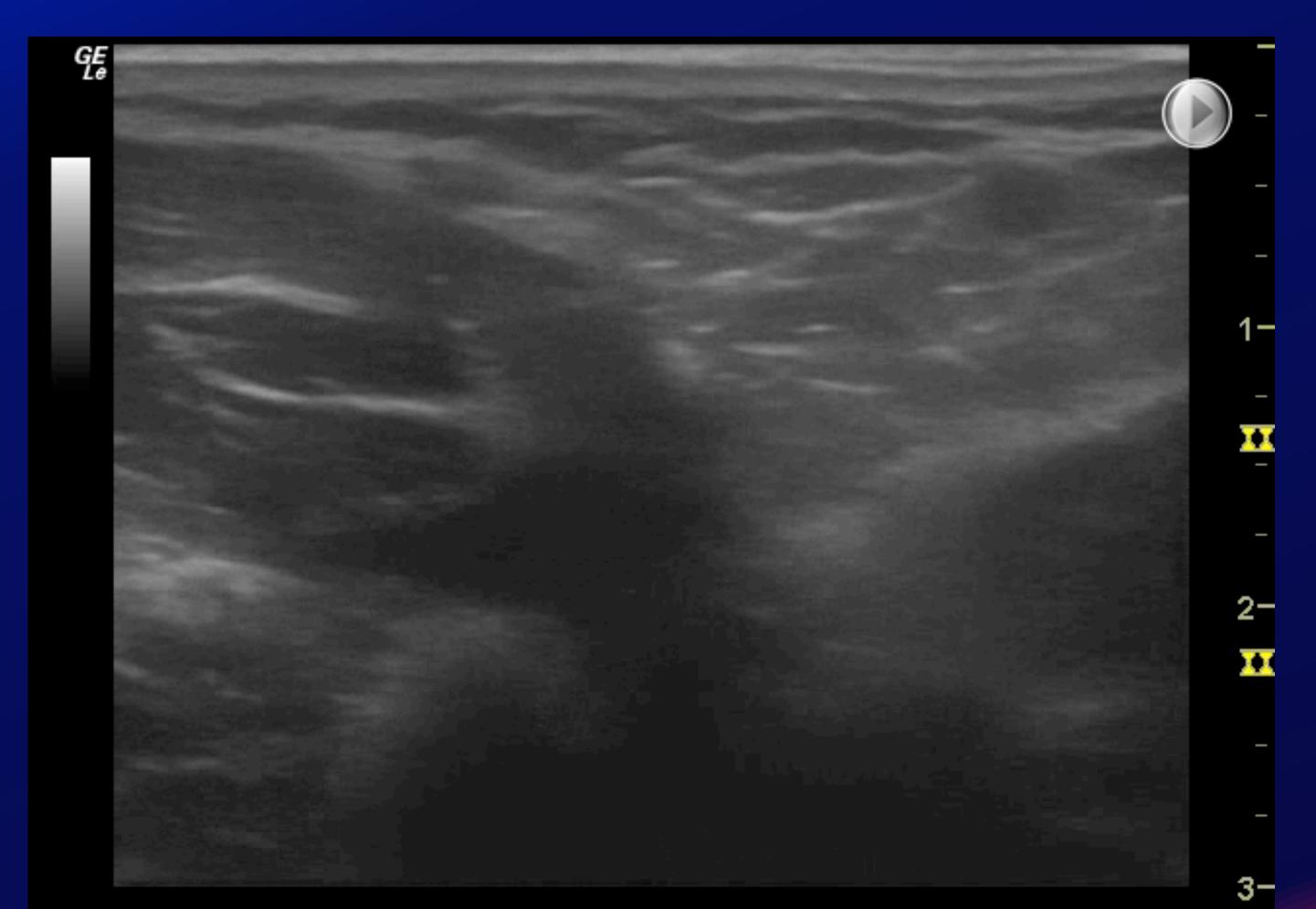
Increased through transmission of US-wave posterior to a weakly attenuating structure

II.

Bright lines under the thick walled or compressed structures (ex. vessels)



Acoustic shadowing Diminished US posterior to a strongly reflecting or attenuating structure, resulting in a dark area

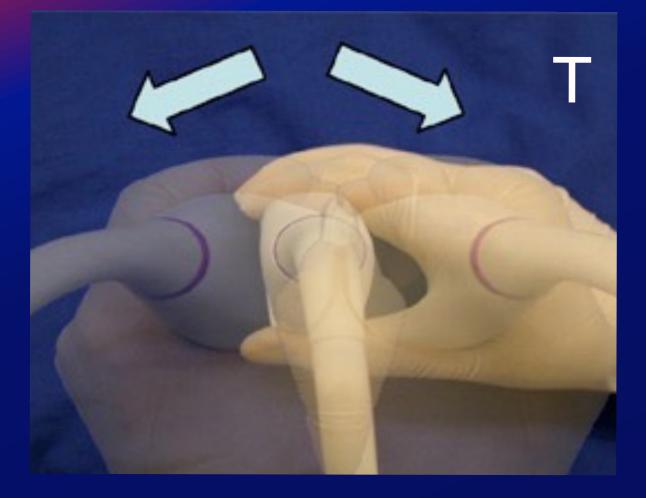


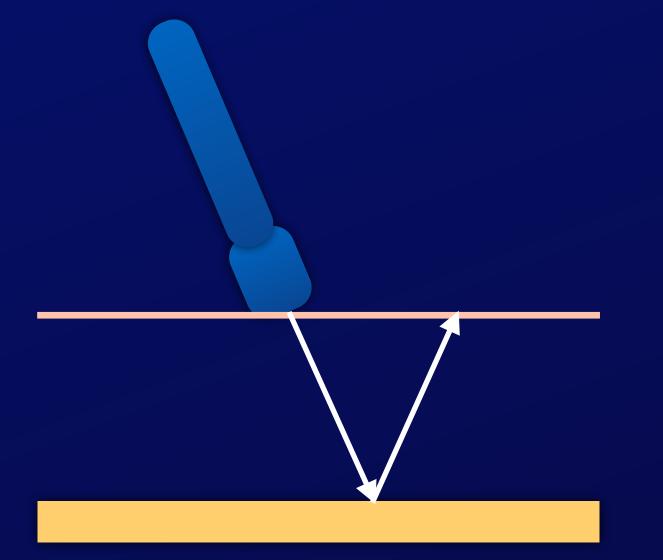
Artifacts

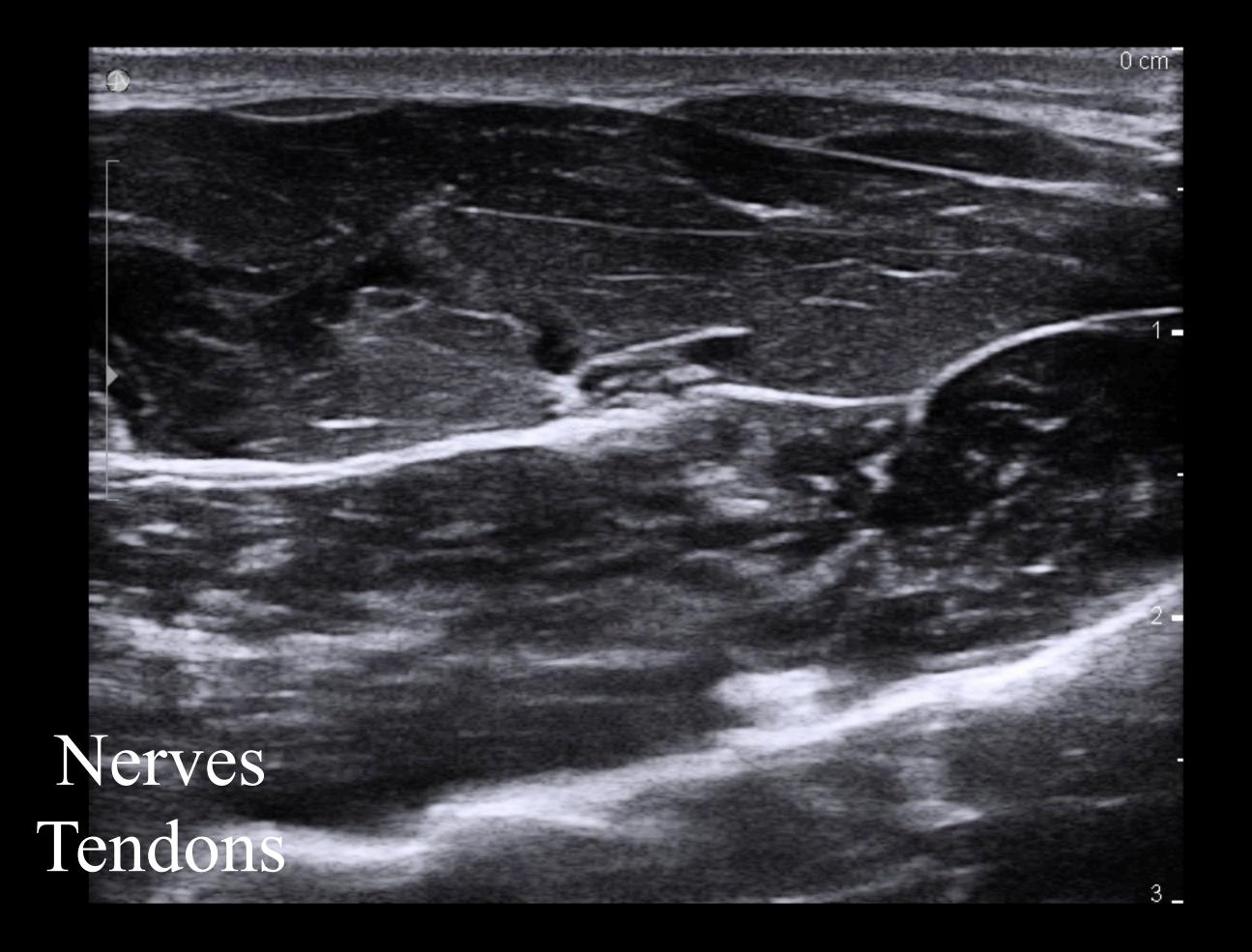
Strong reflextors: calcification, bone

Strong attenuators: solid tissue, dense masses









Artifacts: Anisotropy

Transducer 18L5 A-Gain Level 55 AutoGain On Res / Hz 3/59 Hz B Freq 12 MHz B Gain 15.0 dB 💢 Wi-Fi 100%



Artifacts Reverbation



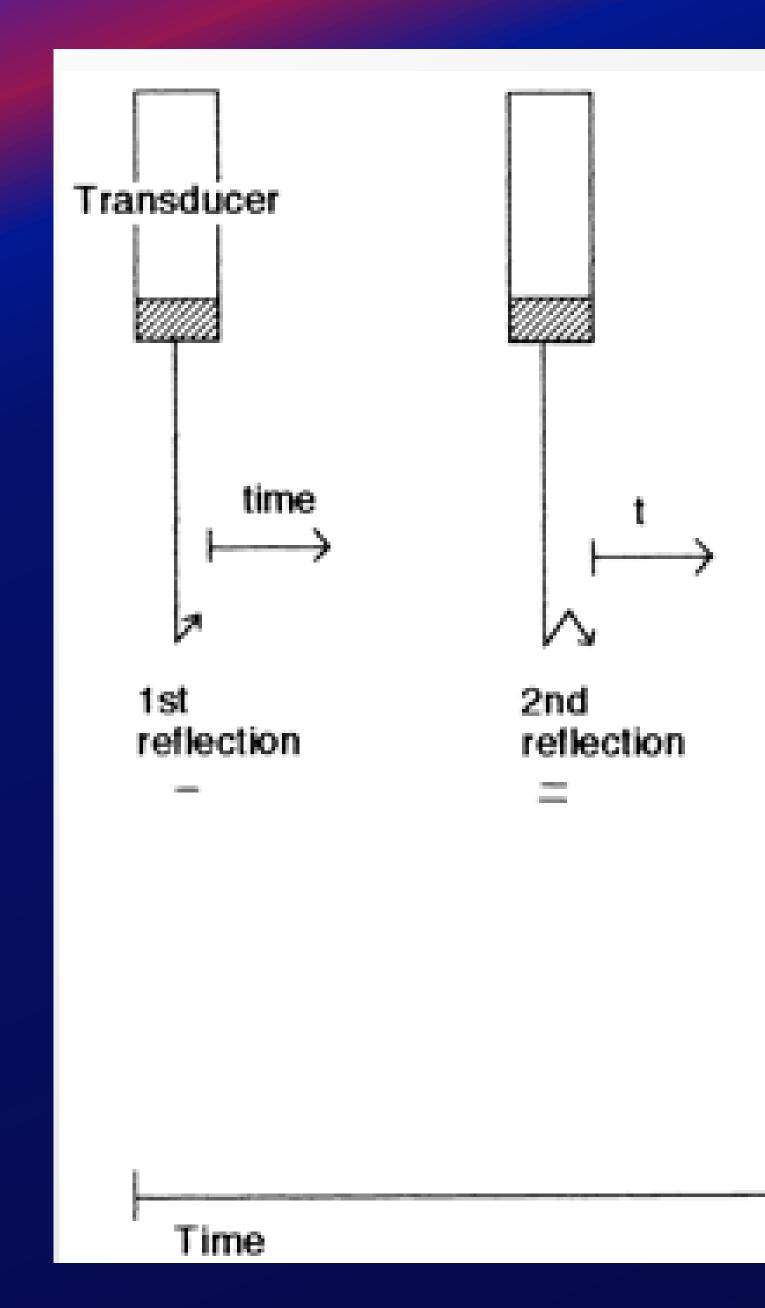
Probe

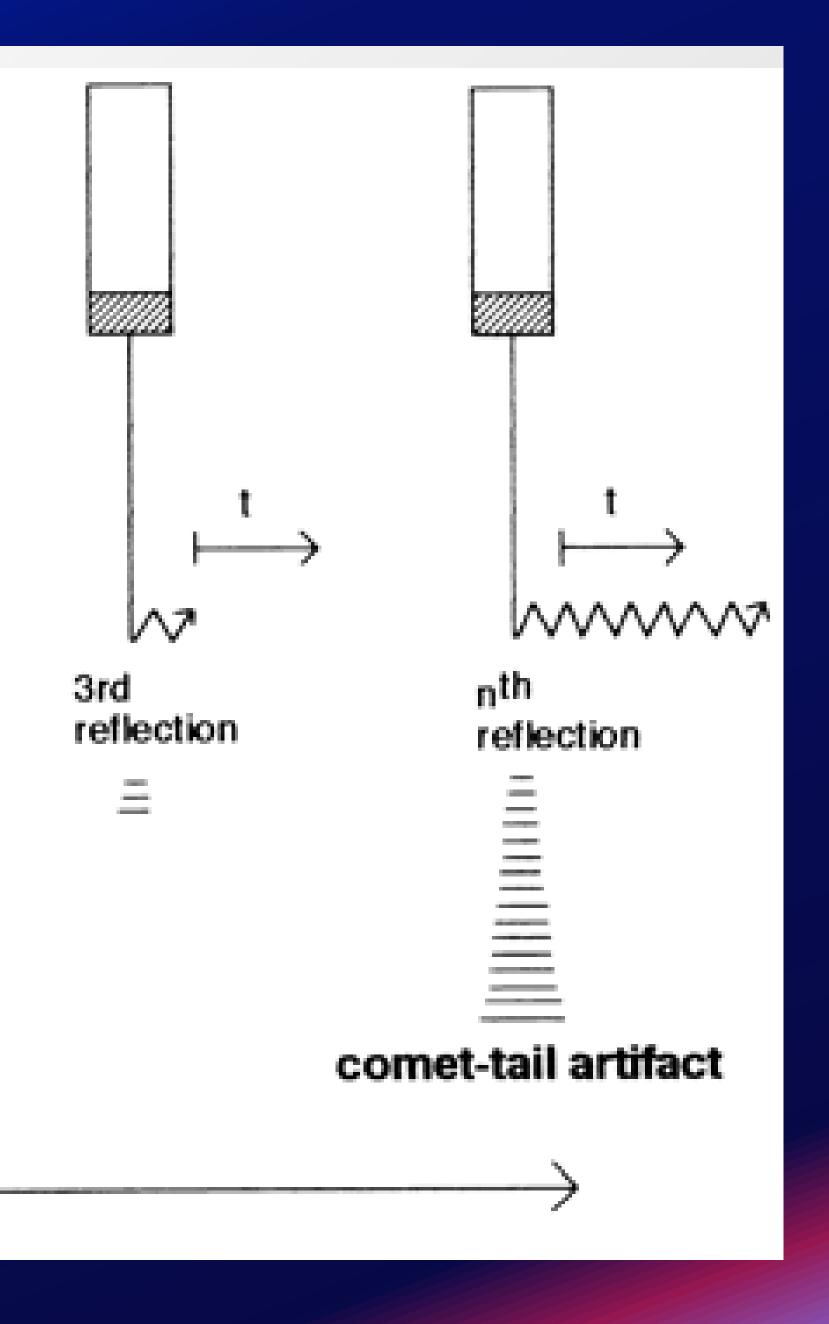
3 om

6 cm

Artifacts Velocity changes







Artifacts Comet-tail artifact

ĢĘ

Pleural effusion = none Pneumothorax = none Paremchymal lung disease = multiple

II

2-

Regional anesthesiologists diagnosing non-neural pathology

Reg Anesth Pain Med 2006;31:555-62

"Artifacts" Anatomy

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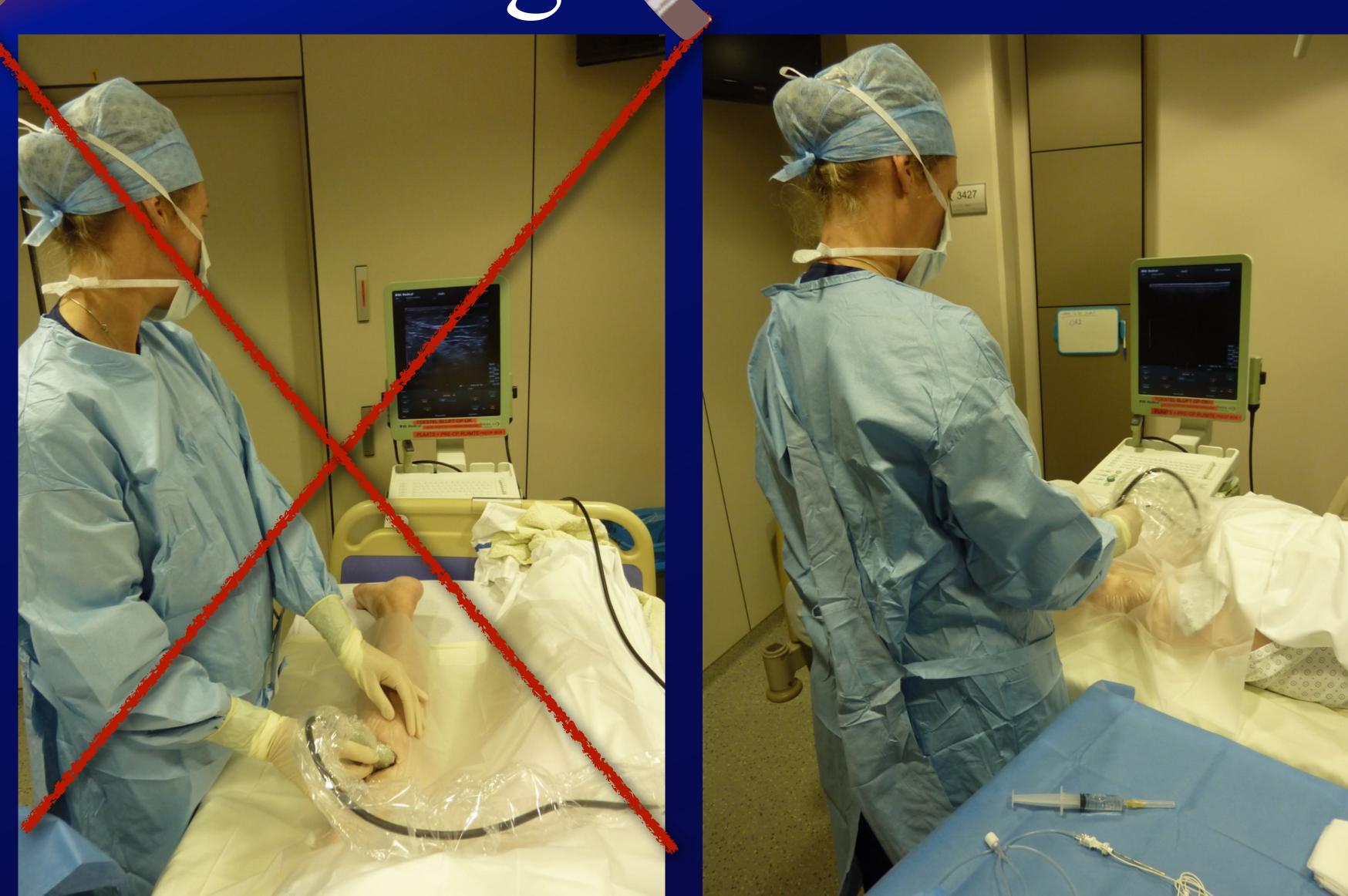
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Learn the importance of transducer pressure	Identify nerves	Learn the in-plane technique, maximizing needle visualization
Learn the importance of transducer alignment	Identify muscles and fascia	Learn the out-of-plane technique
Learn the importance of transducer rotation	Identify blood vessels, distinguish artery • from vein	Learn the benefits and limitations of both techniques
Learn the importance of transducer tilting	Identify bone and pleura	Learn to recognize intramuscular needle location
	Identify common acoustic artifacts	Learn to recognize correct and incorrect local anesthetic spread
	Identify common anatomic artifacts (pitfall errors)	Conduct proper ergonomics
	Identify vascularity associated with needle trajectory	Minimize unintentional transducer movement
	•	Identify intraneuronal needle location





Ergonomics



STOP before you block

Notice for anaesthetists and anaesthetic assistants

- A STOP moment must take place immediately before inserting the block needle
- The anaesthetist and anaesthetic assistant must double-check:
 - the surgical site marking
 - the site and side of the block

National Patient Safety Agency

SAFE ANAESTHESIA LIAISON GROUP



*RA-UK Regional Anaesthesis Linked Kingdom

Nottingham University Hospitals

STOP moment for checking the

correct site and side

For unilateral blocks

Simple double-check

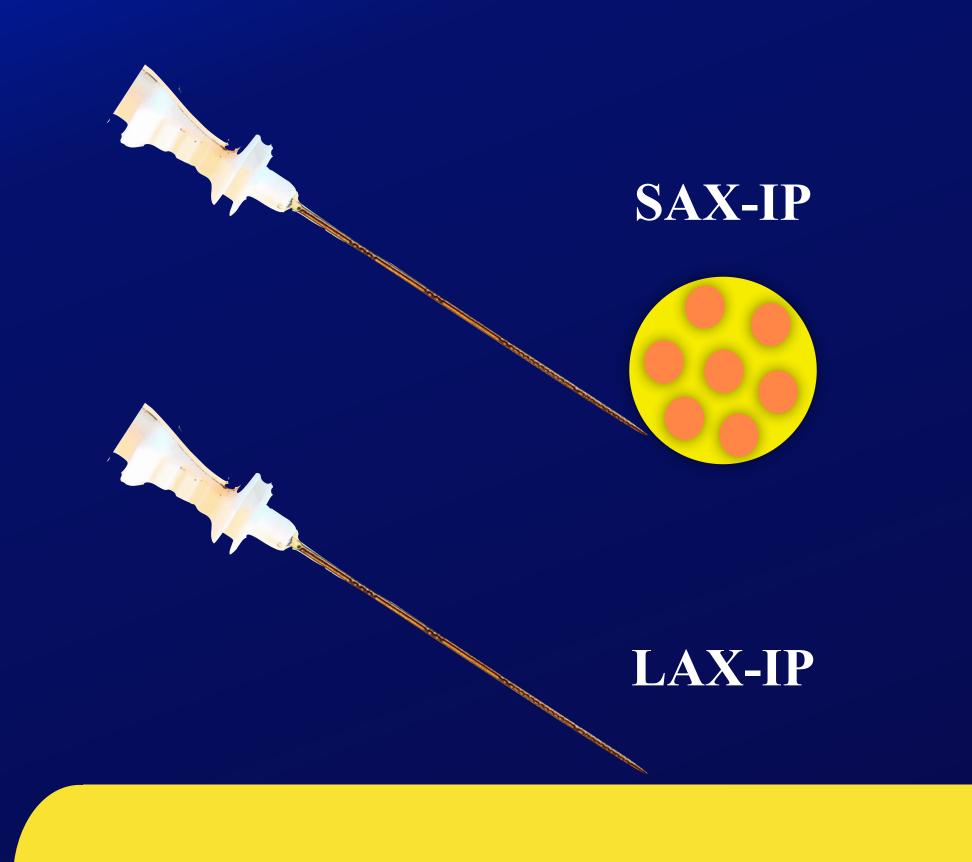
Separate from WHO checklist

Immediately before insertion of needle

Initiated by anyone (anesthetist / nurse)

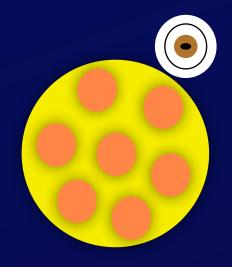


US guided blocks Axis and Plane





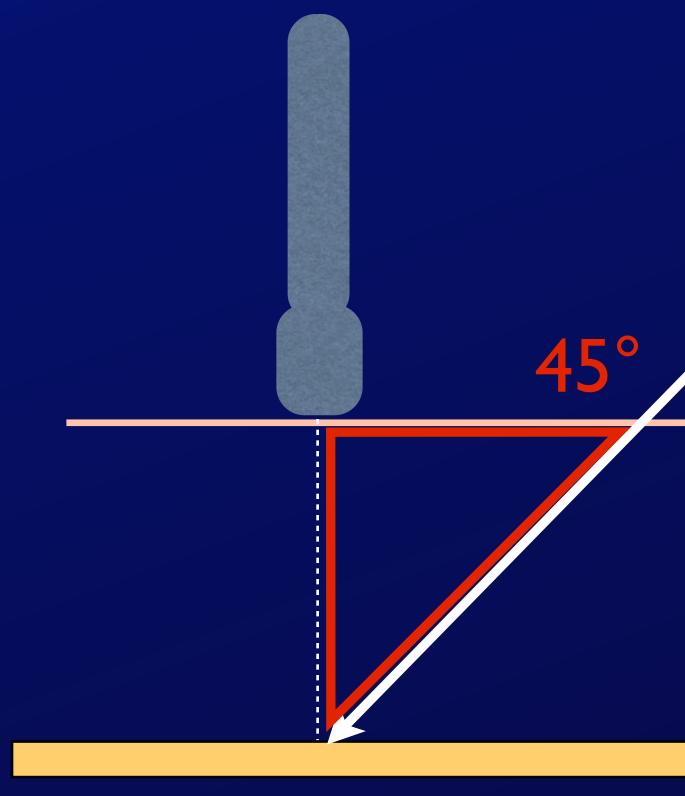
SAX-OOP

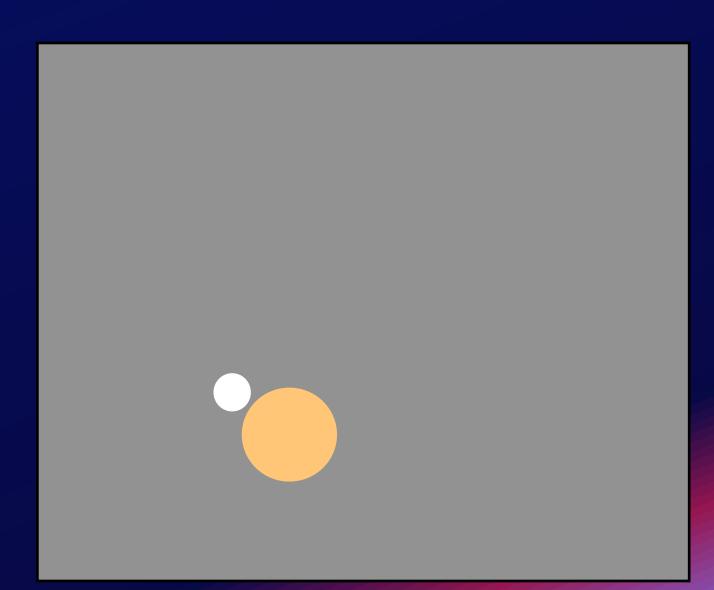


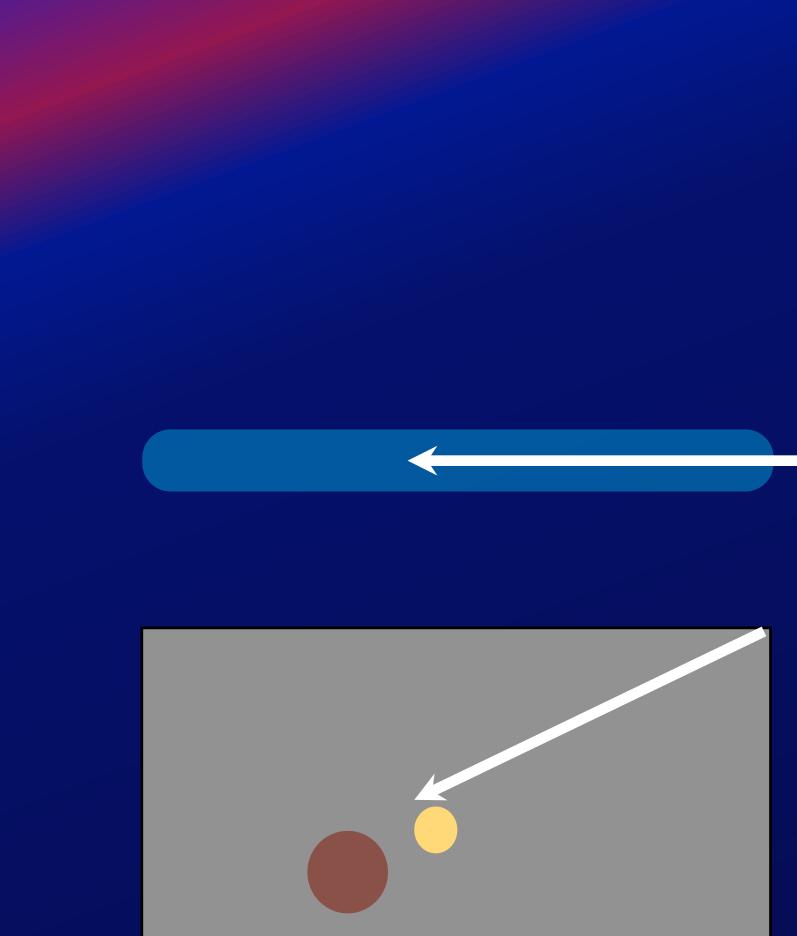
LAX-OOP



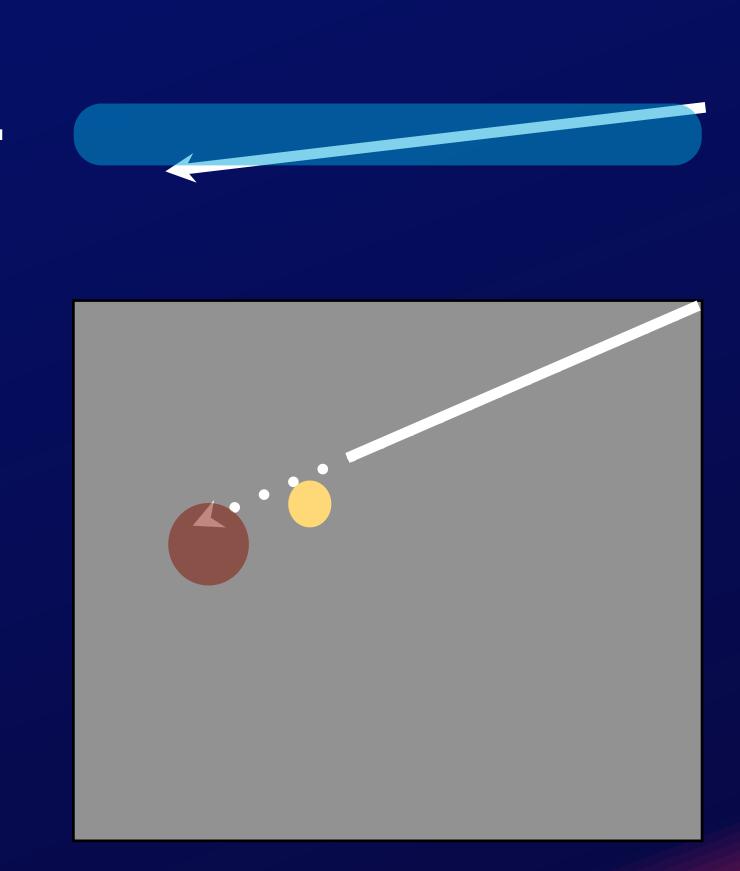
OOP (Crossing the plane)

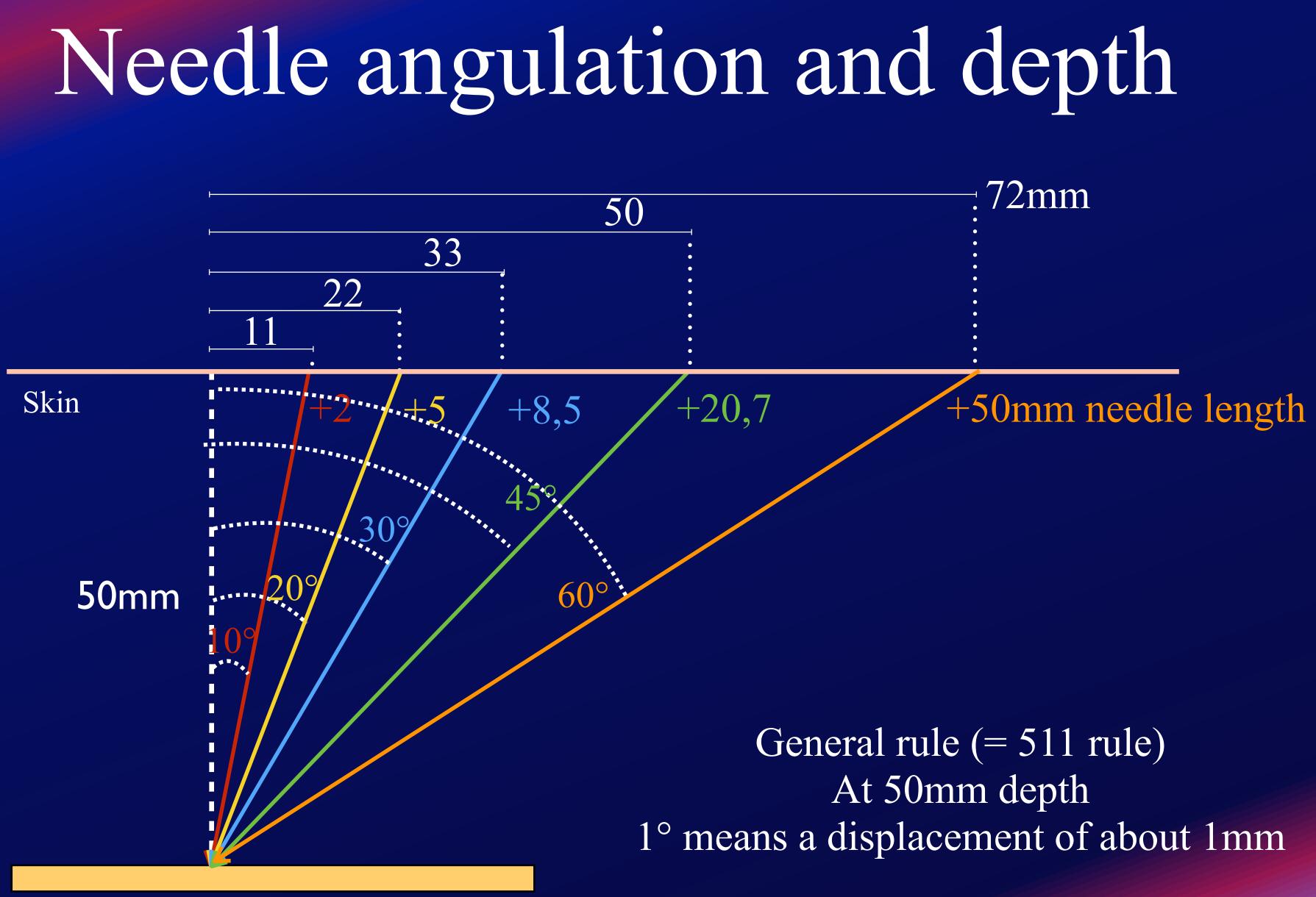






IP





Nerve

Needle technique

Ultrasound

- Visualisation of
 - Nerve, but not fasciculi
 - Epineurium? Bigeleisen RAPM 2010

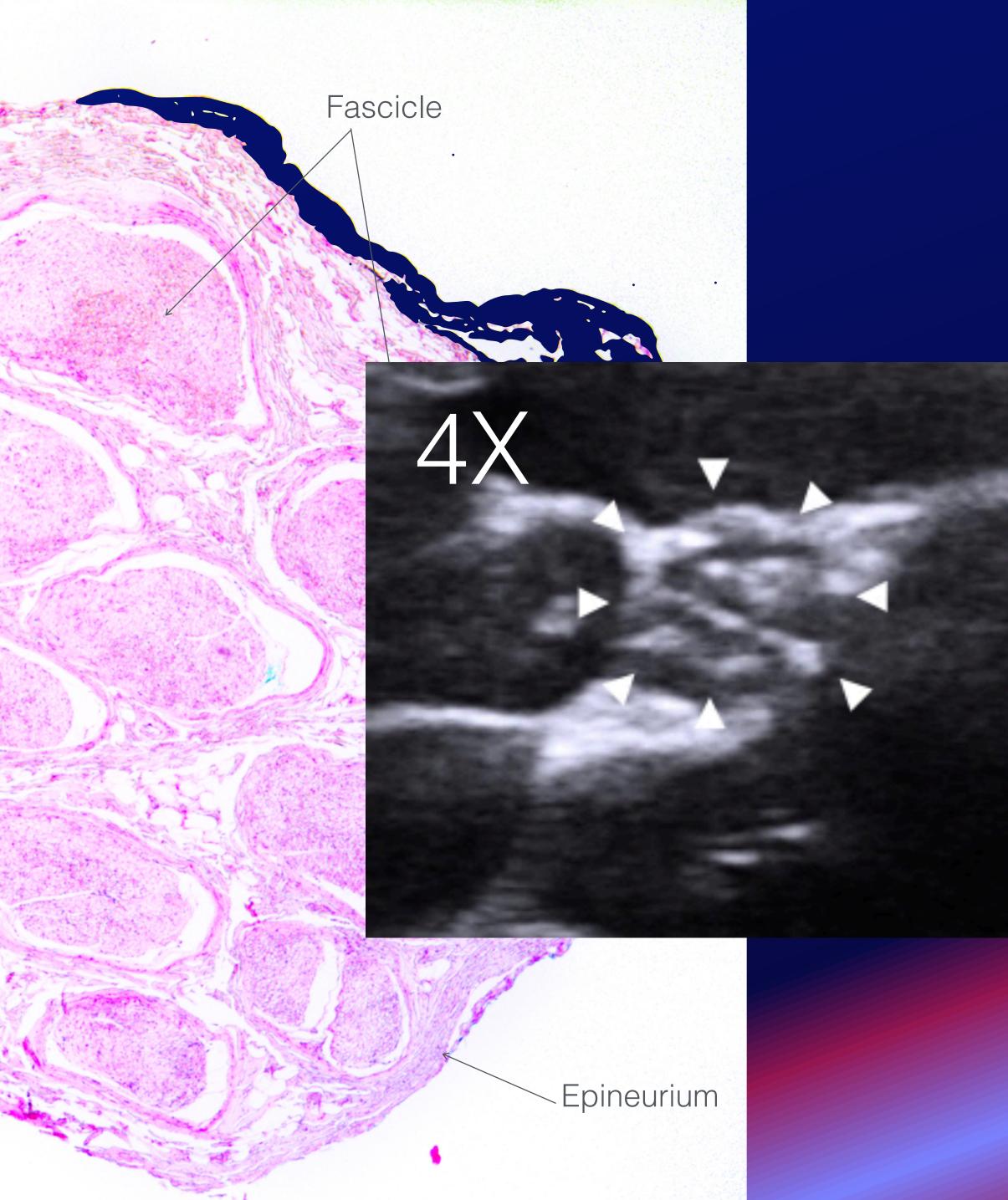
 - Needle penetration into nerve??? •

Deep nerves? Resolution at low frequencies??

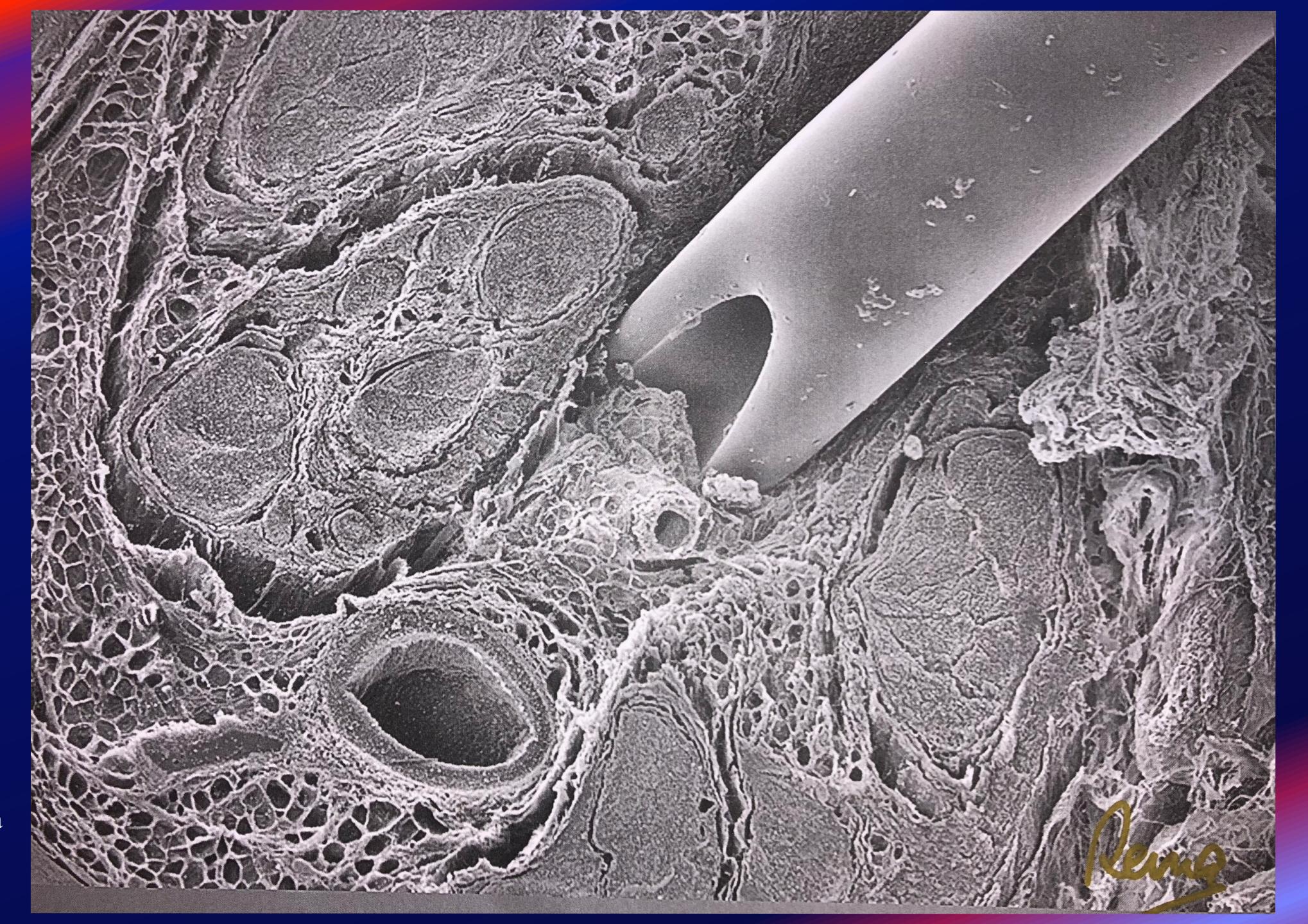
40X Connective tissue

Perineurium

Extrinsic blood vessels







Thanks to M.A. Reina

Direct

US-guided tangential needle approach to the nerve

Tangential

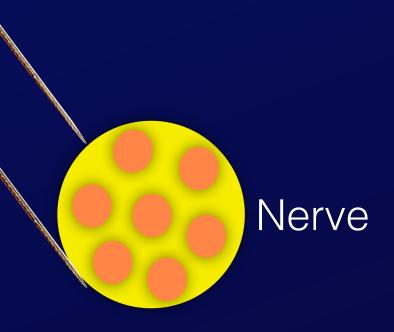
Anaesthesia. 2017 Apr; 72(4): 461-469

Needle Technique



IP

Skin



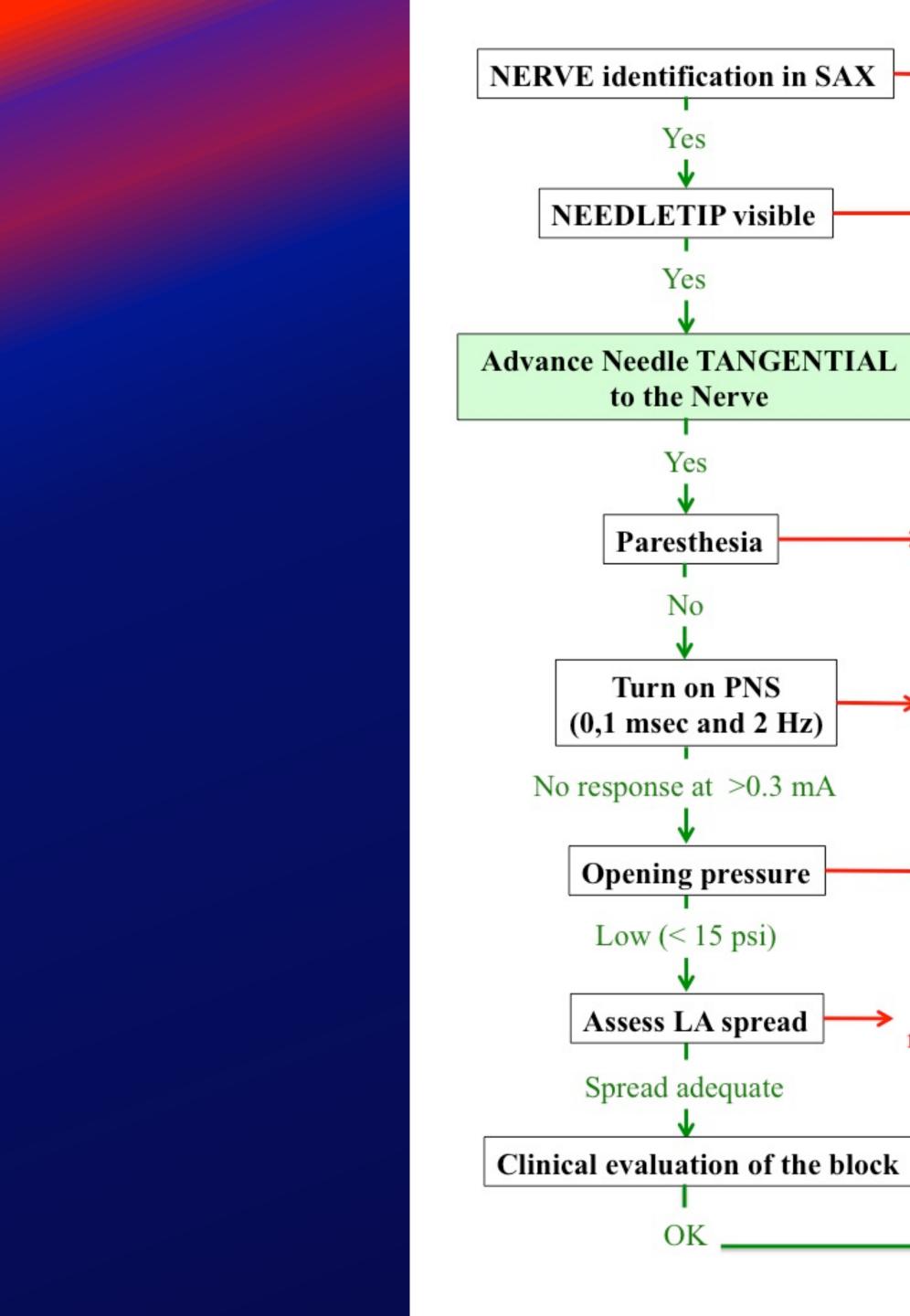
Anaesthesia 2017

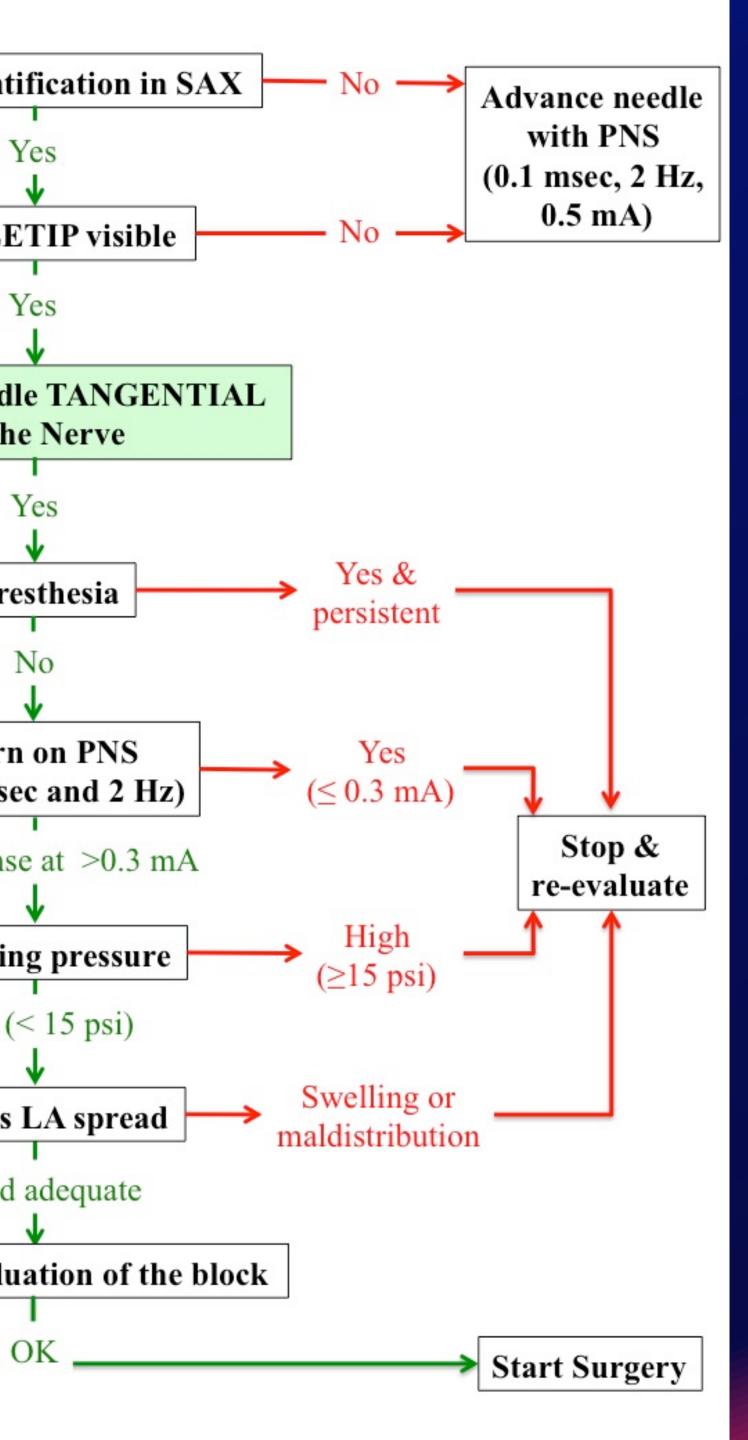
Original Article

the incidence of intraneural injection: a cadaveric study^{*}

L. A. Sermeus,¹ X. Sala-Blanch,^{2,3} J. G. McDonnell,⁴ C. A. Lobo,⁵ B. J. Nicholls,⁶ G. J. van Geffen,⁷ O. Choquet,⁸ G. Iohom,⁹ B. de Jose Maria Galve,¹⁰ C. Hermans¹¹ and M. Lammens¹²

Ultrasound-guided approach to nerves (direct vs. tangential) and





US & Injection

6Stongagardard, Hensensche Bassaga AAA, et al. Insulining section aftants bartand house terter lowor grada deefe dattate id in fusion in menerity ith increased in the second of the Intravasculation Abiabiaence responses ab ob- Dep Matabalisms2023032;52.88892894. 7. 7. Leiberwitzitz Bab? Subinan Batting Trillippe Intraveneus fat familisions and the papereaseas. tests a mixture of 20 mLnft. 58/510 pivaçaine Anesthesiology 2008 essure of Observe local anesthetic spread in oba THROUGHOUT THE INJECTION le NOT only in the beginning lva ain the imothorax in this patient organized in pointaneously. clusion, the presented generation of severe local anaesthetic ad-guided lateral, saggittal information of severe local anaesthetic esthesiologists to the initial and the Sport of the severe local anaesthetic back of the severe local anaesthetic ad-guided lateral, saggittal information of severe local anaesthetic esthesiologists to the initial and the Sport of the severe local anaesthetic back of the severe local anaesthetic beats/min. and the Sport of the severe local anaesthetic beats/min. and the Sport of the severe local anaesthetic beats/min. and the Sport of the severe local anaesthetic beats/min. and the Sport of the severe local anaesthetic beats/min. and the Sport of the severe local anaesthetic beats/min. and the Sport of the severe local anaesthetic beats/min. and the Sport of the severe local anaesthetic beats/min. and the Sport of the severe local anaesthetic beats/min. and the Sport of the severe local anaesthetic beats/min. and the Sport of the severe local anaesthetic beats/min. and the Sport of the severe local anaesthetic beats/min. and the sport of the severe local anaesthetic beats/min. and the sport of the severe local anaesthetic beats/min. and the sport of the severe local anaesthetic beats/min. and the sport of the severe local anaesthetic beats/min. and the sport of the severe local anaesthetic beats/min. and the sport of the severe local anaesthetic beats/min. and the sport of the severe local anaesthetic beats/min. and the sport of the severe local anaesthetic beats/min. and the sport of the severe local anaesthetic beats/min. and the sport of the severe local anaesthetic beats/min. and the sport of the severe local anaesthetic beats/min. and the sport of the severe local anaesthetic beats/min. and the sport of the severe local anaesthetic beats/min. and the severe local anaesthetic beats/min. and the severe local anaesthetic beats/min. and the severe local anaesthetic beats/min. anaesthetic beats/min. and the severe local anaesthet





Intraneural LA during injection



= swelling of the nerve 0.5ml is reliably detected with US N.Moayeri et al.