Basics of ultrasound guided regional anesthesia?

Theoretical background and practical applications

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

Objectives

- General considerations
- Define:
  - Ultrasound generation, frequency, wavelength, attenuation, Doppler
  - Image optimization
  - Image interpretation
  - Needle insertion and injection

Evolution

Peripheral Nerve Stimulator

Ultrasound guided regional anesthesia

Peripheral Nerve Stimulator

Current intensity

For localizing the nerve:

between 0.5 and 2 mA

For avoiding intraneural needle positioning:

between 0.3 and 0.5 mA

PNB with Peripheral Nerve Stimulator

Several disadvantages

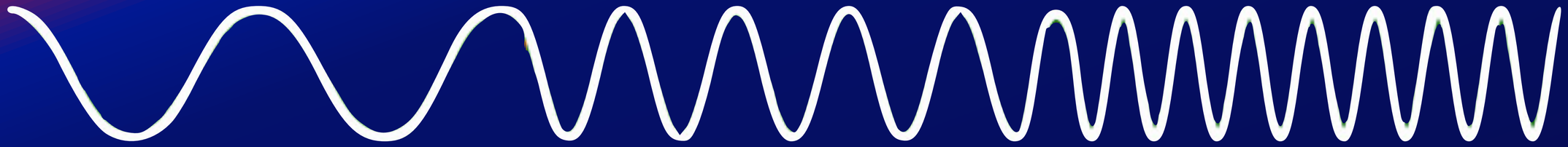
- Blind technique (anatomic variations?)
- Dependent of normal functioning nerves
- Large volumes of LA (risk of LAST)

PNB with Ultrasound

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

ULTRASOUND

Ultrasound: physical definition



0 Hz 16 20 000

Infrasound <20Hz < 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.

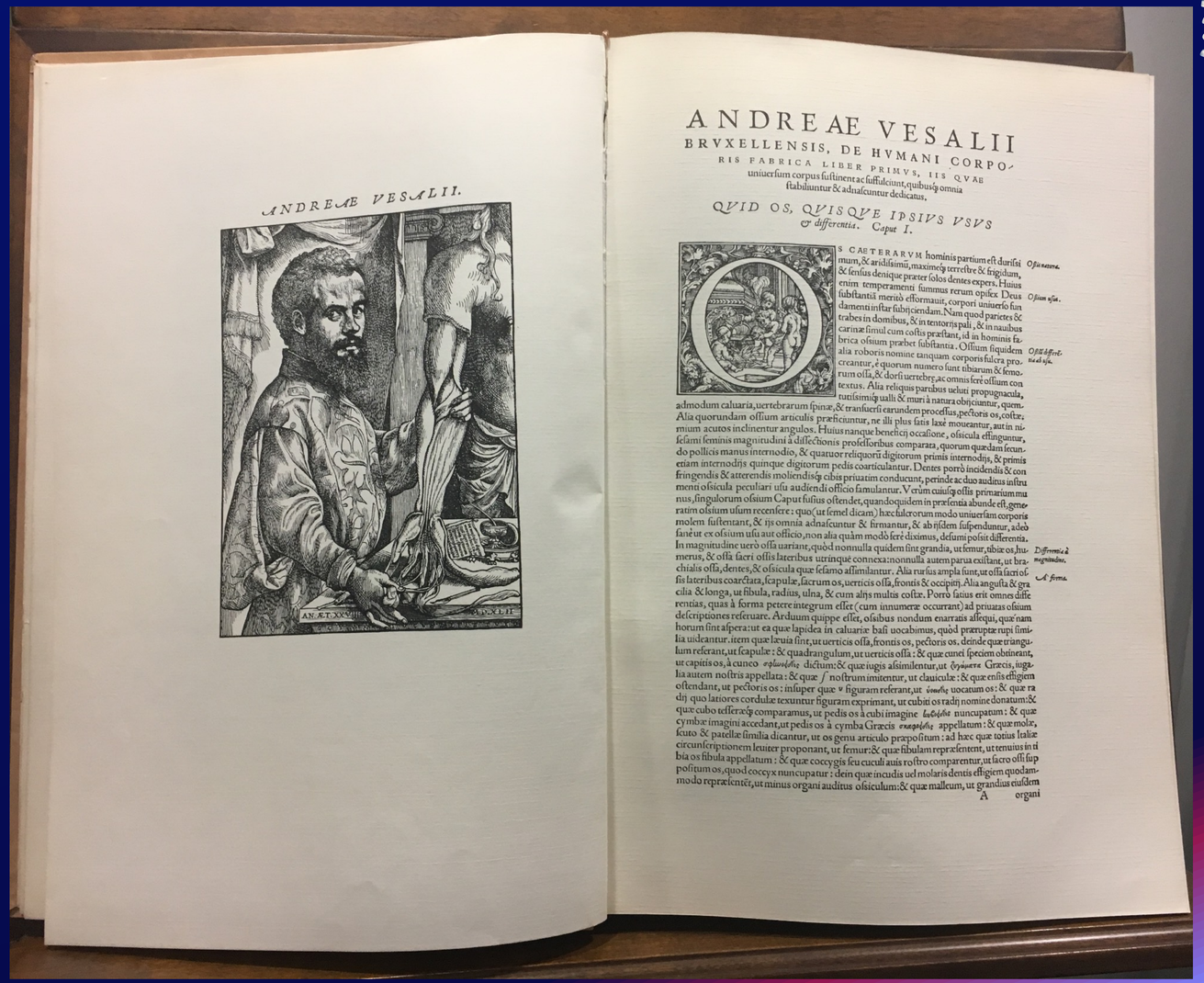
The base

Knowledge of anatomy
(and sonoanatomy)

REMEMBER!!

Anatomy varies
and
we are not all experts

Andreas Vesalius (Brussels1514- Zakinthos 1564)
De humani corporis fabrica libri septem



UGRA: 10 Tasks

1. 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
9. Maintain safety guidelines: resuscitation equipment, aspiration, test dosing, monitoring, patient response, injection characteristics
10. Maintain aseptic technique with respect to US equipment

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, Checketts MR, Bogod D, Tighe S, Moriarty A, Koerner R.

…. 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 kept well away from the drugs and equipment to be used for CNB. Antiseptic

b. The solution must be allowed to dry before the skin is palpated or punctured.

c. The operator should check his/her gloves for contamination with chlorhexidine. If there is

Levels of difficulties

- Deep blocks: degradation of US and needle image

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

Skills

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
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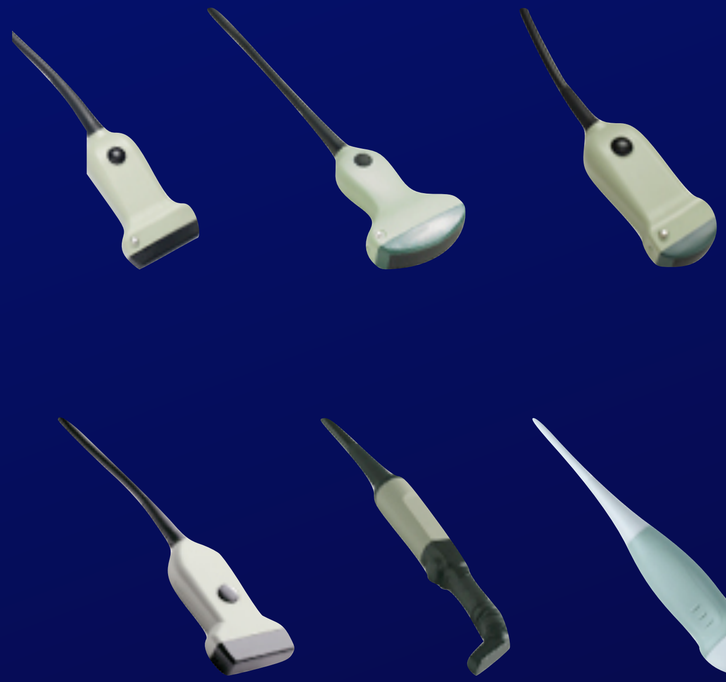
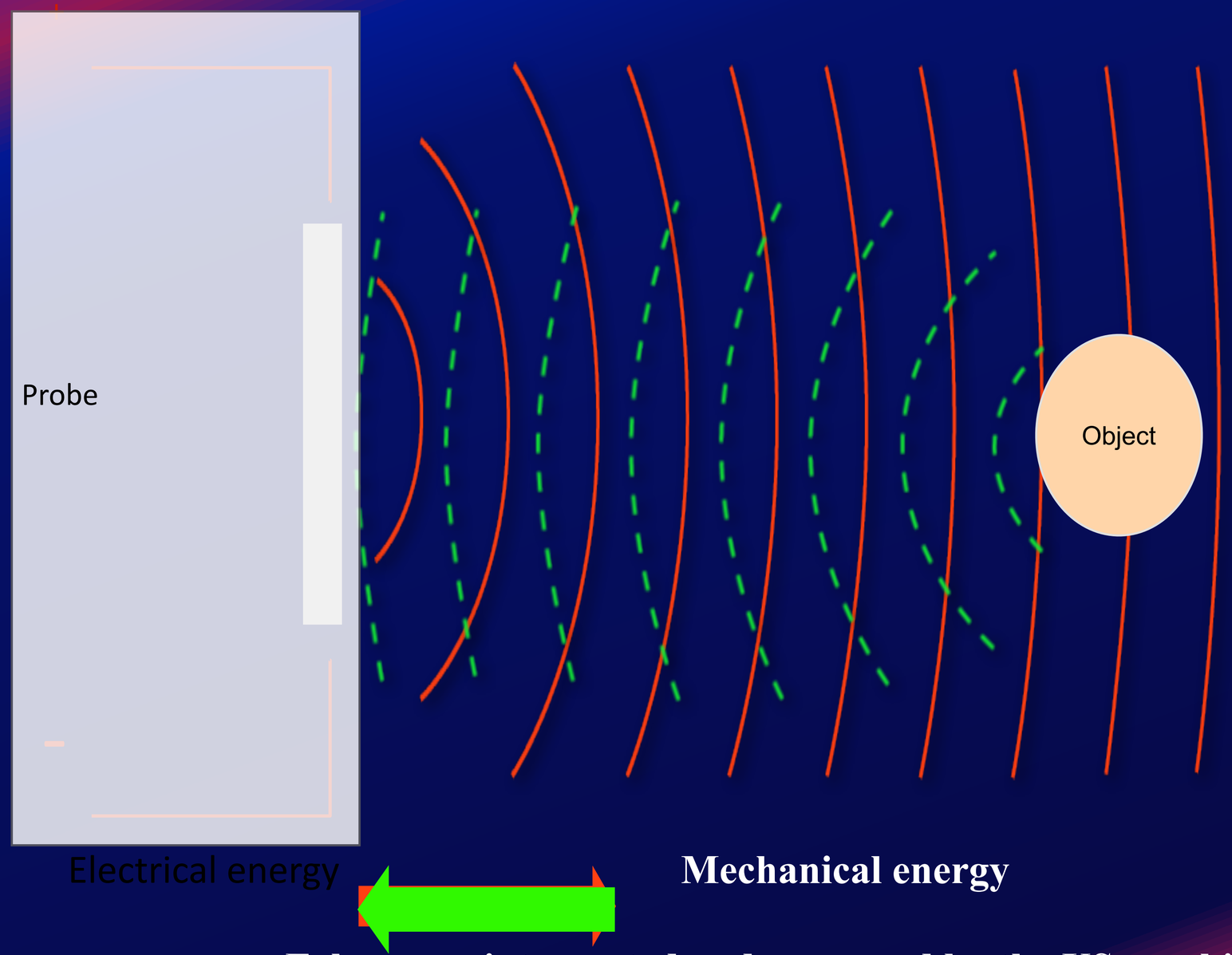
Archiving images		Identify common anatomic artifacts (pitfall errors)	Conduct proper ergonomics
Follow ASRA-ESRA standardization for screen orientation to the patient		Identify vascularity associated with needle trajectory	Minimize unintentional transducer movement
			Identify intraneuronal needle location

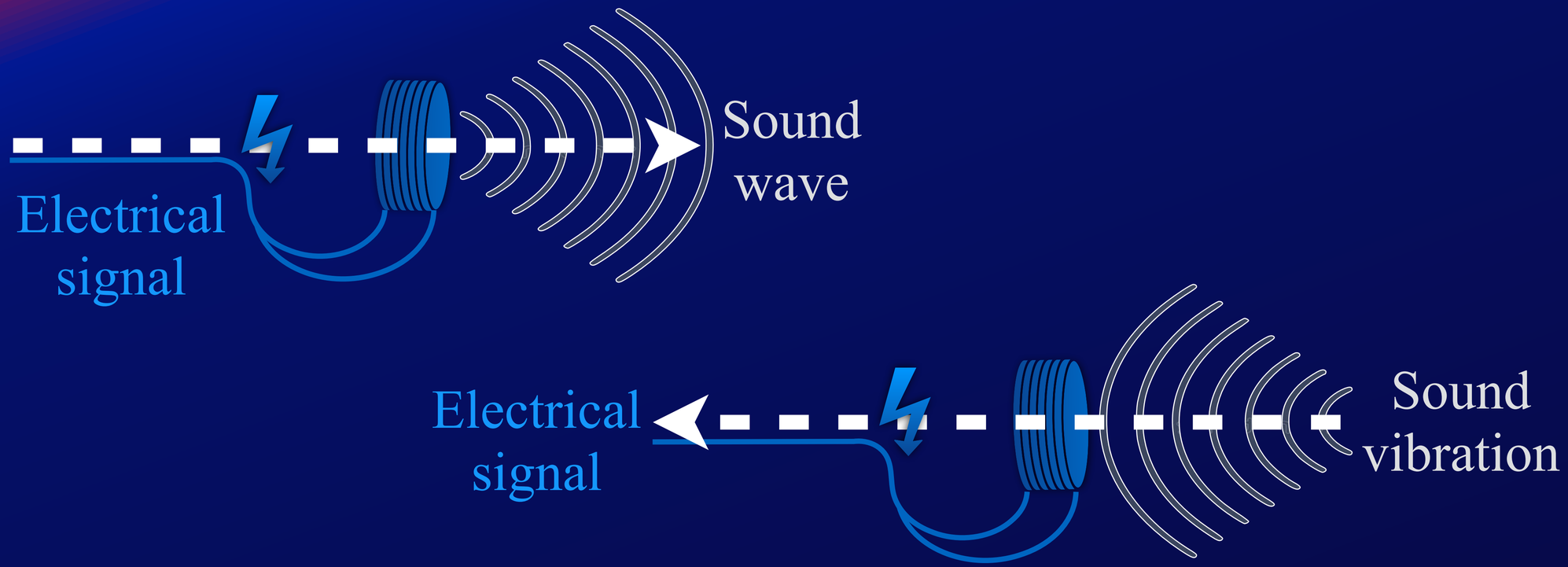
US machine and probes





Echoes are interpreted and processed by the US-machine

Piezoelectric effect

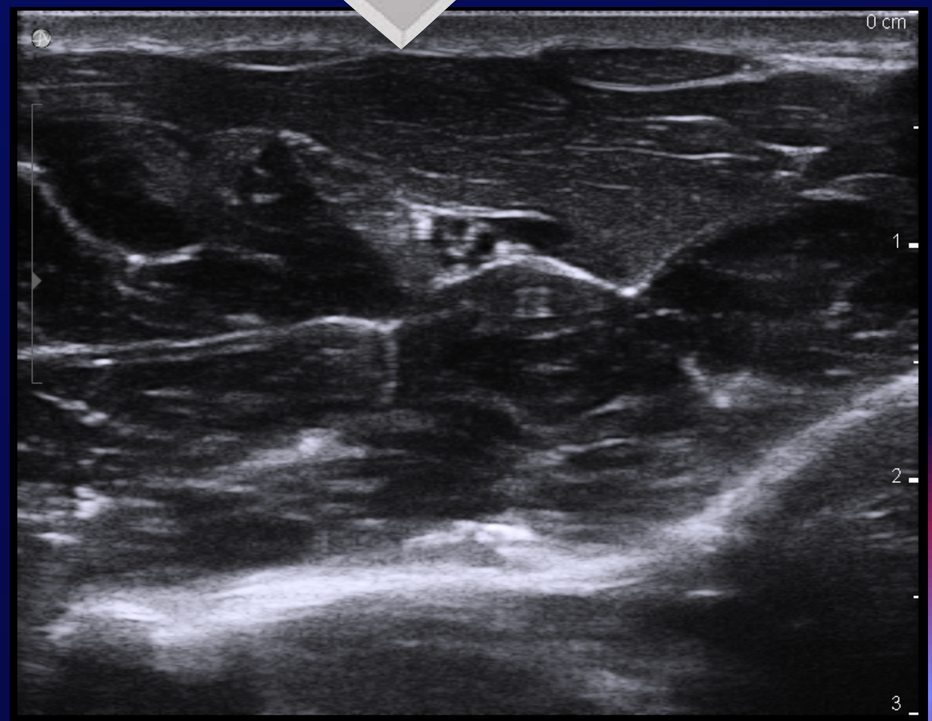


Piezoelectric element

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

US beam

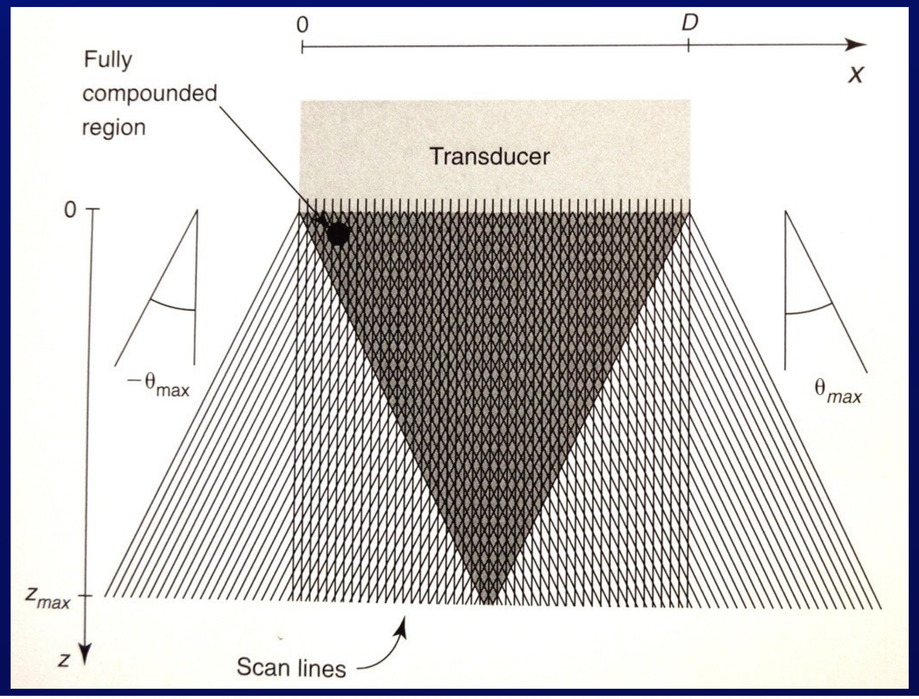
- Pulsed beam
  - Sends waves 1% of time
  - Receives 99% of time
- Beam profile
  - 3D approx. 1 mm thick
- Image produced is “2D”
  - Tomographic slice



Bandwidth

- All US-transducers contain a range of frequencies, termed *bandwidth*
- *Medical US: 2-20MHz*

Spatial compound imaging



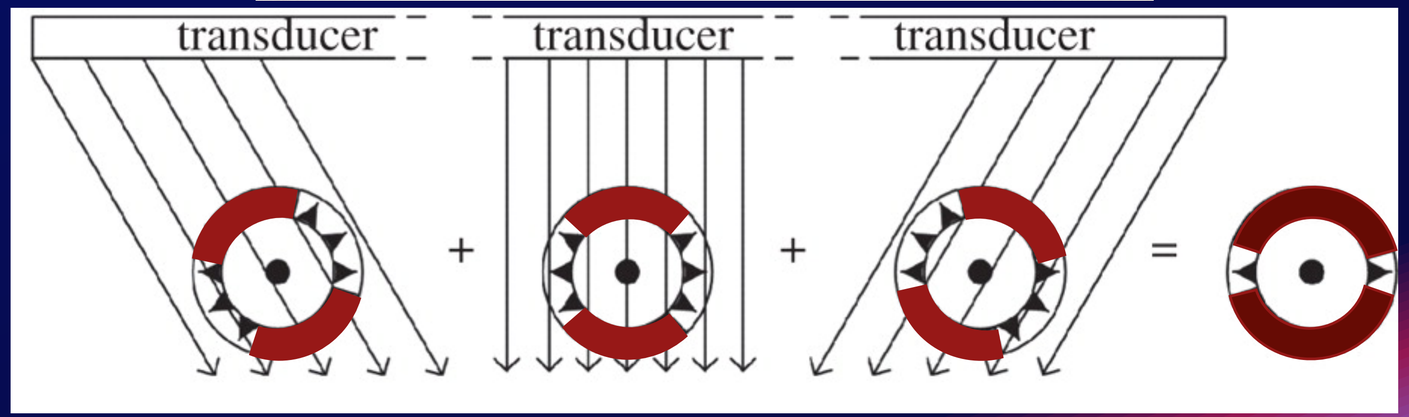
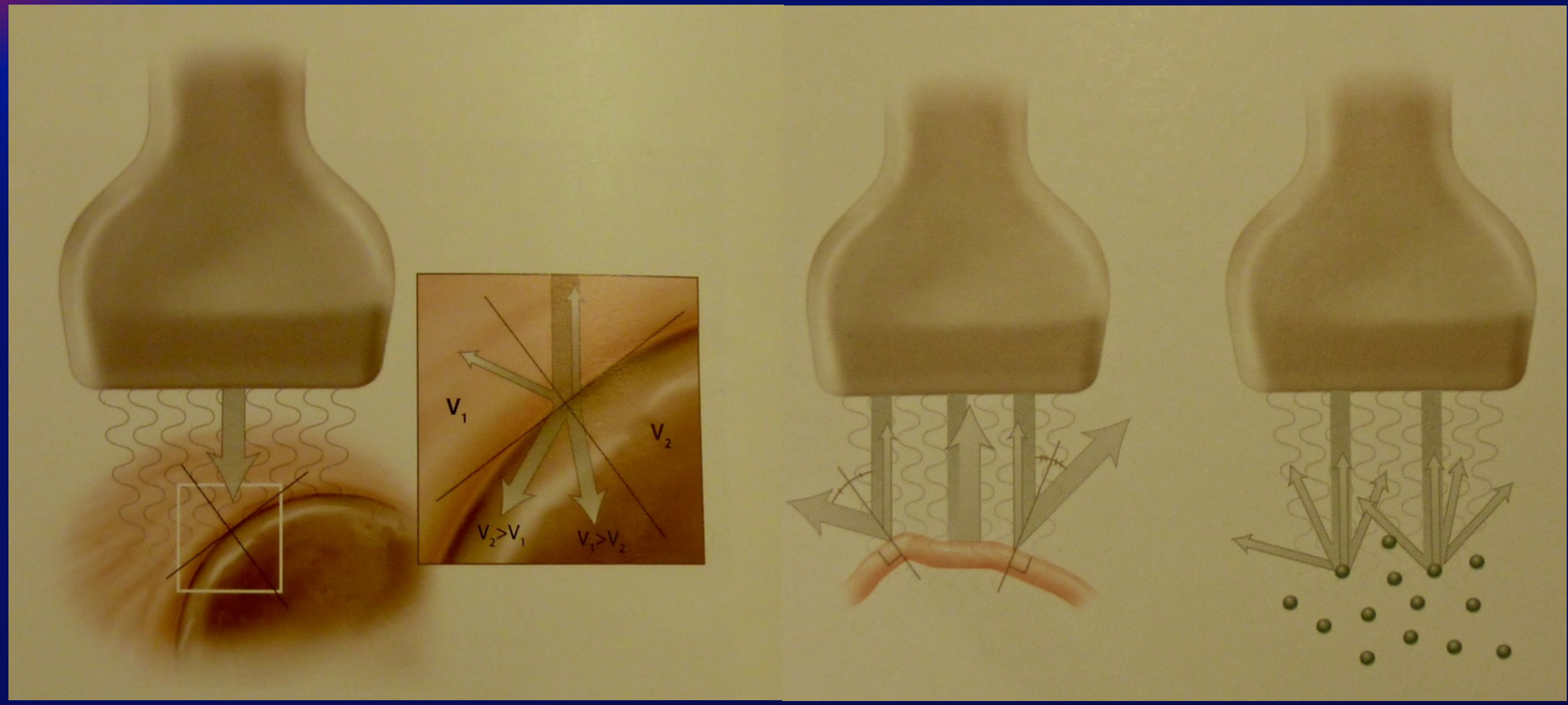


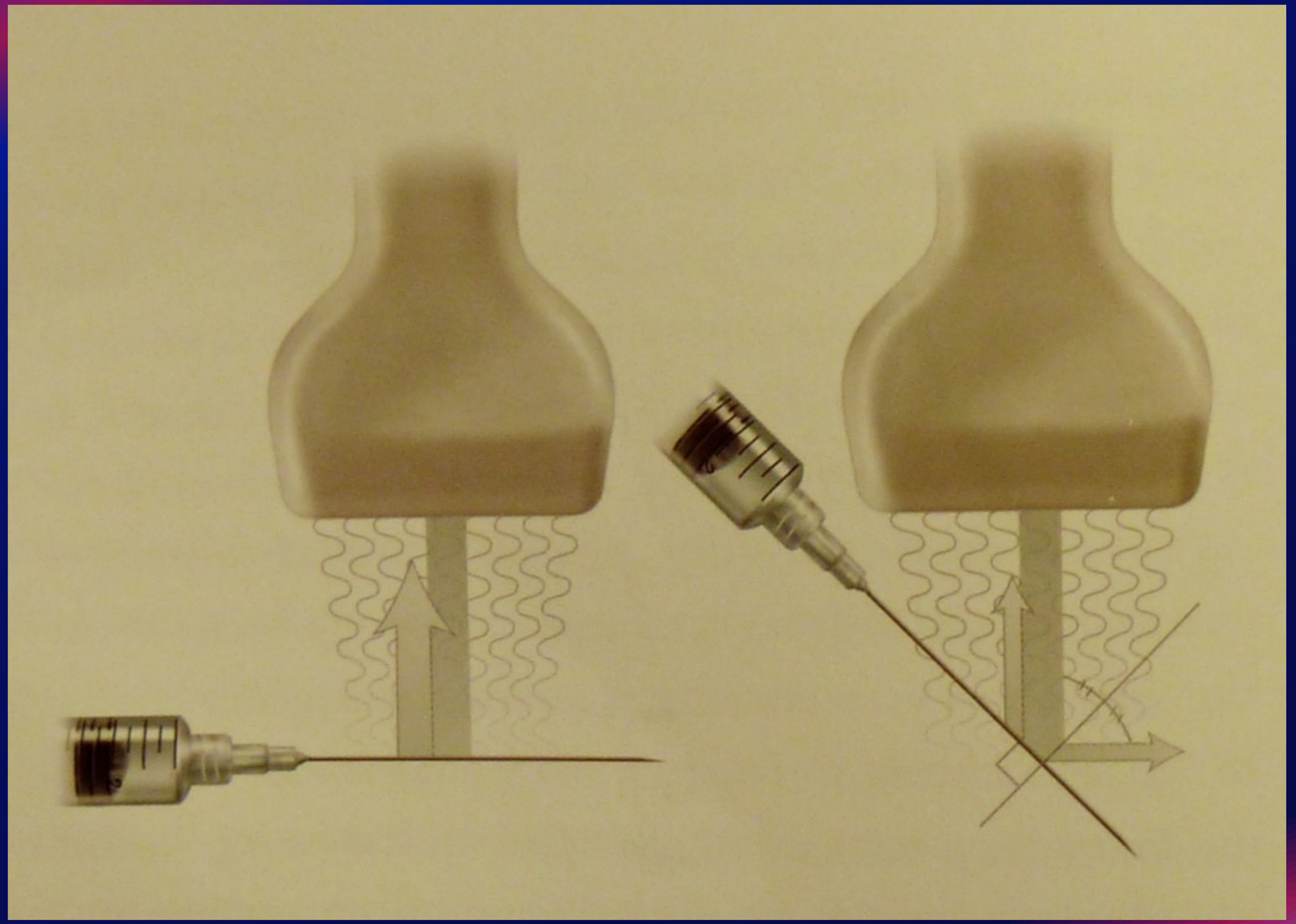
Image generation



Absorption
Refraction
Reflection

Reflection
Refraction

Scattering
Refraction



Penetrance - Resolution
Frequency

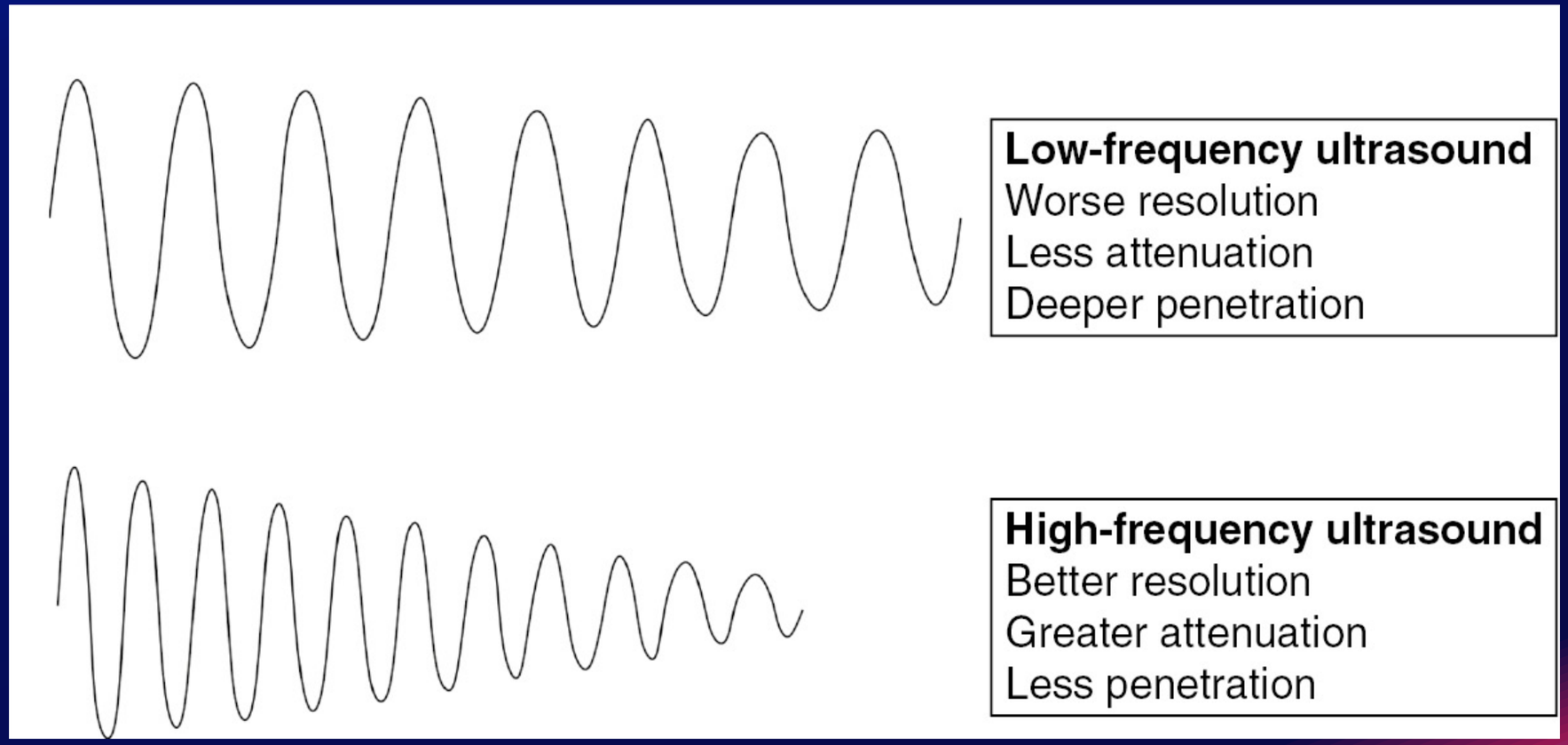
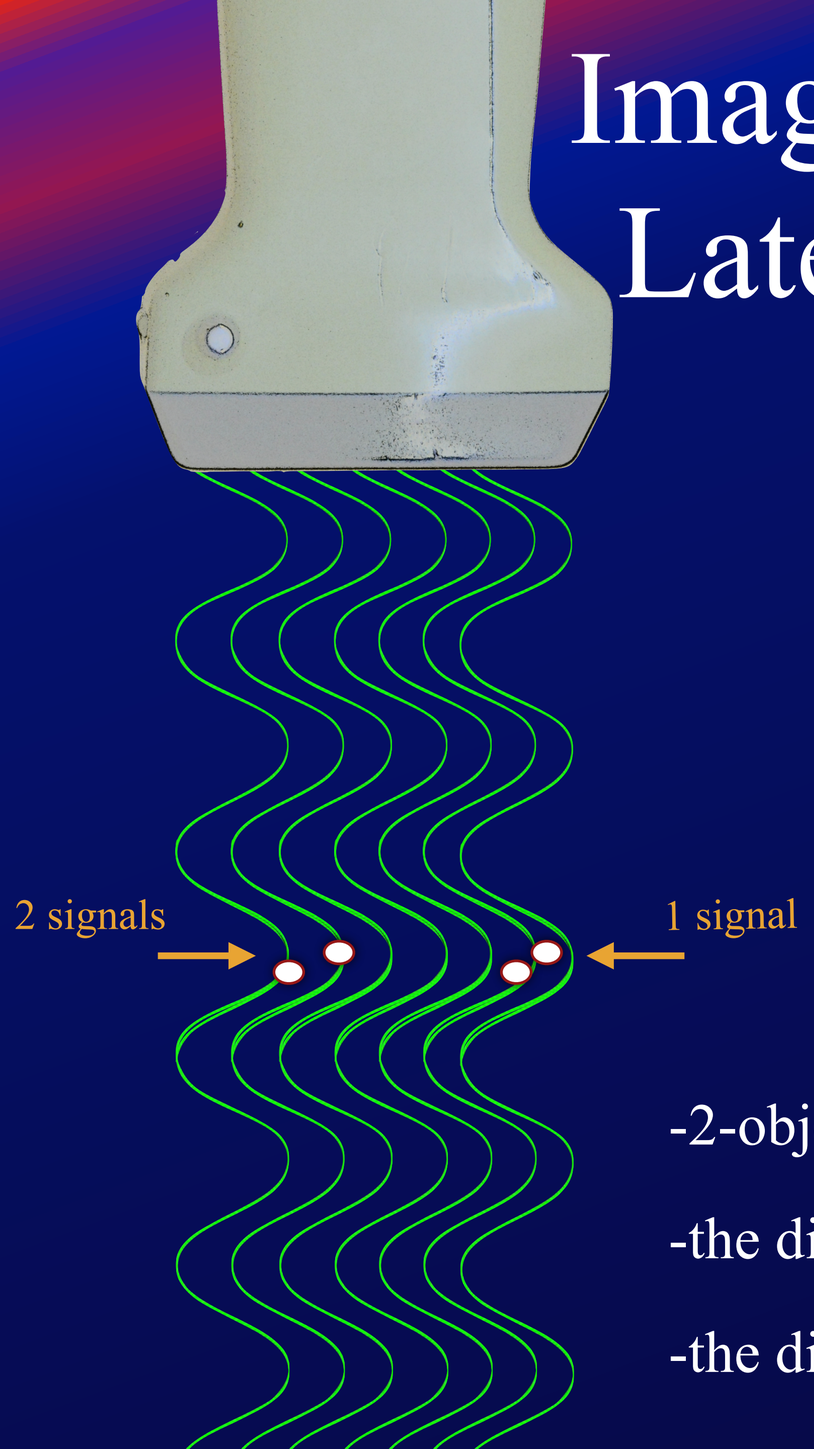


Image optimization
Lateral resolution



-2-objects discrimination depends of

-the distance between individual piezoelectric crystals

-the distance between the objects

Image optimization - Focus

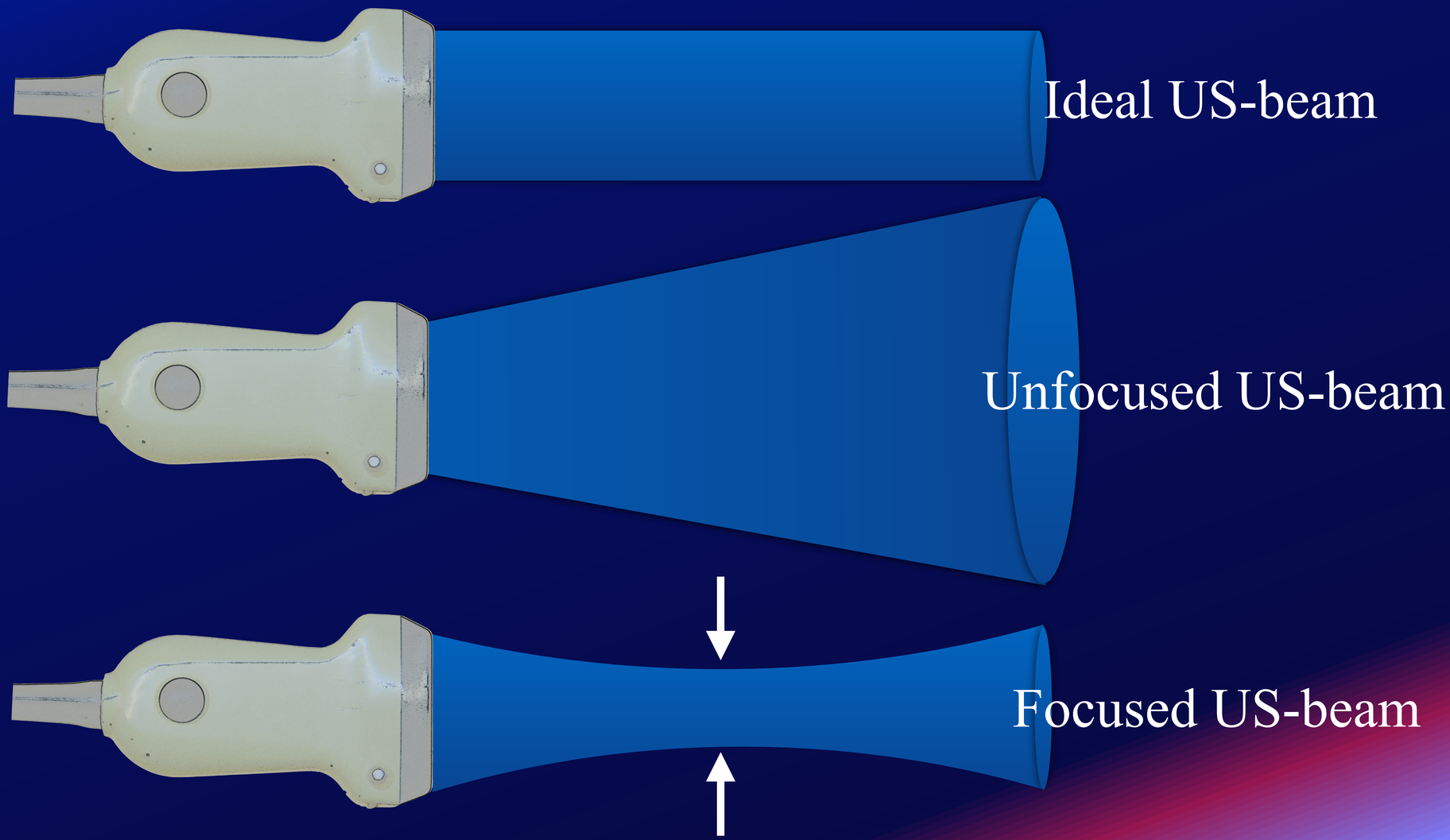
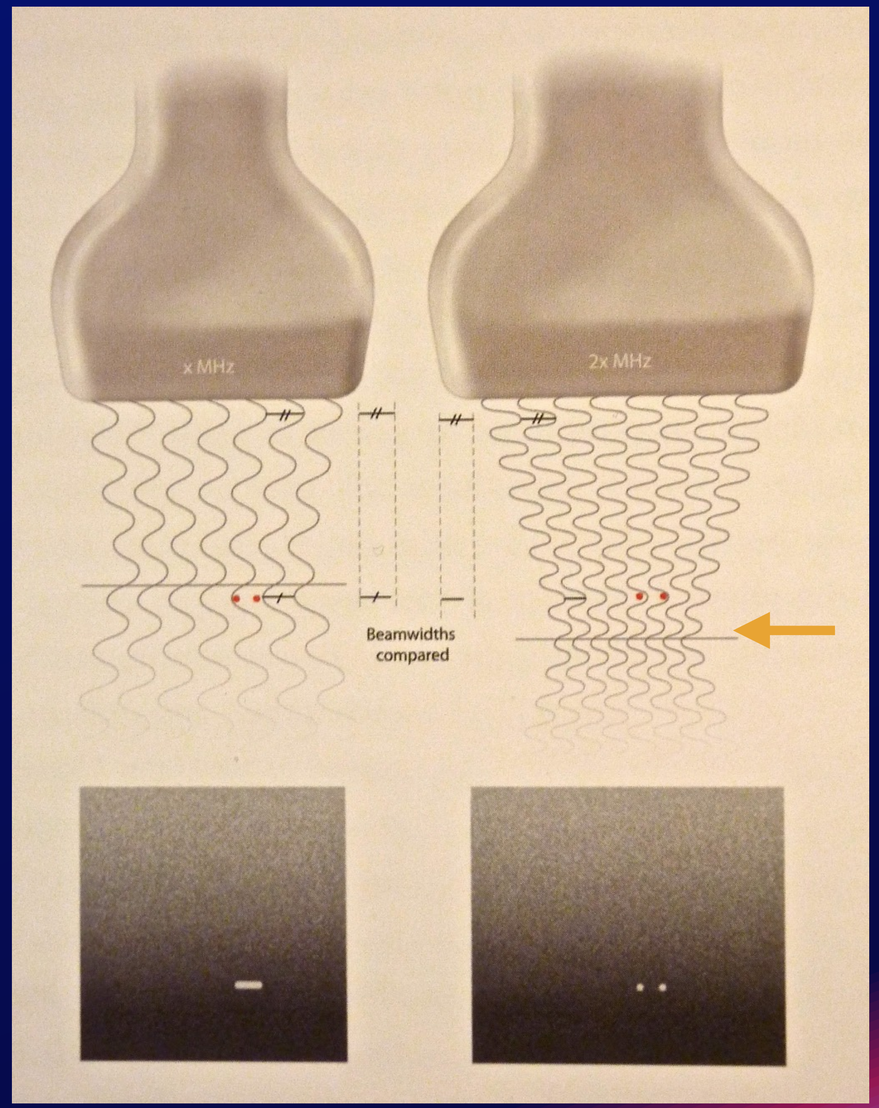


Image optimization

Electronic Focus

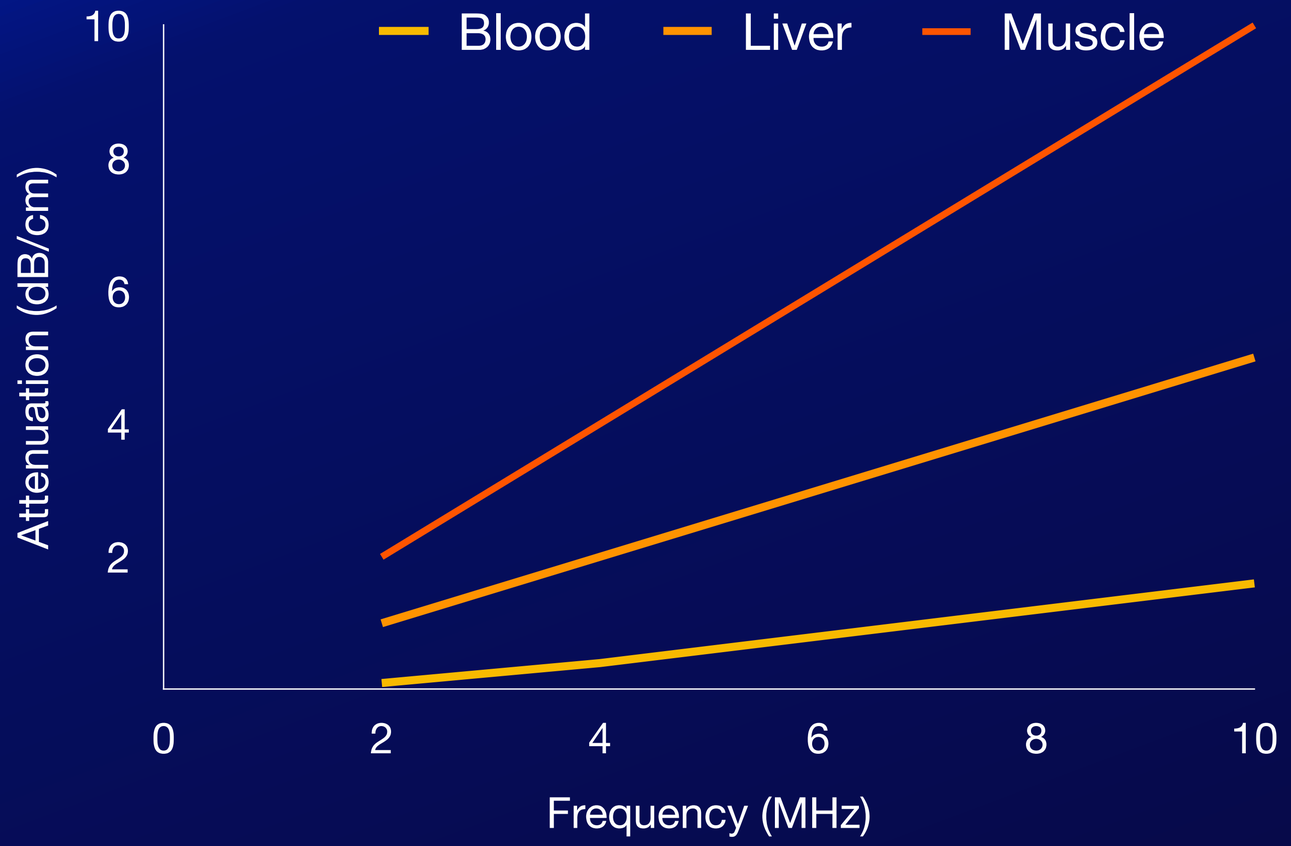
= improved
axial resolution



Attenuation

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

Attenuation - tissue



Higher frequency = more attenuation
More attenuation = less penetration

Velocity in medium

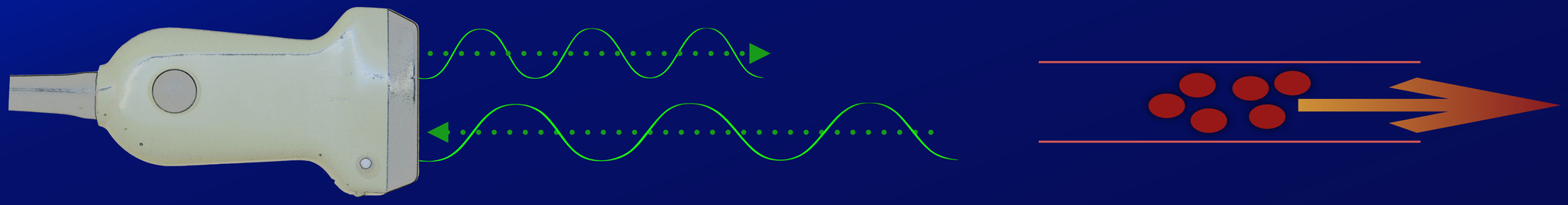
Ultrasound Pulse
Velocity
= determined by the material

$$V=\sqrt{\frac{\text{Stiffness}}{\text{Density}}}$$

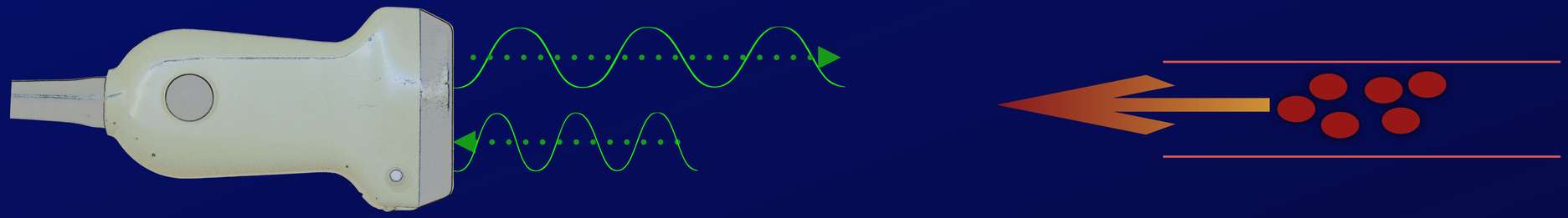
Average for soft tissue
1540m/s

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

Vessel recognition
Color Doppler

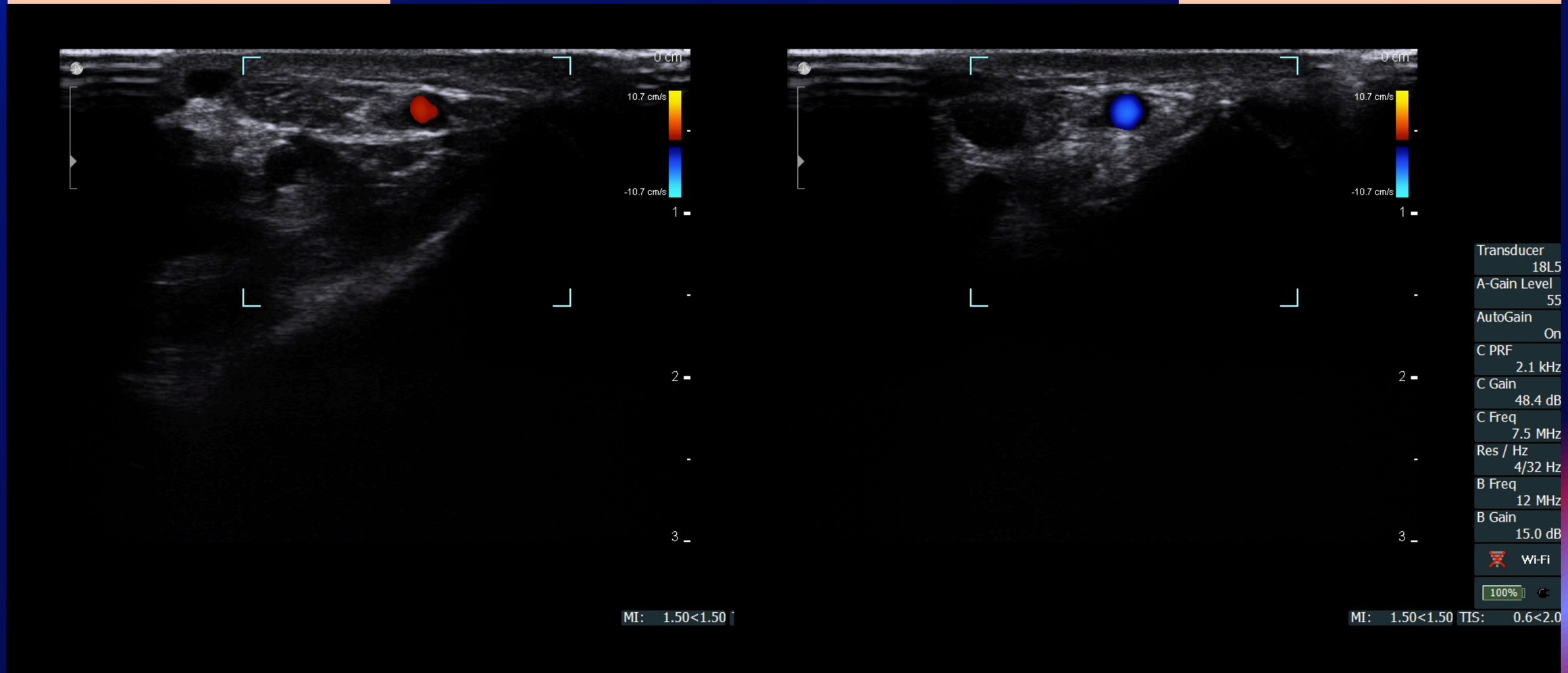


Returning signal: lower frequency



Returning signal: higher frequency

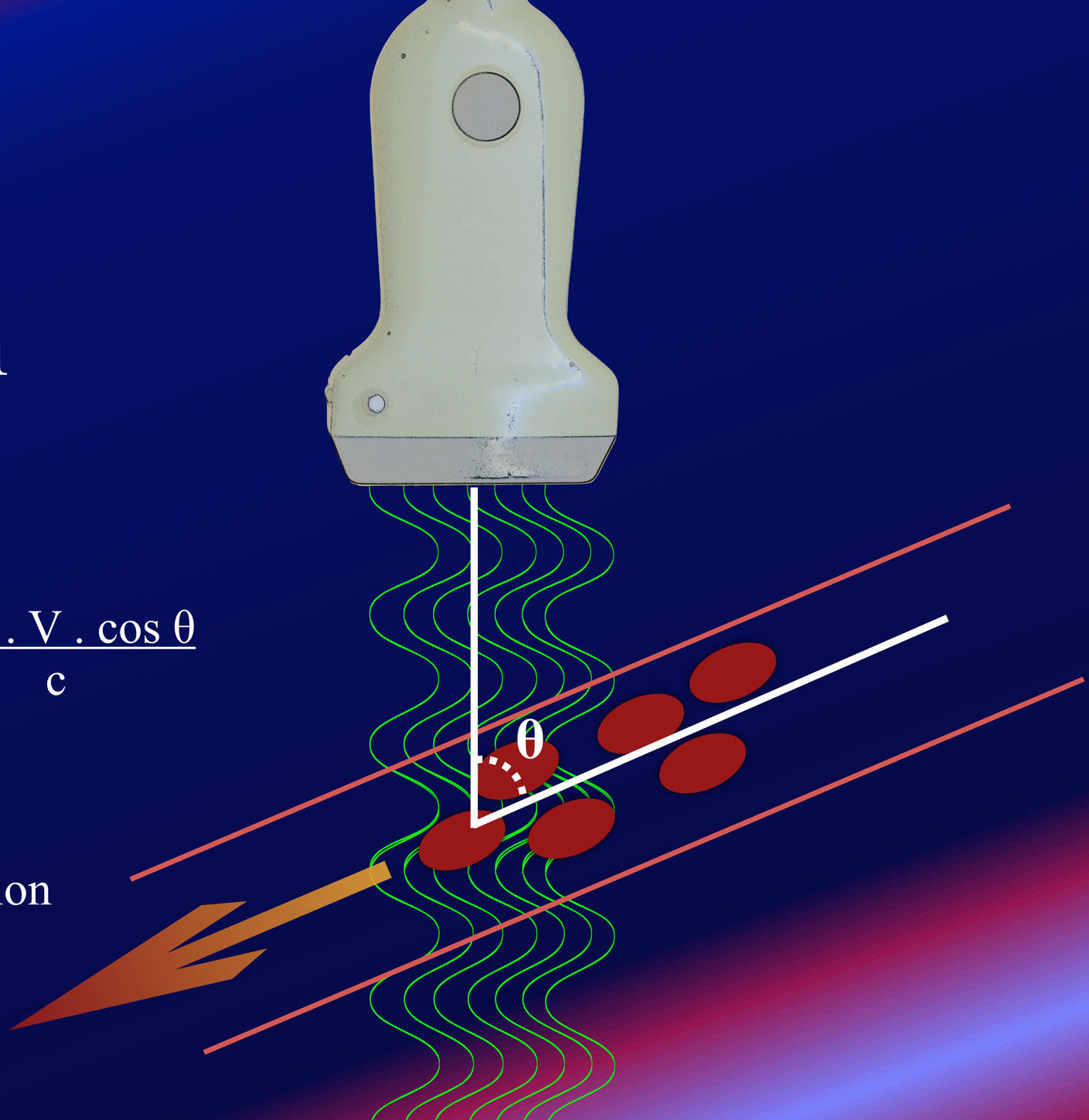
Vessel recognition
Color Doppler



Doppler and Angulation

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

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



On-Off

Frequency

Focus

TGC

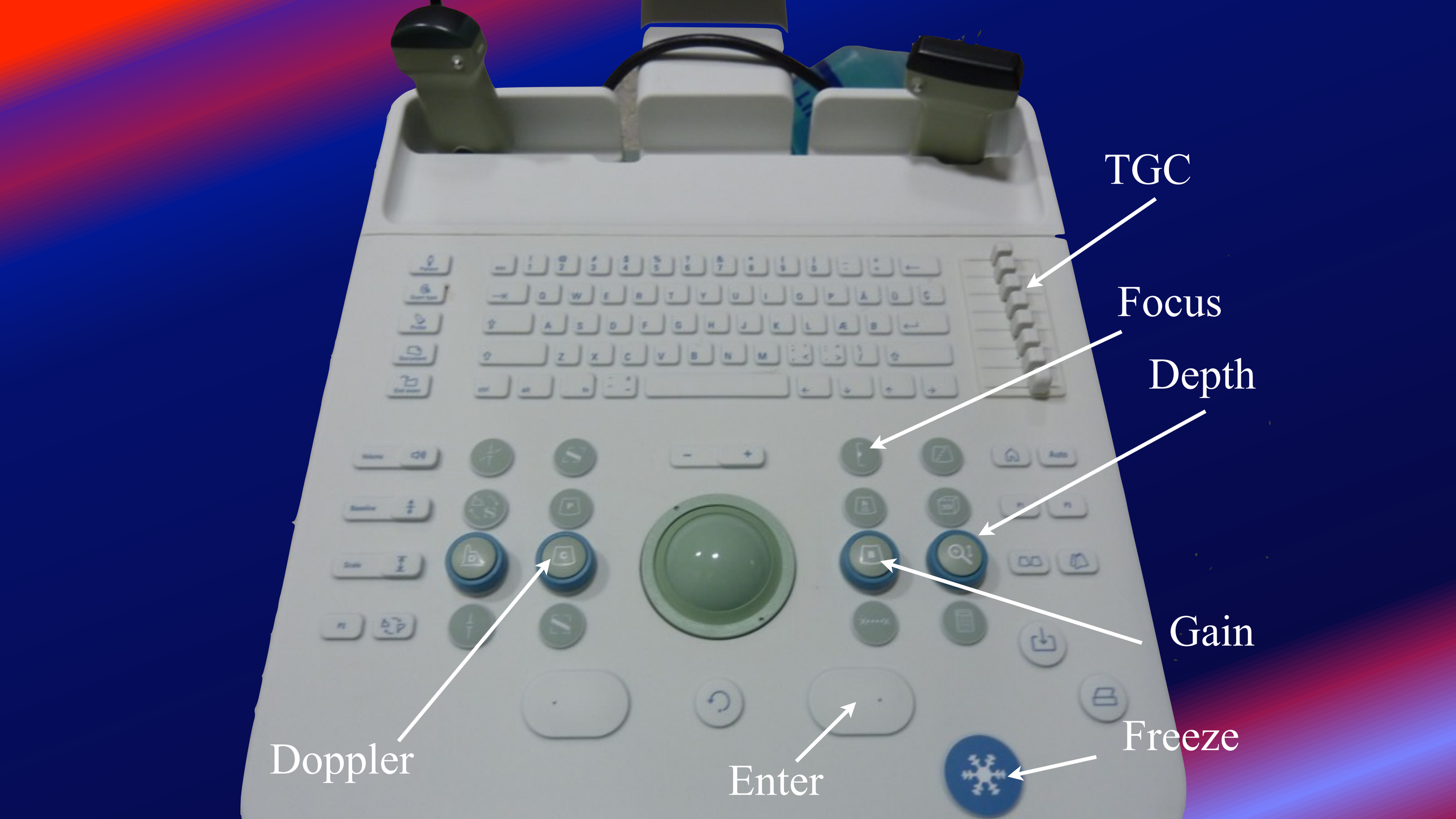
Depth

Doppler

Gain

Enter

Freeze


TGC
Focus
Depth
Gain
Freeze
Enter
Doppler


PATIENT
TRANSDUCER
APPLICATION
PRESET
END EXAM
MEASURE
LABEL
WORKSHEET
REPORT
REV
INV
AUTOGAIN
B CPS+
SPLIT
TGC
SECTOR
100 %
FREQ B
12.0 MHz
FOCUS
12 mm
DEPTH
3.0 cm
GAIN B
50 %
M-MODE
DOPPLER
COLOR
2D
Q
2
1
TGC
Doppler
Frequency
Focus
Depth
Gain
Freeze

1. Gain

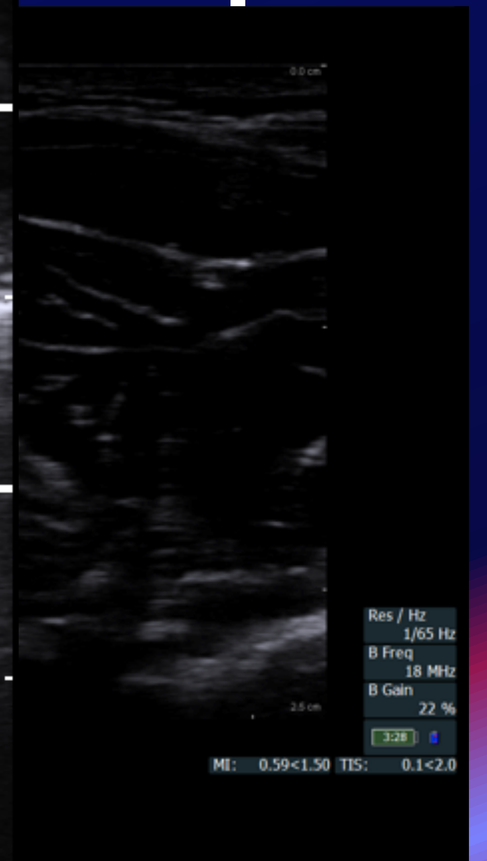
= gray scale optimization by modulation

of the returned US-signals

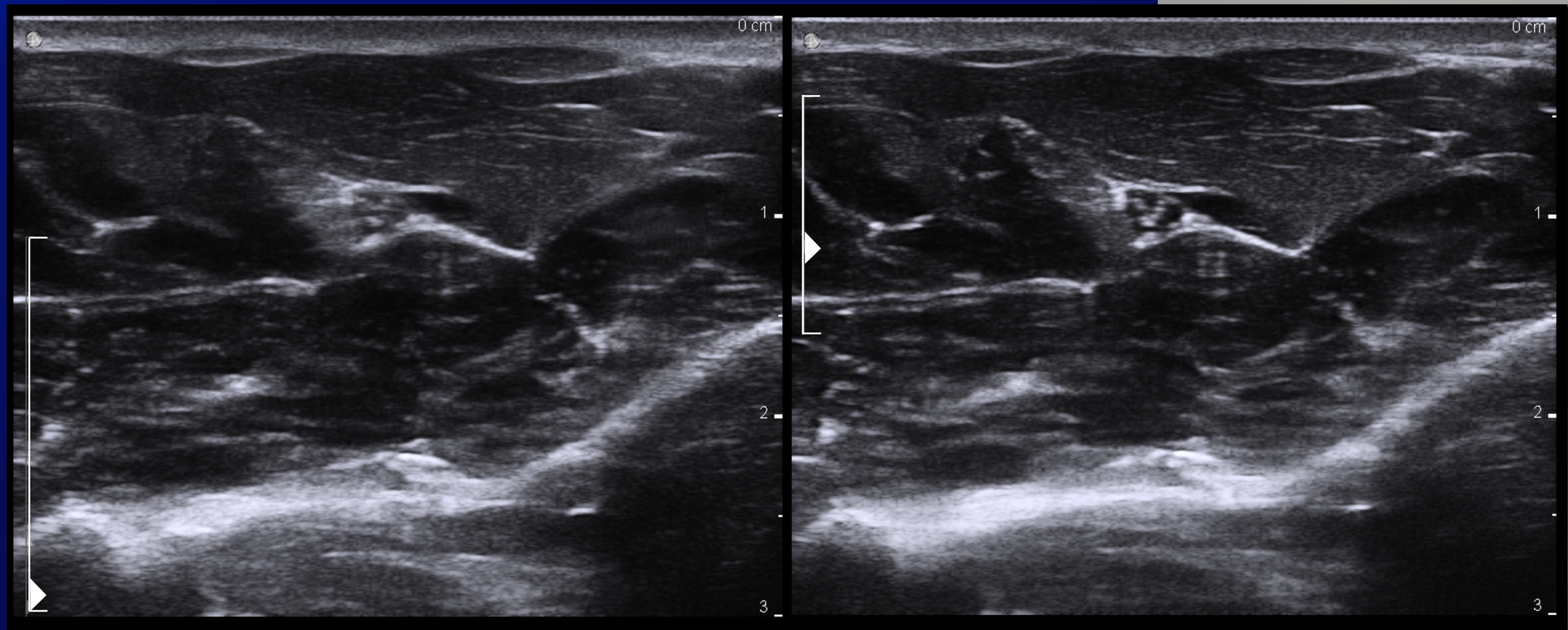
Anechoic = black

Hypo-echoic = grey

Hyper-echoic = white



2. Focal zone

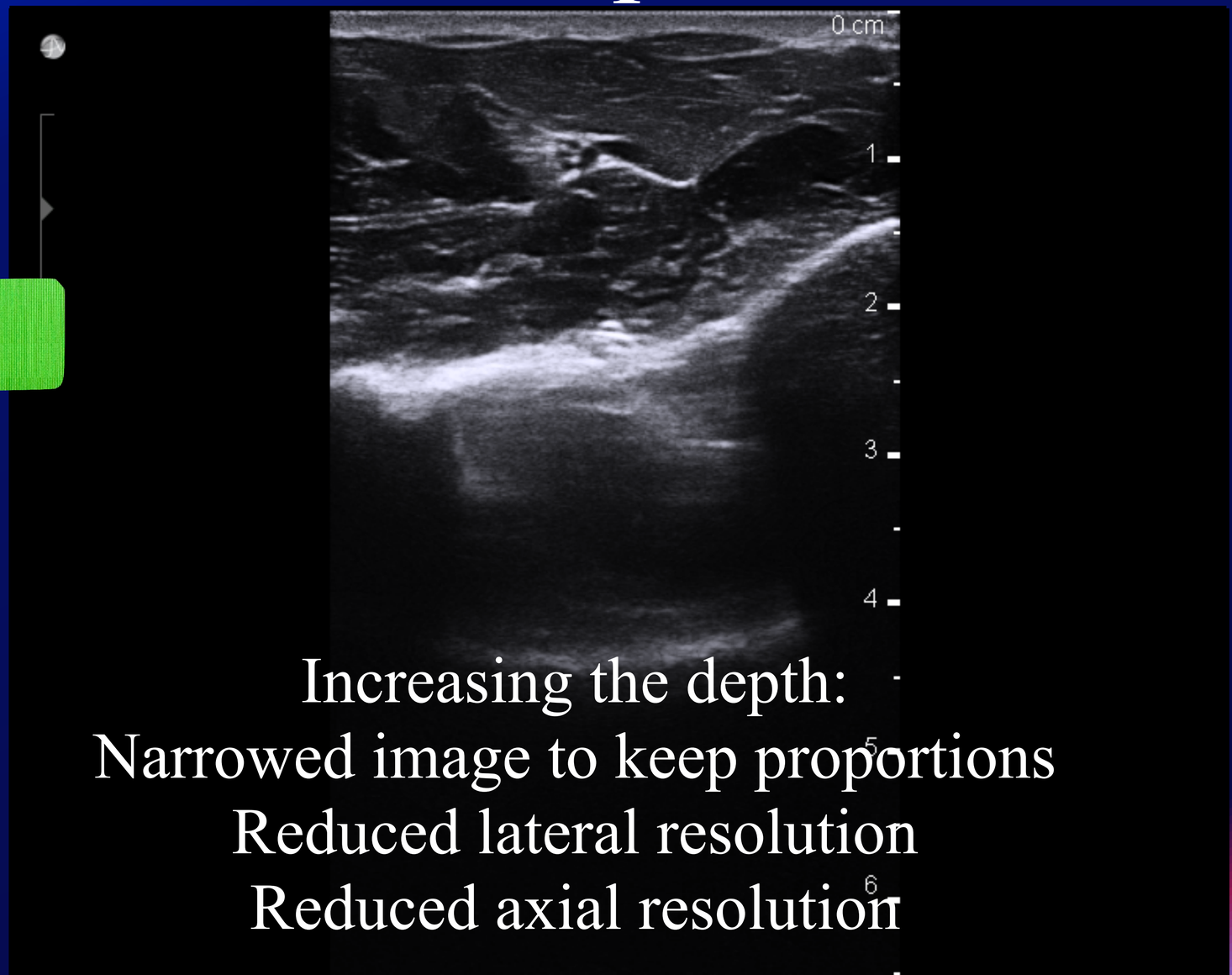


3. Time Gain Compensation

- The gain curve expected a certain attenuation with depth of travel
- Operator controlled adjustment to compensate for the attenuation
- Must be adjusted manually

3. Time Gain Compensation

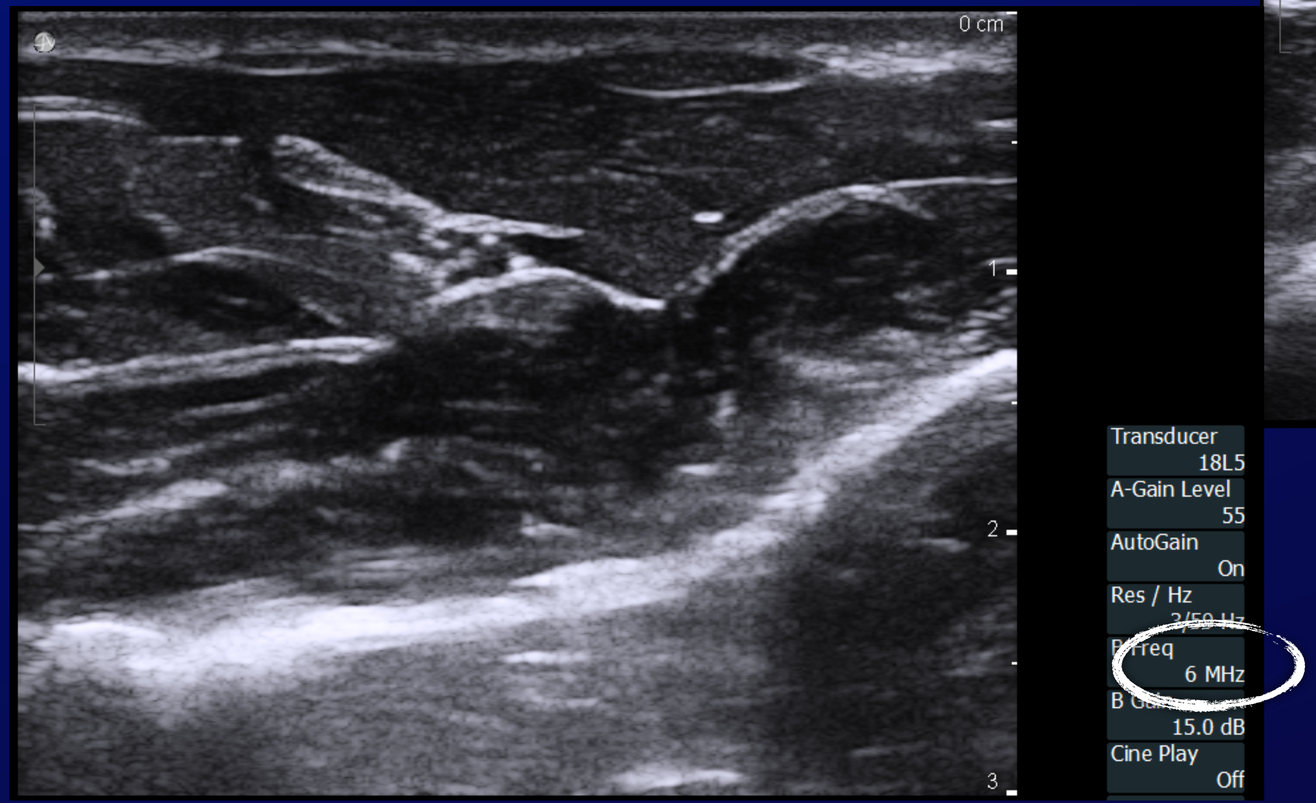
4. Depth

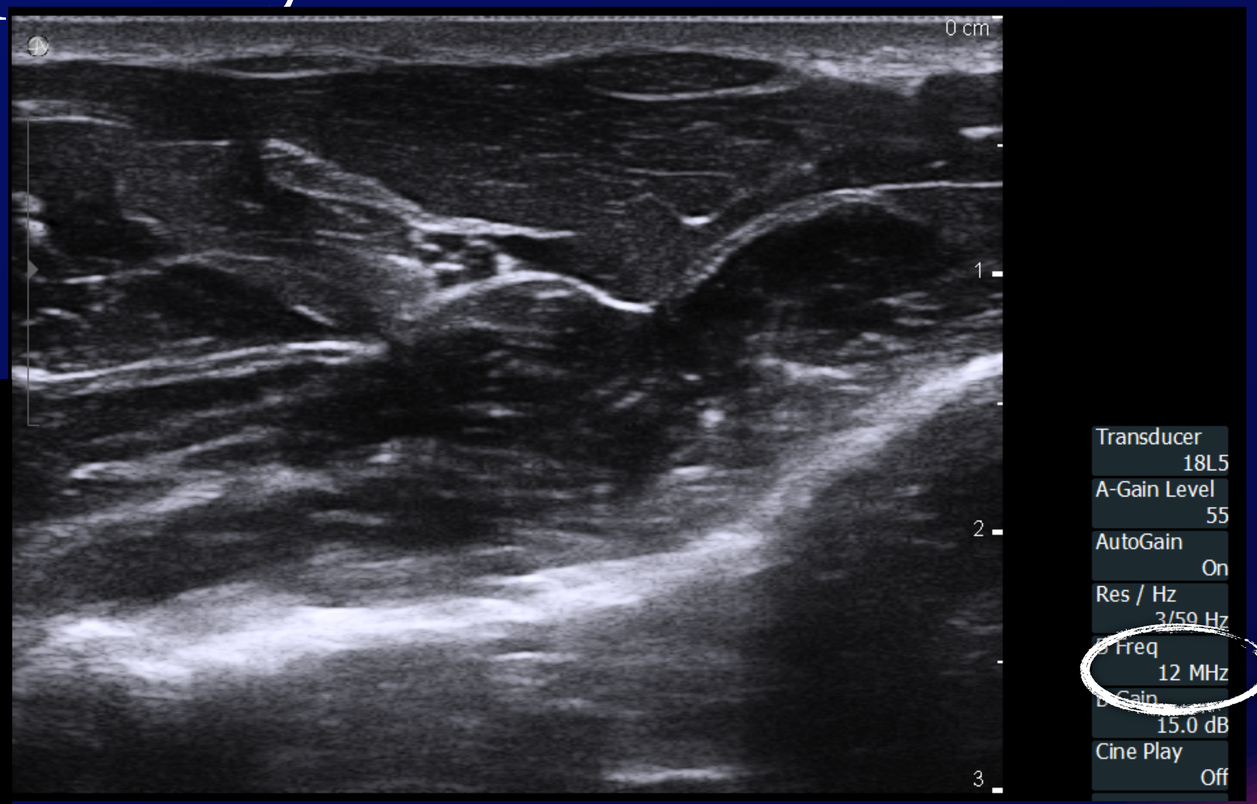


Increasing the depth:
Narrowed image to keep proportions
Reduced lateral resolution
Reduced axial resolution

5. Frequency

The highest possible frequency related to the depth of the target

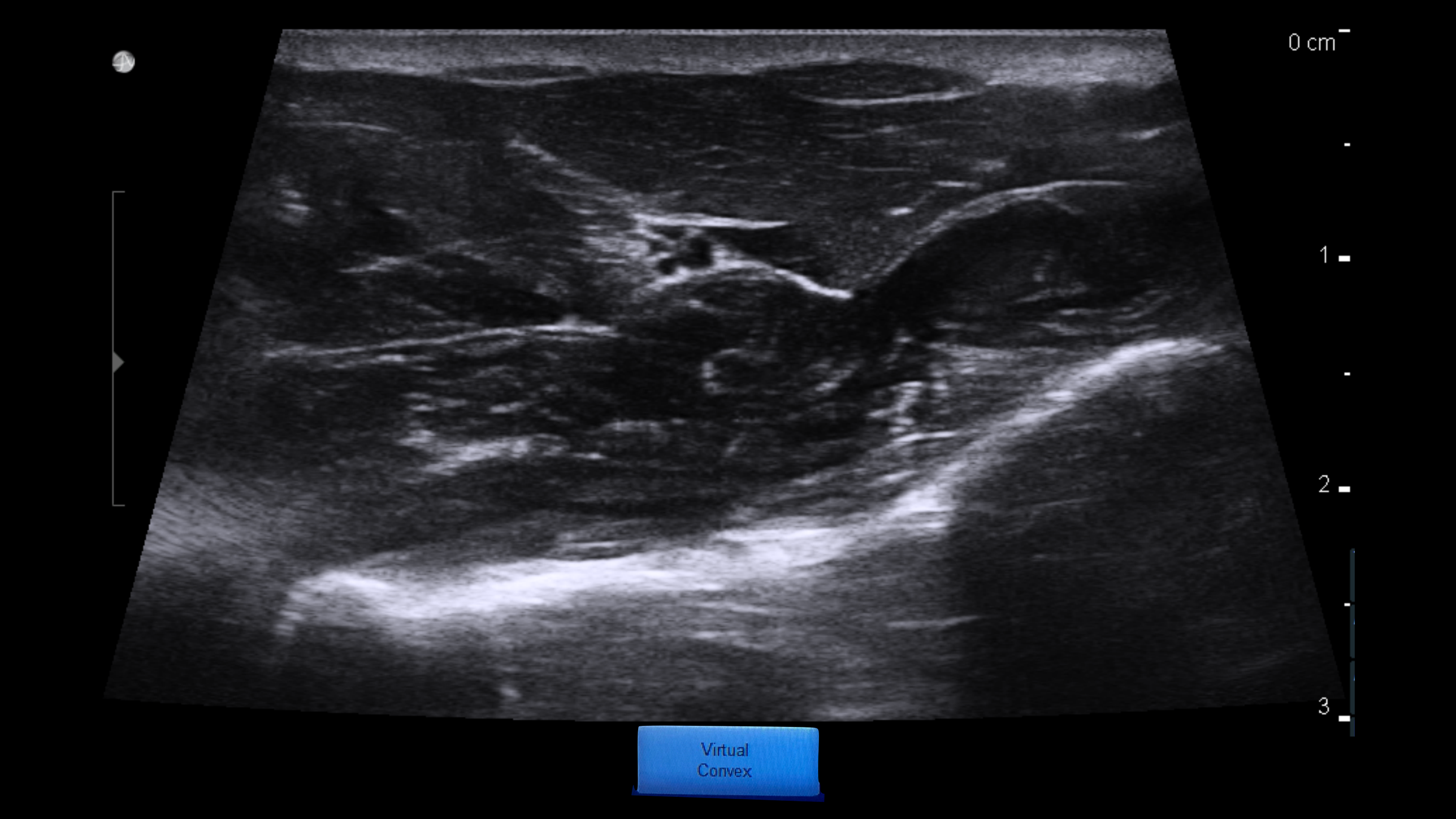




US-machine & Settings

- 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


0 cm
1
2
3
Virtual
Convex

Skills

TABLE 2. Skill Sets Associated With Proficiency

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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.

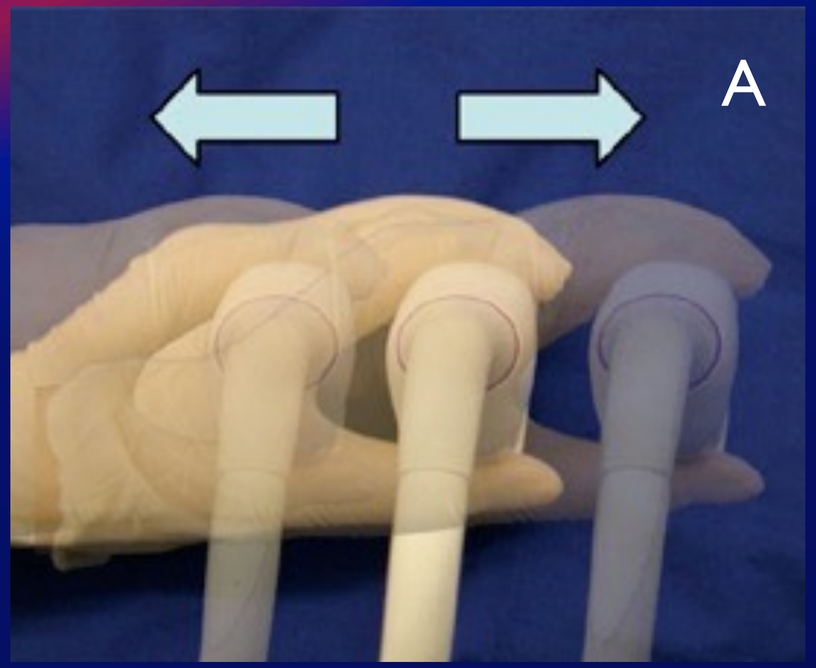
Direct visualization of anatomical structures

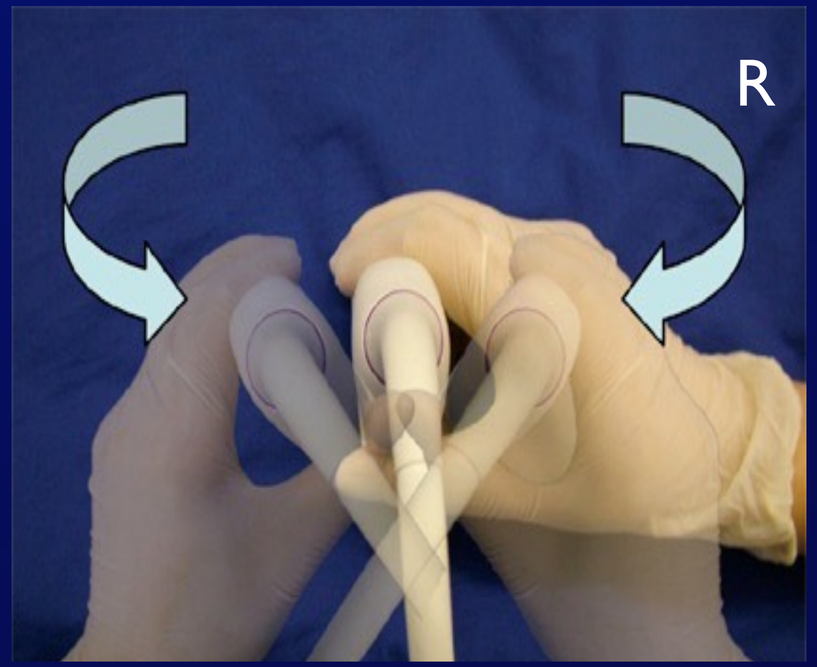
Dynamic tracing for confirmation / or not of anatomy

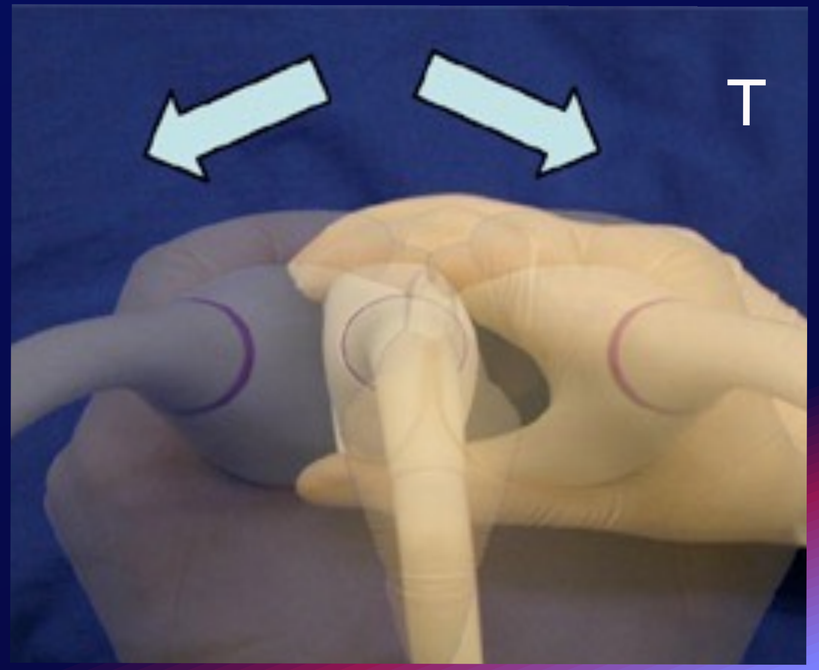
Doppler assessment of vascular structures

Different anatomical site evaluation for ease of block performance

Exploratory Scan

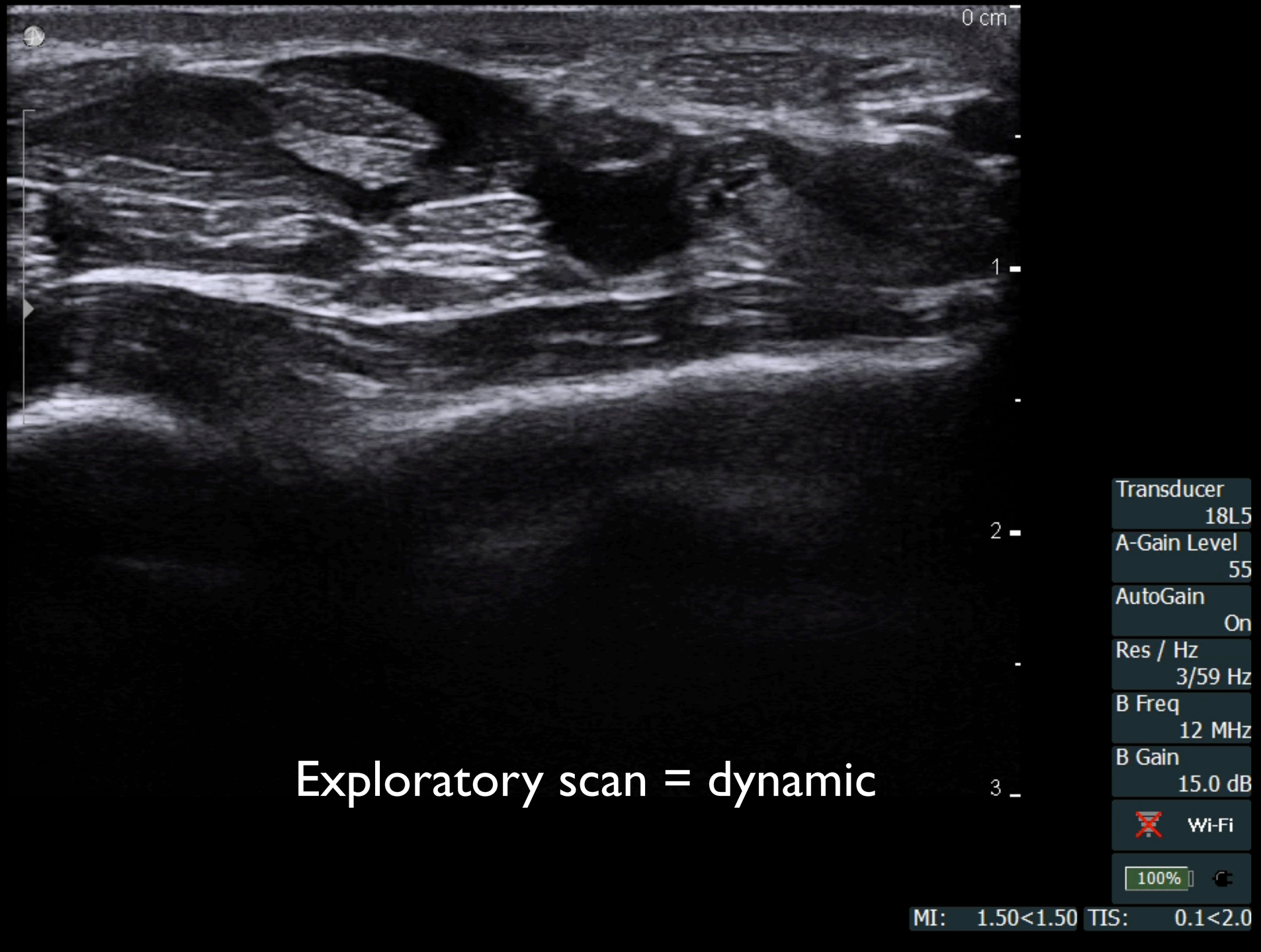






Alignment
Rotation
Tilting
Compression

Exploratory scan ≠ static



Exploratory scan = dynamic

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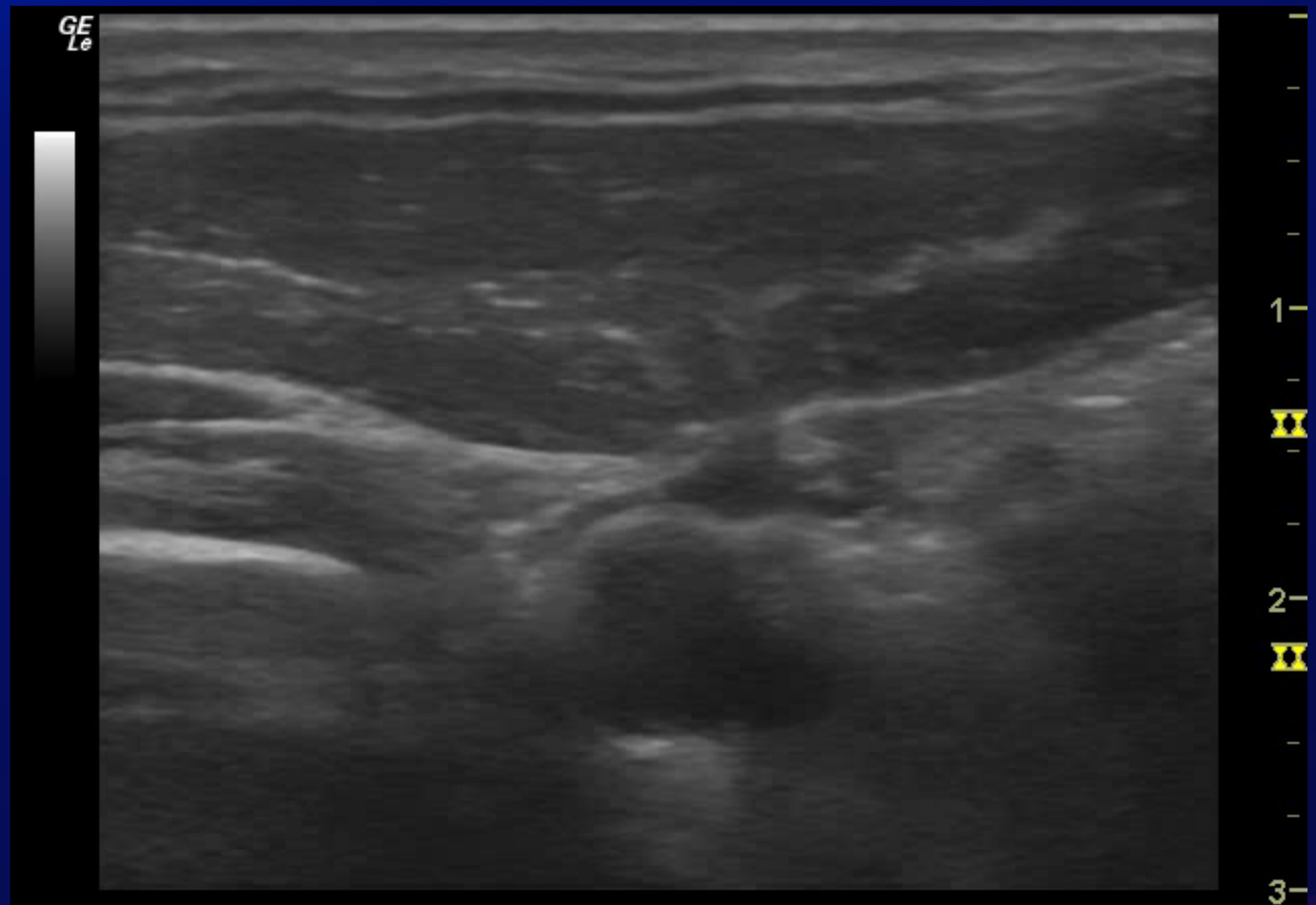
Artifacts

- Not a “true” representation of the tissue imaged
- Artifacts to characterize tissue (medical diagnostic)

Artifacts

Acoustic enhancement

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

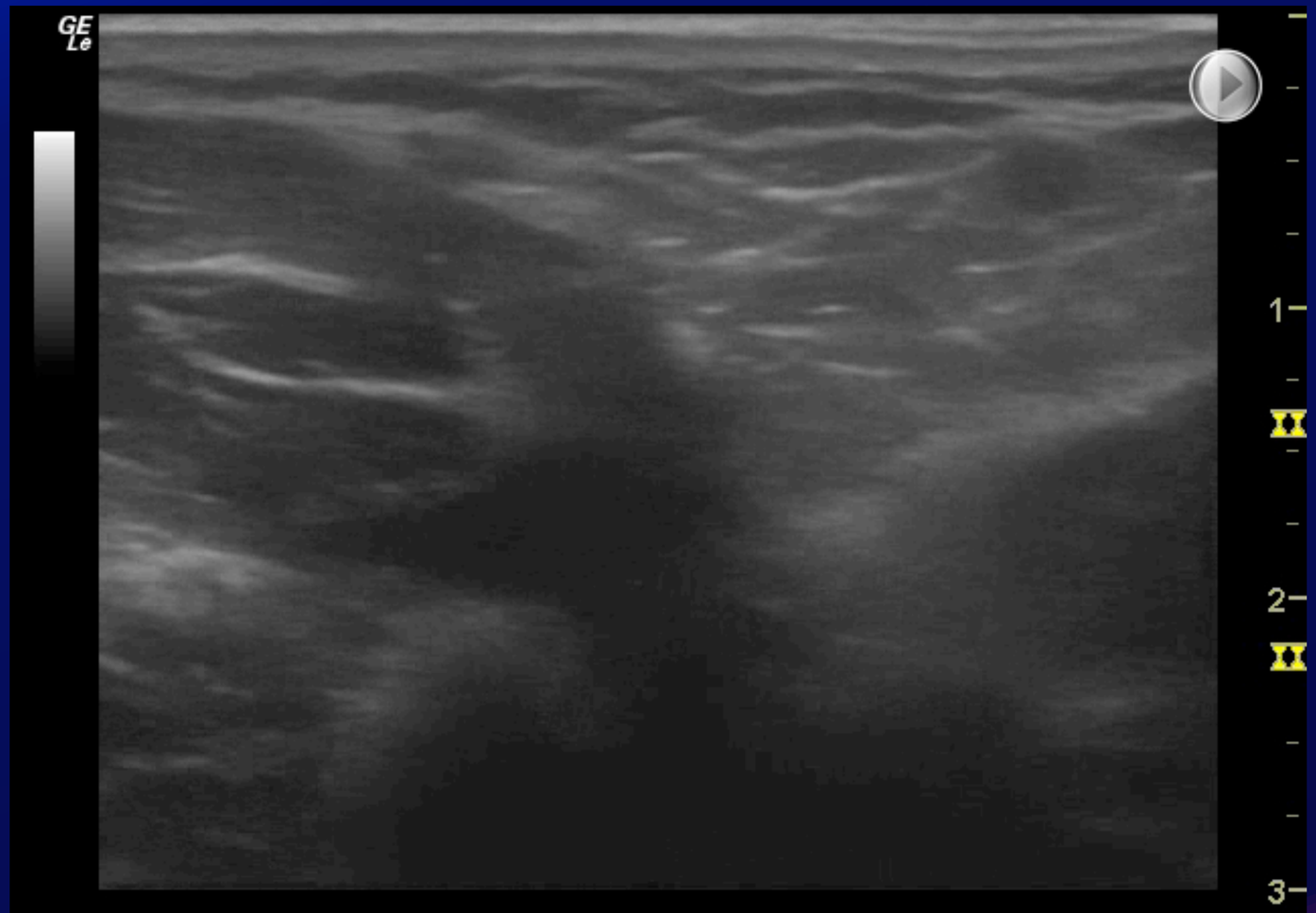


Bright lines under the thick walled or compressed structures (ex. vessels)

Artifacts

Acoustic shadowing

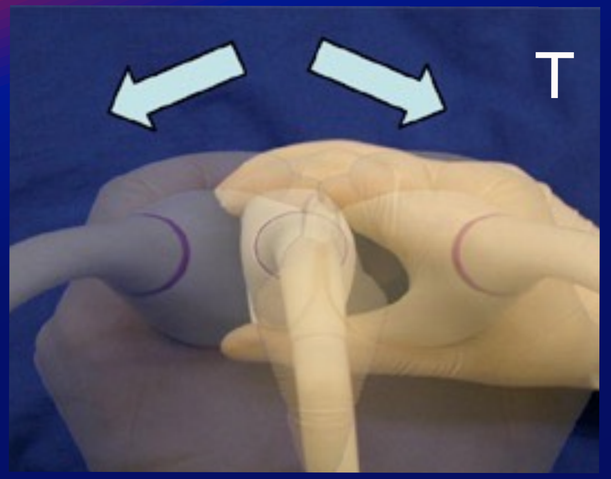
Diminished US posterior to a strongly reflecting or attenuating structure, resulting in a dark area

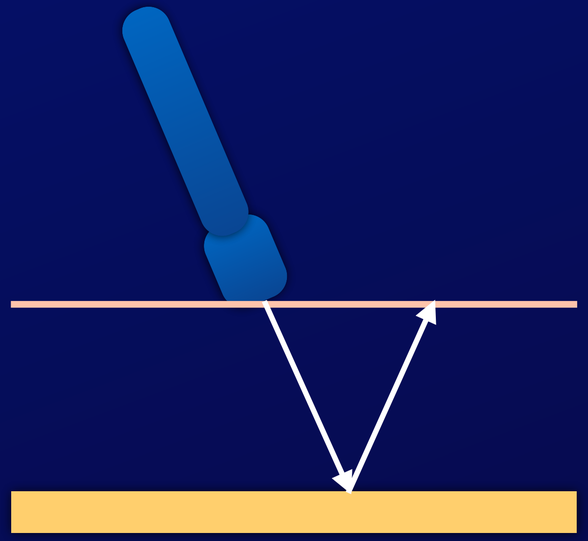


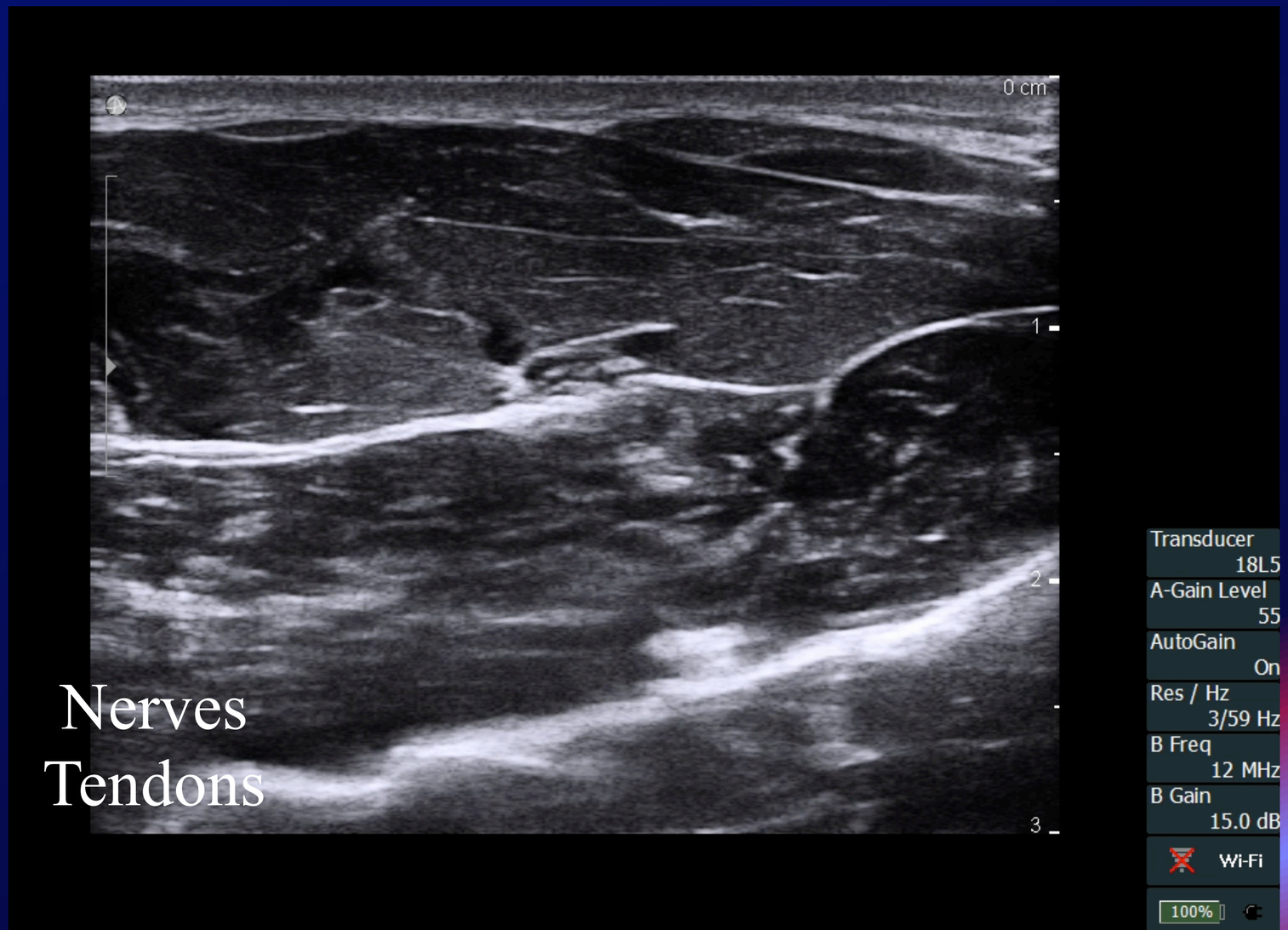
Strong reflextors: calcification, bone

Strong attenuators: solid tissue, dense masses

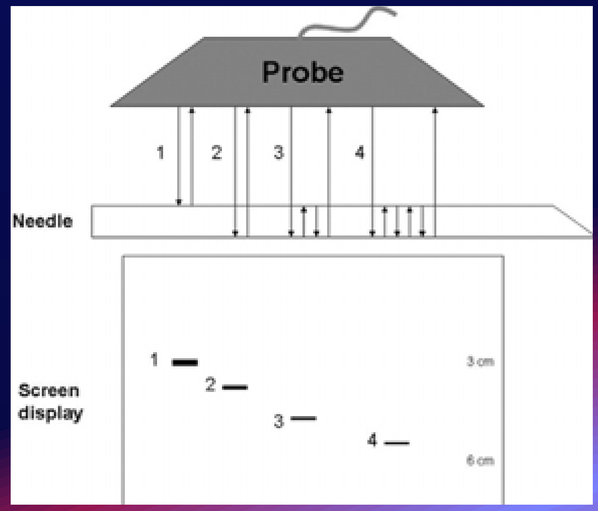
Artifacts: Anisotropy



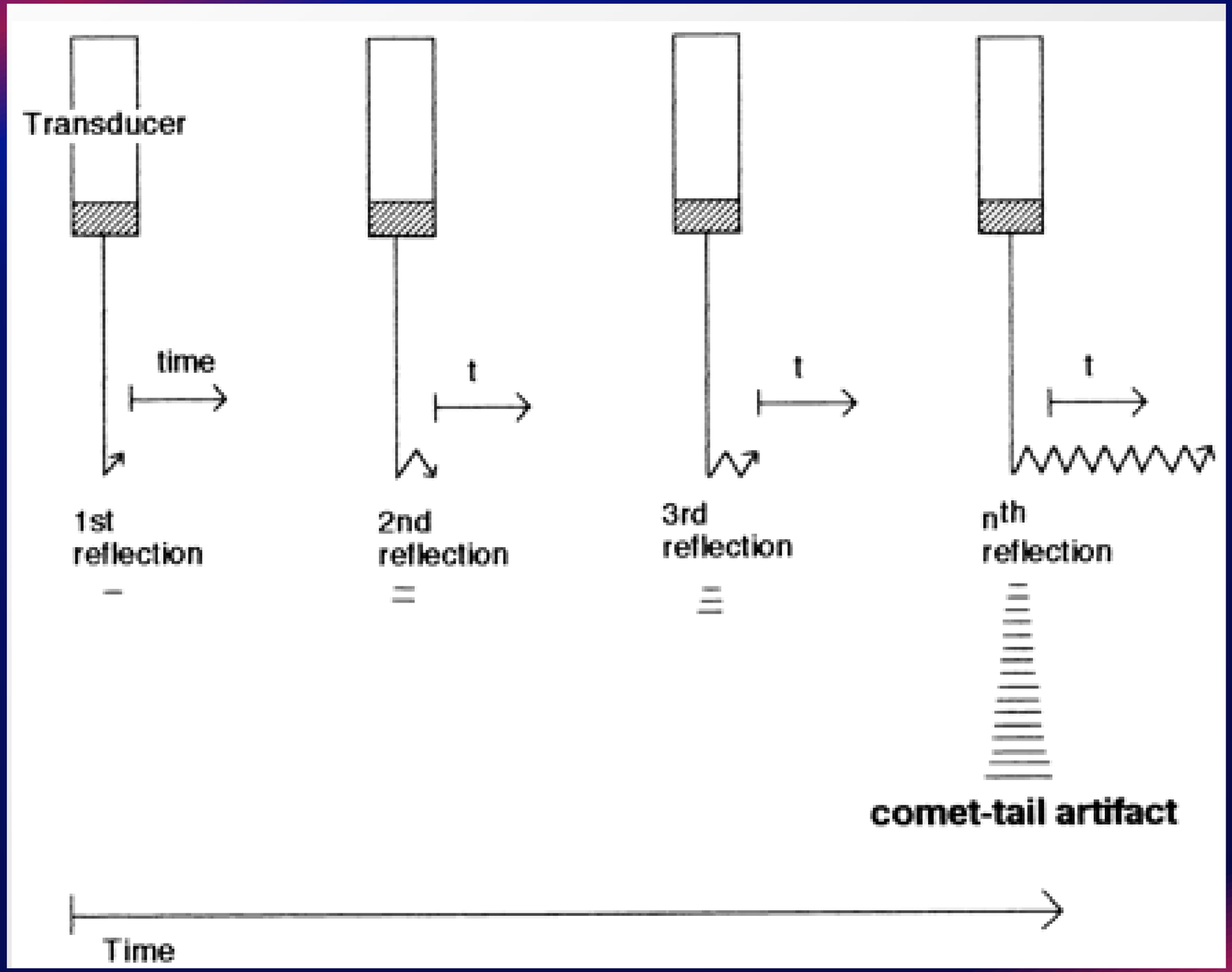




Artifacts
Reverbation

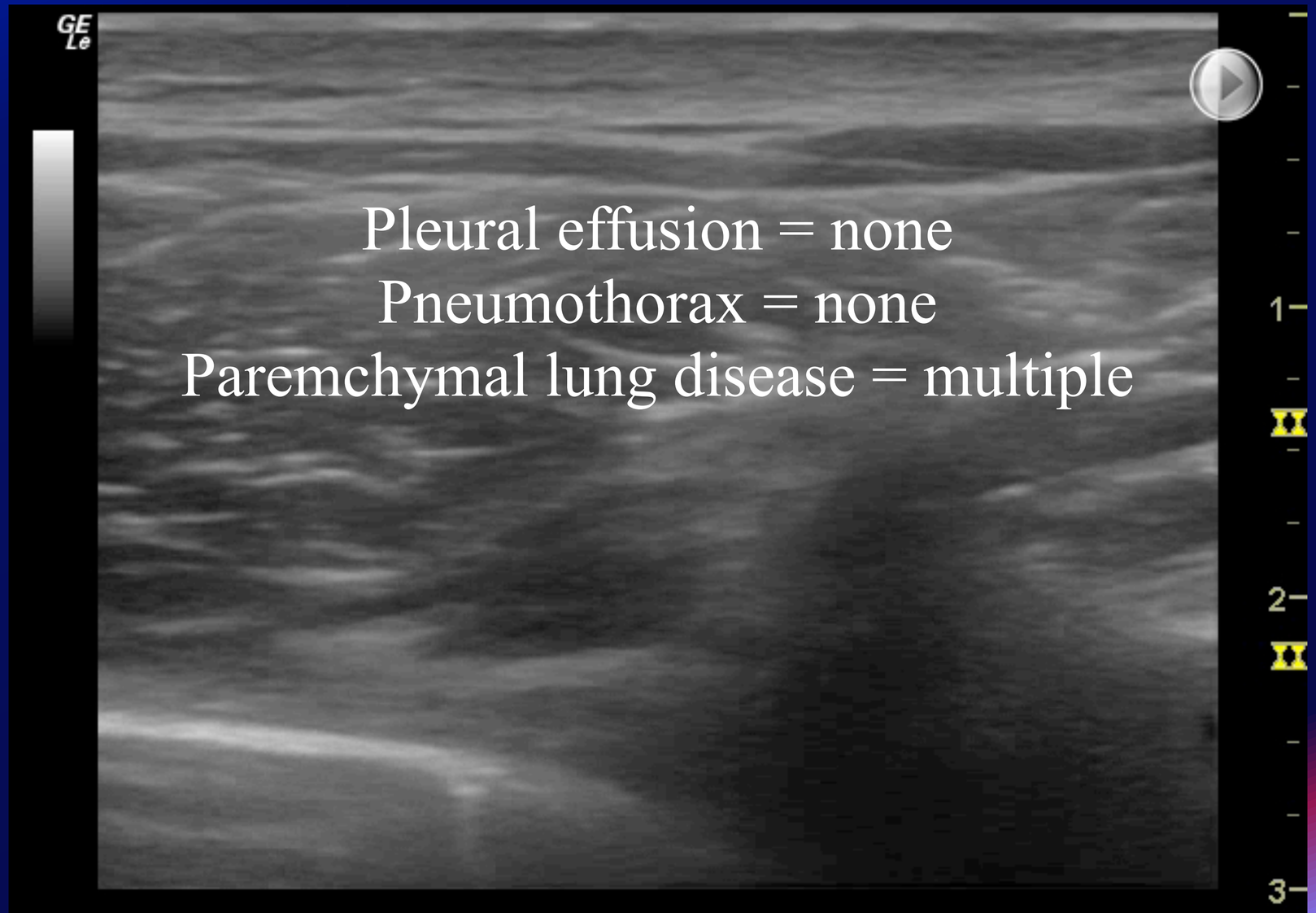


Artifacts
Velocity changes


Transducer
time
t
t
t
1st reflection
2nd reflection
3rd reflection
nth reflection
comet-tail artifact
Time

Artifacts

Comet-tail artifact



“Artifacts” Anatomy

Regional anesthesiologists diagnosing non-neural pathology

Reg Anesth Pain Med 2006;31:555-62

Skills

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

Ergonomics

STOP moment for checking the correct site and side

For unilateral blocks

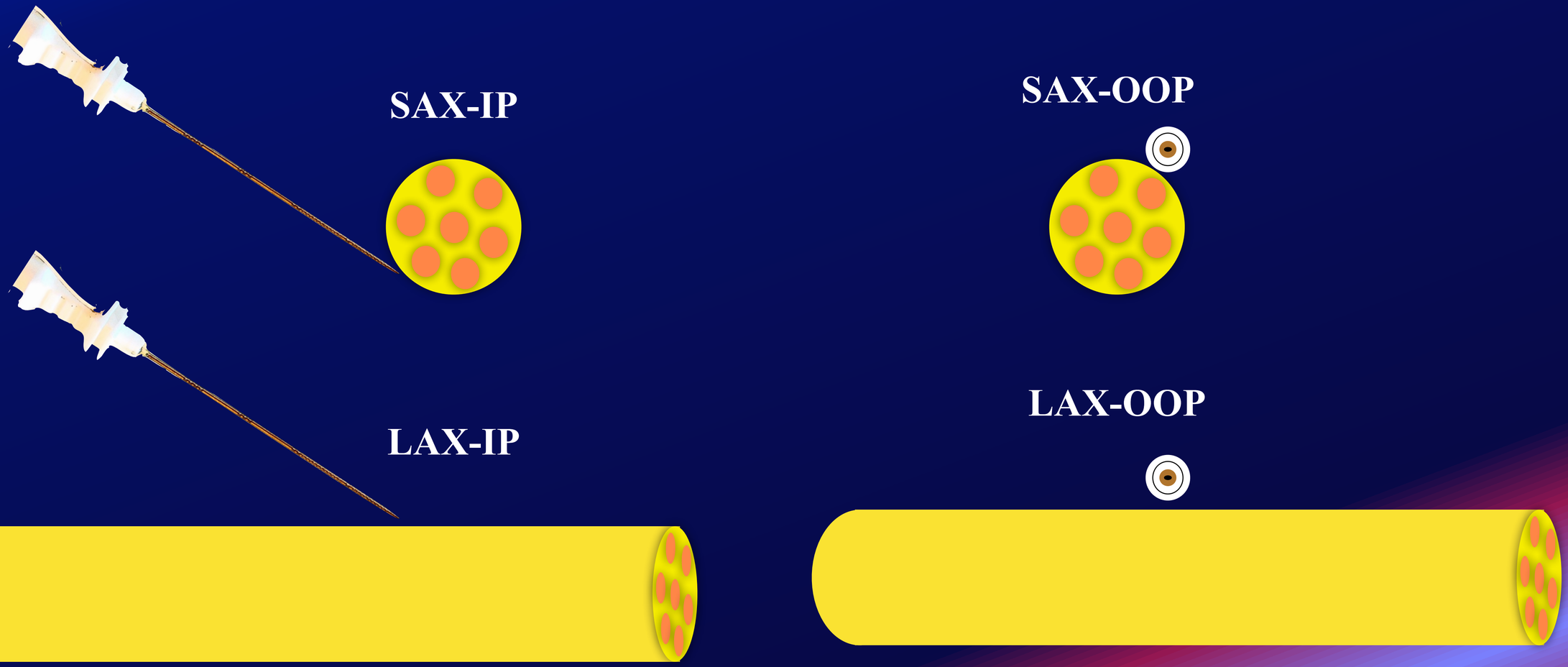
Simple double-check

Separate from WHO checklist

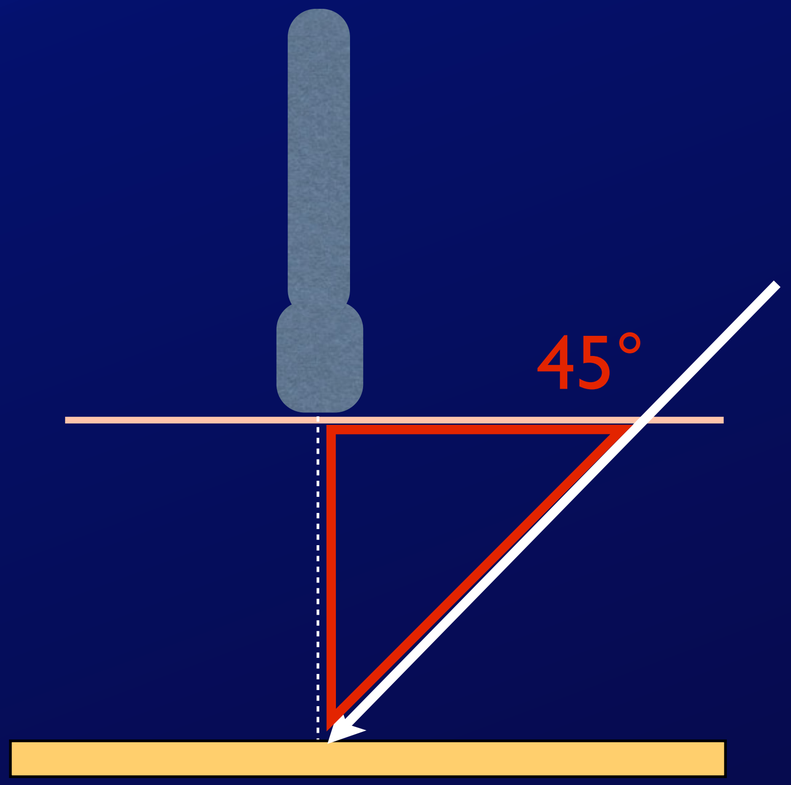
Immediately before insertion of needle

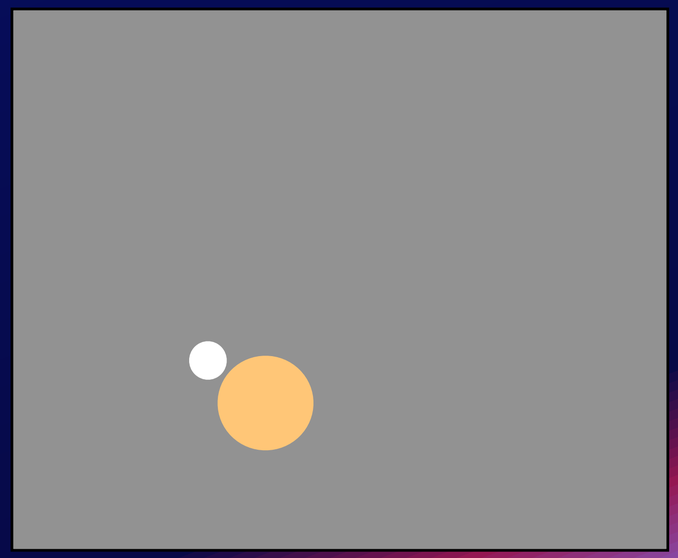
Initiated by anyone (anesthetist / nurse)

US guided blocks
Axis and Plane

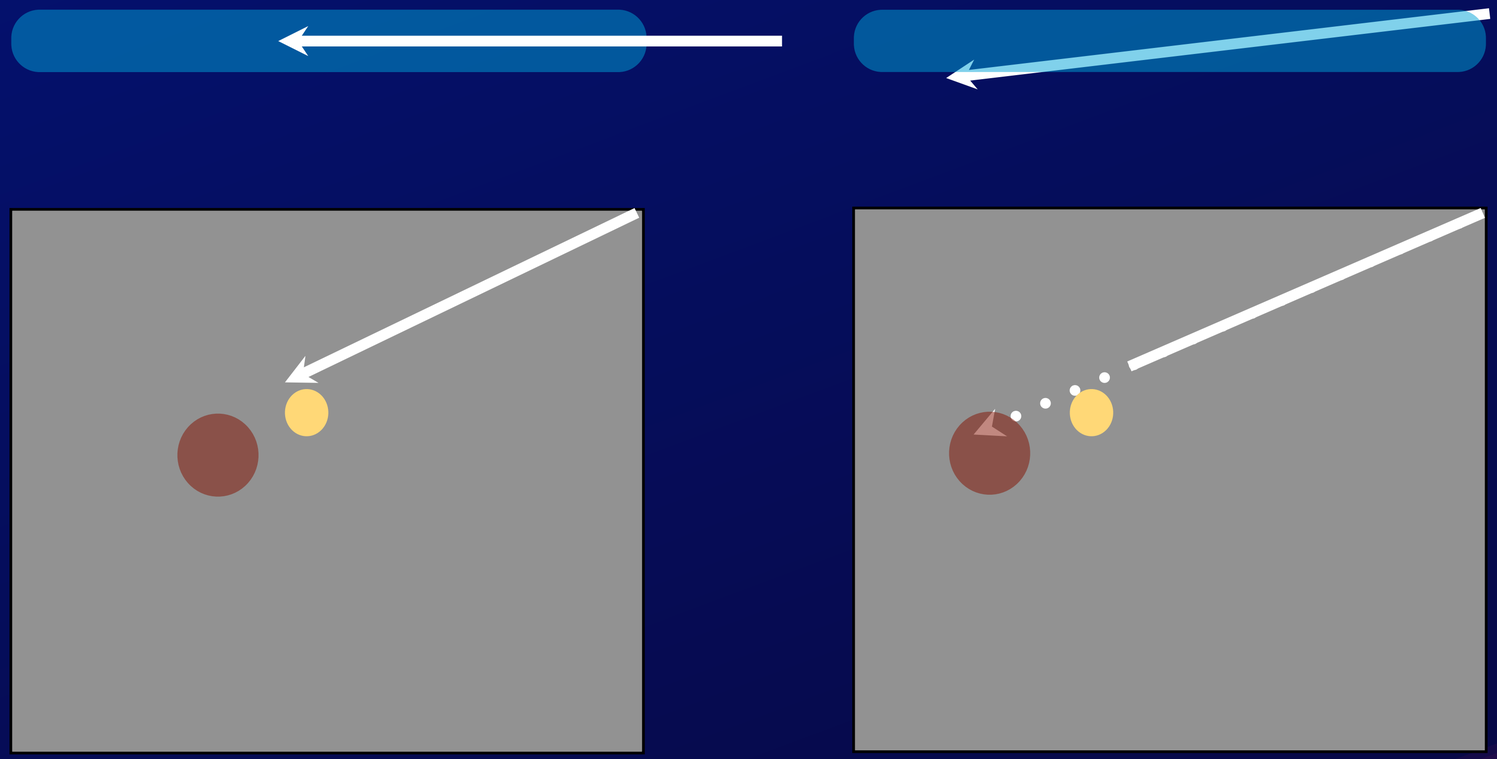


OOP (Crossing the plane)

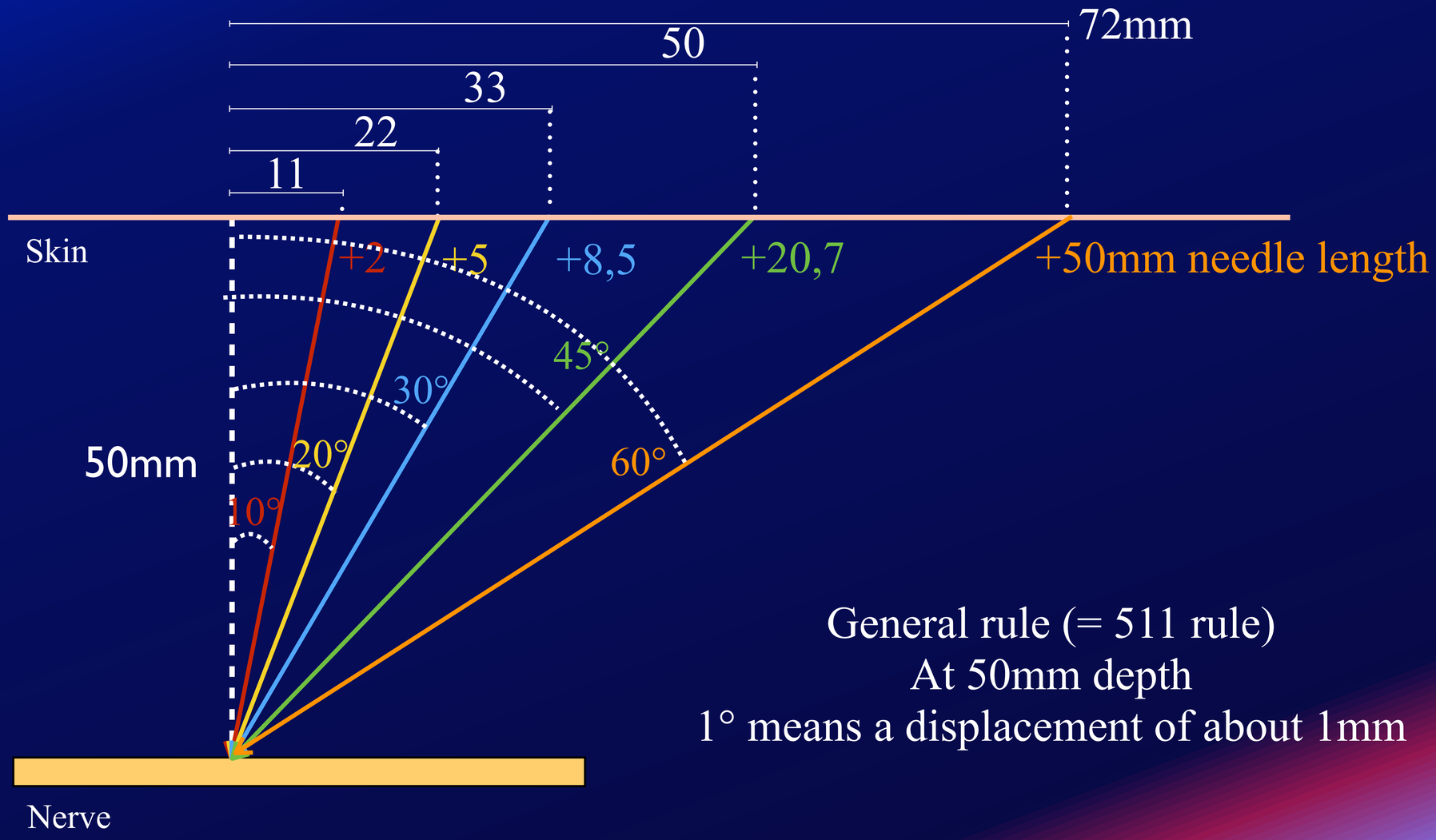




IP



Needle angulation and depth

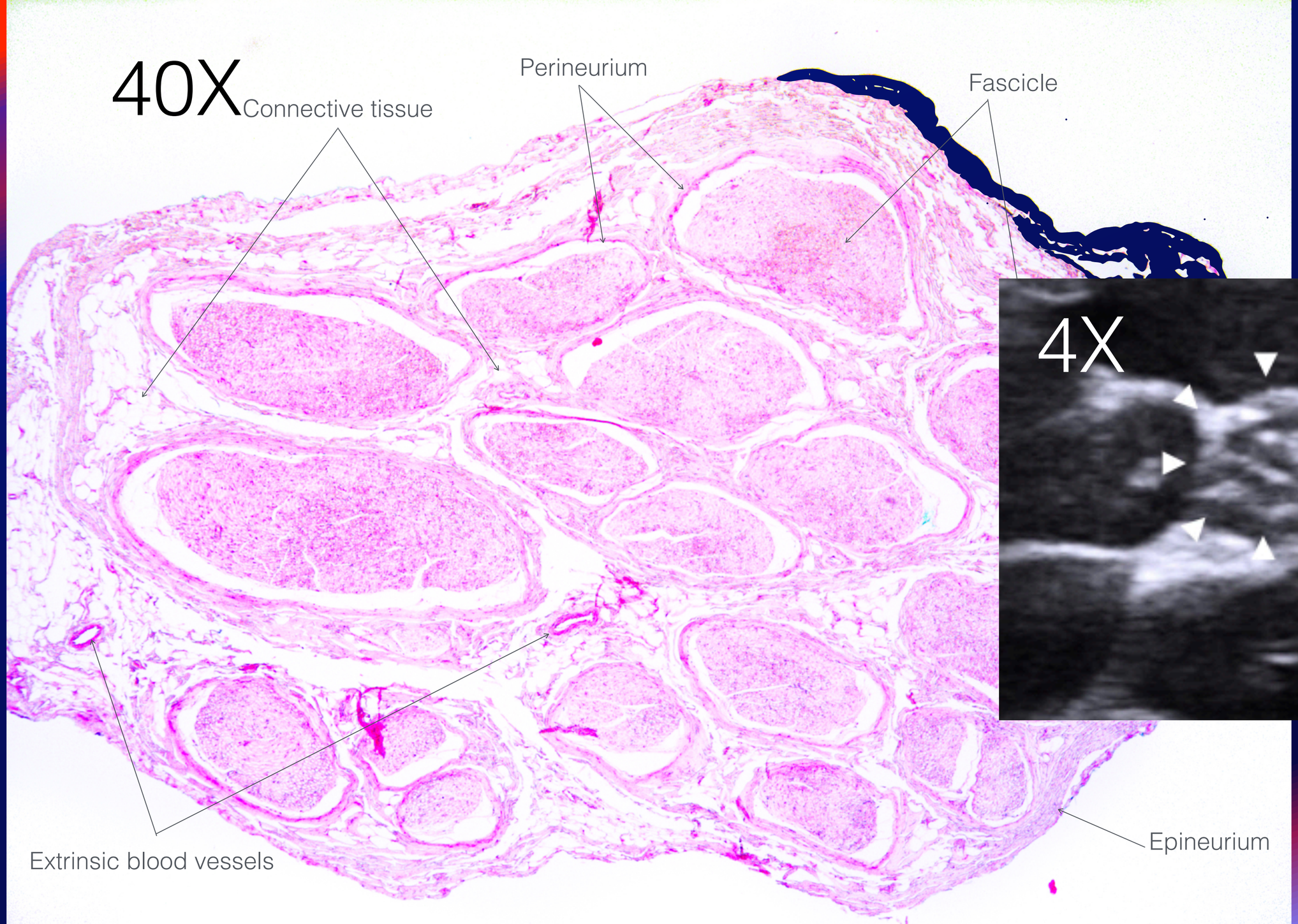


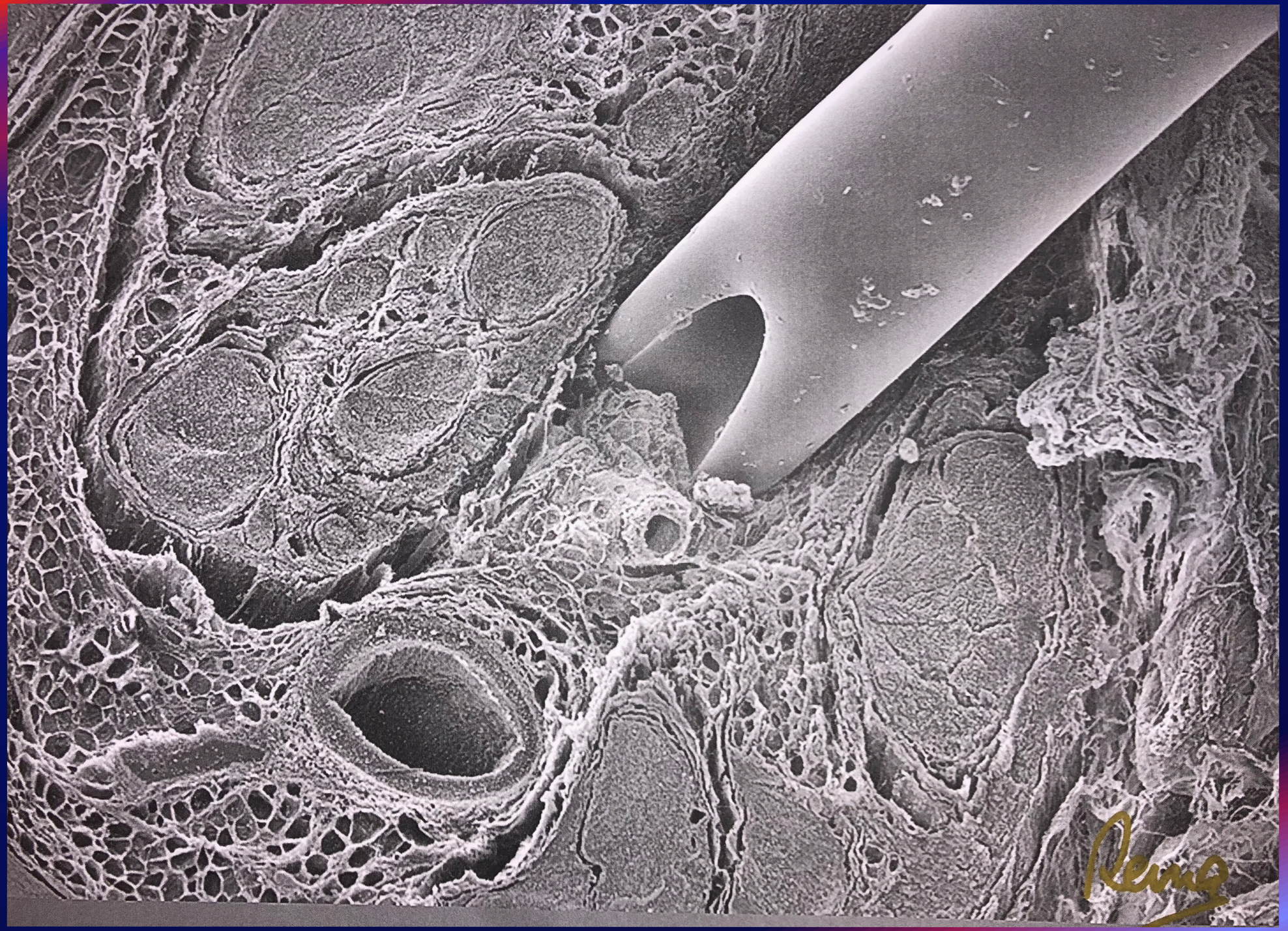
General rule (= 511 rule)
At 50mm depth
1° means a displacement of about 1mm

Needle technique

Ultrasound

- Visualisation of
  - Nerve, but not fasciculi
  - Epineurium? Bigeleisen RAPM 2010
  - Deep nerves? Resolution at low frequencies??
  - Needle penetration into nerve???

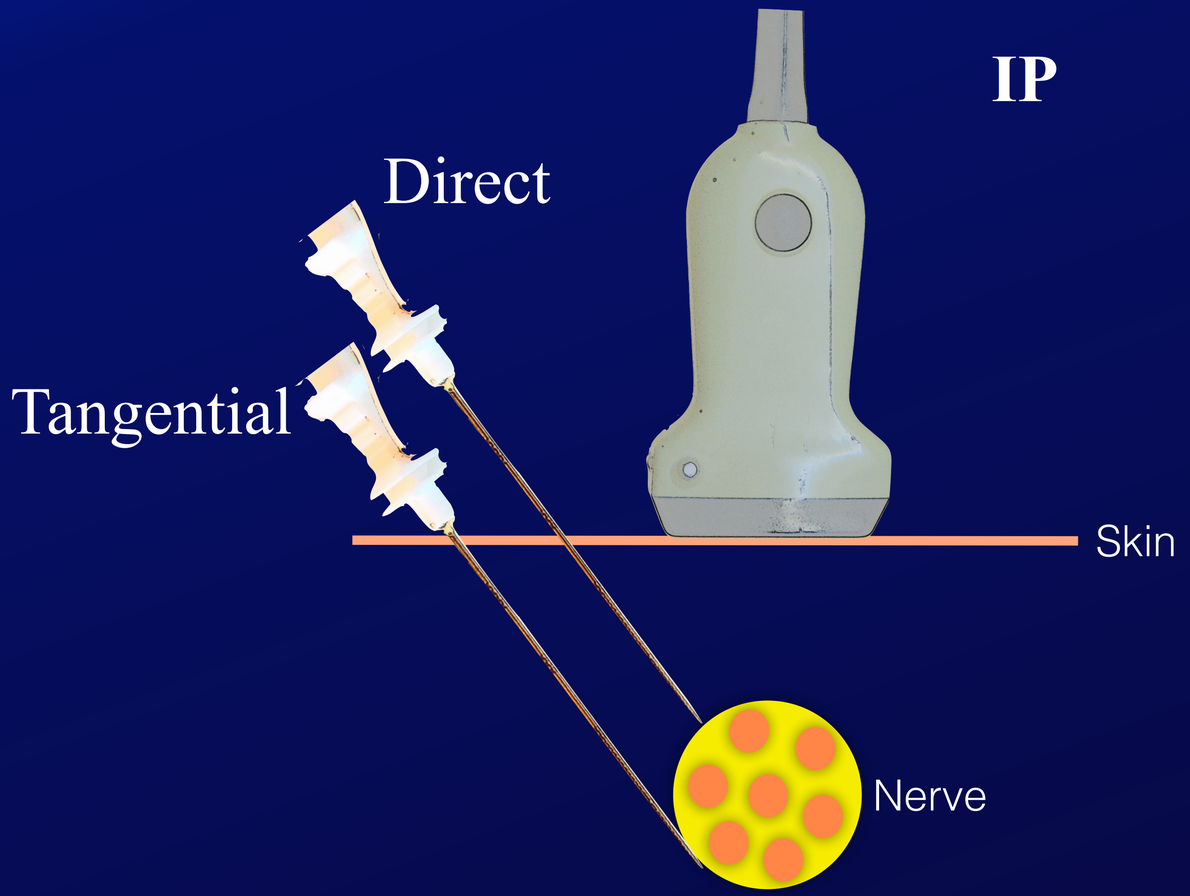

40X
Connective tissue
Perineurium
Fascicle
4X
Extrinsic blood vessels
Epineurium



Thanks to
M.A. Reina

Needle Technique

US-guided tangential needle approach to the nerve



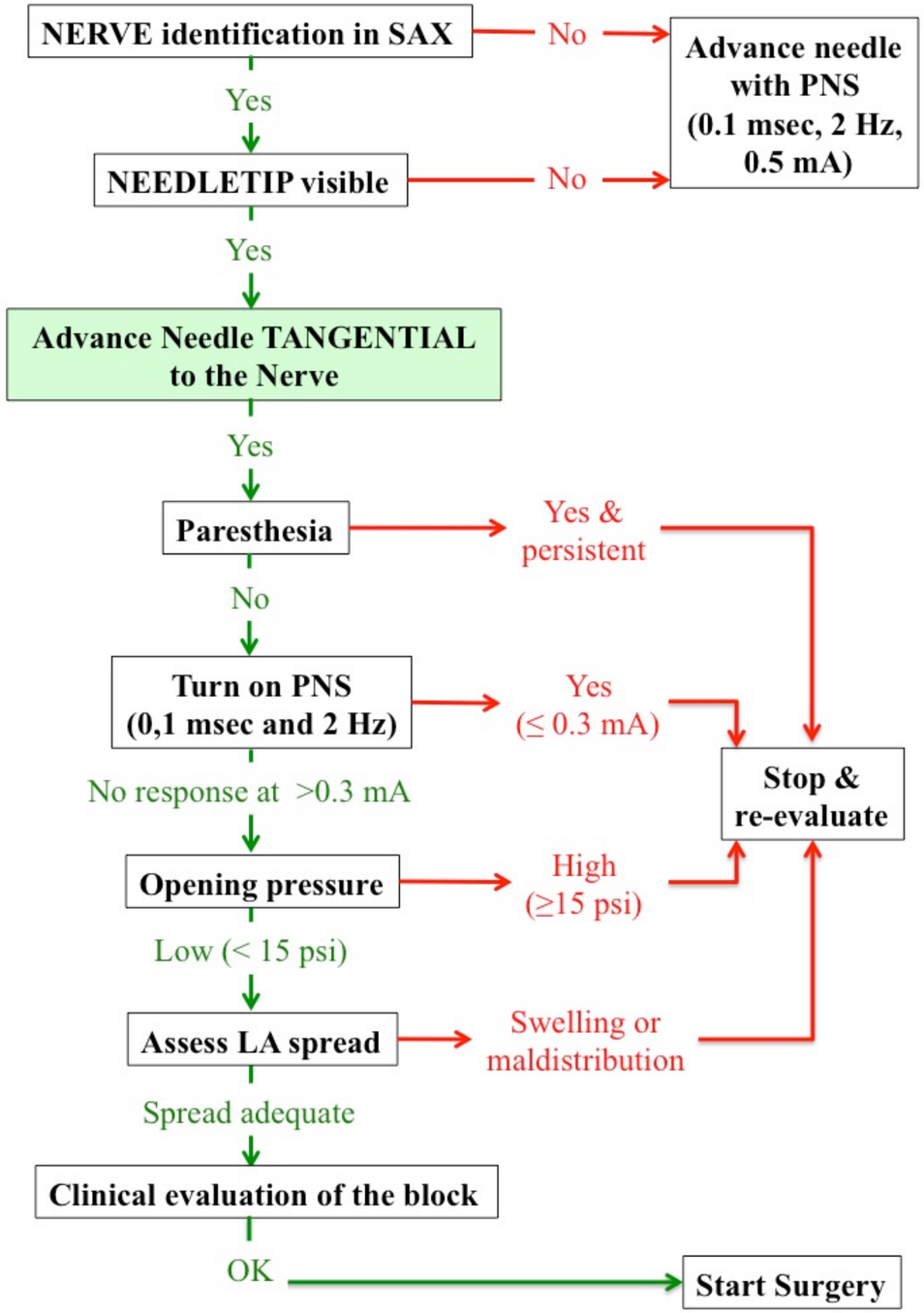
Anaesthesia. 2017 Apr; 72(4): 461-469

Anaesthesia 2017 doi:10.1111/anae.13787

Original Article

Ultrasound-guided approach to nerves (direct vs. tangential) and 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. Hermans[11] and M. Lammens[12]


NERVE identification in SAX
No
Advance needle with PNS (0.1 msec, 2 Hz, 0.5 mA)
Yes
NEEDLETIP visible
No
Yes
Advance Needle TANGENTIAL to the Nerve
Yes
Paresthesia
Yes & persistent
No
Turn on PNS (0,1 msec and 2 Hz)
Yes (≤ 0.3 mA)
Stop & re-evaluate
No response at >0.3 mA
Opening pressure
High (≥15 psi)
Low (< 15 psi)
Assess LA spread
Swelling or maldistribution
Spread adequate
Clinical evaluation of the block
OK
Start Surgery

US & Injection

Ultrasound Guidance for Axillary Plexus Block Does Not Prevent Intravascular Injection

Paul J. Zetlaoui, M.D., Jean-Philippe Labbe, M.D.,† Dan Benhamou, M.D., Ph.D.‡*

Anesthesiology 2008

Observe local anesthetic spread
THROUGHOUT THE INJECTION
NOT only in the beginning

US & Nerve

Intraneural LA during injection

= swelling of the nerve 0.5ml is reliably detected with US

N.Moayeri et al.