Phantoms for training ultrasound guided procedures - importance of simulation and low-cost alternatives

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Learning objectives

- Discuss importance and limitations of simulation in the training for interventional procedures.
- Discuss skills amenable to be trained by simulation
- Demonstrate home-made, low-cost and accessible phantoms for US-guided intervention, their performance and types of training possible.

Background

Training for interventional procedures is a sensitive and important matter.

Currently procedure training still relies in supervised practice in patients.

Understandably, this type of training leads to procedures taking longer, requiring an expert mentor to teach, provide feedback and vigilance.

The two biggest risk in procedures are:

- iatrogenic injury to the patient
- Technical failure (inability to obtain vascular access; needle misplacement in biopsy with sample error).

Currently, there have been less opportunities for trainees:

- Routine invasive diagnostic procedures are increasingly uncommon in favor of less invasive techniques
- Image guided procedures are performed by non-Radiologist

Based on this trends, simulation has been looked uppon as an alternative.

Simulation can be defined as "a situation in which a particular set of conditions is created artificially in order to study or experience something that could exist in reality". In Medicine, these have been looked upon as a way to respond to ethical issues, increased attention to patient cares and advances in diagnostic and therapeutic procedure.

Various simulators for interventional radiology exist and reach from simple homemade synthetic models to very sophisticated virtual reality simulators with haptic feedback. It was found that especially the existing virtual reality simulators already give a good opportunity to practice technically challenging tasks and improve further performance in clinical practice.

Despite simulation models being unable to adequately reproduce every variable involved in training in Surgery and in Life support and Emergency training it is widely accepted as an adequate form of training.

With high fidelity models, clearer benefits have seen demonstrated

- Clearly structured curriculum
- Different levels of difficulties
- Opportunity to retry

Developing a training Curriculum

The following stepwise approach to medical education was proposed by Kern in 1998:

1. Problem identification and general needs assessment
2. Needs assessment of targeted learners
3. Goals and objectives
4. Educational strategies
5. Implementation
6. Evaluation and feedback

Additionally , regarding the recall rate, comparing passive learning vs active lerning, Bruner described in 1966:

- Passive learning recall rate at 3 months is about 3-5%
- Active learning recall rate at 3 monts is about 50%

Including simulation in a training curriculum allows for procedures to be demonstrated, deconstructed and then perdormed by the trainees.

Therefore, simulation not only is ideal for training practical skills, as it may transform a passive learning ativity into an active learning activity, with a much more effective.

Choosing the adequate simulator: Cost-effectiveness and assessing validity

• The models chosen for simulation depend on the objective of the training. The cost of these simulators must be weighed against its proved effectiveness.

- **Material based:** Usually used for core competencies (needle placement, catheter and guide-wire exchange).

- **Animal models:** Organ or live animals better represent the anatomy and physiology, but are much less convenient, more expensive, with political and animal rights issues limiting their use.
- **Virtual reality:** These were developed from developments in game industry and are probably the most expensive. Furthermore, aside from the technical hardware, software development must be tailored for it to be an effective training solution

Assessing validity of simulation

Validation explores whether the simulation is fit for the purpose, including if skills are transferred, if they are useful for maintenance.

- **Content validity:** For content validity to be present, all correct (and incorrect) steps should be reproducible , and relevant cues should be recognizable and actions correctable
- **Face validity:** This occurs when the simulation itself (intruments, imaging) are realistic enough to provide a sense of presence in the "operator".
- **Construct validity:** assessments of the simulation are sufficiently robust to form basis about operator performance (for instance, accreditted Advanced Cardiovascular Life Support)

Which training scenarios would benefit most from simulation?

- Fundamental or entry-level skills and tasks, where the opportunity to train is diminished
- High risk tasks, where traditional apprentice models poses an unacceptable risk to patients (example: stent placement / foreign body retrieval)
- Critical events due to error, risk or complication (Removal of a misplaced coil / recognition and management of ruptured vessel / contrast induced anaphylactic reaction)

Ultrasound guided intervention and phantoms

Ultrasound is vastly accessible mean for image guided procedures, with unique advantages, such as its tolerability, real time needle follow-up, portability, lack of ionizing radiation.

Its main drawbacks are the limitation in deep structures, echogenic tissues, patient adiposity and bowel structures.

Furthermore, more than any other means, it is operator dependent and requires real knowledge of diagnostic imaging for adequate correspondence between every previous examination.

Considering that metrics in simulation training are mostly investigational, justifying investment in costly phantoms may be hard to do.

- When considering training fundamental / entry-level skills, simple and low cost phantoms may provide a suitable solution.

Expected benefits from training with phantoms for Ultrasound guided procedures:

- Improved gross motor behaviours
- Improved hand-eye coordination
- Training different needle-probe approaches (in-plane; out-of-plane)
- Correct procedural sequencing

Which Phantom for US-guided procedures?

Many different types of US phantoms may be used, with different advantages and disadvantages:

	Pros	**Cons**
Animal parts	Realistic Can embed targets	Short shelf-life Messy Infection risk
Tofu	Simple Affordable Portable Complexity degree can be changed (target can be inserted, not embedded	Less available Frail Seeps water Needs refrigeration Uniform ecogenic Infection risk
"Blue Phantom" ®	Portable Realistic No infection issue Large scanning surface Long shelf-life Reusable	Expensive Preformed Cannot embed additional targets Fixed targets Needle tracking Non tissue like haptics

Gelatin based	Cheap Portable Large scanning surface Injectable targets can be embedded Appearance and shape can be modded Transparency can be changed Reproducible	Requires refrigeration (until usage, otherwise it liquefies) Needs to be prepared Needle trackin Fig. 8 on page 7 Relativelly short shelf life Uniform appearance Frail under pressure
Agar	Targets can be embed Portable Targets can be placed More resistant than gelatin	Organic based Less available Preparation time May be expensive
Silicone based	No infection issues	Price Memory after each needle pass
Cadaver based	Anatomical relevance	Infection issues / storage issues Avaiability
Computer based	No infection issues Level of complexity / difficulty may be changed	Expensive IT support Not easily portable Inaccurate haptics

(from: Sultan, Syed Farjad, George Shorten, and Gabriella Iohom. "Simulators for training in ultrasound guided procedures." *Medical ultrasonography* 15.2 (2013): 125-131.)

Commercial materials are usually pricey.

Some low-cost materials have been tested to acquire an adequate realism. and complexity. However, their construction is rather complex and, invariably, training will end damaging them.

This EPOS focus on materials that

- Are safe
- Provide an acceptable target
- Require minimum investment
- Are easily replaced

This characteristics unsure that they are more easily implemented.

We will focus building agar and gelatin based phantoms on the rest of our assignement due to the following:

- They are safe and easy to build
- They are versatile
- May provide adequate haptics

Images for this section:

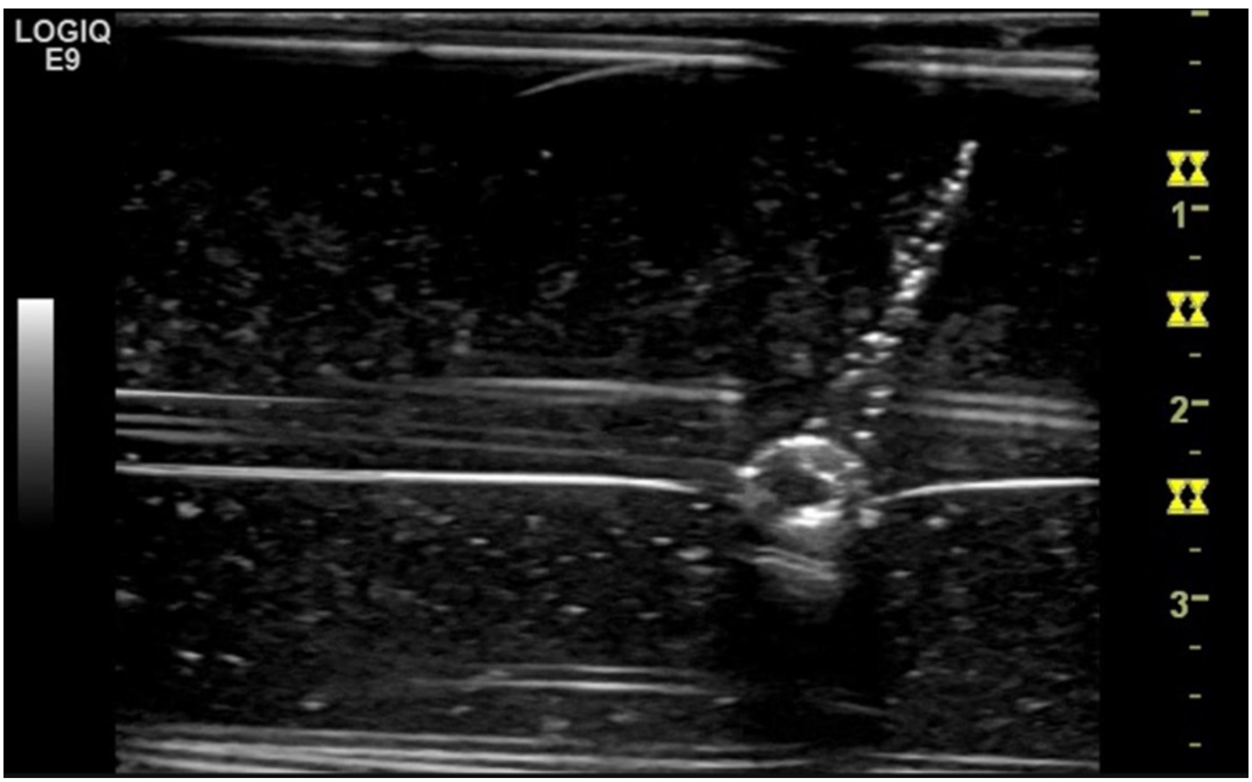


Fig. 8: Needle passage: Reverberation artifacts with gas after several tries.

Findings and procedure details

In this section we'll describe the preparation of phantoms for US-guided procedures.

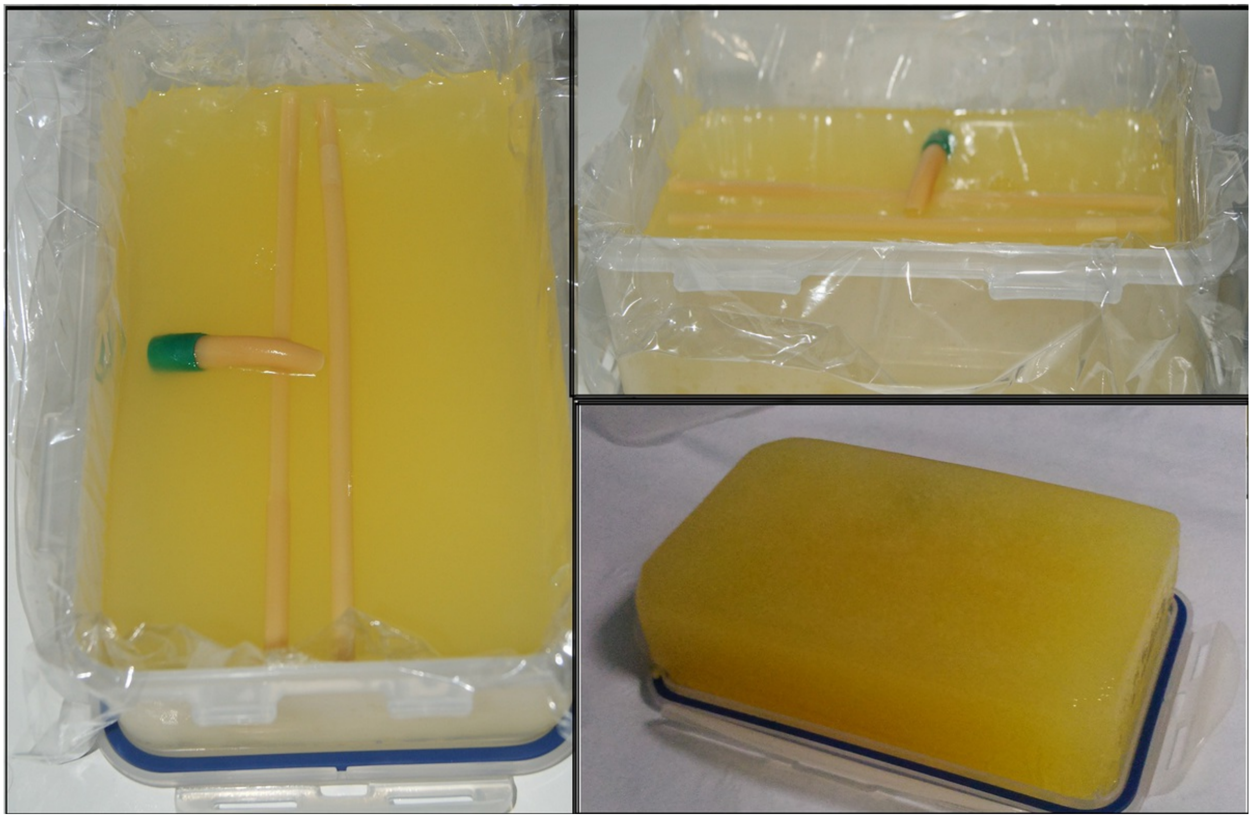


Fig. 1: Left and top right: First layer of agar-gelatin was poured in a PVC container, targets were placed on top of first layer (cling wrap was used to further removal of the phantom) Bottom right: Final product with second layer
References: Medical Imaging, Faculty of Medicine of Coimbra, University Hospital of Coimbra - Coimbra/PT

Gelatin phantom

The greatest advantage of gelatin phantoms (aside from it's price) is the fact that its transparecy can be changed.

The following material is required for gelatin phantoms:

- Gelatin (about 8 table spoon per liter)
- Corn-flower (2 to 6 table spoon per L) (echogenic) Fig. 2 on page 19

- Cellophane plastic wrap
- PVC box (or other container)
- Target

Instructions for gelatin based phantom:

- Gently boil ½ the amount of water with the corn-flower until completely dissolved
- Add gelatin powder and stir untill it has solved
- Add the remaining ½ water
- After homogeneous concentration is obtained, let the mixture cool for 30 minutes
- Place the mixture in the container (the plastic wrap is used to for latter removal of the phantom)
- Place in fridge for 10-12 hours

Agar phantom

Compared to gelatin, agar is much sturdier and touch resistant. However it is opaque.

The following material is required for agar phantoms:

- Powdered Agar (about 4 table spoon per liter)
- Cellophane plastic wrap
- PVC box (or other container)
- Target

Instructions for agar based phantom:

- Gently boil the amount of water with the agar until disolved
- Embed targets when possible (agar solifies rather quickly)
- Let the mixture cool for 30 minutes
- Place in fridge for 2-4 hours

Note: if embed targets will be used, making this process in two steps might be desirable (many objects float).

Tip: use of an hand blender may help speed the process

Preparing the material: the targets

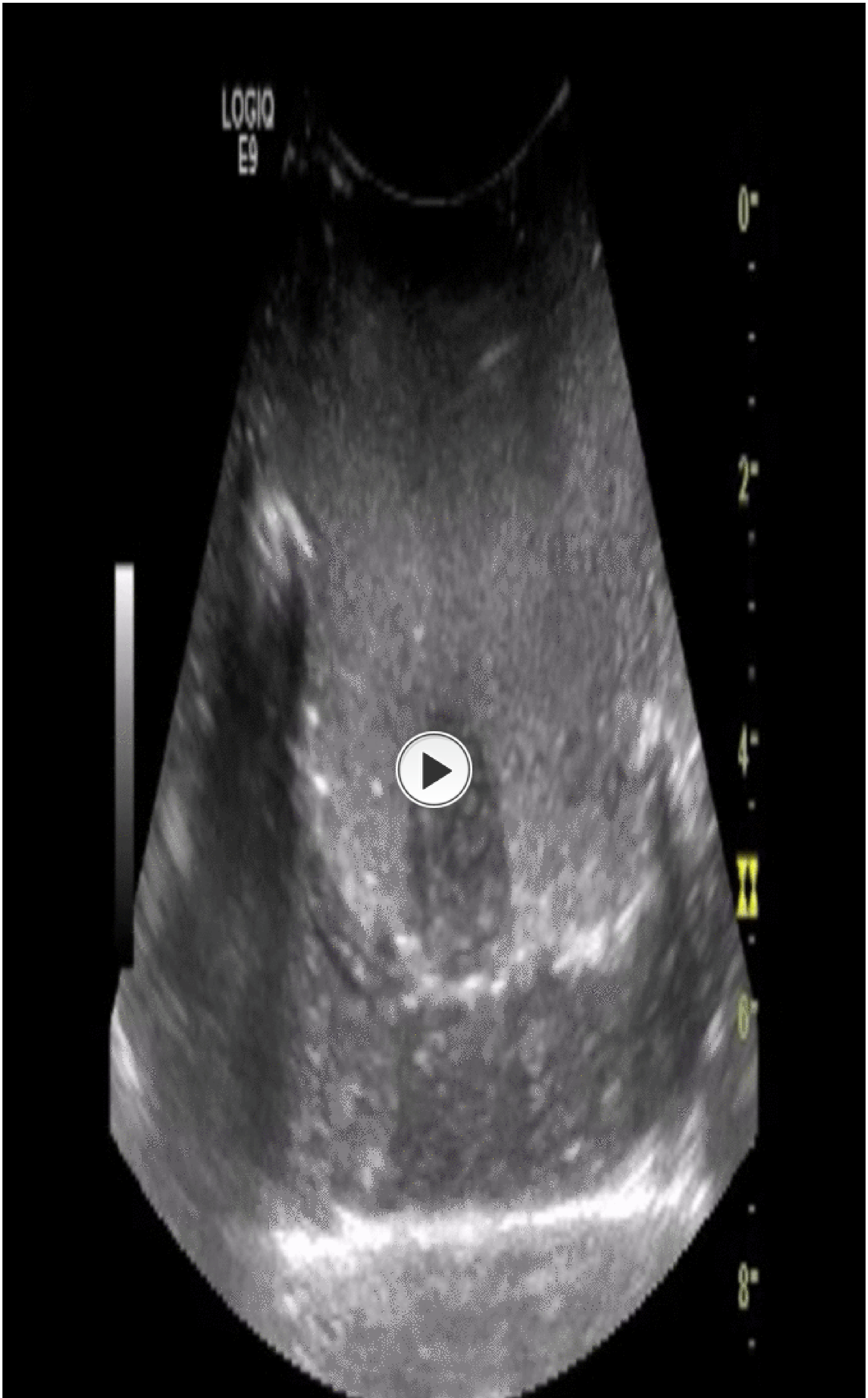

LOGIQ
E9
0"
2"
4"
6"
8"

Fig. 12: Latex glove filed with agar, while the surrounding agar was more echogenic due to presence of corn flower. Needle was placed in a glove finger. Resistance could be felt.
References: **- Coimbra/PT**

Using latex tubing, gloves or other material, suitable scenarios may be created.

- Latex tubing may be used as a simulated vessel. Fig. 5 on page 20
- Glove fingers may be filled with water (or with phantom material with different ecogenicity) and used as a target. Fig. 4 on page 20
- If core biopsied are to be trained, making coloured gelatin to fill glove finger may be desirable.
- Using multiple targets may be a way to increase complexity.

More complex low-cost phantoms have been described, for instance:

- Nephrostomy
- Pericardiocentesis

Such phantoms may also be reproduced according to the authors methods, being much more complex and difficult to replicate on large scale.

Practical curricula for phantom training in ultrasound intervention - Needle handling and visibility

- In-line needle placement and guiding
- Out-of-plane needle guiding and placement
- Bevel orientation Fig. 9 on page 22
- Angulatio to probe Fig. 3 on page 19

Practical curricula for phantom training in ultrasound intervention- large and small targets Fig. 6 on page 21

- In-line targetting
- Out-of-plane targetting

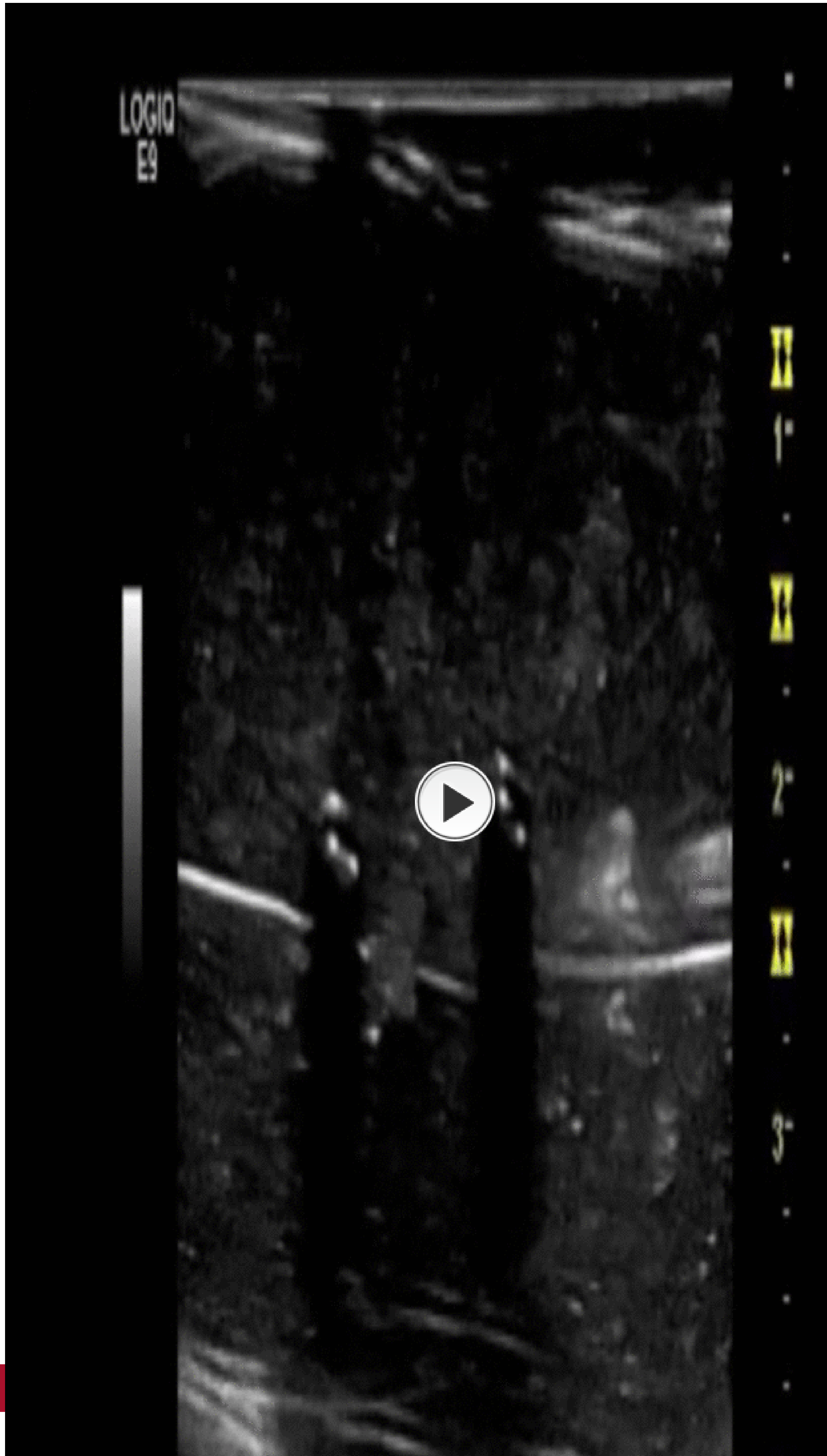

LOGIQ
E9
1
2
3

Fig. 14: Parallel Foley tube, with in-plane targetting of one of them.
References: - Coimbra/PT

- "Structure avoidance" Fig. 7 on page 22
- Placing needle anterior to target
- Placing needle posterior to target

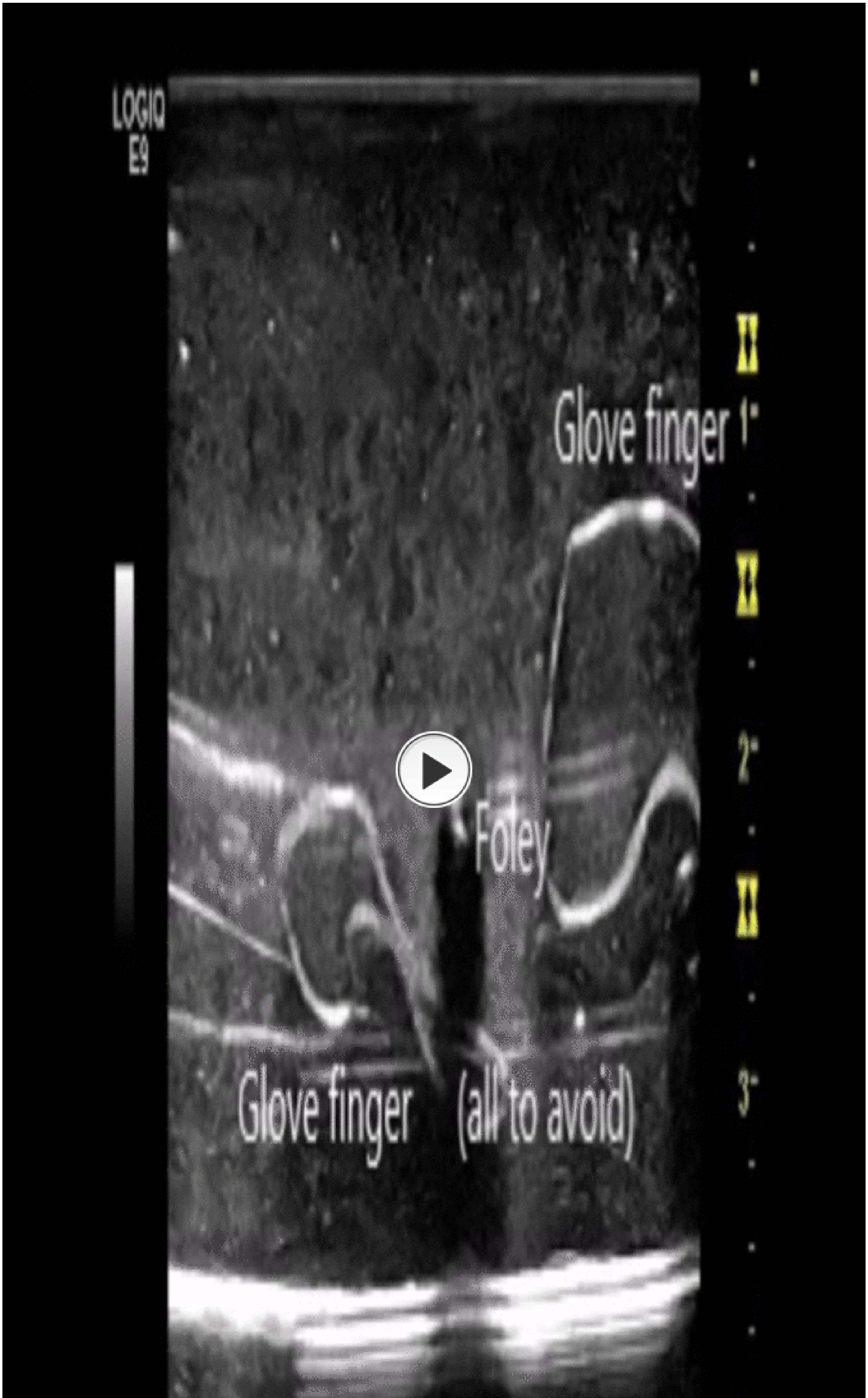

LOGIQ
E9
Glove finger
1
2
Foley
3
Glove finger
(all to avoid)

Fig. 10: Clip showing structure avoidance.
References: - Coimbra/PT

Specific techniques

- Central venous access
- Arterial access (Seldinger technique)
- Fine needle aspiration
- Core-Biopsy
- Drainage
- Trocar
- Hydrodissection

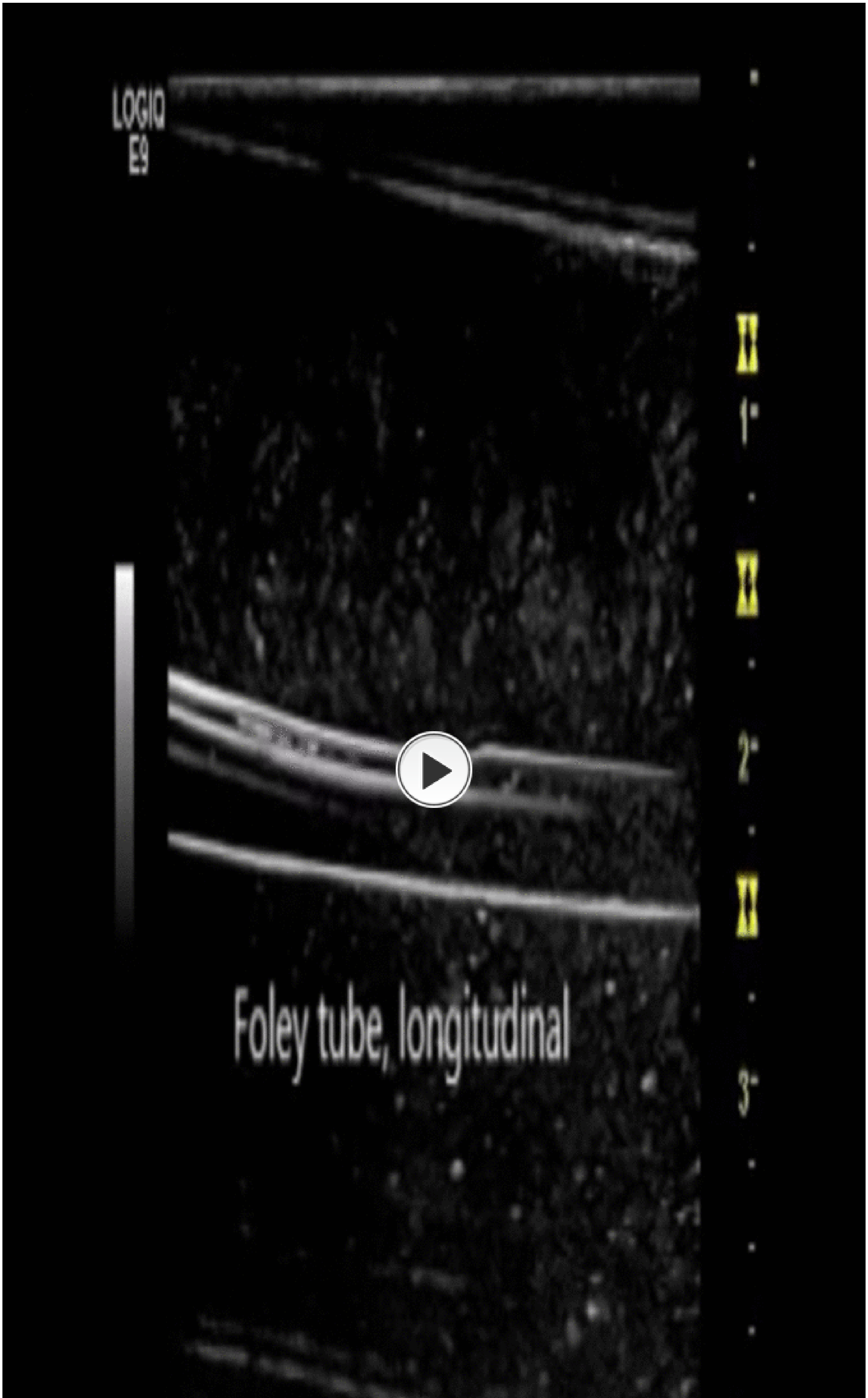
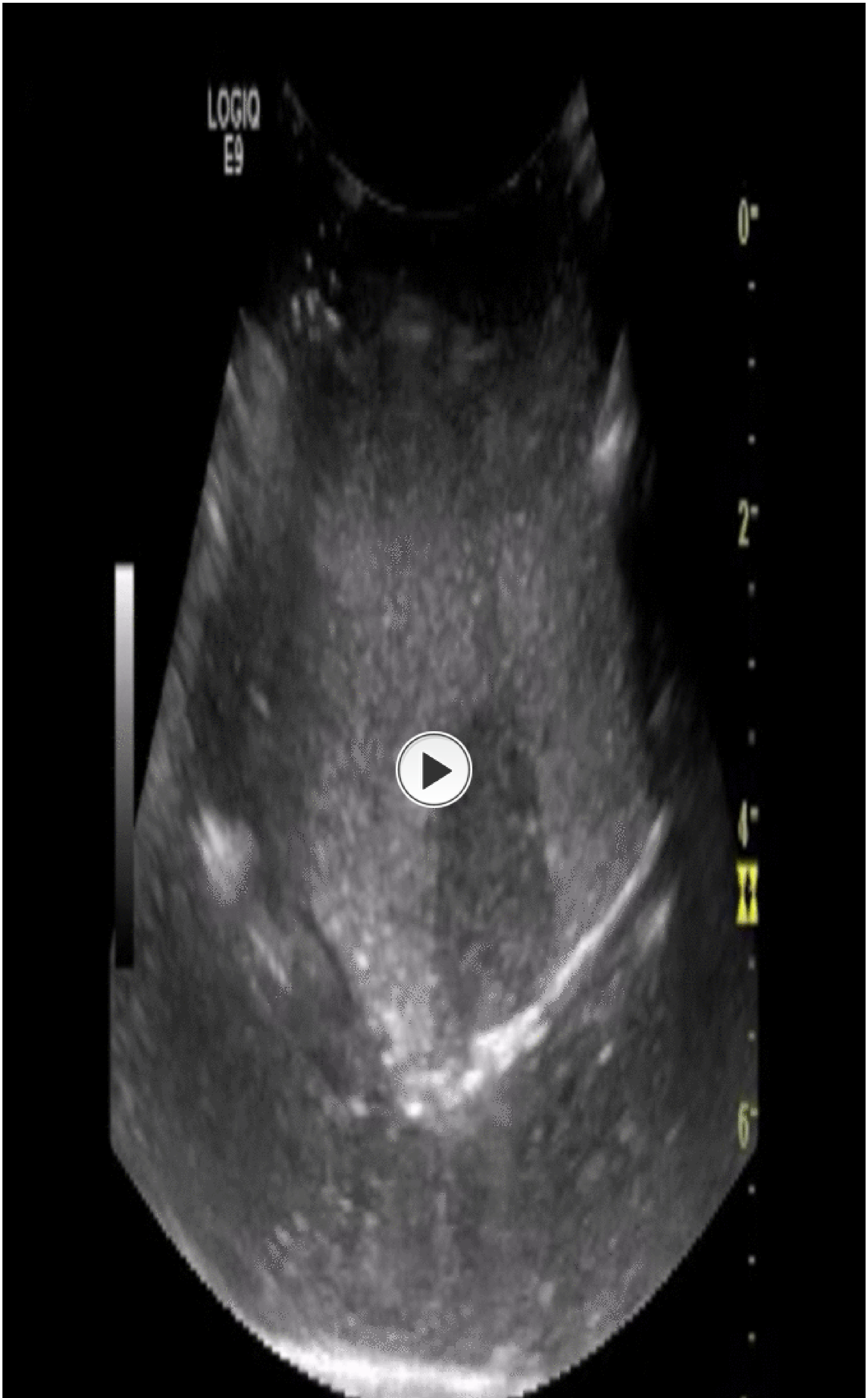

LOGIQ
E9
Foley tube, longitudinal
1
2
3

Fig. 11: After proper probe alignement, in-line needle was inserted in the foley tube - type of skill necessary for instance for central venous access.
References: - Coimbra/PT



LOGIQ
E9
0
2
4
6

Fig. 13: After the needle was placed between the two structures, a slight amount of water was injected. Hydrodissection consists on separating two structures and involves adequate needle placement between them. This is an important skill, for instance, for displacing a bowell or to identify adequate needle placement innerve blocks.
References: - Coimbra/PT

Images for this section:

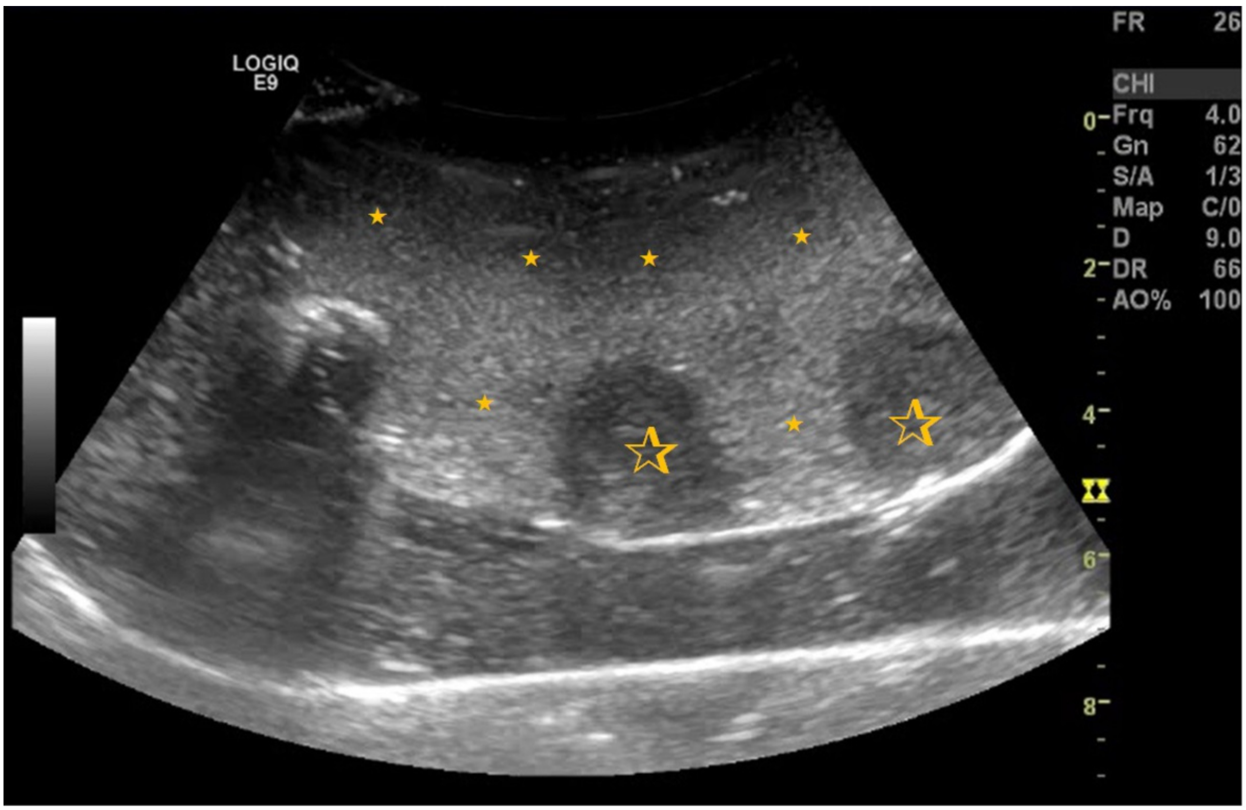


Fig. 2: Agar based phantom. A glove filled with agar was placed inside a plastic bag, glove fingers can be seen (empty star) Plastic bg was filled with agar and cornflower for echogenicity (filled star).

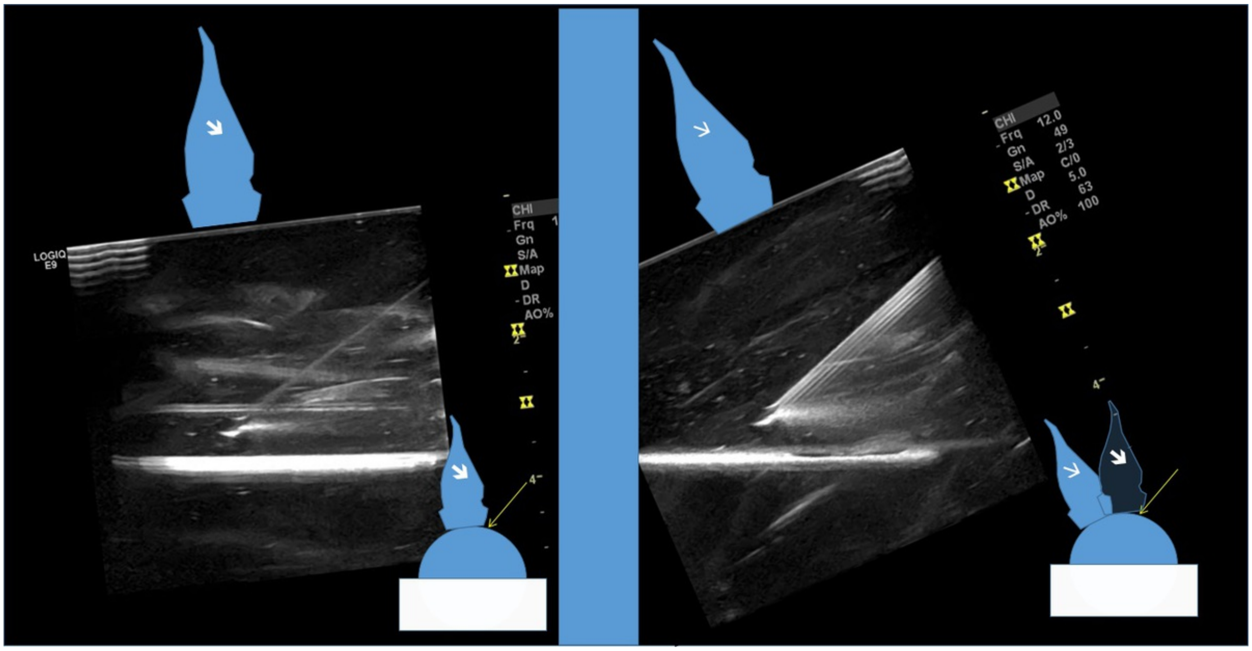


Fig. 3: Agar based phantom - needle visibility Right, fat arrow: needle more vertical to probe Left, skinny arrow: much more visible needle with after probe placed at a more perpendicular location. Note: Image tilting reflects concave phantom morphology.

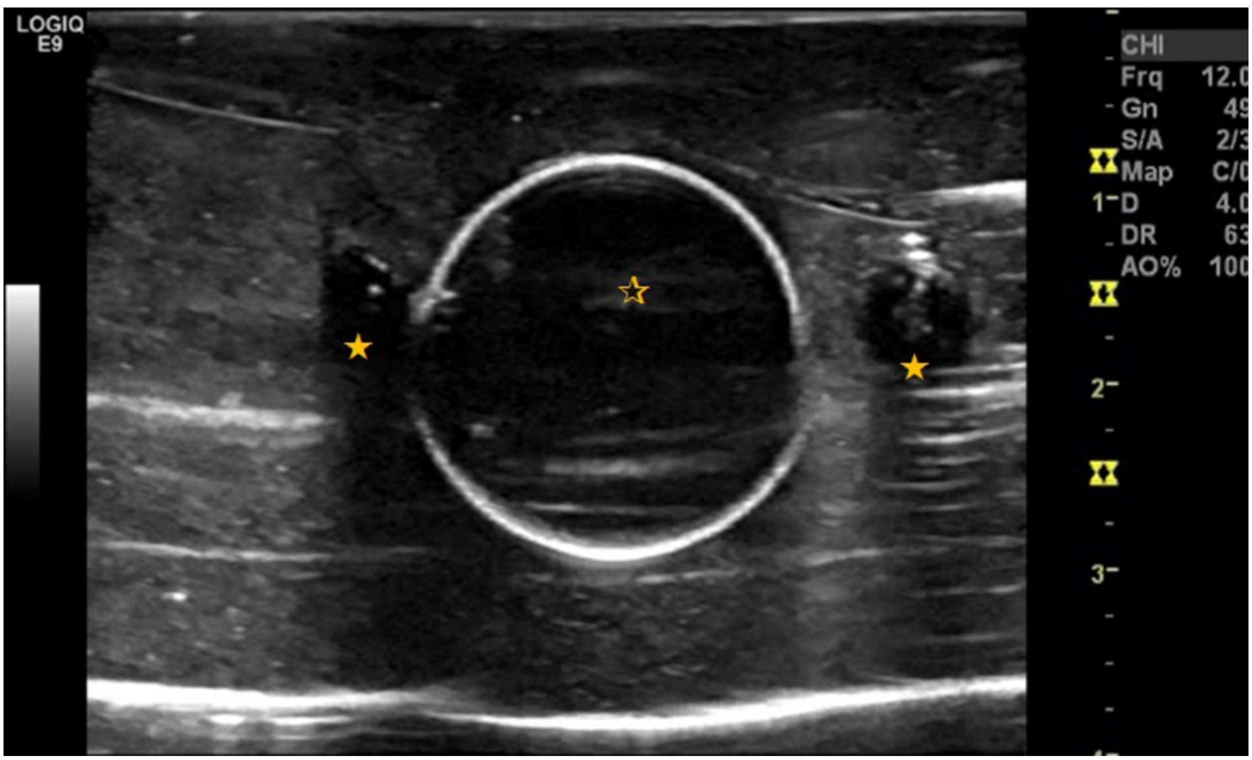


Fig. 4: Agar based phantom. Two foley tubes (filled star) were placed paralel to each other. A glove finger was filled with gelatin to simulate a cyst (empty star).

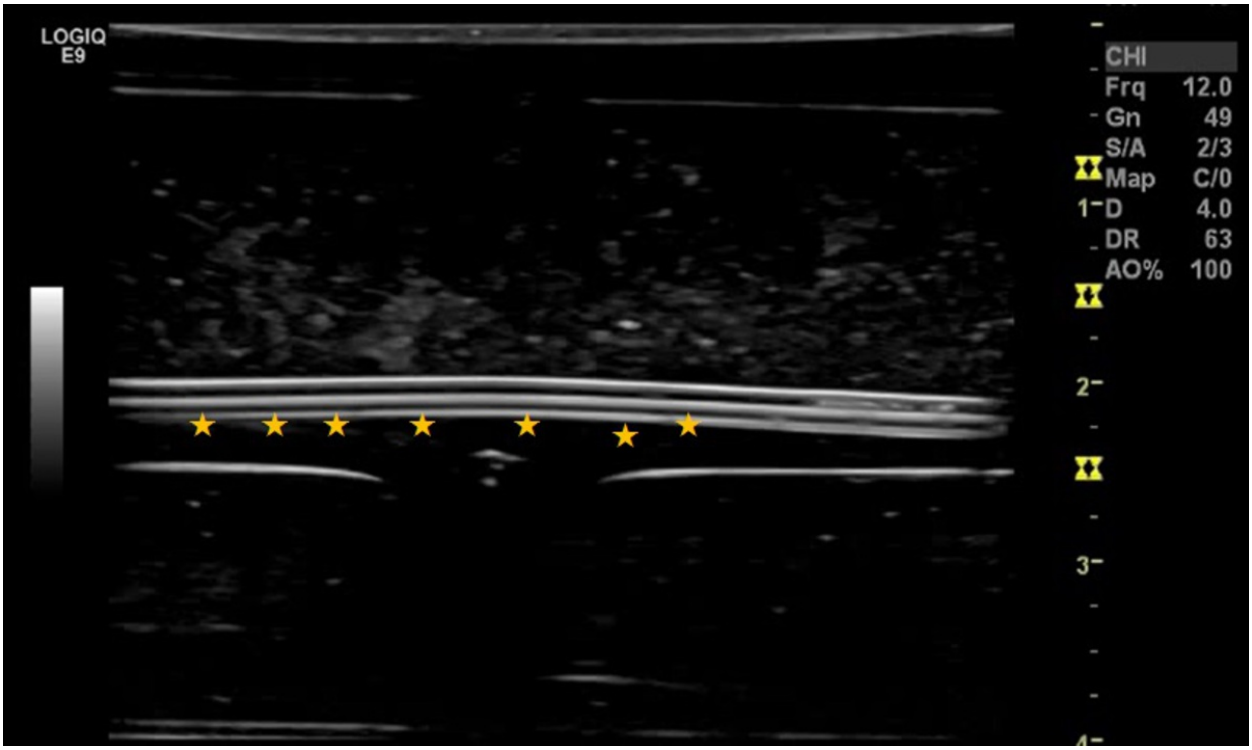


Fig. 5: Longitudinal view: Foley tube.

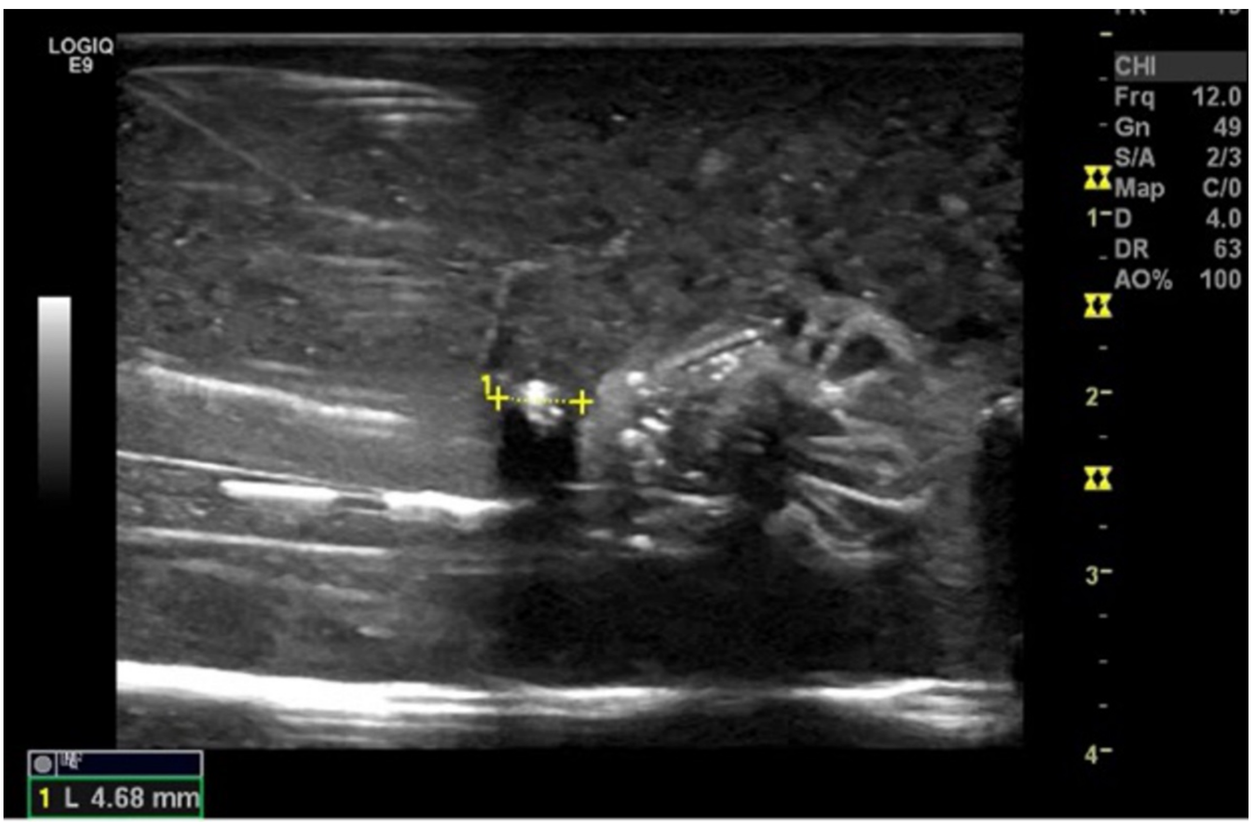


Fig. 6: Foley tube measures approximately 5 mm in width - good for small target practice.

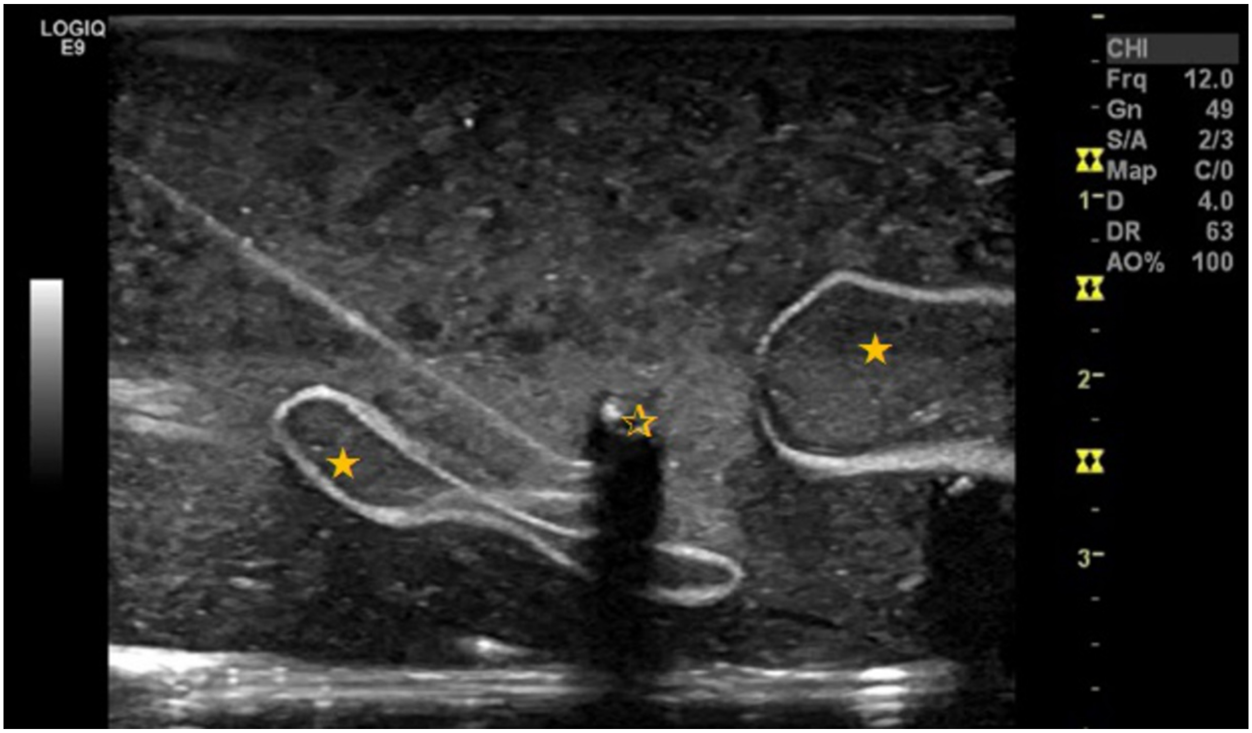


Fig. 7: Effect of needle bevel orientation regarding needle visibility. With the bevel up the needle is better appreciated.

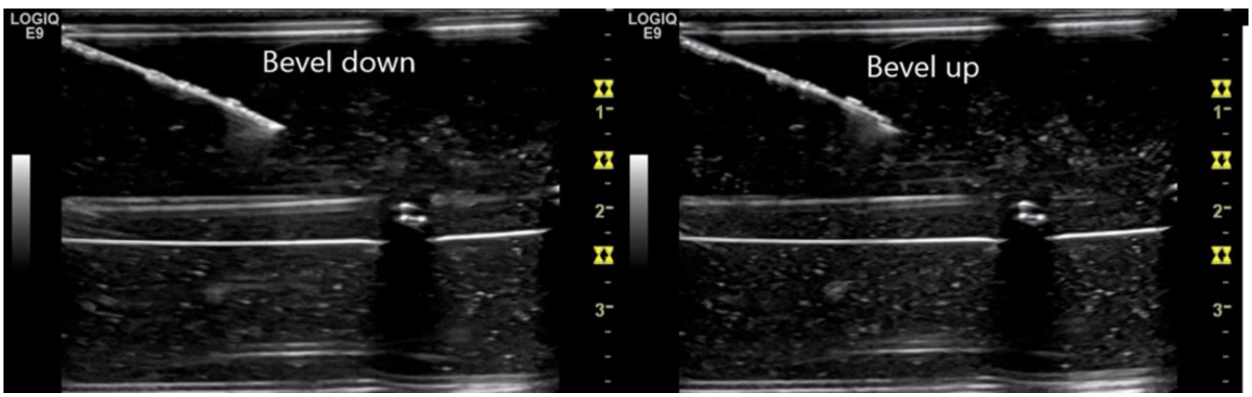


Fig. 9

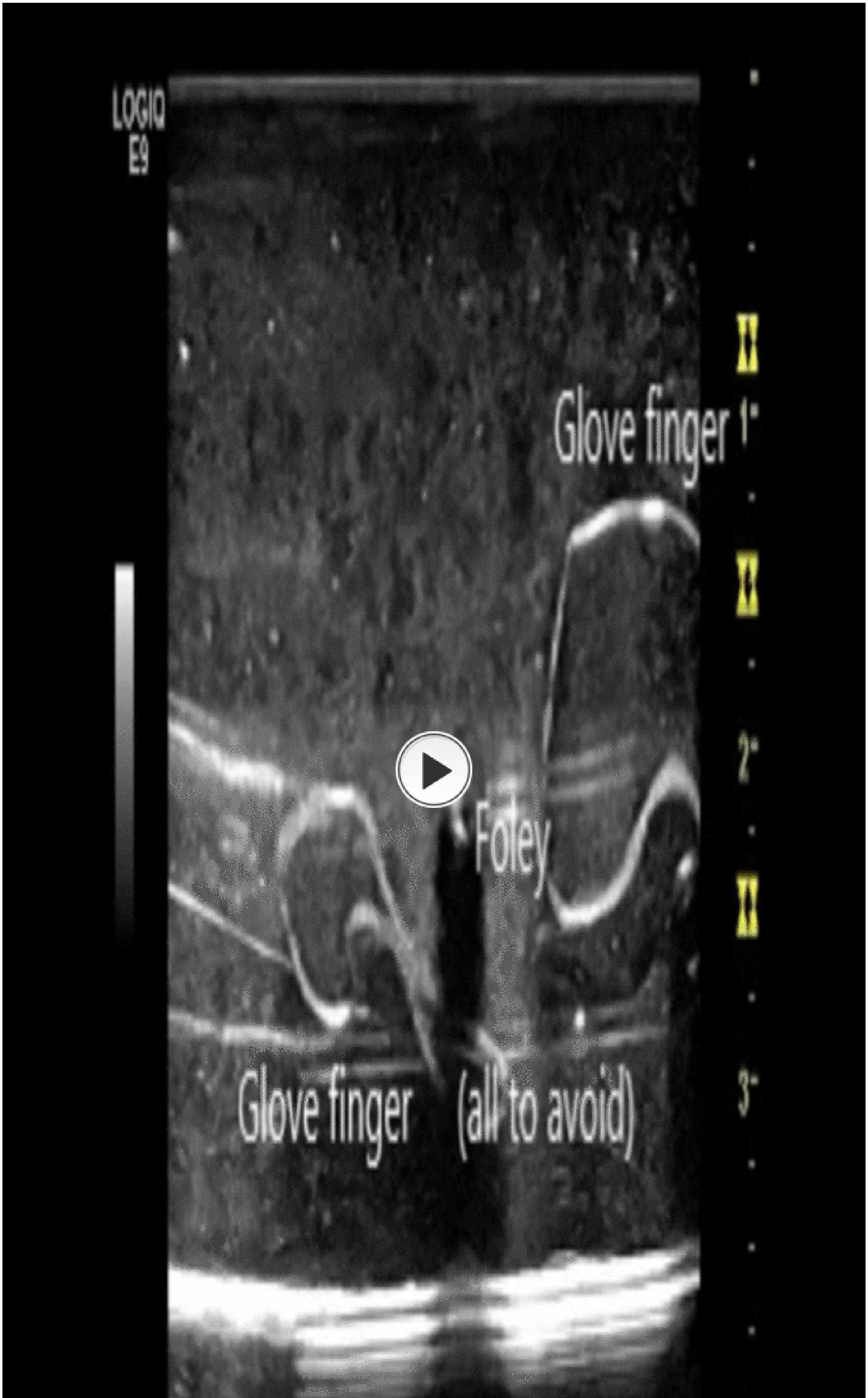

LOGIQ
E9
Glove finger
Foley
Glove finger
(all to avoid)
1"
2"
3"

Fig. 10: Clip showing structure avoidance.

Conclusion

To the authors knowledge, no simulation training has been able to substitute tutored clinical practice.

However, there are advantages for using simulation training right away, as simulations are ideal for:

- Procedural sequencing
- Cognitive and communication skills
- Gross motor behaviors
- Teamwork within context
- Training residentes
- Team training

Benefits in training have been objectivelly identified especially with:

- Clearly structured curriculum
- Different levels of difficulties
- Give the opportunity to retry

In terms of medical education, even this low-cost models have advantages, such as:

- active learning instead of passive learning
- Improved gross motor behaviours
- Improved hand-eye coordination
- Training different needle-probe approaches (in-plane; out-of-plane)
- Correct procedural sequencing

We find it likelly that at least some of this skills may transfer when starting an tutored apprentorship.

A less obvious application of this type of simulation lies in Undergraduate (medical students) training with phantoms.

In 2004, Baerlocher and collegues discussed the position and role of the interventionalist in "turf wars". They stated that interventional radiologists are "the best trained to perform these procedures as a result of a strong foundation in diagnostic radiology, and therefore can potentially offer the best product, if this is not the case already. We should therefore focus on how to protect our turf in the interest of protecting or best serving the public."

Medical students are a strategic point in order to raise awareness of any medical field, particularly Radiology. Courses and seminars, including cheap, accessible, disposable phantoms are an excellent tool for causing a remarkable impression of Interventional Radiology, in Medical Students. This will hopefully increase the number of future interested in the field, as well as increase the awareness of the solutions it has to offer for future referring physicians.

Personal information

References

Mendiratta-Lala, Mishal, et al. "The use of a simulation center to improve resident proficiency in performing ultrasound-guided procedures." *Academic radiology* 17.4 (2010): 535-540.

Sultan, Syed Farjad, George Shorten, and Gabriella Iohom. "Simulators for training in ultrasound guided procedures." *Medical ultrasonography* 15.2 (2013): 125-131.

Hunt, Andres, et al. "Low cost anatomically realistic renal biopsy phantoms for interventional radiology trainees." *European journal of radiology* 82.4 (2013): 594-600.

Rock, B. G., A. P. Leonard, and S. J. Freeman. "A training simulator for ultrasound-guided percutaneous nephrostomy insertion." (2014).

Gould, D. "Using simulation for interventional radiology training." *The British Journal of Radiology* 83.991 (2010): 546-553.

Patrick Stumpp, "Medical Education in Interventional Radiology" CT- and MR-Guided Interventions in Radiology, 2013, pp 565-571, Springer

Campo dell'Orto, Marco, et al. "Assessment of a Low-Cost Ultrasound Pericardiocentesis Model." *Emergency medicine international* 2013 (2013).

Baerlocher, Mark O., and Murray R. Asch. "The future interventional radiologist: clinician or hired gun?." *Journal of Vascular and Interventional Radiology* 15.12 (2004): 1385-1390.

Barry Issenberg, S., et al. "Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review*."*Medical teacher* 27.1 (2005): 10-28.