We are IntechOpen, the world's leading publisher of Open Access books
Built by scientists, for scientists

5,800
Open access books available

142,000
International authors and editors

180M
Downloads

154
Countries delivered to

Our authors are among the
TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Chapter

Revision of Training Models on Ultrasound-Guided Vascular Access: Presentation of an Animal Model

J.M. López Álvarez, O. Pérez Quevedo, S. Alonso-Graña López-Manteola, J. Naya Esteban, J.F. Loro Ferrer and D.L. Lorenzo Villegas

Abstract

Simulation has been defined as the representation of something as real. It is necessary for performing the ultrasound-guided vascular cannulation technique correctly. The use of training models for diagnostic or therapeutic procedures: improves the quality of care for patients; decreases stress level that it can produce the realization of a new technique directly on the patient and; can be used as many times as the model is reproduced, also serving as a method for the resolution of some problems that may appear related to the in vivo technique. The evidence shows that simulation plays an important role in the acquisition of skills to perform invasive procedures. The use of ultrasound in vascular accesses whether peripheral or central, arterial, or venous, improves the success rate in the canalization and reduce the complications derived from the technique in certain critical situations (coagulopathy, thrombocytopenia, obesity, etc.) specially in pediatric patients given the variability of depth and diameter of its vessels with respect to the adult population. To facilitate learning in the technique of echoguided puncture, a training model is presented that is easily reproducible, economical and with a high fidelity in relation to the punctures performed on the patient.

Keywords: training, simulation, model, ultrasound

1. Introduction

Simulation has been defined as the presentation of something as real, it means a situation in which some conditions are artificially created to resemble the reality [1–3]. This is used with the objectives of studying something or training in a new medical procedure. To implement a technique such as the ultrasound-guided vascular access, a series of skills must be acquired in order to reach the required aptitudes to perform vascular cannulations in a proper manner [2–5].

These skills include the following: (a) knowledge and comprehension of the device to be used as well as their technical bases, in our study, the ultrasound machine and ultrasonography; (b) the visualization and optimization of the vascular image and of the needle, and; (c) the ability to acquire the required skills to use the ultrasound probe and to insert the needle (puncture) when performing the procedure of ultrasound-guided vascular access [6–11].

The use of simulation models as diagnostic or therapeutic procedures training models has the following advantages: (a) they increase patients' assistance quality, especially if these techniques are associated to complications and risks; (b) they decrease the stress level eventually provoked by the direct performance of a new technique on patients, and; (c) they can be used as many times as the model is reproduced, so they can be additionally used to solve some problems that could arise from the "in vivo" performance of the technique [10, 12, 13].

Evidence shows that simulation plays an important role in the acquisition of skills required to perform invasive procedures [13, 14]. The use of ultrasound scan on vascular access increases the success rate of the cannulation and reduce the complications derived from this technique. Irrespective of these vessels are peripheral or central and arteries or veins [15–18]. However, the ultrasound-guided vascular access is displaced for the benefit of the classical technique ("blindly" oriented by anatomic references) by some reasons, such as the learning curve that every invasive technique requires and the ultrasound machine preparation required to perform this technique (probe sterilization, choice of the proper "pre-set," puncture plane, etc.). The preference for the classical technique occurs even when it takes the risk of complications associated, which increase under certain critical conditions (coagulopathy, thrombocytopenia, obesity, etc.). These considerations are especially relevant in pediatric patients due to their vessels' depth and diameter variability, which is higher than in adult patients [19, 20].

2. Model types

It is noticeable that experimental, simulation, or no-human models are used infrequently in learning invasive techniques/procedures such as ultrasound-guided vascular access. Any training process on a simulation model represents an opportunity to practice the technique without taking risks and entails the learning of the use of ultrasounds. All of the above is feasible to increase patients' security when performing invasive procedures on children [8, 13].

The training models usually are extremely expensive, hardly available, or not good at transmitting ultrasounds in an optimal manner.

Most of the training or experimental models than can be used to perform simulations for the ultrasound-guided vascular access training are synthetic or biological. Some of them are commercially available and other can be constructed manually by any person [11, 21–23]. They are the following: (a) "in vivo" models performed on research animals; (b) commercially available models such as Blue Phantom® or silicon or latex models, and; (c) synthetic handcrafted models constructed by using gelatine/agar or tissue animal models constructed by using chicken thighs, turkey thighs, or chicken breast [14, 24, 25]. Each of these models must contains tubular structures inside, that can be made on plastic, latex, or rubber, and filled with liquid, in order to simulate the vessels to be cannulated.

These models can be classified as cannulation-puncture models or puncture-localization models depending on the use of them.

2.1 Characteristics of an ideal training model

An ideal training model to perform ultrasound-guided vascular access procedures should:

- reproduce texture and resistance of human tissue;
- have enough penetration surface to transmit correctly the ultrasounds;
- permit the identification and localization of the different tissue structures;
- obtain an optimal image;
- permit different difficulty and complexity levels when the procedure is performed;
- avoid, to the extent possible, the visibility of the puncture needle path;
- permit the visualization of the needle;
- have long average life;
- be easily transportable, and reproducible in any environment;
- be easily available and inexpensive.

3. Advantages and disadvantages of the different ultrasound-guided vascular access training models

3.1 Blue Phantom®

Commercially available simulator to be used as a training model of procedures in which ultrasounds are used as vascular access guides (**Figure 1**).

They are expensive, not-transportable, and not-changeable, although the latest models permit even simulate arterial pulse (**Figure 2**). The puncture needle entry point and path usually remain visible. The puncture performance sensation on this model is different from that on human tissues. They require maintenance and deteriorates after multiple puncture performances. They are not easily available nor affordable [21–23].

3.2 Silicone models

Commercially available models consisting of a silicone model containing a tubular structure which permits the vascular access simulation and that can be refilled after each puncture performance. They have a long average life, and they are easily transportable. However, they offer a small surface area due to their small size, they are expensive and not easily available to all [11, 26, 27]. The puncture needle entry point and path remain visible after multiple puncture performances (**Figure 3**).

3.3 Agar/gelatine models

It consists of an agar or gelatine model in which a tubular elastic structure is inserted (in some cases, Penrose surgical drains of different sizes). They have been used by radiologists to train and teach ultrasound-guided procedures (**Figure 4**). They are easy to construct by using everyday kitchen utensils and they are ideal for hand-eye coordination learning and improvement [28, 29].

However: (a) they usually show an uniform appearance of the ultrasound image (**Figure 5**) without identifiable muscle or tendon structures (with the exception of preparations including any component like mucilage); (b) the puncture needle

Figure 1.
Blue Phantom® model.

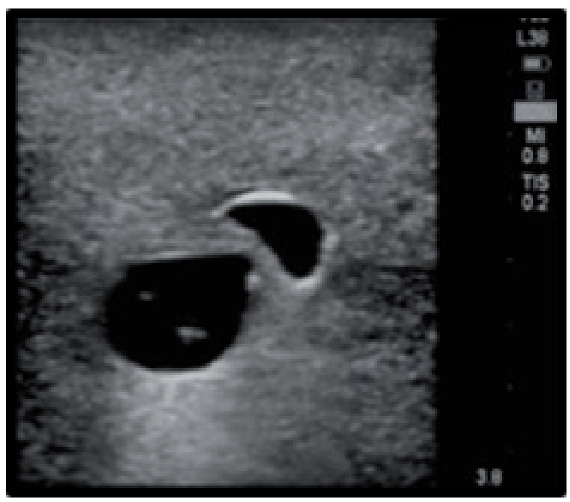

Figure 2.
Ultrasound image of internal jugular vein and carotid artery (Blue Phantom® model).

entry point and path remain visible after some puncture performances; (c) their puncture performance sensation is different from that on human tissues; (d) depending on the gelatine concentration used during their construction, they can be easily damaged, and; (e) the needle sideways movements during its introduction into the agar/gelatine could be hardly controllable when trying to puncture the vessel.

3.4 Animal models

(a) “In vivo”: the use of research animals results in high cost and laborious preparation when optimal conditions are required (sedation, mechanical ventilation or respiratory support, monitoring, etc.) as well as in a limited number of punctures; (b) “artificial”: they are manually constructed by using pork, turkey or chicken thighs, pork-belly, tofu or sausage/cold meat piece as *muscle structure*, and different elastic components (urinary catheters, chest drains, metallic trocar, serum infusion systems, etc.) as *vascular structure*. By using them, a real sensation

DOI: http://dx.doi.org/10.5772/intechopen.101901

Figure 3.
Silicone model for ultrasound-guided vascular access.

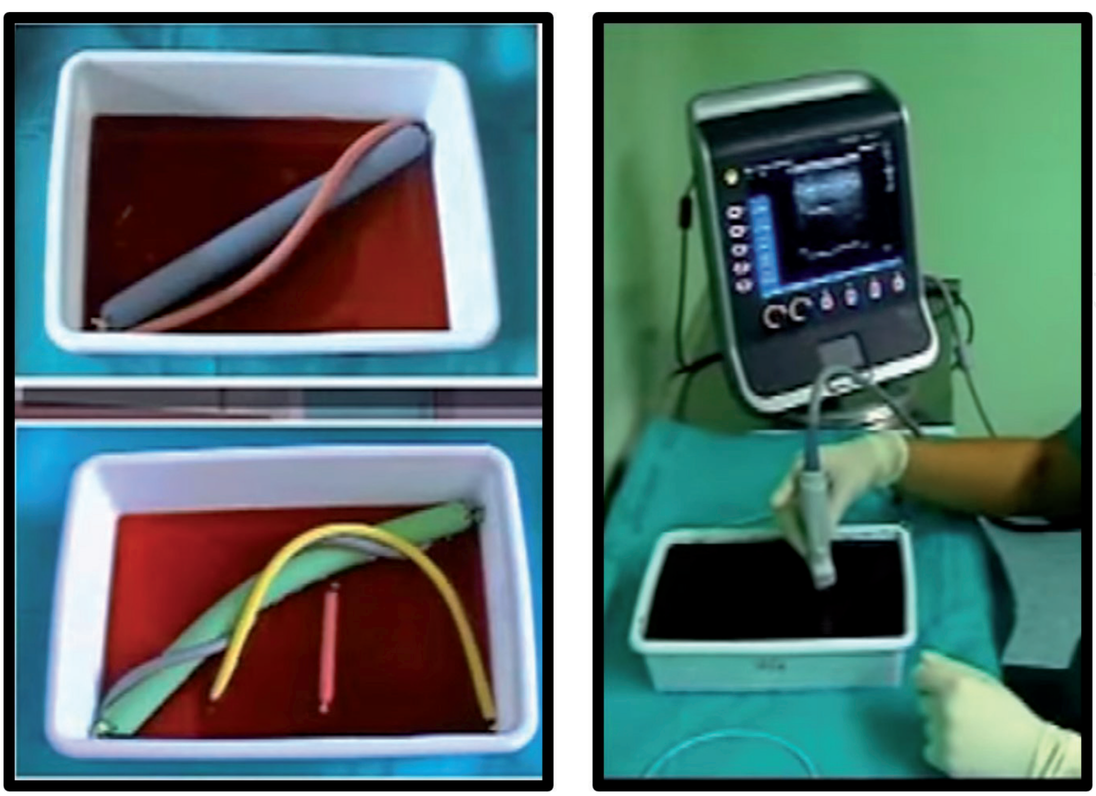

Figure 4.
Gelatine model: Penrose drains using different water-soluble colorants, which are fixed to different gelatine layers (image courtesy of Dr. Vicente Roqués).

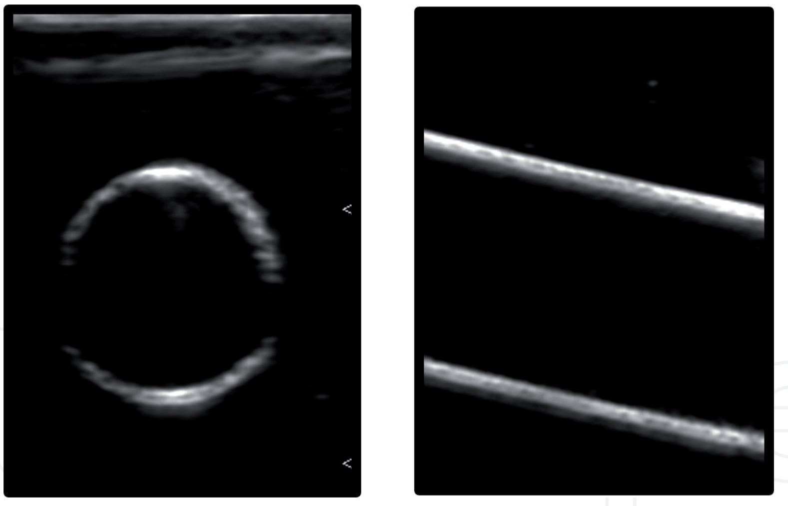

Figure 5.
Ultrasound image of transversal axis (left) and longitudinal axis (right) within the gelatine model.

of different tissues is created with respect to both the ultrasound image perspective and the sensation obtained when performing puncture and cannulation/vascular access. These models show an affordable preparation, but their construction needs a certain amount of time. In addition, they are inexpensive as well as easily transportable and manageable. Their design permits different complexity levels with respect to different vessels diameter and depth, so the difficulty level can be increased as progress is made on the training process. With respect to their disadvantages, these models' conservation needs refrigeration, their average life is short (some weeks to get their muscle structure deteriorated) and they must be carefully constructed in order to reduce their risk of air introduction into their vascular structure [8, 15, 25].

The main advantages and disadvantages of the main cannulation-puncture models are shown in **Table 1**.

3.5 Simulation software

Simulators provided with high software-algorithm-based fidelity have been used as training models on ultrasound-guided procedures. Their disadvantages include their high cost and the need for software support. Their advantages include the absolute lack of infection control problems, the possibility of changing the complexity/difficulty level. Simulators can be installed in not clinical settings, such as training rooms, and they can be available at any time of the day or night [30, 31].

3.6 Puncture-localization models

These are artificial models frequently used by radiologists for the training on localization and puncture of nodular or cystic structures, mainly hepatic mammary or thyroid ones [11, 26, 27]. These models are used to get familiarize with the ultrasound machine and with the puncture technique in ultrasound-guided procedures. The *tissue/muscle component* can be: piece of poultry breast, liver or tofu, sausage/cold meat piece or surgical gloves filled with a warm water dilution containing food thickener. The *vascular/nodular component* can be whole/pitted olives, cheese puffs-blocks, jelly beans or gumdrops, wires or knitting needles, etc. and they must be included inside the tissue/muscle component (**Figure 6**).

Models	Advantages	Disadvantages
Blue Phantom®	Transportable	Human tissue texture not reproduced
	Long average life	Very visible puncture needle entry point
	Large surface area	Poor resemblance to real vascular and muscular images
		Expensive
Silicone	Transportable	Small surface area
	Long average life	Expensive
		Very visible puncture needle path
Agar/gelatine	Transportable	Uniform appearance of ultrasound image
	Inexpensive	Human tissue texture not reproduced
	Easy construction	Strong puncture needle path
		Easily damaged
		Possible air artifacts within the vascular structure
Animal "in vivo"	High resemblance to reality	Not transportable
	Large surface area	Expensive
		Large facility and authorization required
		Limited needle punctures
Animal "artificial"	Transportable	Short average life
	Easy construction	Preparation time required
	Inexpensive	Possible air artifacts within the vascular structure
	Human tissue texture reproduced	
	High resemblance to real vascular and muscular images	

Table 1.
Training models for ultrasound-guided vascular access: "pros and cons."

4. Animal model construction and description

The training model described here consists of the following [8]:

4.1 Muscle component

Piece of bird breast that can be acquired at any grocery store/shop and with the following approximated measures (length, width, height): 10 cm × 10 cm × 3 cm (**Figure 7**). Frozen poultry breast is preferably used; being defrosted in a refrigerator within 24 hours before performing the vascular punctures.

4.2 Vascular component

Tubular structure made in elastic material (modeling balloon) filled with 10 ml of water with water-soluble colorant and sealed on both sides by using knots (**Figure 8**).

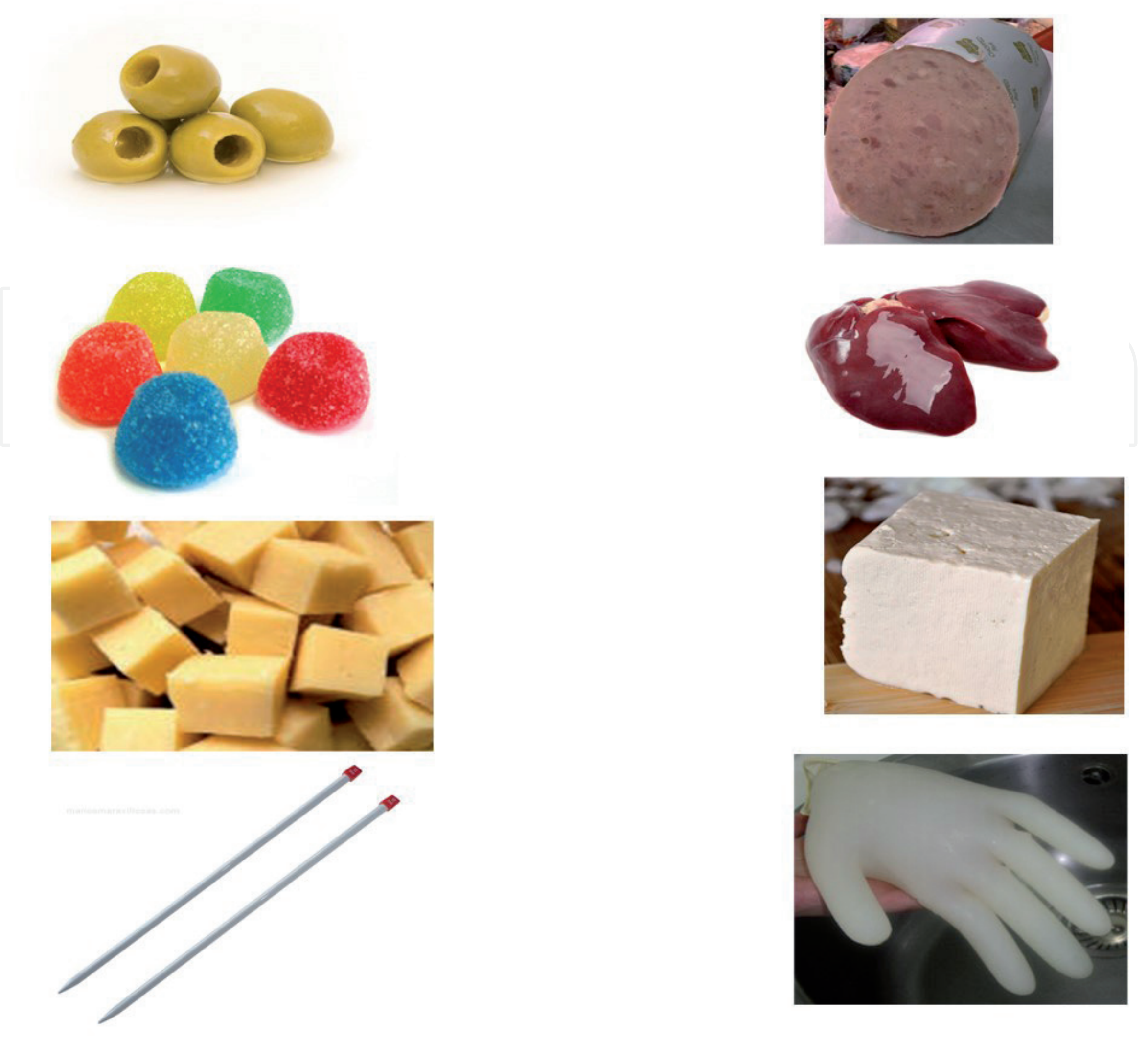

Figure 6.
Components of different puncture-localization models. Left: vascular-nodular structure. Right: tissue-muscle structure.

Both components simulate the muscle and the vascular structures of pediatric patients. The development of this model is based on the introduction of an eight French thoracic drain together with its puncture trocar passing longitudinally through the muscle component and at different depth levels. This simulates the different depths at which vessels are located in children depending on their age and weight. After that, the trocar is retired, and the drain plastic piece remains inside the muscle structure. In the drain distal part, the elastic tubular structure distal end is sutured in the knot area. When pulling the drain in the opposite direction, the device stays inside the muscle structure and then, it is prepared to be visualized and cannulated in an ultrasound-guided manner in this experimental model (**Figure 9**).

A system of clamps fixed at different length permits the application of different tension values on the elastic structure. Depending on these different tension values, three different diameter ranges can be obtained, which are comparable to pediatric patients' vessels diameters. Thus, different ultrasound-guided vascular access difficulty levels can be obtained (**Figure 10**).

To perform puncture and cannulation, a 3-French and 11-cm-length catheter is used, with a 30-cm radiopaque guide and a 5.5-mm needle. Each unit of this model permits the performance of more than 100 punctures without resulting

DOI: http://dx.doi.org/10.5772/intechopen.101901

Figure 7.
Training model muscle component sizes.

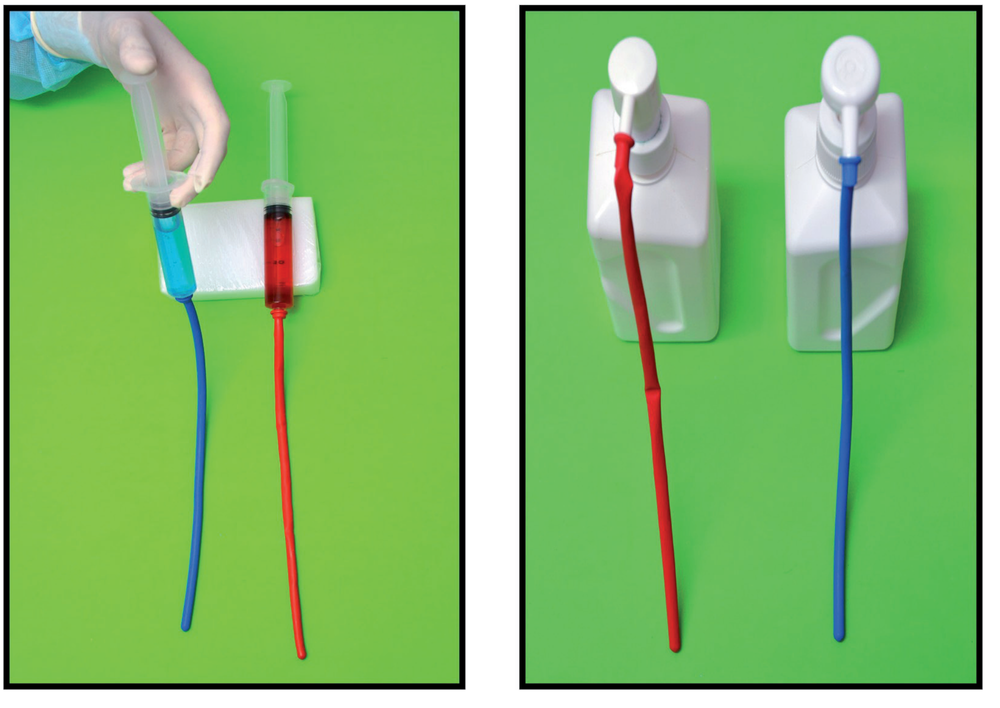

Figure 8.
Vascular structure filling with water-soluble colorant, by using a syringe (left) or a dispenser (right).

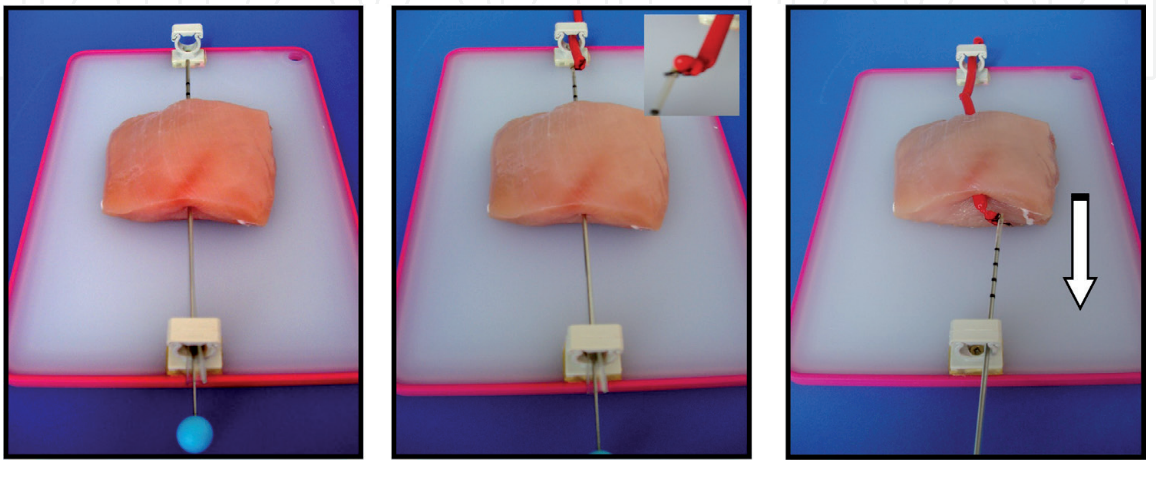

Figure 9.
Left: Puncture trocar passing longitudinally through the model muscle tissue. Middle: Drain suture on the side of the vascular structure which is isolated distal portion (details in the upper-right corner). Right: Placement of the vascular structure inside the muscle structure, and after the traction of the drain sutured to the vascular structure.

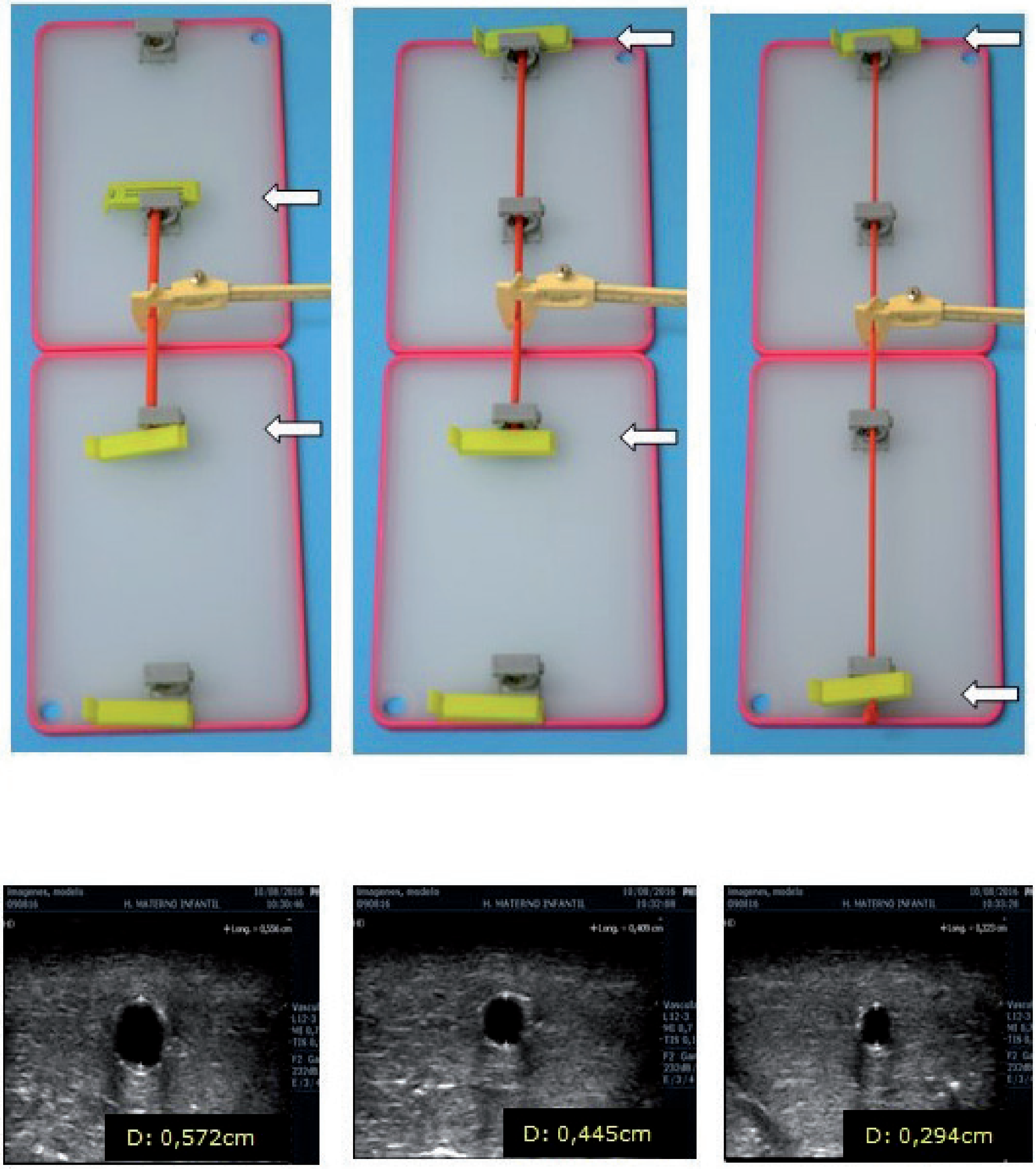

Figure 10.
Vessel's diameters (D1–D3) depending on the stretching degree of the elastic structure with its clamps (arrows) and their ultrasound representation.

deteriorated at a cost of approximately 3 €. The model is replicable and reusable, and it lasts for approximately 6 hours at room temperature. When sessions last less than 6 hours, the model can be stored in an airtight container and refrigerated again. This increases its durability without affecting neither the visualization quality nor the puncture technique.

Ultrasound gel or aqueous solution (double-distilled water or saline 0.9%) are recommended to get a better visualization of the vascular structures.

By using a linear probe ultrasound machine, choosing the "preset vascular," and 2-cm depth, the vascular structure in the training model as well as its correlation with the real image "in vivo" in the patient can be observed (**Figure 11**).

After visualizing the vessel, the depth and diameter of the elastic tubular structure, which is similar to the pediatric patient's vessel, are determined.

DOI: http://dx.doi.org/10.5772/intechopen.101901

It can be stablished 3 depth levels and 3 diameter levels according to preliminary results from 300 depth and diameter measurements of the most common pediatric patients' central vessels. Within these data, different weights and sizes referenced by our group were found (**Table 2**). These measurements were valid with a 99% reliability.

The average values of these measurements are included within nine categories obtained by combining different vessels depths (three ranges) and diameters (three ranges) inside the muscular structure of the training model (**Table 3**).

The training model described permits to perform vessel puncture and cannulation in an ultrasound-guided manner in the three most used vascular-access ultrasound axes: transverse axis-out of plane, oblique axis-in plane, and longitudinal axis-in plane (**Figures 12**–**14**).

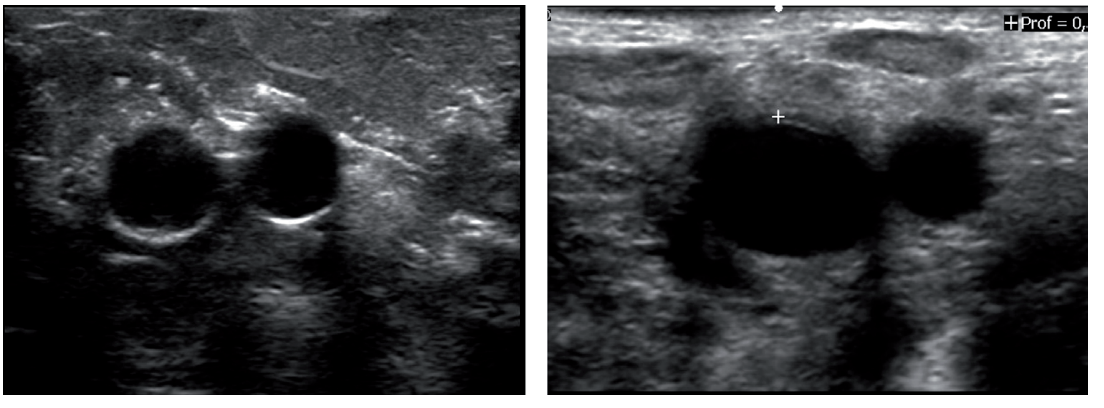

Figure 11.
Experimental training model image (left) with respect to the "in vivo" real image (right).

Weight range	Depth average (SD)	Diameter average (SD)
<10 kg	0.56 cm (0.14)	0.30 cm (0.03)
10–30 kg	0.65 cm (0.17)	0.50 cm (0.18)
30–50 kg	0.90 cm (0.24)	0.69 cm (0.08)
>50 kg	1.65 cm (0.14)	0.70 cm (0.03)

SD, standard deviation.

Table 2.
Depth and diameter measurements (in centimeters: cm) of the main central vessels within the pediatric population (n = 300).

Depth	Diameter
P1: 0.5–1.0 cm	D1: 0.51–0.65 cm
P2: 1.01–1.50 cm	D2: 0.36–0.50 cm
P3: 1.51–2.0 cm	D3: 0.20–0.35 cm

Table 3.
Depth ranges (P1–3) and diameter ranges (D1–3) measured in centimeters (cm) used in the training model for ultrasound-guided vascular access.

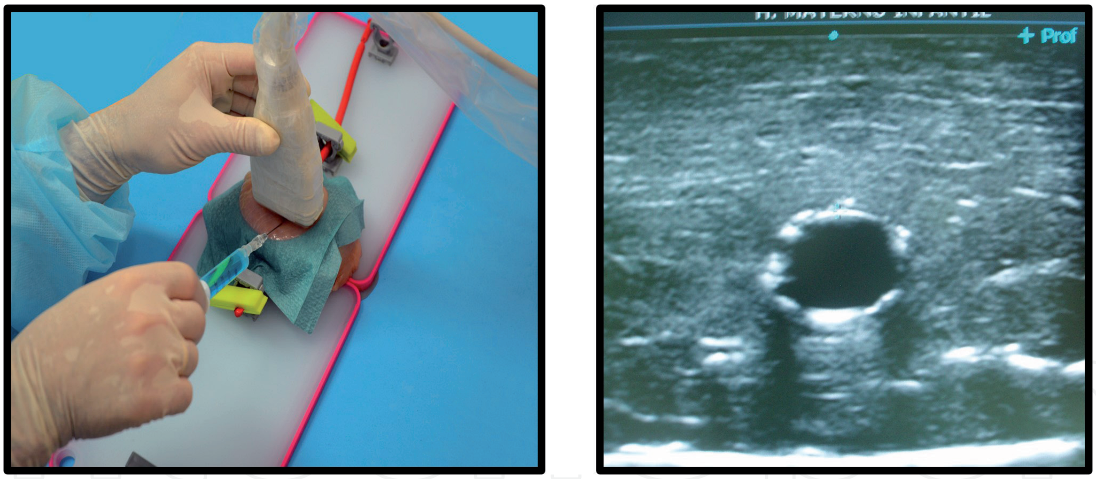

Figure 12.
Left: Puncture needle in the transverse axis-out of plane. Right: Vascular structure ultrasound image in the transverse axis-out of plane.

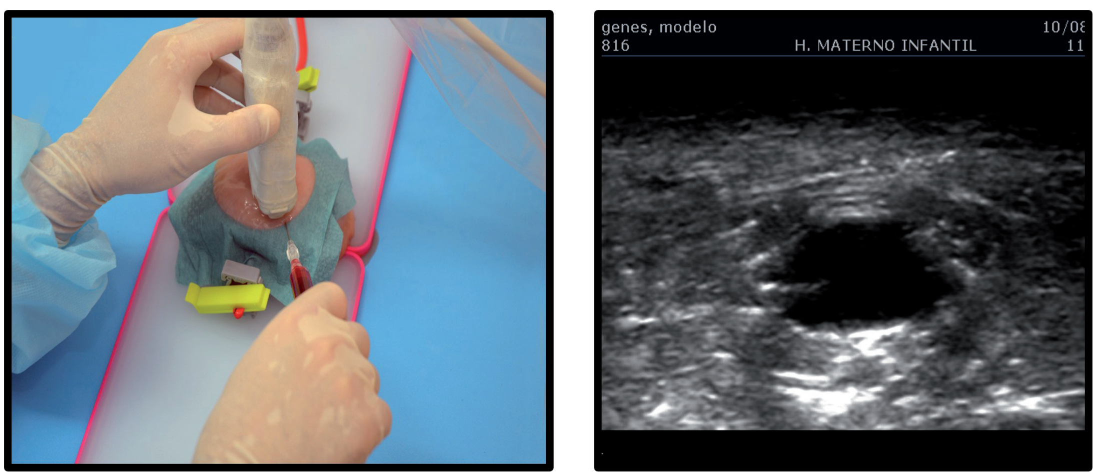

Figure 13.
Vascular visualization and image of the puncture needle in the oblique axis-in plane.

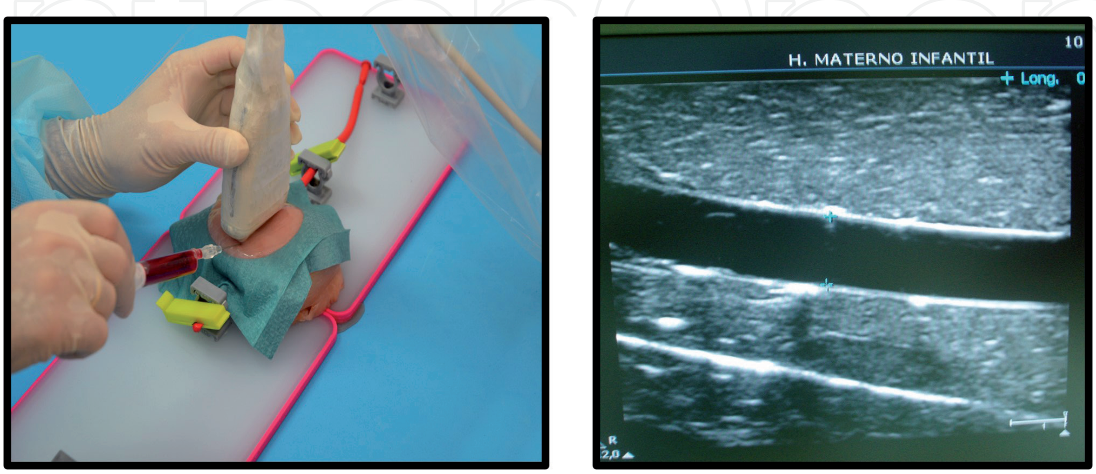

Figure 14.
Vascular visualization and image of the puncture needle in the longitudinal axis-in plane.

5. Considerations to be highlighted with respect to the training models on ultrasound-guided vascular access

Ultrasound-guided vascular access is a tool to decrease the probability of making errors, the risk of complications, and the number of attempts when performing a vascular access [10, 12, 13, 32].

This technique requires a proper training in order to optimize the learning curve which is characteristic of every invasive procedure [17, 18].

Every simulation model, even the most rudimentary and crude, is a useful tool to improve the results of ultrasound-guided vascular access. It will make it possible to minimize the probability of complications and, with respect to the professionals performing this technique, their trust in this technique performance will be increased [11, 14, 24].

The simulation model described by our research team to perform ultrasound-guided vascular access has been used in more than 800 punctures [8, 17, 18]. After testing most of the previously described models, it could be said that the structure provided by this model is closely similar to pediatric patient's muscular and vascular structures, and that it resembles these patients' vessels anatomy, depth, and diameter with respect to the children's weight. This model improves the learning curve to acquire the skill required by this technique when it is performed by doctors trained in vascular access by following the instructions of the classical technique ("blindly" oriented by anatomic references), by doctors not trained in vascular access or by nurses to cannulate peripherally inserted central catheter [14, 24].

This model is inexpensive, easy to prepare and transportable, and it permits the visualization of the vascular structures, the measurement of these structures, the ultrasound-guided cannulation, and the visualization of the needle from the different ultrasound axes. It also permits maneuvering in response to access difficulties, such as needle replacement/reinsertion, and checking the correct cannulation by visualizing the guide inside the vascular structure [8].

In addition, this model reproduces the different depth and diameter ranges of children's vessels. So, taken together with the above, each simulation performed by using this model can be used to develop the skills required to perform ultrasound-guided vascular accesses [19, 20].

Author details

J.M. López Álvarez[1,2]*, O. Pérez Quevedo[1], S. Alonso-Graña López-Manteola[1], J. Naya Esteban[2,3], J.F. Loro Ferrer[4] and D.L. Lorenzo Villegas[5]

1 Unit of Pediatric Intensive Medicine, Mother and Child University Hospital of the Canary Islands, Canary Islands, Spain

2 Department of Nursing, Fernando Pessoa-Canarias University, Las Palmas de Gran Canaria, Spain

3 Unit of Interventive Vascular Radiology, Mother and Child University Hospital of the Canary Islands, Canary Islands, Spain

4 Department of Clinical Sciences, University of Las Palmas de Gran Canaria, Spain

5 Fernando Pessoa-Canarias University, Las Palmas, Spain

*Address all correspondence to: jmloal@hotmail.com

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

[1] Nestel D, Groom J, Eikeland-Husebø S, O'Donnell JM. Simulation for learning and teaching procedural skills: The state of the science. Simulation in Healthcare. 2011;**Suppl.6**(7):S10-S13. DOI: 10.1097/SIH.0b013e318227ce96

[2] Schmidt GA, Kory P. Ultrasound-guided central venous catheter insertion: Teaching and learning. Intensive Care Medicine. 2014;**40**:111-113

[3] Rothschild JM. Ultrasound guidance of central vein catheterization. In: Making Health Care Safer: A Critical Analysis of Patient Safety Practices. Evidence Report/Technology Assessment: Number 43. AHRQ Publication No. 1-E058, July 2001: Chapter 21. Rockville, MD: Agency for Healthcare Research and Quality; 2001

[4] Franco Sadud R, Schnobrich D, Mathews BK, Candotti C, Abdel-Ghani S, Pérez MG, Chu Rodgers S, Mader MJ, Haro EK, Dancel R, Cho J, Grikis L, Lucas BP. Recommendations on the Use of Ultrasound Guidance for Central and Peripheral Vascular Access in Adults: A Position Statement of the Society of Hospital Medicine. 2019. Available from: https://n9.cl/p5rui

[5] Naur TMH, Nilsson PM, Pietersen PI, Clementsen PF, Konge L. Simulation-Based Training in Flexible Bronchoscopy and Endobronchial Ultrasound-Guided Transbronchial Needle Aspiration: A Systematic Review. 2017. Available from: https://n9.cl/2394

[6] Ault MJ, Rosen BT, Ault B. The use of tissue models for vascular access training. Journal of General Internal Medicine. 2006;**21**:514-517

[7] Kendall JL, Faragher JP. Ultrasound-guided central venous access: A homemade phantom for simulation. CJEM. 2007;**9**:371-373

[8] Pérez Quevedo O, López Alvarez JM, Limiñana Cañal JM, Loro Ferrer JF. Design and application of model for training ultrasound-guided vascular cannulation in pediatric patients. Medicina Intensiva. 2016;**40**(6):364-370. DOI: 10.1016/j.medin.2015.11.005

[9] Rippey JCR, Blanco P, Carr PJ. An affordable easily constructed model for training in ultrasound-guided vascular access. The Journal of Vascular Access. 2015;**16**(5):422-427

[10] Moureau N et al. Evidence-based consensus on the insertion of central venous access devices: Definition of minimal requirements for training. British Journal of Anaesthesia. 2013;**110**: 347-356

[11] Kim YH. Ultrasound phantoms to protect patients from novices. The Korean Journal of Pain. 2016;**29**(2): 73-77. DOI: 10.3344/kjp.2016.29.2.73

[12] Adhikari S, Schmier C, Marx J. Focused Simulation Training: Emergency Department Nurses' Confidence and Comfort Level in Performing Ultrasound-Guided Vascular Access. 2015. Available from: https://cutt.ly/ccgRTDz

[13] Vieira RL, Gallagher RA, Stack AM, Werner HC, Levy JA. Development and evaluation of a program for the use of ultrasound for central venous catheter placement in a Pediatric Emergency Department. Pediatric Emergency Care. 2013;**29**:1245-1248

[14] Hocking G et al. A review of the benefits and pitfalls of phantoms in ultrasound-guided regional anesthesia. Regional Anesthesia and Pain Medicine. 2011;**36**:162-170

[15] Baddoo H, Djagbletey R, Owoo C. A simple tissue model for practicing ultrasound guided vascular cannulation. Ghana Medical Journal. 2014;**48**:47-49

[16] Syed Farjad S et al. Simulators for training in ultrasound guided procedures. Medical Ultrasound. 2013;**15**(2):125-131

[17] López-Álvarez JM, Pérez-Quevedo O, Naya-Esteban J, Ramirez-Lorenzo T, López-Manteola SA, Lorenzo-Villegas DL. Evaluation of training in pediatric ultrasound-guided vascular cannulation using a model. Journal of Medical Ultrasound. 2020;**29**(3):171-175. DOI: 10.4103/JMU.JMU_109_20

[18] López-Álvarez JM, Pérez-Quevedo O, Naya-Esteban J, et al. Ultrasound-guided pediatric vascular cannulation by inexperienced operators: Outcomes in a training model. Journal of Ultrasound; 2021. DOI: 10.1007/s40477-021-00585-9

[19] López Álvarez JM, Pérez Quevedo O, Santana Cabrera L, Escot CR, Loro Ferrer JF, Lorenzo TR, et al. Vascular ultrasound in pediatrics: Estimation of depth and diameter of jugular and femoral vessels. Journal of Ultrasound. 2017;**20**(4):285-292. DOI: 10.1007/s40477-017-0272-3

[20] López Alvarez JM, Pérez Quevedo O, Santana Cabrera L, Rodríguez Escot C, Ramírez Lorenzo T, Limiñana Cañal JM, et al. Vascular ultrasound in pediatrics: Utility and application of location and measurement of jugular and femoral vessels. Journal of Medical Ultrasonics. 2018;**45**(3):469-477. DOI: 10.1007/s10396-017-0853-y

[21] Schofer JM, Nomura JT, Bauman MJ, Sierzenski PR. Prospective durability testing of a vascular access phantom. The Western Journal of Emergency Medicine. 2010;**11**(4):302-305

[22] Hauglum SD, Crenshaw NA, Gattamorta KA, Mitzova-Vladinov G. Evaluation of a low-cost, high-fidelity animal model to train graduate advanced practice nursing students in the performance of ultrasound-guided central line catheter insertion. Simulation in Healthcare. 2018;**13**(5):341-347. DOI: 10.1097/SIH.0000000000000337

[23] Ryan LK, Foster FS. Tissue equivalent vessel phantoms for intravascular ultrasound. Ultrasound in Medicine & Biology. 1997;**23**(2):261-273. DOI: 10.1016/s0301-5629(96)00206-2

[24] Pepley DF, Sonntag CC, Prabhu RS, Yovanoff MA, Han DC, Miller SR, et al. Building ultrasound phantoms with modified polyvinyl chloride: A comparison of needle insertion forces and sonographic appearance with commercial and traditional simulation materials. Simulation in Healthcare. 2018;**13**(3):149-153. DOI: 10.1097/SIH.0000000000000302

[25] Sanchez-de-Toledo J, Villaverde I. Advanced low-cost ultrasound-guided vascular access simulation: The chicken breast model. Pediatric Emergency Care. 2017;**33**(9):e43-e45. DOI: 10.1097/PEC.0000000000000620

[26] Wang X, Joyce C, Kuipers JJ. Making a convenient, low-cost phantom with a previously unreported material for practicing ultrasound-guided procedures. Clinical Ultrasound. 2021;**49**(9):987-991. DOI: 10.1002/jcu.23065

[27] Kwon SY, Hong SH, Kim ES, Park HJ, You Y, Kim YH. The efficacy of lumbosacral spine phantom to improve resident proficiency in performing ultrasound-guided spinal procedure. Pain Medicine. 2015;**16**(12):2284-2291. DOI: 10.1111/pme.12870

[28] Chao SL, Chen KC, Lin LW, Wang TL, Chong CF. Ultrasound phantoms made of gelatin covered with hydrocolloid skin dressing. The Journal of Emergency Medicine. 2013;**45**(2):240-243. DOI: 10.1016/j.jemermed.2012.11.022

[29] Morrow DS, Broder J. Cost-effective, reusable, leak-resistant ultrasound-guided vascular access trainer. The Journal of Emergency Medicine. 2015;**49**(3):313-317. DOI: 10.1016/j.jemermed.2015.04.005

[30] Shanks D, Wong RY, Roberts JM, Nair P, Ma IW. Use of simulator-based medical procedural curriculum: The learner's perspectives. BMC Medical Education. 2010;**10**:77. DOI: 10.1186/1472-6920-10-77

[31] Barsuk JH, McGaghie WC, Cohen ER, O'Leary KJ, Wayne DB. Simulation-based mastery learning reduces complications during central venous catheter insertion in a medical intensive care unit. Critical Care Medicine. 2009;**37**(10):2697-2701

[32] López Álvarez JM, Pérez Quevedo O, Ramírez Lorenzo T, Limiñana Cañal JM, Loro Ferrer JF. Ultrasound-guided vascular cannulation. Experience in critically-ill pediatric patients. Archivos Argentinos de Pediatría. 2018;**116**(3):204-209. DOI: 10.5546/aap.2018.eng.204

IntechOpen