The critical role of high-fidelity simulation in ultrasound education and training

CAE

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Introduction

> "One day, we will be able to know exactly what we are treating in full detail, with anatomical detail using ultrasound, which has no side effects or dangers compared to other modalities."
>
> Dr. André Denault
>
> *Professor of Anesthesia and Critical Care, Montreal Heart Institute*

Diagnostic ultrasound, also called sonography or diagnostic medical sonography, uses high-frequency sound waves to provide real time medical imaging that can provide valuable information for diagnosing and treating a variety of diseases and conditions.[1]

Widely acknowledged as safe and effective, the use of ultrasound imaging continues to grow and evolve. As ultrasound usage increases, so does the demand for individuals skilled in ultrasound techniques, with high-fidelity simulation playing an increasingly critical role in the education and training of the next generation of healthcare professionals.

Efficiency and safety in ultrasound imaging

While magnetic resonance imaging (MRI) or computed tomography (CT) scanning can be potentially harmful and a point-in-time "snapshot," ultrasound uses sound waves and provides continuous real-time imagery.

The U.K.'s National Health Service identifies three main types of ultrasound scans[2] as:

- **External**—a small probe is placed on the skin and moved over the body. External ultrasounds can be used to examine organs in the abdominal and pelvic areas, as well as muscles and joints.
- **Internal**—a small probe is inserted into the vagina or rectum. Internal ultrasounds can be used to get a closer look at the prostate gland, ovaries or womb.
- **Endoscopic**—a probe is attached to an endoscope, which is then inserted into the body, typically through the mouth. Endoscopic ultrasounds can be used to examine the esophagus and stomach.

Considered by the U.S. Food and Drug Administration to have an "excellent safety record,"[3] ultrasound imaging can:

- Achieve the desired level of image detail, without risk to medical staff or patients
- Function with a single operator, often using a handheld device
- Provide diagnostic capabilities at a lower cost, an especially attractive quality for low- and middle-income countries.[4]

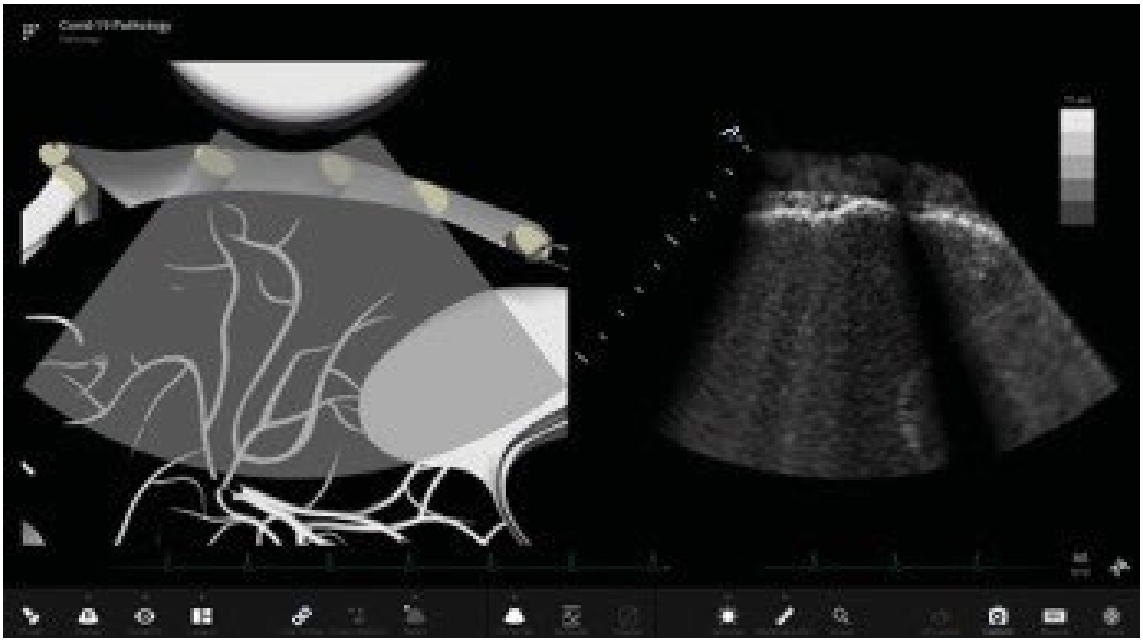
Dr. André Denault, professor of anesthesia and critical care at the Montreal Heart Institute (MHI), predicts that, "One day, we will be able to know exactly what we are treating in full detail, with anatomical detail using ultrasound, which has no side effects or dangers compared to other modalities."

Increasing usage of point-of-care ultrasound

For traditional, consultative ultrasound imaging, a sonographer or radiologist acquires, analyzes and optimizes a series of ultrasound scans. Like traditional ultrasound, bedside or point-of-care ultrasound (POCUS) provides safe, real-time imaging in a cost-efficient manner, with the added benefit of portability. While a sonographer or radiologist is not required for POCUS, it can be performed by a variety of clinicians that can have potentially limited ultrasound training. Although POCUS can also effectively address a single or small number of clinical questions, thorough ultrasound examination requires the expertise of highly trained professionals.

Commonly used in acute and critical-care environments, POCUS has been shown to decrease the length of emergency department stays and improve patient outcomes. Increased integration of POCUS in medical education has shown the potential for growth in collaborative management and coordinated patient care.[5]

POCUS is being used with increasing frequency in low- and middle-income countries,[4] as advances in ultrasound technology have generally resulted in more affordable machines.[6]



COVID-19 propels POCUS to the forefront

POCUS has provided a safer, more accessible way to assess COVID-19 patients while reducing risk of transmission.

The use of handheld devices, as in POCUS, can assist in reducing the use of personal protective equipment (PPE) and address concerns about infection control.[7] As such devices are more easily disinfected, their use may also help limit the number of healthcare workers and medical devices exposed to COVID-19.[8] Furthermore, using POCUS for the initial examination of a patient can provide guidance on the need for further imaging, thereby ensuring PPE usage is as efficient as possible.[9]

Additionally, a study on the effectiveness of POCUS training found that it has played an important role in evaluating cardiopulmonary pathology in presumed and confirmed COVID-19 patients.[10]

Rising importance of training skilled professionals

According to the Society for Academic Emergency Medicine (SAEM), the value and need for clinical ultrasound education have not changed during the pandemic and have arguably grown.[7] The COVID-19 pandemic has only reinforced the importance of preparing for future global emergencies in which POCUS will be an asset. Continued education to train future POCUS healthcare professionals is essential.[11]

In addition to training the next generation of sonography practitioners, POCUS education has been shown to have a positive impact on healthcare management.[5] As the Journal of Hospital Medicine urges, "Practicing hospitalists must continue to collaborate with their institutions to build POCUS capabilities."[12]

Current approaches to ultrasound imaging education

Globally, the profile of healthcare professionals performing ultrasound imaging varies. According to the European Journal of Ultrasound:

- Physicians practice and deliver ultrasounds in many European countries.
- In some English-speaking countries, notably Australia, Canada and the U.S., trained sonographers perform ultrasounds.[13]

In countries like Canada, which has ultrasound educational programs dedicated to training future sonographers, accredited programs often include didactic and clinical components.[14]

For the SAEM, POCUS educational components typically include understanding the indications for imaging, learning skills for image acquisition, interpreting ultrasound images and learning how to integrate findings into medical decision-making.[11] Simulation, both practice-based and clinical-based, is often incorporated into POCUS training to assess competency and ensure quality assurance.[5]

At the MHI, anesthesiology residents complete a two-day training using simulators within their first two months to learn and experience bedside ultrasound in their first year as residents, and transesophageal echocardiogram (TEE) in their third year. In addition, they have a one-month rotation on bedside ultrasound in the intensive care unit.

Addressing the shortage of skilled ultrasound imaging professionals

Given the need for certified ultrasound imaging professionals, the question remains: Will there be enough skilled individuals to conduct necessary ultrasound work? Healthcare professionals are anticipating the answer is no.

PubMed-indexed and peer-reviewed journal, JMIR Medical Education sees an imbalance in the healthcare professionals educated and trained well enough in the use of ultrasound imaging.[15] Reports and Data predicts, "Dearth in skilled professionals to handle the equipment or lack of training may hinder the growth of the ultrasound market in the coming years."[16]

The Australasian Sonography Association cites, "A 10-year critical shortage of sonographers in Australia, caused by the poor availability of clinical training placements."[17]

As Dr. Sam Orde, University of Sydney associate professor and director of the Nepean Hospital Intensive Care Unit, explains, "Critical care doctors are learning an advanced form of imaging with little direction at times. It's often difficult for critical care doctors to get time in echocardiogram labs."

Lack of time to practice in a lab, or through clinical placements is a widespread issue for many areas of specialty.

If sonography training doesn't increase availability and access, artificial intelligence (AI) is a potential alternative. AI can address some ultrasound challenges, such as the shortage of trained sonographers.[18]

Some view this prospect with trepidation, given removing the sonographer would then eliminate the interaction between sonographer and patient.

Simulation in ultrasound education, training and research

Between the COVID-19 pandemic and the global shortage of clinical sites for sonography training, simulation is playing an increasing role in the education of the next generation of healthcare professionals to perform ultrasound imaging.

Simulation in clinical education

Simulation is a core component in educating healthcare practitioners. Simulation sessions can draw from a variety of technologies, creating an interactive learning experience that can include Standardized Patients (SP) and manikins.

During the COVID-19 pandemic, augmented and virtual reality simulation have played an important role.[19]

The Healthcare Simulation Dictionary—Second Edition defines high-fidelity simulation as, "Simulation experiences that are extremely realistic and provide a high level of interactivity and realism for the learner. It can apply to any mode or method of simulation; for example: human, manikin, task trainer, or virtual reality."

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>
> Healthcare Simulation Dictionary–Second Edition

High-fidelity simulation offers compelling advantages, including:

- **Efficiency**—providing more learners with more opportunities to practice skills and gain experience in stressful situations in a risk-free environment, potentially accelerating learning, and allowing learners to build competency at their own pace. The Yale Journal of Biology and Medicine reinforces this idea, stating, "Simulators and e-learning can allow efficiency in resource allocation and control cost in orienting new students to ultrasound. Advances in ultrasound technology have created newer, more affordable machines which can decrease cost considerably."
- **Effectiveness**—proving more effective (knowledge retention, performance), compared to other teaching methods.[20]

  For example, high-fidelity simulation learning has shown to increase test results for French medical students on the National Ranking Examination, when compared to traditional forms of learning.[21]
- **Education**—creating opportunities to increase anatomical understanding beyond training healthcare professionals.

  Denault refers to simulation's ability to recreate and reexamine anatomy and pathology, "You can see gout pathology with ultrasound better than with MRI or CT scan."

Simulation advantages in ultrasound training

An article in Radiography, the official peer-reviewed journal of the Society and College of Radiographers and the European Federation of Radiographer Societies, recommends the incorporation of preclinical simulation into the core curriculum of sonographer courses to improve student performance, reduce the burden on clinical staff and increase patient safety during the early stages of ultrasound education.[22]

Orde finds value in simulation for learners at various levels. "Particularly when teaching candidates learning basic-level echocardiogram, the simulator is extremely powerful to demonstrate different pathology. At an advanced level, simulation helps to assess competence," he says.

Ultrasound requires theoretical knowledge and practical experience, and simulation offers:

- A safe environment to learn and practice using ultrasound[15]
- A controlled, learner-centered environment that allows for continued practice without patient discomfort or harm[15]
- The opportunity for real-time feedback on a range of topics, from positioning technique to interpersonal skills
- Improved technique proficiency, compared with traditional apprenticeship models [23]

While simulation-based learning cannot (yet) effectively replace clinical experience, it can add value to comprehensive POCUS training. Appropriately designed cases can be used to assess a trainee's ability to recognize both common and rare diagnoses, and demonstrate reproducible image acquisition and interpretation.[5]

For future sonographers, learning effective ultrasound techniques requires hands-on practice with a transducer. When COVID-19 prompted clinical sites to close, simulation created the possibility for portions of ultrasound education to continue remotely.

> "Ultrasound simulation demonstrates the utility of kinetic learning (e.g., where to put your hand) versus cognitive learning (e.g., what to do with the information once you've got it)."
>
> Dr. Sam Orde
>
> *Associate Professor, University of Sydney*
> *Director of the Intensive Care Unit, Nepean Hospital*

The Radiological Society of North America recognizes hands-on practice with high-fidelity computerized manikins as another confidence-builder for training radiologists.[24]

This is especially true for some areas of specialty. For example, when there is limited training exposure to delicate exams such as transvaginal, testicular and obstetrics, simulation can allow for more efficient learning opportunities.

Potential of simulation in research

Despite these advantages, simulation can be underused in ultrasound education, especially in a research capacity, Denault suggests, if the potential and possibilities for use are not fully understood.

Continued research could address questions such as:

- Is simulation the best way to learn something?
- Is simulation the best way to teach certain abilities?
- Does simulation make certain tasks faster or more efficient?

Orde sees potential to leverage simulation in sonography-related research to understand when a learner achieves competence. "At the moment, assessment is relatively subjective," he says. "With high-fidelity simulation, there is potential to have the same pathology, same difficulty of scanning, same everything, to accurately determine if scanning and conclusions are correct."

CAE Healthcare, your resource for ultrasound education and training

Today's ultrasound instructors and learners face unique challenges that stem from the COVID-19 pandemic, including the closure of college campuses and simulation centers, and reduced exposure to clinical patients. Then, there are pre-existing constraints to overcome in terms of access and training due to limited funding and/or instructor availability.

Within these realities, instructors and learners are often seeking quality, high-fidelity training options that allow for learning at a distance and the ability to build a custom curriculum.

CAE Healthcare recognizes and effectively addresses both pandemic-driven and pre-existing needs with:

- A full suite of ultrasound simulation solutions
- Consulting services for deeper customization
- On-demand, free education with a variety of webinars

Full suite of ultrasound simulation

CAE Healthcare's comprehensive suite of ultrasound simulation training solutions can be used for in-person or remote education, with a range of options that include robust, high-fidelity simulation, durable task trainers, and interactive e-learning tools and content.

Complete Ultrasound Training Suite for COVID-19

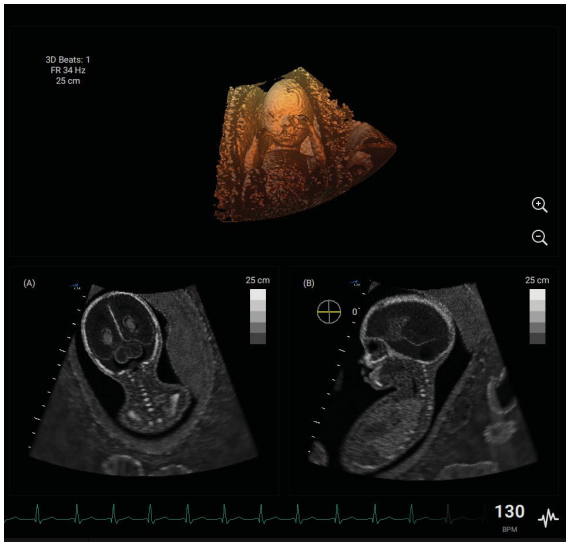
The CAE Healthcare Complete Ultrasound Training Suite for COVID-19 provides hands-on foundational training to help healthcare professionals learn to scan and assess coronavirus patients using POCUS, an efficient, accessible and safe way to assess COVID-19 patients that reduces the risk of transmission.

The Suite combines the best of three CAE Healthcare hardware and software product platforms:

- **CAE Vimedix 3.0**
- **CAE Blue Phantom**
- **CAE ICCU e-Learning**

Find more information on CAE's Complete Ultrasound Training Suite for COVID-19, visit **caehealthcare.com/covid19**.

CAE Vimedix 3.2



CAE Vimedix is a comprehensive and easy-to-use ultrasound simulation platform for developing cognitive and psychomotor skills. To aid ultrasound trainees in building proficiency for clinical preparedness, the platform includes a gaming laptop, manikin, simulative probes and software program featuring remote-learning capabilities.

The Vimedix 3.2 software update enables even more advanced technology for realistic scanning and structural detail for accuracy. Improved fidelity and realism in Vimedix 3.2 means more granular anatomy for the heart and abdominal organs; 3D/4D scanning for cardiac, abdominal and OB-GYN modalities; and multiplanar reconstruction (MPR), an imaging technique which converts data from a certain plane, i.e., axial, into another anatomical plane view, for cross-sectional visualization.

Users of the customizable Vimedix 3.0 platform with an active support and maintenance contract can enjoy the upgrade to Vimedix 3.2 for free.

Learn more about CAE Vimedix at **caehealthcare.com/vimedix**.

The Vimedix 3.2 system replicates real-time visual, physical and ergonomic attributes of ultrasound scanning, and features:

- Simulator content and kinematic metrics, which are validated through numerous scientific publications published in peer-reviewed journals
- Continuous development of new functionalities and content, including a COVID-19 case study
- Customizable content and curricula, with custom filters and pre-sets

Self-directed, instructional content modules make ultrasound learning easily scalable within Vimedix 3.2, and allow learners to independently practice basic probe movements, optimization of image settings, obtaining views using target cut planes and echocardiographic measurements. Plus, with localization, a variety of global markets can take advantage of this training tool.

Modules to meet your training needs

Through a vast library of more than 200 pathologies, self-directed learning activities, visualization tools and validated performance metrics within Vimedix 3.2, users can increase competencies in assessing patients. As the only ultrasound simulator to allow trainees across multiple disciplines to build expertise, available manikins allow for practice in cardiac, abdominal and OB-GYN modalities.

Vimedix 3.2 Cardiac	Vimedix 3.2 Abdo	Vimedix 3.2 OB-GYN
Learn transthoracic echocardiography (TTE) and TEE	Learn to perform abdominal scans and focused assessment with sonography for trauma (FAST) exams	Learn to perform transabdominal and transvaginal ultrasound exams
3D/4D and MPR cardiac ultrasound for advanced assessment and diagnosis	Pleural Pathology Pack features a fully animated lung and respiratory variation of the inferior vena cava (IVC)	Pathologies include the first and second trimesters
The option to hide pathology names using Stealth Mode	Self-directed FAST exam exercise for efficient scanning of trauma in augmented reality with CAE VimedixAR	Ability to perform standard obstetrics measurements and calculations on different fetal positions
Color Doppler and Spectral Doppler (plus, Pulsed Wave and Continuous Wave) of the heart		

Available as an add-on module and supported throughout the Vimedix 3.0 platform, CAE VimedixAR is the first truly immersive ultrasound training application where instructors can guide and teach students in a new and innovative way.

Powered by Microsoft HoloLens 2, VimedixAR provides a holistic view of the anatomy through cut planes. With VimedixAR, learners can:

- Experience anatomy in fully rendered 3D holograms
- Virtually walk around the manikin and obtain different anatomical views
- Elevate, rotate and actively engage with realistic views of internal physiology
- Build deeper understanding of the cut plane with respect to anatomical structures
- Intuitively develop mastery of psychomotor skills to safely manage cardiac, abdominal and OB-GYN ultrasonography

Higher fidelity builds competency, improves accuracy

The newly added 3D/4D ultrasound functionality with MPR in Vimedix 3.2 allows educators to:

- Teach advanced technologies in ultrasound
- Build custom curriculum
- Capture, crop and reconstruct complex 3D structures
- Give both early and fully qualified learners the ability to learn in a risk-free environment—without time pressures or consequences of failure

To build out the 3D/4D and MPR functionality within Vimedix 3.2, CAE Healthcare collaborated with Dr. Feroze Mahmood, director of cardiac anesthesia at Beth Israel Deaconess Medical Center and professor of anesthesiology at Harvard Medical School, along with a team from the Valve Research Group including: Dr. Robina Matyal, Dr. Aidan Sharkey, Dr. Omar Chaudhary, Vincent Baribeau, Dr. Huma Fatima, Dr. Syed Hamza Mufarrih and Dr. Nada Qureshi.

Mahmood considers MPR superior to 2D. He says, "It goes beyond the creation of pretty pictures. There is more information embedded, which allows for improved accuracy and precision."

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>
> Dr. Feroze Mahmood
>
> *Professor of Anesthesiology*
> *Harvard Medical School*
> *Director of Cardiac Anesthesia,*
> *Beth Israel Deaconess Medical Center*

In ultrasound simulation, MPR allows ultrasound learners and educators to capture measurements that would not otherwise be possible. Mahmood says, "You can improve accuracy and precision when you really understand the thickness of the walls in the heart.

Flexibility for remote learning

Vimedix 3.2 allows educators to livestream a predetermined curriculum through web conferencing on streaming platforms, such as Microsoft Teams, WebEx, Zoom and more. When an instructor initiates a session directly from the Vimedix laptop, students can sign in remotely to control and interact with the simulator's features.

Success in the field

The American University of Beirut Medical Center provided an interactive ultrasound simulation workshop in 2019, for physicians, nurses, ultrasound technicians, residents and medical students.

Featuring CAE Vimedix, the simulation-focused workshop included:

- Studying healthcare professionals' need for practicing using ultrasound via simulation
- Understanding simulation's importance in ultrasound education

Following the intervention, the majority of participants agreed ultrasound simulation:

- Provided a realistic setting
- Allowed for training and identification of pathologies
- Should be part of the curriculum either in medical school or residency[15]

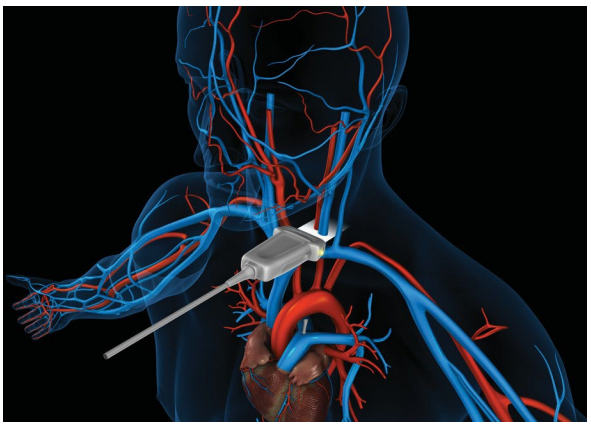
Learn how Vimedix 3.2's capabilities in video conferencing, screen sharing, curriculum development and mixed-reality simulation can benefit your program by visiting **caehealthcare.com/ultrasound-simulation/vimedix**.

CAE Blue Phantom

When full-body manikins are not required for ultrasound simulation, CAE Blue Phantom has all the correct anatomy required for teaching and practicing a particular procedure. Realistic and durable, Blue Phantom is ideal for repeated practice to master ultrasound techniques. All 175 models in the product portfolio are made with patented SimulexUS™ tissue, which is self-healing and replicates the acoustic properties of human tissue.

Explore CAE Blue Phantom ultrasound training models at **caebluephantom.com**.

CAE's ICCU Learning Management System



CAE ICCU e-Learning curricula for ultrasound education helps learners understand the key principles of bedside ultrasound. Offered as a standalone, as part of the CAE Complete Ultrasound Training Suite for COVID-19 and with Vimedix 3.2, the ICCU e-Learning platform features:

- **e-Learning portal**—a collection of interactive multimedia that covers components of focused cardiac TTE and TEE ultrasound exams, assessment of central and peripheral vessels, assessment of the pleural space and lung, and ultrasound-guided procedures for peripheral vascular access
- **Learning center**—a free, online collaborative community that features clinical cases, articles and cases
- **Seminars**—a collection of bedside ultrasound training seminars that feature highly trained critical care physicians and certified sonographers

Discover the benefits of ICCU e-Learning at **caehealthcare.com/ultrasound-simulation/iccu**.

Consulting services for deeper customization

The CAE Healthcare Academy faculty is comprised of experienced healthcare professionals who are experts in simulation. Work with us to address your unique needs in ultrasound training and education, including:

- Design
- Facilitation
- Programming
- Center management

Connect with a CAE Healthcare Academy representative at **training@caehealthcare.com**.

On-demand, free education

CAE Healthcare is your resource for ultrasound education and training, including how to prepare the next generation of sonography professionals. CAE Healthcare shares expertise via free webinars that cover topics such as:

- COVID-19
- Simulation education
- Distance learning options

Visit **caehealthcare.com/education/webinars** to register.

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CAE Healthcare offers simulation-based patient, imaging, interventional and learning solutions to improve patient safety and outcomes. Our leading-edge products and learning modules provide risk-free practice and professional development to physicians, nurses, EMS responders, military medics, students and allied health professionals around the world.

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