Journal of Visualized Experiments

Ultrasonographic Assessment during Cardiopulmonary Resuscitation

--Manuscript Draft--

Article Type:	Invited Methods Article - JoVE Produced Video
Manuscript Number:	JoVE59144R2
Full Title:	Ultrasonographic Assessment during Cardiopulmonary Resuscitation
Section/Category:	JoVE Medicine
Keywords:	ultrasonography, cardiac arrest, cardiopulmonary resuscitation, circulation, airway, trachea, breathing, ventilation
Corresponding Author:	Wei-Tien Chang, M.D., Ph.D. National Taiwan University Hospital and College of Medicine Taipei, Taiwan TAIWAN
Corresponding Author's Institution:	National Taiwan University Hospital and College of Medicine
Corresponding Author E-Mail:	wtchang@ntu.edu.tw;weitienchang@gmail.com
Order of Authors:	Wan-Ching Lien
	Chih-Heng Chang
	Wei-Tien Chang, M.D., Ph.D.
	Wen-Jone Chen
Additional Information:	
Question	**Response**
Please indicate whether this article will be Standard Access or Open Access.	Standard Access (US$2,400)
Please indicate the **city, state/province, and country** where this article will be **filmed**. Please do not use abbreviations.	Taiwan

Dear Editor:

Thank you very much for your invitation! We are pleased to submit this manuscript entitled "**US-CAB for Ultrasonographic Assessment during Cardiopulmonary Resuscitation: Method and Protocol**" for consideration of publication in ***Journal of Visualized Experiments*.**

Ultrasonography (US) is increasingly used during CPR, and has been suggested as an integral part during resuscitation. A novel US-CAB protocol integrates several US techniques into a systematic assessment of the circulation, airway and breathing status during CPR in an ALS-compliant manner, and has been demonstrated its feasibility and impact on CPR outcomes. This manuscript aims at a detailed description of the method and protocol of US-CAB, and the key points to be followed.

The authors declare that the manuscript, as submitted or its essence in another version, is an original work, not under consideration for publication elsewhere, and will not be published elsewhere while under consideration by ***Journal of Visualized Experiments*.** The authors have no commercial associations or sources of support that might pose a conflict of interest.

If any further information is needed, we will be more than happy to provide according to the request or comments from the editor or reviewers. If possible, we hope this manuscript can be published or at least "in press" by Jan. 31, 2019. We look forward to hearing from you with precious comments and suggestions in the near future.

Sincerely yours

Wei-Tien Chang, MD, Ph.D.

Department of Emergency Medicine, National Taiwan University Hospital and College of Medicine, No. 7, Chung-Shan South Road, Taipei 100, Taiwan

Tel: +886-2-23562831

Fax: +886-2-23223150

E-mail: wtchang@ntu.edu.tw

TITLE:
Ultrasonographic Assessment During Cardiopulmonary Resuscitation

AUTHORS AND AFFILIATIONS:
Wan-Ching Lien[1], Chih-Heng Chang[2], Wei-Tien Chang[1,3], Wen-Jone Chen[1,3]

[1]Department of Emergency Medicine, National Taiwan University Hospital and College of Medicine, Taipei, Taiwan, China
[2]Department of Emergency Medicine, National Taiwan University Hospital Chin-Shan Branch, New Taipei City, Taiwan, China
[3]Cardiovascular Division, Department of Internal Medicine, National Taiwan University Hospital and College of Medicine, Taipei, Taiwan, China

Corresponding Author:
Wei-Tien Chang (wtchang@ntu.edu.tw)

Email Addresses of Co-authors:
Wan-Ching Lien (wanchinglien@ntu.edu.tw)
Chih-Heng Chang (herman90021@gmail.com)
Wei-Tien Chang (wtchang@ntu.edu.tw)
Wen-Jone Chen (wjchen1955@ntu.edu.tw)

KEYWORDS:
ultrasonography, cardiac arrest, cardiopulmonary resuscitation, circulation, airway, trachea, breathing, ventilation

SUMMARY:
Here, we present a US-CAB (Ultrasound, Circulation/Airway/Breathing) protocol for use during cardiopulmonary resuscitation (CPR). US-C evaluates the subxiphoid view of the heart and inferior vena cava. After intubation, tracheal US (US-A) and lung US (US-B) help confirm endotracheal intubation and proper ventilation.

ABSTRACT:
The US-CAB (Ultrasound, Circulation/Airway/Breathing) protocol integrates several sonographic techniques into a structured assessment of the circulation, airway, and breathing status of a patient during cardiopulmonary resuscitation (CPR) in an advanced life support-compliant manner. US-C provides a subxiphoid view of the heart, to look for potentially reversible causes of disease, such as pericardial effusion, pulmonary embolism, hypovolemia, and acute coronary thrombosis. Sonographic cardiac activity during CPR not only helps differentiate pseudo-pulseless electrical activity (PEA) from true PEA but also represents a higher chance of the return of spontaneous circulation (ROSC) and survival. Evaluation of the inferior vena cava (IVC) shows the fluid status of the patient and indicates the best methods to use for fluid resuscitation. If aortic dissection is suspected, a subxiphoid view of the aorta is suggested for identifying an intimal flap. Once intubation is done, tracheal ultrasound (US-A) at the suprasternal notch helps

differentiate endotracheal intubation (one air-mucosal interface with one comet-tail) from esophageal intubation (double tract sign). Immediately following US-A, bilateral lung US (US-B) should be done to confirm proper bilateral ventilation using the lung sliding sign. In addition, US-C can be serially followed to see the dynamic changes in the cardiac chambers and IVC, or any cardiac contraction suggestive of ROSC. US-B can also detect coexisting lung or pleural pathologies without interfering with the performance of CPR. The main concern when implementing this method is maintaining high-quality CPR without delays in chest compressions when performing US-CAB. Rigorous training and continued practice are key to minimize any interruptions during resuscitation.

INTRODUCTION:

Effective cardiopulmonary resuscitation (CPR) for cardiac arrest is key to successful revival of a patient. Circulation (C), airway (A), and breathing (B) are the three crucial components in either basic (BLS) or advanced life support (ALS). The evaluation of the C-A-B status during CPR basically relies on pulse checks, auscultation, and capnography[1]. In true clinical conditions, however, CPR is often complex and chaotic, and these methods may have limitations[2,3]. For example, the accuracy of pulse checks is often suboptimal even when performed by healthcare providers[4]. More than half of one lung intubations might be misdirected if guided by auscultation alone[5]. Even wave capnography can be affected by factors such as low cardiac output, low pulmonary flow, and use of epinephrine during CPR[2]. Therefore, more effective, accurate evaluation of the C-A-B status is mandatory.

When trying to search for the etiology of cardiac arrest or any potentially reversible factors during CPR, medical history and physical examination are often insufficient. The detection of reversible causes, such as the 5Hs (i.e., hypoxia, hypovolemia, hyperkalemia/hypokalemia, acidosis, and hypothermia) and the 5Ts (i.e., cardiac tamponade, tension pneumothorax, pulmonary thromboembolism, coronary thrombosis, and toxins or tablets), often requires advanced examinations.

Ultrasound (US) is a useful imaging modality in emergency and critical care settings. The European Resuscitation Council (ERC) Guidelines suggest that US can be an integral part of resuscitation[6]. US can readily identify critical but potentially reversible factors that negatively affect CPR, such as cardiac tamponade, pulmonary thromboembolism, and hypovolemia[7-9]. US also helps rule out pneumothorax and acute coronary syndrome. Moreover, US confers prognostic implications even when CPR is being performed. The presence of sonographic cardiac activity during CPR has been reported to confer higher chances of ROSC, survival, and hospital discharge[10,11]. In addition to sonographic evaluation of the heart and circulation status, tracheal US is employed for confirmation of proper endotracheal intubation[12], while lung US is applied to confirm proper bilateral pulmonary ventilation[13].

While high-quality CPR with minimal interruptions to the compressions is the most important factor for resuscitation, it is important to understand how to seamlessly integrate US into the process of resuscitation without interfering with CPR. We therefore developed a novel, ALS-compliant US-CAB protocol for use during CPR[14]. This paper presents a detailed description of the settings, personnel, and instruments necessary for better integration of the US protocol into the regular CPR process that first-line physicians can easily incorporate and implement into their practice.

PROTOCOL:

This procedure was approved by the Institutional Review Board of the National Taiwan University Hospital and registered at ClinicalTrials.gov (NCT02952768).

1. Instrumentation

1.1. Use a US machine equipped with a curvilinear 2–5 MHz probe. A portable US is more suitable for CPR.

2. Personnel and their roles in the resuscitation team

2.1. Ideally, a resuscitation team should be comprised of six members: 1) a leader; 2) a member for airway management (A) and ventilation (B); 3) one for chest compressions (C); 4) one for defibrillation (D); 5) one for intravenous (IV) catheterization and medication; and 6) a recorder.

2.2. If the personnel is limited, have the roles overlap. When US is integrated into the CPR process, the sonographer should be an independent member of the team who is well trained and experienced in resuscitation US and can intervene and interpret the US images in a timely manner without interrupting or delaying resuscitation efforts. However, the leader can also be the sonographer. He or she can use US to search for any potentially reversible causes of resuscitation failure as early as possible while leading the whole CPR process.

3. Cardiopulmonary resuscitation process

3.1. Perform all resuscitation procedures according to the ALS guidelines[6].

3.2. When US is integrated into the CPR process, strict control to minimize interruption of the chest compressions is the highest priority. Restrict the hands-off interval for pulse checks/rhythm analysis and simultaneous US evaluation to no longer than 10 s.

3.2.1. Use a timer with preset alarms to remind the sonographer of the time intervals. Set the alarm for every 2 min of CPR and 10 s for pulse checks.

4. **US-CAB protocol**

4.1. **US-C**: Use cardiac US (US-C) at the start of CPR and at the end of the first five cycles of chest compressions.

4.1.1. Use the subxiphoid four-chamber view (**Figure 1A**) to check pericardial effusion, the size of the right and left ventricles, and sonographic cardiac activity.

4.1.2. Turn the probe 90° (parallel to the long axis of the patient) to measure the diameter of the IVC (**Figure 1B**).

4.2. **US-A**: Use US-A to check the endotracheal tube location after intubation.

4.2.1. Place the probe transversely at the suprasternal notch (**Figure 1C**).

4.2.2. Note the one air-mucosal interface with one comet-tail artifact (single tract sign) for tracheal intubation.

4.2.3. Move the probe to the lateral side of the neck to reconfirm the single tract sign.

4.2.4. Perform reintubation if there are two air-mucosal interfaces with two comet-tail artifacts (double tract sign)[12].

4.3. **US-B**: Use US-B to check proper ventilation.

4.3.1. Put the probe on either side of the chest at the 4th–5th intercostal spaces over the midaxillary line (**Figure 1D**).

4.3.2. Detect lung sliding to evaluate pulmonary ventilation[11,13].

4.3.3. If lung sliding is absent on one side, adjust the depth of the endotracheal tube until bilateral lung sliding is noticed.

4.4. **US-C**: Repeat US-C every 2 min when chest compression is stopped for pulse checks.

4.5. Repeat US-AB after transportation and bed transfer of the patient.

5. Settings and approach during CPR

5.1. Keep the US machine ready in the resuscitation room of the emergency department. In cases of in-hospital cardiac arrest, a portable US device can be brought to the scene immediately, and turned on instantly.

5.2. Because a lot of resuscitation procedures are performed around the head, neck, and chest of the patient (e.g., chest compressions, defibrillation, intubation, ventilation, etc.), place the US machine in the caudal area of the patient (**Figure 2**). For example, it should be located over the patient's right side for a right-handed sonographer and vice versa. This way the sonographer can get the probe ready and immediately assess the patient's condition.

6. Image acquisition and recording

6.1. Have the US images interpreted by the sonographer and print or store important images for medical records and further discussion with the resuscitation team.

6.2. Ideally, store the US images in the hard disk of the US machine for regular (e.g., monthly) review, either for quality assurance or teaching purposes. Video recording is even better, as it not only provides important information that is less well characterized by still photos but also offers materials for training or subsequent analysis.

7. Data interpretation and analysis

7.1. Have the sonographer interpret the US images during CPR on-site to help with clinical judgement and decision making. A sonographer, after structured training and continued practice, can perform sonographic evaluation and interpret the data in real CPR scenarios. The interpretation and discussion of the data can also be done by all resuscitation team members during debriefing immediately after the post-CPR phase. The discussion focuses not only on US diagnosis, but on the therapeutic interventions and impact on CPR outcomes following the US examination.

7.2. For research purposes, also have interpretation done afterwards by blinded researchers.

REPRESENTATIVE RESULTS:

US-C with subxiphoid evaluation of the heart displays a cardiac four-chamber view as shown in **Figure 3A**. At this point, detection of any of the three typical patterns suggestive of specific etiologies or reversible factors is possible.

Identify the presence and characters of pericardial effusion: If pericardial effusion is present, notice if the right heart chambers (i.e., the right atrium or even the right ventricle) are compressed. If compression of the right atrium and ventricle is noted (**Figure 3A**), pericardiocentesis is indicated and should be done immediately. If there is no compression of the right heart chambers, whatever the effusion amount is, CPR should be continued and pericardiocentesis should not be performed to not waste time. Pericardial effusion is also of diagnostic value. If the echogenicity is high or blood clots are present in the pericardial sac, the etiology could be cancer, aortic dissection with rupture into pericardium, etc. The nature of the pericardial effusion and the possible underlying etiologies can guide the decision whether to perform pericardiocentesis.

If pericardial effusion is absent, evaluate the size of the ventricles. If the right ventricle is dilated, with the interventricular septum compressing the left ventricle, increased right ventricular pressure is likely. Pulmonary embolism should be taken into consideration in this case, especially if there is jugular vein engorgement or unilateral leg swelling.

If the right heart chambers are small in size or even collapsed, marked hypovolemia is suspected in patients with substantial gastrointestinal bleeding or dehydration.

While verifying the three typical patterns (i.e., cardiac tamponade, pulmonary embolism, and hypovolemia), sonographic cardiac activity should be clarified. This can help differentiate pseudo-PEA from true PEA, detect fine ventricular fibrillation, and identify regional wall motion abnormalities in specific coronary artery territories.

US-C with subxiphoid evaluation of the IVC can be demonstrated by a vertical approach (**Figure 1B**). Visual identification of the IVC diameter helps assess the fluid status of the patient (**Figure 3B**). The IVC can also be evaluated with the subxiphoid transverse view (**Figure 3C**).

US-C with subxiphoid verification of the descending abdominal aorta can be approached via a vertical (**Figure 3D**) or transverse view (**Figure 3C**). Though optional, this evaluation is recommended if aortic dissection is suspected from clinical presentation or when hemopericardium is observed on US-C cardiac evaluation (**Figure 3A**).

US-A for confirmation of the location of the endotracheal tube can be done after intubation or any time during CPR when dislodgement is suspected. Endotracheal intubation is confirmed if a single tract sign is observed (**Figure 4A**). If there is a double tract sign, esophageal intubation is highly likely.

US-B is usually done immediately after US-A when auscultation or capnography is being performed by other team members. However, it can also be done any time during CPR when displacement of the endotracheal tube with one lung intubation is suspected, or when specific etiologies such as pneumothorax (**Figure 4B**) or hemothorax need to be ruled out.

FIGURE AND TABLE LEGENDS:

Figure 1: Ultrasonographic (US) approach in US-CAB protocol. (**A**) Subxiphoid assessment of the heart. (**B**) Subxiphoid vertical approach for assessment of the inferior vena cava and aorta. (**C**) Tracheal US with the probe placed transversely on the anterior neck superior to the suprasternal notch. (**D**) Lung US with probe placed on mid axillary line at the 4th to 5th intercostal space, left side first and then right side.

Figure 2: Settings of ultrasound (US) and sonographers during cardiopulmonary resuscitation.

Figure 3: Representative images of US-C, A and B. (**A**) Subxiphoid four-chamber view of the heart showing pericardial effusion with compression of the right ventricle (arrow). (**B**) Subxiphoid vertical view of the IVC. (**C**) Subxiphoid transverse view of the IVC and aorta. (**D**) Subxiphoid vertical view of the aorta.

Figure 4: Ultrasonographic (US) assessment of endotracheal tube location and bilateral ventilation. (**A**) Tracheal US demonstration of single air-mucosa interface (asteroid = single comet tail sign). (**B**) Lung US assessment for lung sliding sign (left, 2D image; right, M-mode image).

DISCUSSION:

US is a noninvasive, real-time, and readily available imaging modality in emergency and critical care settings. Application of US during CPR plays an important role in diagnosis, guidance of therapeutic intervention, or monitoring[15]. While many US protocols have been introduced for use with CPR, the US-CAB protocol complies with the sequence of advanced life support (ALS). It integrates important US techniques to detect possibly reversible causes of any issues, and to evaluate the C-A-B status during the whole process of resuscitation[11,14].

The scanning sequence of the US-CAB protocol is: 1) C, at the start of resuscitation; 2) AB, after intubation; 3) C, every 2 min during pulse checks and rhythm analysis; 4) AB, after transportation. US-C helps detect possible reversible causes of cardiac arrest and the existence of cardiac contractility. US-AB is used for confirmation of endotracheal tube location and proper ventilation. This can guide the first-line physician's management resuscitation appropriately. For example, when pericardial effusion is detected, pericardiocentesis can be performed immediately. When a double tract sign is noted after intubation, removal of the endotracheal tube and reintubation can be quickly accomplished.

According to our experience, the hands-off interval for pulse checks and rhythm analysis (which takes less than 10 s) is enough for sonographic examination after proper training[11,14]. However, if the sonographer cannot complete US-C within 10 s, the team needs to resume chest compressions. US-C can be performed again during the next pulse check.

Tracheal ultrasound (US-A) exhibits a high sensitivity and a high specificity for confirmation of tracheal intubation[12]. However, evidence is still lacking for detection of the supraglottic airway. In addition, pitfalls occur in patients with proximal esophageal dilatation, which mimics a double tract sign[16].

Although the scanning sequence is performed in an arbitrary order, the order can be changed according to a sonographer's experience. For example, US-B can be performed at the start of resuscitation while using a bag-ventilation mask (BVM) to rule in proper ventilation or rule out pulmonary pathologies. In addition, US-B can be first performed on the right side of the patient, and then on the left side. Because the right side is checked first, if sliding is detected, it is evident that the endotracheal tube is in the trachea even when checking the right bronchus (which can be identified in the next step and also gives a baseline for comparison on the left side). If sliding is not seen, the airway can be checked again, then pneumothorax can be considered.

Concerns regarding interruption of chest compressions to use US have been raised[17,18]. Perfect integration of the US-CAB protocol into the CPR process necessitates familiarity with the US-C, US-A, and US-B techniques, qualified personnel, optimal instruments, and well-organized teamwork. Structured training and continued practice are needed, and show remarkable improvement in US performance[18,19]. Therefore, the potential delay of chest compressions can be minimized. Moreover, experienced individuals can try subxiphoid US-C when chest compression is ongoing[20]. Though the quality of imaging can be limited by a number of factors, such as obesity, it is possible to get a glance at the heart and IVC to rule out important reversible causes for CPR failure as quickly as possible. Similarly, though the initial assessment of US-A and

US-B are usually performed immediately after intubation, when chest compressions stop for auscultation, the follow-up US-AB can also be done during chest compressions whenever dislodgement or displacement of the endotracheal tube is suspected.

In conclusion, US-CAB is feasible and provides diagnostic and prognostic abilities during CPR. Through rigorous training and continued practice, as well as adequate integration of the protocol with an organized resuscitation team, the impact of US-CAB protocol can be maximized.

ACKNOWLEDGMENTS:
This study was supported in part by the grants from the Ministry of Science and Technology, Taiwan (MOST 103-2511-S-002-007). The authors would like to thank Dr. Chih-Hsien Wu and Mr. Jen-Chih Sung for helping the preparation of the photographs and film.

DISCLOSURES:
The authors have nothing to disclose.

REFERENCES:
1. Soar, J. et al. European Resuscitation Council Guidelines for Resuscitation 2015: Section 3. Adult advanced life support. *Resuscitation.* **95**, 100–147 (2015).
2. Takeda, T. et al. The assessment of three methods to verify tracheal tube placement in the emergency setting. *Resuscitation.* **56** (2), 153–157 (2003).
3. Levine, R., Wayne, M., Miller, C. End-tidal carbon dioxide and outcome of out-of-hospital cardiac arrest. *New England Journal of Medicine.* **337**, 301–306 (1997).
4. Moule, P. Checking the carotid pulse: diagnostic accuracy in students of the healthcare professions. *Resuscitation.* **44** (3), 195–201 (2000).
5. Sitzwohl, C. et al. Endobronchial intubation detected by insertion depth of endotracheal tube, bilateral auscultation, or observation of chest movements: randomised trial. *British Medical Journal.* **341**, c5943 (2010).
6. Monsieurs, K. et al. European Resuscitation Council Guidelines for Resuscitation 2015: Section 1. Executive summary. *Resuscitation.* **95**, 1–80 (2015).
7. Breitkreutz, R. et al. Focused echocardiographic evaluation in life support and peri-resuscitation of emergency patients: a prospective trial. *Resuscitation.* **81** (11), 1527–1533 (2010).
8. Hernandez, C. et al. C.A.U.S.E.: Cardiac arrest ultra-sound exam--a better approach to managing patients in primary non-arrhythmogenic cardiac arrest. *Resuscitation.* **76** (2), 198–206 (2008).
9. Perera, P., Mailhot, T., Riley, D., Mandavia, D. The RUSH exam: Rapid Ultrasound in SHock in the evaluation of the critically lll. *Emergency Medicine Clinics of North America.* **28** (1), 29–56 (2010).
10. Blyth, L., Atkinson, P., Gadd, K., Lang, E. Bedside focused echocardiography as predictor of survival in cardiac arrest patients: a systematic review. *Academic Emergency Medicine.* **19** 1119–1126 (2012).
11. Lien, W. C. et al. US-CAB protocol for ultrasonographic evaluation during cardiopulmonary resuscitation: validation and potential impact. *Resuscitation.* **127**, 125–131 (2018).
12. Chou, H. C. et al. Real-time tracheal ultrasonography for confirmation of endotracheal

tube placement during cardiopulmonary resuscitation. *Resuscitation.* **84** (12), 1708–1712 (2013).
13. Sim, S. S. et al. Ultrasonographic lung sliding sign in confirming proper endotracheal intubation during emergency intubation. *Resuscitation.* **83** (3), 307–312 (2012).
14. Lien, W. C. et al. A novel US-CAB protocol for ultrasonographic evaluation during cardiopulmonary resuscitation. *Resuscitation.* **115**, e1–e2 (2017).
15. Roelandt, J. R. Ultrasound stethoscopy. *European Journal of Internal Medicine.* **15**, 337–347 (2004).
16. Lien, W. C., Chang, W. T. A Potential Pitfall of Tracheal Ultrasound for the Confirmation of Endotracheal Intubations. *Journal of Ultrasound in Medicine.* In Press (2019).
17. Huis In 't Veld, M. A. et al. Ultrasound use during cardiopulmonary resuscitation is associated with delays in chest compressions. *Resuscitation.* **119**, 95–98 (2017).
18. Clattenburg, E. J. et al. Point-of-care ultrasound use in patients with cardiac arrest is associated prolonged cardiopulmonary resuscitation pauses: A prospective cohort study. *Resuscitation.* **122** (1), 65–68 (2018).
19. Lien, W. C. et al. Data on evaluation of proficiency for the US-CAB curriculum. *Data in Brief*. **16** (17), 965–968 (2017).
20. Lien, W. C., Chang, W. T., Ma, M. H., Chen, W. J. Ultrasonography during CPR: Hands-off or hands-on? *Resuscitation.* **125**, e8–e10 (2018).

Figure 1

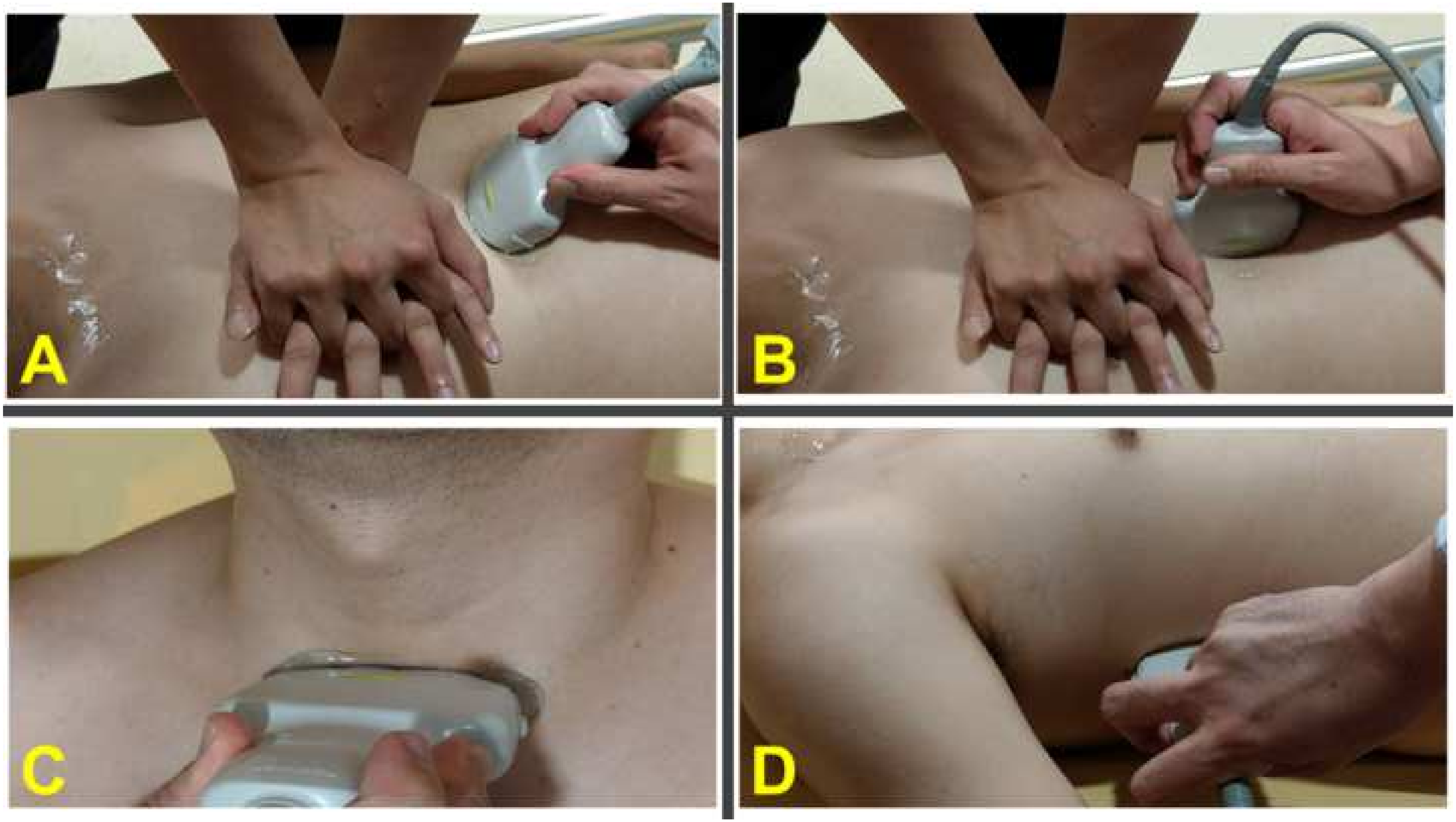


Figure 2

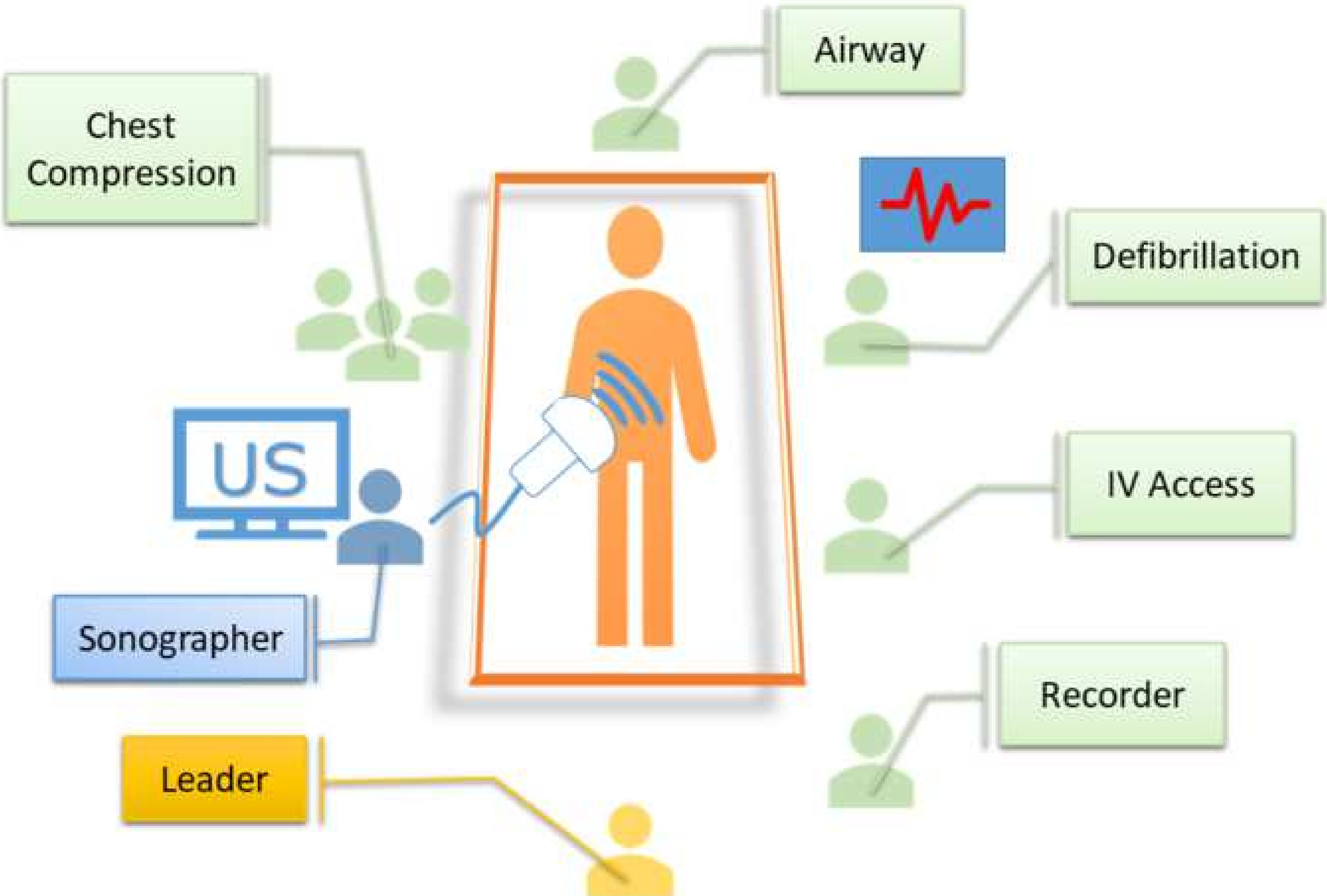

Airway
Chest Compression
Defibrillation
US
IV Access
Sonographer
Recorder
Leader

Figure 3

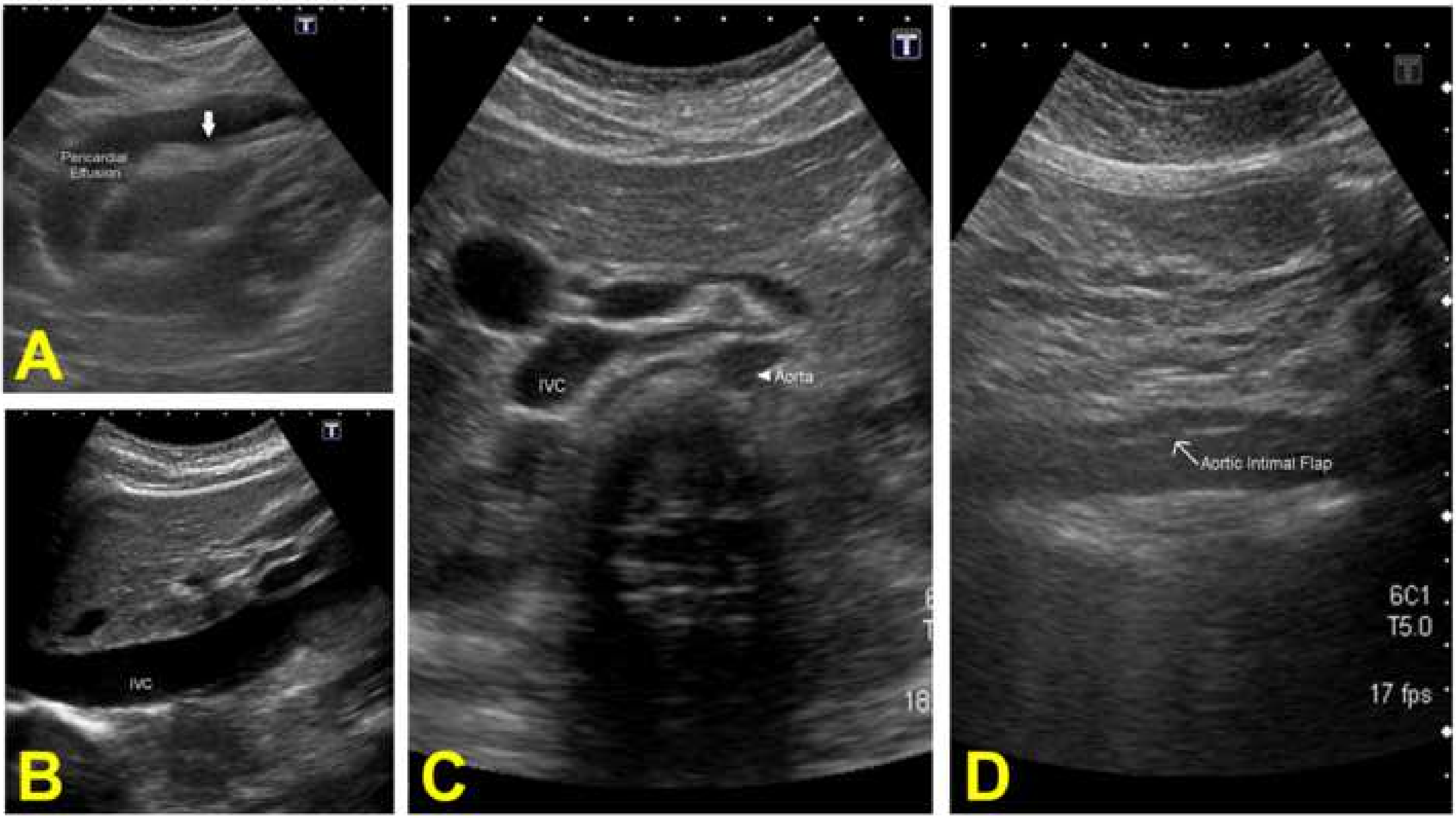
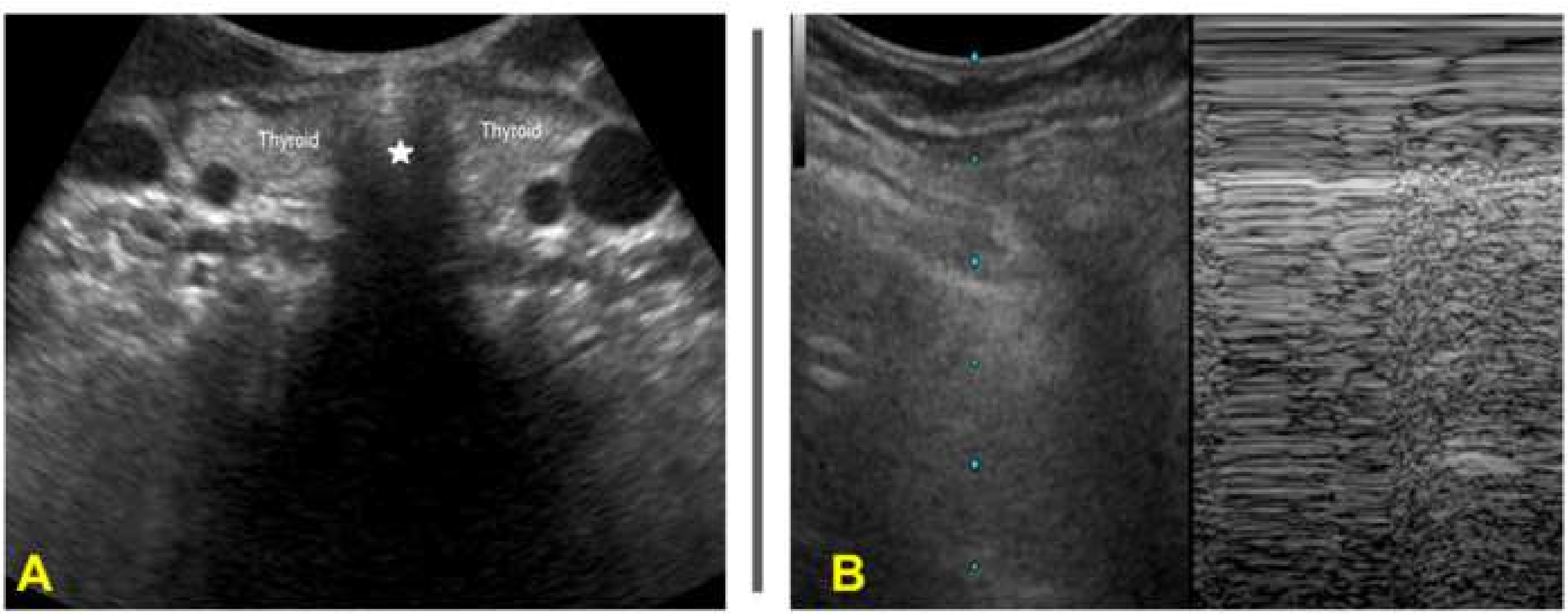

A
Pericardial Effusion
B
IVC
C
IVC
Aorta
D
Aortic Intimal Flap
6C1
T5.0
17 fps

Figure 4



Name of Material/ Equipment	Company	Catalog Number	Comments/Description
Ultrasound	Cannon, Japan	SSA-550A	nil

1 Alewife Center #200
Cambridge, MA 02140
tel. 617.945.9051
www.jove.com

ARTICLE AND VIDEO LICENSE AGREEMENT

Title of Article:	US-CAB for Ultrasonographic Assessment during Cardiopulmonary Resuscitation – Method and Protocol
Author(s):	Wan-Ching Lien, Chih-Heng Chang, Wei-Tien Chang*, Wen-Jone Chen

Item 1: The Author elects to have the Materials be made available (as described at http://www.jove.com/publish) via:

☑ Standard Access ☐ Open Access

Item 2: Please select one of the following items:

☑ The Author is **NOT** a United States government employee.

☐ The Author is a United States government employee and the Materials were prepared in the course of his or her duties as a United States government employee.

☐ The Author is a United States government employee but the Materials were NOT prepared in the course of his or her duties as a United States government employee.

ARTICLE AND VIDEO LICENSE AGREEMENT

1. **Defined Terms.** As used in this Article and Video License Agreement, the following terms shall have the following meanings: “**Agreement**” means this Article and Video License Agreement; “**Article**” means the article specified on the last page of this Agreement, including any associated materials such as texts, figures, tables, artwork, abstracts, or summaries contained therein; “**Author**” means the author who is a signatory to this Agreement; “**Collective Work**” means a work, such as a periodical issue, anthology or encyclopedia, in which the Materials in their entirety in unmodified form, along with a number of other contributions, constituting separate and independent works in themselves, are assembled into a collective whole; “**CRC License**” means the Creative Commons Attribution-Non Commercial-No Derivs 3.0 Unported Agreement, the terms and conditions of which can be found at: http://creativecommons.org/licenses/by-nc-nd/3.0/legalcode; “**Derivative Work**” means a work based upon the Materials or upon the Materials and other pre-existing works, such as a translation, musical arrangement, dramatization, fictionalization, motion picture version, sound recording, art reproduction, abridgment, condensation, or any other form in which the Materials may be recast, transformed, or adapted; “**Institution**” means the institution, listed on the last page of this Agreement, by which the Author was employed at the time of the creation of the Materials; “**JoVE**” means MyJove Corporation, a Massachusetts corporation and the publisher of The Journal of Visualized Experiments; “**Materials**” means the Article and / or the Video; “**Parties**” means the Author and JoVE; “**Video**” means any video(s) made by the Author, alone or in conjunction with any other parties, or by JoVE or its affiliates or agents, individually or in collaboration with the Author or any other parties, incorporating all or any portion of the Article, and in which the Author may or may not appear.

2. **Background.** The Author, who is the author of the Article, in order to ensure the dissemination and protection of the Article, desires to have the JoVE publish the Article and create and transmit videos based on the Article. In furtherance of such goals, the Parties desire to memorialize in this Agreement the respective rights of each Party in and to the Article and the Video.

3. **Grant of Rights in Article.** In consideration of JoVE agreeing to publish the Article, the Author hereby grants to JoVE, subject to **Sections 4** and **7** below, the exclusive, royalty-free, perpetual (for the full term of copyright in the Article, including any extensions thereto) license (a) to publish, reproduce, distribute, display and store the Article in all forms, formats and media whether now known or hereafter developed (including without limitation in print, digital and electronic form) throughout the world, (b) to translate the Article into other languages, create adaptations, summaries or extracts of the Article or other Derivative Works (including, without limitation, the Video) or Collective Works based on all or any portion of the Article and exercise all of the rights set forth in (a) above in such translations, adaptations, summaries, extracts, Derivative Works or Collective Works and(c) to license others to do any or all of the above. The foregoing rights may be exercised in all media and formats, whether now known or hereafter devised, and include the right to make such modifications as are technically necessary to exercise the rights in other media and formats. If the “Open Access” box has been checked in **Item 1** above, JoVE and the Author hereby grant to the public all such rights in the Article as provided in, but subject to all limitations and requirements set forth in, the CRC License.

4. **Retention of Rights in Article.** Notwithstanding the exclusive license granted to JoVE in **Section 3** above, the Author shall, with respect to the Article, retain the non-exclusive right to use all or part of the Article for the non-commercial purpose of giving lectures, presentations or teaching classes, and to post a copy of the Article on the Institution's website or the Author's personal website, in each case provided that a link to the Article on the JoVE website is provided and notice of JoVE's copyright in the Article is included. All non-copyright intellectual property rights in and to the Article, such as patent rights, shall remain with the Author.

5. **Grant of Rights in Video – Standard Access.** This **Section 5** applies if the "Standard Access" box has been checked in **Item 1** above or if no box has been checked in **Item 1** above. In consideration of JoVE agreeing to produce, display or otherwise assist with the Video, the Author hereby acknowledges and agrees that, Subject to **Section 7** below, JoVE is and shall be the sole and exclusive owner of all rights of any nature, including, without limitation, all copyrights, in and to the Video. To the extent that, by law, the Author is deemed, now or at any time in the future, to have any rights of any nature in or to the Video, the Author hereby disclaims all such rights and transfers all such rights to JoVE.

6. **Grant of Rights in Video – Open Access.** This **Section 6** applies only if the "Open Access" box has been checked in **Item 1** above. In consideration of JoVE agreeing to produce, display or otherwise assist with the Video, the Author hereby grants to JoVE, subject to **Section 7** below, the exclusive, royalty-free, perpetual (for the full term of copyright in the Article, including any extensions thereto) license (a) to publish, reproduce, distribute, display and store the Video in all forms, formats and media whether now known or hereafter developed (including without limitation in print, digital and electronic form) throughout the world, (b) to translate the Video into other languages, create adaptations, summaries or extracts of the Video or other Derivative Works or Collective Works based on all or any portion of the Video and exercise all of the rights set forth in (a) above in such translations, adaptations, summaries, extracts, Derivative Works or Collective Works and (c) to license others to do any or all of the above. The foregoing rights may be exercised in all media and formats, whether now known or hereafter devised, and include the right to make such modifications as are technically necessary to exercise the rights in other media and formats. For any Video to which this **Section 6** is applicable, JoVE and the Author hereby grant to the public all such rights in the Video as provided in, but subject to all limitations and requirements set forth in, the CRC License.

7. **Government Employees.** If the Author is a United States government employee and the Article was prepared in the course of his or her duties as a United States government employee, as indicated in **Item 2** above, and any of the licenses or grants granted by the Author hereunder exceed the scope of the 17 U.S.C. 403, then the rights granted hereunder shall be limited to the maximum rights permitted under such statute. In such case, all provisions contained herein that are not in conflict with such statute shall remain in full force and effect, and all provisions contained herein that do so conflict shall be deemed to be amended so as to provide to JoVE the maximum rights permissible within such statute.

8. **Protection of the Work.** The Author(s) authorize JoVE to take steps in the Author(s) name and on their behalf if JoVE believes some third party could be infringing or might infringe the copyright of either the Author's Article and/or Video.

9. **Likeness, Privacy, Personality.** The Author hereby grants JoVE the right to use the Author's name, voice, likeness, picture, photograph, image, biography and performance in any way, commercial or otherwise, in connection with the Materials and the sale, promotion and distribution thereof. The Author hereby waives any and all rights he or she may have, relating to his or her appearance in the Video or otherwise relating to the Materials, under all applicable privacy, likeness, personality or similar laws.

10. **Author Warranties.** The Author represents and warrants that the Article is original, that it has not been published, that the copyright interest is owned by the Author (or, if more than one author is listed at the beginning of this Agreement, by such authors collectively) and has not been assigned, licensed, or otherwise transferred to any other party. The Author represents and warrants that the author(s) listed at the top of this Agreement are the only authors of the Materials. If more than one author is listed at the top of this Agreement and if any such author has not entered into a separate Article and Video License Agreement with JoVE relating to the Materials, the Author represents and warrants that the Author has been authorized by each of the other such authors to execute this Agreement on his or her behalf and to bind him or her with respect to the terms of this Agreement as if each of them had been a party hereto as an Author. The Author warrants that the use, reproduction, distribution, public or private performance or display, and/or modification of all or any portion of the Materials does not and will not violate, infringe and/or misappropriate the patent, trademark, intellectual property or other rights of any third party. The Author represents and warrants that it has and will continue to comply with all government, institutional and other regulations, including, without limitation all institutional, laboratory, hospital, ethical, human and animal treatment, privacy, and all other rules, regulations, laws, procedures or guidelines, applicable to the Materials, and that all research involving human and animal subjects has been approved by the Author's relevant institutional review board.

11. **JoVE Discretion.** If the Author requests the assistance of JoVE in producing the Video in the Author's facility, the Author shall ensure that the presence of JoVE employees, agents or independent contractors is in accordance with the relevant regulations of the Author's institution. If more than one author is listed at the beginning of this Agreement, JoVE may, in its sole

discretion, elect not take any action with respect to the Article until such time as it has received complete, executed Article and Video License Agreements from each such author. JoVE reserves the right, in its absolute and sole discretion and without giving any reason therefore, to accept or decline any work submitted to JoVE. JoVE and its employees, agents and independent contractors shall have full, unfettered access to the facilities of the Author or of the Author's institution as necessary to make the Video, whether actually published or not. JoVE has sole discretion as to the method of making and publishing the Materials, including, without limitation, to all decisions regarding editing, lighting, filming, timing of publication, if any, length, quality, content and the like.

12. **Indemnification.** The Author agrees to indemnify JoVE and/or its successors and assigns from and against any and all claims, costs, and expenses, including attorney's fees, arising out of any breach of any warranty or other representations contained herein. The Author further agrees to indemnify and hold harmless JoVE from and against any and all claims, costs, and expenses, including attorney's fees, resulting from the breach by the Author of any representation or warranty contained herein or from allegations or instances of violation of intellectual property rights, damage to the Author's or the Author's institution's facilities, fraud, libel, defamation, research, equipment, experiments, property damage, personal injury, violations of institutional, laboratory, hospital, ethical, human and animal treatment, privacy or other rules, regulations, laws, procedures or guidelines, liabilities and other losses or damages related in any way to the submission of work to JoVE, making of videos by JoVE, or publication in JoVE or elsewhere by JoVE. The Author shall be responsible for, and shall hold JoVE harmless from, damages caused by lack of sterilization, lack of cleanliness or by contamination due to the making of a video by JoVE its employees, agents or independent contractors. All sterilization, cleanliness or decontamination procedures shall be solely the responsibility of the Author and shall be undertaken at the Author's expense. All indemnifications provided herein shall include JoVE's attorney's fees and costs related to said losses or damages. Such indemnification and holding harmless shall include such losses or damages incurred by, or in connection with, acts or omissions of JoVE, its employees, agents or independent contractors.

13. **Fees.** To cover the cost incurred for publication, JoVE must receive payment before production and publication the Materials. Payment is due in 21 days of invoice. Should the Materials not be published due to an editorial or production decision, these funds will be returned to the Author. Withdrawal by the Author of any submitted Materials after final peer review approval will result in a US$1,200 fee to cover pre-production expenses incurred by JoVE. If payment is not received by the completion of filming, production and publication of the Materials will be suspended until payment is received.

14. **Transfer, Governing Law.** This Agreement may be assigned by JoVE and shall inure to the benefits of any of JoVE's successors and assignees. This Agreement shall be governed and construed by the internal laws of the Commonwealth of Massachusetts without giving effect to any conflict of law provision thereunder. This Agreement may be executed in counterparts, each of which shall be deemed an original, but all of which together shall be deemed to me one and the same agreement. A signed copy of this Agreement delivered by facsimile, e-mail or other means of electronic transmission shall be deemed to have the same legal effect as delivery of an original signed copy of this Agreement.

A signed copy of this document must be sent with all new submissions. Only one Agreement is required per submission.

CORRESPONDING AUTHOR

Name:	Wei-Tien Chang
Department:	Department of Emergency Medicine
Institution:	National Taiwan University Hospital and College of Medicine
Title:	US-CAB for Ultrasonographic Assessment during Cardiopulmonary Resuscitation – Method and Protocol

Signature: Wei-Tien Chang Date: Sep. 18, 2018

Please submit a **signed** and **dated** copy of this license by one of the following three methods:

1. Upload an electronic version on the JoVE submission site
2. Fax the document to +1.866.381.2236
3. Mail the document to JoVE / Attn: JoVE Editorial / 1 Alewife Center #200 / Cambridge, MA 02140

Dear Sir:

Thank you for giving us the opportunity to revise our manuscript, JoVE59144 "US-CAB for Ultrasonographic Assessment during Cardiopulmonary Resuscitation: Method and Protocol."

The followings are the response to the comments.

EDITORIAL COMMENTS: We have revised the manuscript as your suggestions.

1. Please take this opportunity to thoroughly proofread the manuscript to ensure that there are no spelling or grammar issues.
2. Please avoid using abbreviations and punctuation in the title.
3. Please provide an email address for each author.
4. Please rephrase the Short Abstract to clearly describe the protocol and its applications in complete sentences between 10-50 words:
5. Please rephrase the Long Abstract to more clearly state the goal of the protocol.
6. Please include an ethics statement before the numbered protocol steps, indicating that the protocol follows the guidelines of your human research ethics committee.
7. Please revise the protocol to contain only action items that direct the reader to do something. The actions should be described in the imperative tense in complete sentences wherever possible. Avoid usage of phrases such as could be; should be; would be; throughout the Protocol. Please include all safety procedures and use of hoods, etc. However, notes should be used sparingly and actions should be described in the imperative tense wherever possible. Please move the discussion about the protocol to the Discussion.
8. The Protocol should be made up almost entirely of discrete steps without large paragraphs of text between sections. Please simplify the Protocol so that individual steps contain only 2-3 actions per step and a maximum of 4 sentences per step. Use sub-steps as necessary. Please move the discussion about the protocol to the Discussion.
9. Much of the protocol is general and abstract. We need specific details of a specific experiment to film.
10. Please include single-line spaces between all paragraphs, headings, steps, etc.
11. After you have made all the recommended changes to your protocol (listed above), please highlight 2.75 pages or less of the Protocol (including headings and spacing) that identifies the essential steps of the protocol for the video, i.e., the steps that should be visualized to tell the most cohesive story of the Protocol.
12. Please highlight complete sentences (not parts of sentences).

Please ensure that the highlighted part of the step includes at least one action that is

written in imperative tense. Please do not highlight any steps describing anesthetization and euthanasia.
13. Please include all relevant details that are required to perform the step in the highlighting. For example: If step 2.5 is highlighted for filming and the details of how to perform the step are given in steps 2.5.1 and 2.5.2, then the sub-steps where the details are provided must be highlighted.
14. Please combine all panels of one figure into a single image file.
15. Discussion: Please discuss critical steps within the protocol.
16. Please revise the table of the essential supplies, reagents, and equipment to include the name, company, and catalog number of all relevant materials including software in separate columns in an xls/xlsx file.

REVIEWERS' COMMENTS:

Reviewer #1:

Minor Concerns:

1- you have mentioned that you check US-B after the patient has been intubated and you had checked US-A. I think that even before intubating the patient (in some cases the patient may not be intubated in early stage of CPR) US-B is applicable and you can find out if ventilation is done correctly by BVM and you can rule out pneumothorax or hemothorax.

Ans: Thank you for your comments. We add it into the discussion. It’s a good idea to do US-B before intubation to find out the pathologies earlier or to monitor ventilation status while using bag-ventilation masks. Although the scanning sequence is arbitrarily ordered, the order can be changed according to sonographers’ experience.

2- You have recommended to check initially the left hemithorax and then the right side. I think doing the opposite may work better. This is the rational: if you check right first, if you see sliding you become sure that ETT is in trachea even in right bronchus that can be identified in next step (because A has priority to B) and also gives you a baseline for checking and comparison the left side and if you don't see sliding you go for checking airway again then thinking about pneumothorax. But when you check first the left side if you don't see sliding then you should check the right side and if you did not found sliding then go for checking A. This may cause some delay in detecting airway problems.

Ans: Thank you for your comments. We add it into the discussion. US-B to perform at the left first is based on the sequence of auscultation (left side then right side to detect one-lung intubation) after intubation. However, the idea you provide is very good that we can try it in the future.

Reviewer #2:

Major Concerns:

The only major concern that I see is the lack of description of other methods for airway management such as the placement of supraglottic airways. How do the authors expect ultrasound to be in such cases?

Ans: Thank you for your comments. We do not have much experience regarding ultrasound for SGA. However, it is a good idea that we could apply ultrasound in the pre-hospital setting in the future.

Best,
Lien WC
Chang WT