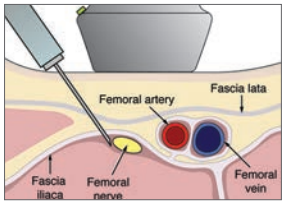
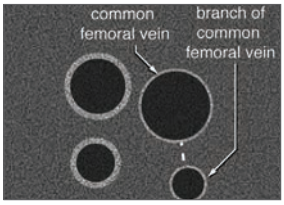
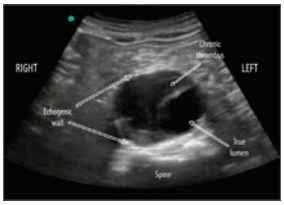
POINT-OF-CARE ULTRASOUND FOR EMERGENCY PHYSICIANS

"THE EDE BOOK"







STEVE SOCRANSKY AND RAY WISS

WITH GREG HALL, BEN HO, ANDREW SKINNER,
JOEL TURNER, MICHAEL WOO, AND ROBERT CHEN

POINT-OF-CARE ULTRASOUND FOR EMERGENCY PHYSICIANS

"THE EDE BOOK"

EDE2

STEVE SOCRANSKY AND RAY WISS

WITH GREG HALL, BEN HO, ANDREW SKINNER,
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Point-of-Care Ultrasound for Emergency Physicians
Steve Socransky, MD Ray Wiss, MD

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If it is our patients who will reap the greatest benefit from this book, it is our families who sacrificed the most for its creation. This book could not have been published without the love and support of Patti and Claude, Jacob and Michelle, and Liam and Julianne.

Steve Socransky
Ray Wiss

PREFACE

This book combines the course manuals of The Emergency Department Echo ("EDE", pronounced "Eddie") Course and The EDE 2 Course. We have titled this book *Point-of-Care Ultrasound for Emergency Physicians*, but we suspect that most Canadian emergency physicians will call it "The EDE Book". The EDE Course saw the light of day in 2001 when emergency ultrasound was in its infancy in Canada. It has taught the basic indications for emergency ultrasound to over 7000 physicians, or roughly half of the Canadian emergency medicine workforce. The EDE 2 Course began teaching advanced emergency ultrasound indications to Canadian emergency physicians in 2009 and has been similarly popular.

Why publish the course manuals as a book? A tongue-in-cheek answer might be "Insanity!" It has been a ludicrous amount of work. But we felt that the EDE pedagogical style and approach to point-of-care ultrasound (POCUS) was a worthy and needed addition to the medical literature. The most distinctive aspect of The EDE Courses has been the focus on image generation. When emergency physicians first began investigating the possibility of using ultrasound themselves, a big secret was concealed from them: image *interpretation* is easy. The real challenge is image *generation*: putting the image on the screen. Once on the screen, interpretation is straightforward in the vast majority of cases.

You may be thinking "But we're physicians. We took anatomy. We know where the heart is. We know where the aorta and uterus are." True, but irrelevant. Ultrasound forces you to work in planes of the body that medical school did not teach, and probe manipulation is an entirely new skill set. Learning POCUS sends us back to that first day of medical school or "EDE kindergarten". This is an uncomfortable feeling, but learning image generation and how to move the probe is a necessary first step.

There are quite a few differences between this book and the original course manuals. First, we put the text through a careful and sometimes painful(!) editing process. There is greater uniformity in the organization of the sections of each chapter or module. A section has been added for subclavian central line placement in the Vascular Access module. A discussion of lung rockets has been added to the Thoracic EDE module. The chapters on diagnostic scans have a box summarizing the key points in image generation. All of the illustrations have been created professionally. The photos have all been redone with the help of a professional photographer and models. The ultrasound images have been updated to a higher quality. Where still images cannot tell the whole story, we will be making ultrasound videos available via the EDE 2 website (www.ede2course.com) or another electronic format. Unlike a traditional reference book, but as with the EDE course manuals, we have limited the number of references to a select few for most of the chapters. The vast majority of the techniques presented are based on the accumulated experience of the authors. In addition, online resources are so ubiquitous that we felt it would be better to save some paper.

The EDE and EDE 2 Course manuals are presented to you separately, starting with the original Introduction from *The EDE Course Manual*. Each of you will utilize this book in a different way. Novices may only read the first part and move on to the second part once they gain more experience. The more skilled among you may only want to read Part 2. Others may only read selected chapters. Adapt how you use this book to your own learning style and individual needs. Even if you have taken both courses and pored over the manuals more than once, you will still find something new and possibly illuminating in the pages that follow.

The Introduction and Conclusion of each course manual have been left largely intact. They lay out the course philosophy and post-course action plan so well that we are avoiding repetition by not including their many elements in this Introduction to the book. However, before we send you forward, we felt that a discussion of the difference between point-of-care ultrasound and elective ultrasound would be worthwhile.

What is POCUS and how does it differ from elective ultrasound?

The name of the "EDE" Course was borne out of the need to stress that these are two different entities. POCUS is performed by physicians of different specialties, paramedics, and nurses. It is performed by the clinician taking care of the patient, with full knowledge of the clinical scenario. The scan can therefore focus on the specific clinical question and avoid needlessly scanning organs or parts of the body that will not hold the answer. POCUS includes scans not traditionally performed by imaging specialists. It is always available on an emergent basis. The POCUS sonographer needs to possess two skill sets: image generation and interpretation. Image interpretation is performed at the same time as image generation. Interpretation is therefore performed using dynamic images. Because the clinician caring for the patient performs the ultrasound, a report of the scan is not generated in most Canadian EDs, although a report of varying detail is generated in some jurisdictions for nonclinical reasons. As with heart sounds and fundoscopic examination, a well-trained physician should document POCUS scans with a note in the chart.

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Wow! Who to thank? There are so many people who have helped with The EDE and EDE 2 Courses since 2001. Patients, participants, models, local organizers, course coordinators, course instructors, and many more. Ultimately, they have all contributed to this book in some way. A few people, however, require specific mention.

The writing of this book has truly been a team effort. It started with the other authors, Greg Hall, Ben Ho, Andrew Skinner, Joel Turner, Michael Woo, and Robert Chen. This book could not have been written without their dedicated efforts. They have been there since the beginning of The EDE 2 Course as the earlier drafts of the chapters were created and modified multiple times. And then there's the rest of the team.

Dan Thomson of Image Video in Sudbury has been the "Go-To" techie guy for many aspects of this book. Dan created earlier versions of the layout and edited the ultrasound images to a presentable format. He has been great with supplying basic crash courses on how to get Adobe InDesign and Photoshop do what you want them to. Stephen Mader, Lima Colati, and the rest of the team at Artery Studios in Toronto have been indispensable. They have done a masterful job of changing our original Power Point graphics from something that looked like it was done by a fifth-grader (or a physician who thinks they know how to do everything!) into something that approaches artwork. Heck, it's almost sexy! Michele Dalgarno is a great young photographer in Toronto who re-shot all of the photos. She helped us to take our hodgepodge of old photos and interpret them, and provided us with a professional and standardized look that was previously lacking. In addition, she supplied great snacks at the photo shoots! After Ray and I were finished with the text, Harold Otto from Nova Scotia, copy editor extraordinaire, picked through in fine detail to find the little bits that escaped our eyes. Amanda Kirkpatrick is a young Sudbury nurse who helped us avoid complete insanity by tackling some of the more blindingly tedious tasks of the editing process. Drs Lionel Marks de Chabris from Sudbury, Mike Betzner and Rob Hall from Calgary, Chris Fox from UC Irvine, Claude Topping from Quebec City, and Chuck Wurster from Dartmouth pitched in with assists on some of the illustrations, photos, and ultrasound images. Chuck also deserves thanks for his contribution to the pediatric bladder section of Bladder EDE, which was created while he was working on The EDE Course for Registered Nurses. Lastly, Dr Claude Gervais' artsy side led to the creation of The EDE Course logo.

And where would we be without the ultrasound systems? Drew D'Aguilar and George Noseworthy and the team from Sonosite Canada, and Richard Boothroyd and Mike Mercer and the team from Esaote Canada have been incredibly supportive of the EDE Courses over the years and with the book. We couldn't have done it without them.

Bringing the book to its final format has been left to the expert hands of John Beadle. If you think the book layout is clean and stylish, it's thanks to John. John Dickey and Dan Larocque of Pensivo, who are based in Ottawa, have been handling the online presence of EDE 2 for the last couple of years. They will be helping make videos available on the EDE 2 website to complement the book content. Going forward, their expertise in distance education will be put to work in creating an iPhone app and getting the course lectures online. Lastly, kudos go to Grant Tanabe and the gang at Thistle Printing who have brought the book to final fruition in its printed format. Along with TTS Distributing, they are graciously handling the shipping end on our behalf and keeping all those boxes out of our basements.

Steve Socransky, MD
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Spring 2012

ONLINE VIDEO LIST

If you have taken The EDE and EDE 2 Courses, you know how we harp on the fact that real-time interpretation beats the interpretation of still images hands down. We have done our utmost to provide you with the best figures possible, but in some cases the still ultrasound images in this book are not enough to fully illustrate what we are trying to communicate. To provide you with an optimal understanding of what normal and pathologic cases will look like on the screen, we will be making the following videos available on the EDE 2 website. Just go to www.ede2course.com to learn more.

Here is the list of videos that you will find on the website:

Obstetrical EDE
- Live intrauterine pregnancy

Renal/Bladder EDE
- Ureteric jets

IVC EDE
- Less than 50% collapse
- Greater than 50% collapse

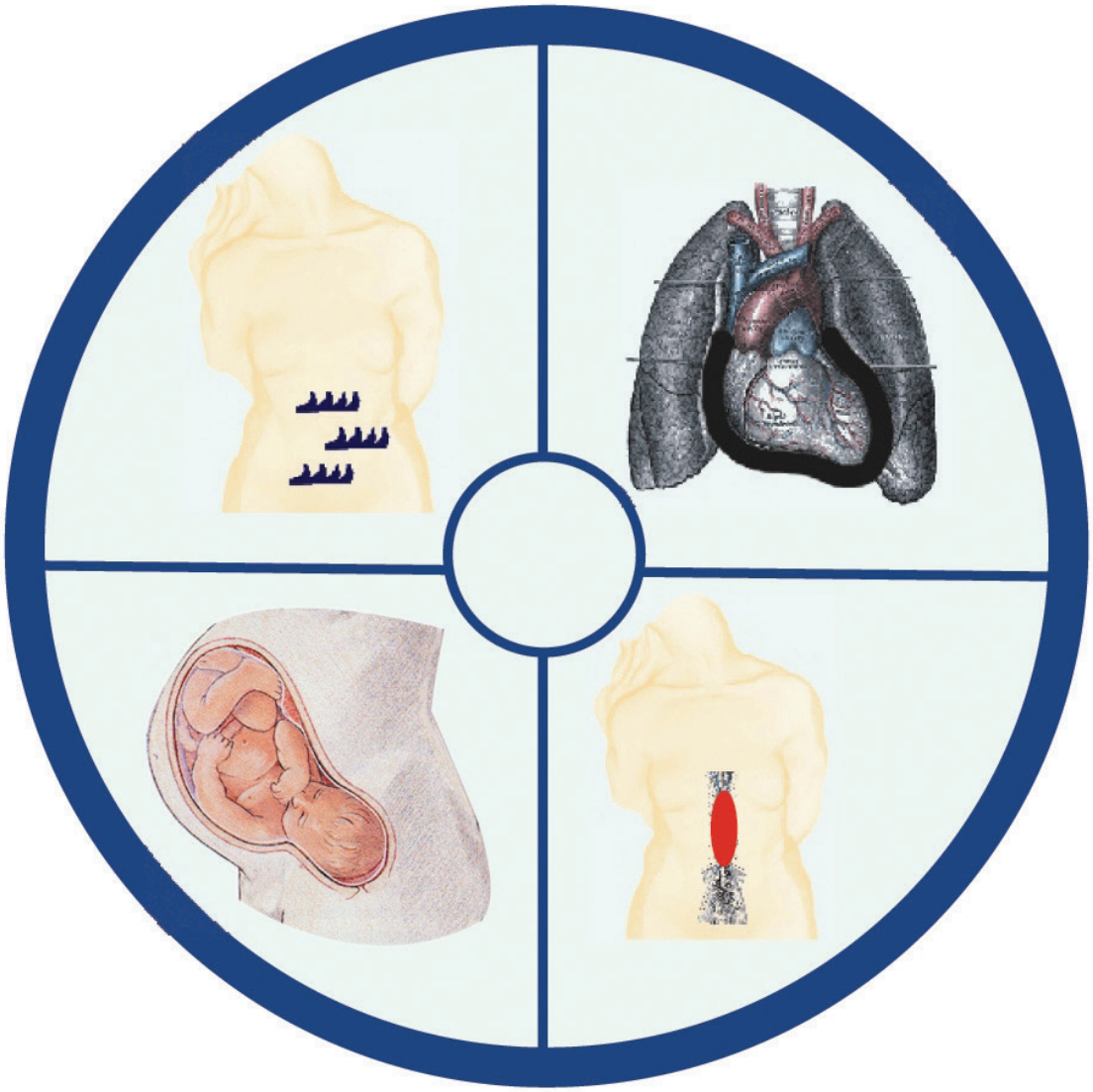
Advanced Cardiac EDE
- Normal left ventricular function
- Gross systolic left ventricular dysfunction
- An empty left ventricle
- Right ventricular strain

Thoracic EDE
- Normal lung sliding
- Absent lung sliding
- A lung point

DVT EDE
- Normal vein compression
- Lack of vein compression in the presence of a deep venous thrombosis

Ocular EDE
- Retinal detachment
- Posterior vitreous detachment
- Vitreous hemorrhage

THE EMERGENCY DEPARTMENT ECHO (EDE) COURSE MANUAL



INTRODUCTION - THE EDE COURSE

Course Philosophy

I found the following sentence on the very first page of the very first handout of the very first ED Ultrasound course I attended. It described the way ultrasound waves were generated by the piezoelectric effect:

"In simple terms, the piezoelectric effect is the phenomena whereby a crystalline material with a dipole moment vibrates at a given frequency when an alternating current is applied."

In simple terms?!? I was still reeling from that one when they flashed the first ultrasound image on the screen. It looked like what I imagine a blizzard must look like to someone who is very myopic, looking through a dirty window.

For reasons I can't explain, I did not run screaming from the room. Rather, I kept going to courses and training sessions until I achieved "independent practitioner" status (as per the American College of Emergency Physicians).

Along the way I became convinced that it was possible for emergency physicians to become rapidly comfortable with ultrasound techniques if the following pedagogical principles were applied:

1) Focus exclusively on the key indications for this modality.

2) Teach only those elements of ultrasound physics that are essential to know how to get the machine to work and to be able to interpret the images.

3) Precede all ultrasound images by simple explanatory graphics, to make the "snowstorm" a little clearer.

4) Omit all extraneous material, especially any reference to the piezoelectric effect.

This course is the result of that belief. In ten intense hours, you will become adept at generating and interpreting ultrasound images that will allow you to rule in or rule out common, life-threatening conditions that you have all had to manage.

It is essential to read this text before taking the course, so that the didactic sessions can serve as confirmatory exercises only. This allows us to spend a maximum amount of time doing hands-on scanning.

I hope you enjoy getting to know "Eddie"!

Dr. Ray Wiss
Course Director
The EDE Course
www.the-ede-course.com
Sudbury, Ontario
September 2001

Course Goals

The purpose of this course is to teach you, in a rapid and simple manner, how to use a basic ultrasound unit to dramatically alter your management of patients in whom one of five life-threatening conditions is a possibility: non-cardiogenic shock, pericardial tamponade, intra-abdominal hemorrhage, ruptured abdominal aortic aneurysm and ectopic pregnancy. These are universally recognized as the key indications for ultrasound to be performed by emergency physicians because patient instability sometimes mandates that management decisions based on ultrasound findings be made in minutes (making consultation with a radiologist impossible). Equally important, but less well-known, is the fact that the ultrasound images generated in these situations are easily interpretable.

To achieve the objective of making you a functional ED sonographer as quickly as possible, all extraneous information has been removed and only the essentials remain. This should not worry you. We already interpret ECGs, x-rays and CT scans with only a vague idea of how these images were produced. So it is with ultrasound. We could talk for hours about the piezoelectric effect and spatial pulse length, but we won't. During this course, you will only learn exactly what you need to know to get a usable image on the screen and to interpret that image. This concept is so important that it is reflected in the very name of the course. You will not be taught how to do ultrasound examinations. Rather, this course will teach you how to do an Emergency Department Echo (an E.D.E.– pronounced "Eddie"), a completely different creature.

Your primary goal when performing an EDE is to be a safe sonographer. You may be surprised to find that the key to this does not lie in accurately calling an EDE positive or negative. Rather it lies in knowing when an EDE is inconclusive. You have gotten along just fine without EDE until now. If EDE enables you to acquire high-quality information about your patient, use it. If the information is of uncertain quality, discard it. In those cases, you must proceed as though the scan was not done at all and manage the patient the same way you would have before EDE. EDE is only an adjunct to your clinical skills, and should in no way take precedence over those skills.

This course is not intended to teach you how to be a formal ultrasonographer. This generally requires one to two years of training, most of which has little or no bearing on emergency medicine. Nor is this course meant to teach you how to get the most out of your ultrasound machine. As EDE continues to evolve, certain advanced applications will begin to be widely used. Should you wish to pursue this avenue you are encouraged to take further courses with a more specialized curriculum.

Finally, this course must be seen as only the first step in your development as an emergency sonographer. Afterwards, you must do regular scans in the context of an established ED Ultrasound program, in which you will benefit from continual feedback and quality assurance.

Glossary

You can't get away from this. When you learn a new technique in medicine, it comes with a bunch of new terms. I include these basic ones so that you can make sense of what other ultrasound texts are saying. I have tried to keep the language of this text as simple as possible, often following the sonographic term with a more descriptive or intuitive expression (in brackets).

Echogenic: A material that produces echoes (i.e., ultrasound waves bounce off). The more echogenic a substance is, the whiter the image it produces on the screen.

Echolucent: A material that does not produce echoes (i.e., allows ultrasound waves to pass through). The more echolucent a substance is, the blacker the image it produces on the screen.

Hyperechoic: More echogenic (therefore whiter/brighter) than surrounding tissue.

Hypoechoic: Less echogenic (therefore darker) than surrounding tissue.

Isoechoic: Just as echogenic as (and therefore indistinguishable from) surrounding tissue.

Anechoic: Producing no echoes at all. The resulting image, therefore, will be completely black.

Near field: The top half of the ultrasound screen. Represents that part of the body closest to the probe.

Far field: The bottom half of the ultrasound screen. Represents that part of the body furthest from the probe.

Elective Ultrasound: A scan done by ultrasound technologists or radiologists, in the Diagnostic Imaging department, with a machine that costs 5-10 times what an EDE machine costs.

Scan: Ultrasound lingo for a sonographic examination. Can cause confusion initially, as people wonder whether one is referring to an ultrasound exam or a CT scan. In this text, "scan" always refers to an ultrasound examination. Can be used as a noun ("That guy needs a scan"), a verb ("We've got to scan that guy") or an adjective ("That guy was just not scanable").

CARDIAC EDE

Ray Wiss

Introduction

The first use of bedside ultrasound for many emergency physicians came via the FAST (Focused Abdominal Sonography for Trauma) scan. This key element of bedside ultrasound combines Cardiac EDE and Abdominal EDE. We tackle Cardiac EDE in this chapter and then move on to Abdominal EDE in the next chapter. Cardiac EDE is useful in two settings: cardiac arrest and patients in whom you want to rule out pericardial tamponade.

In the past, hundreds of thousands of futile and protracted attempts at resuscitation have occurred in hospitals the world over. We have known that the vast majority of these efforts were going to be in vain, but have found it difficult to stop. There is a growing body of literature which strongly suggests that cardiac standstill on EDE is a useful additional data point to confirm that further life-support maneuvers will be fruitless (1). It is traditional to listen for heart tones with a stethoscope to confirm death. Why listen when you can look? The finding of the stone heart on EDE will help you make a decision.

Now think of all the patients you have seen with chest pain, shortness of breath, or thoracic trauma. The vast majority of them will not have a pericardial effusion (PCE) or develop cardiac tamponade (2). But in the ones who will, it will be very useful to detect their effusions sooner rather than later. Even if you are not concerned that your patient has a clinical presentation consistent with tamponade, the presence of a PCE will be an important clue in the patient's work-up.

Literature going back to the 1990s has shown that emergency physicians and surgeons can learn the FAST scan with, at most, fifty training scans (3-4). Yet many clinicians have struggled in their first attempts to incorporate bedside ultrasound into their practice. Why? Many have focused their training on image recognition. However, like almost all positive EDE scans, a PCE is easy to identify. The real challenge of EDE is not image recognition, but image generation. Do you think you know how to generate an image of the heart efficiently simply because you know where the heart is located? Think again! Only by slavishly following a method for image generation, such as the one outlined below, will you be able to generate interpretable images efficiently, quickly, and reproducibly.

Knobology and Preparation

Prior to scanning, "Dive the Depth": set the depth to maximum. You will repeat this preparatory adjustment in knobology in a large number of scans. Even in children, the heart can be a long way from the probe. If you start scanning at the factory preset (or worse, at the depth your colleague was using to scan a near-surface structure moments before) you can waste time or even make a bad mistake if you do not realize you are only looking at the first few centimeters of body. Start with the default gain setting but be prepared to adjust it as needed.

The curved array probe that is used for most abdominal scans works perfectly well for Basic Cardiac EDE. If you have one, a phased array probe can be used as well.

How to Perform Cardiac EDE

Although Cardiac EDE can be performed from a number of views, by far the best approach is the subxiphoid view. The probe is placed below the xiphoid process and aimed almost straight up. This is sometimes called the subcostal view. There are several other views, such as the parasternal and the apical. These are covered in the Advanced Cardiac EDE module. But for the beginner EDE practitioner, none is as good as the subxiphoid. It is technically easier to perform and it enables you to complete your scan while staying out of the way of colleagues who may be intubating, placing chest tubes, performing CPR, etc. Finally, the subxiphoid view is better than other views for identifying a PCE.

CARDIAC EDE

CARDIAC EDE - THE STEPS

1. Place the probe flat on the abdomen, just cephalad to the umbilicus.
2. Slide the probe up the midline of the abdomen.
3. Identify the heart and center it on the screen.
4. Identify the pericardium.
5. Perform an anterior-posterior sweep of the heart.

Figure 2: Your hand should be completely over the probe without any fingers below it.

STEP 1

The most important thing to realize about the subxiphoid view is that it is ... subxiphoid. The natural tendency of beginners is to start right at the xiphoid, as close as possible to the heart. People who do this are ignoring one of the key concepts of ultrasound, to wit: getting a good image is all about windows. And the key acoustic window here is the liver. That is the window that allows you to peer from the abdomen into the chest. Necessarily, this means that the probe will need to be caudad to the liver.

It is therefore vital to start the scan very low on the abdomen, just a bit above the umbilicus (Figure 1). In this manner, you will be certain to start the scan well below the liver. You will be surprised to see how far from the heart you can be in many patients when you discover an acceptable image. This will occur at the point where the probe comes into contact with the liver. As with all basic EDE scans done in the transverse plane, the indicator should be oriented to patient right.

In placing the probe on your starting point, you will note that the hand must be completely over the probe (Figure 2). If fingers are caught under the probe, you will not be able to lay your hand flat on the abdomen. This is necessary to see the heart, which is an anterior structure in the chest.

Just as you did for Aortic EDE, a generous runway of gel should be applied from the umbilicus to the xiphoid before you start the scan.

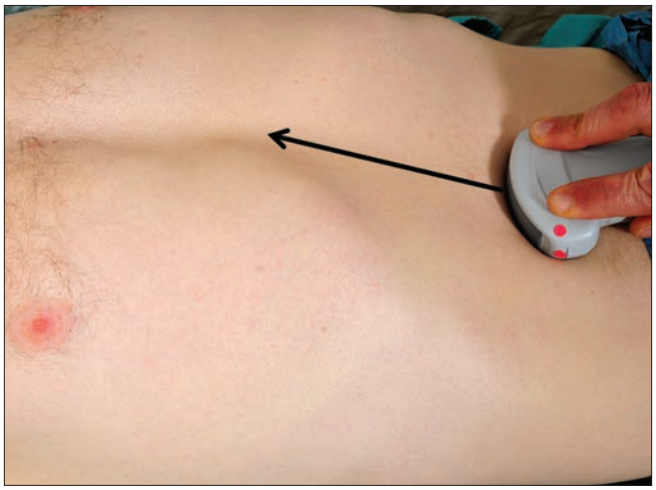


Figure 1: Your starting point is just above the umbilicus. Slide the probe towards the liver (in the midline) in Step 2.

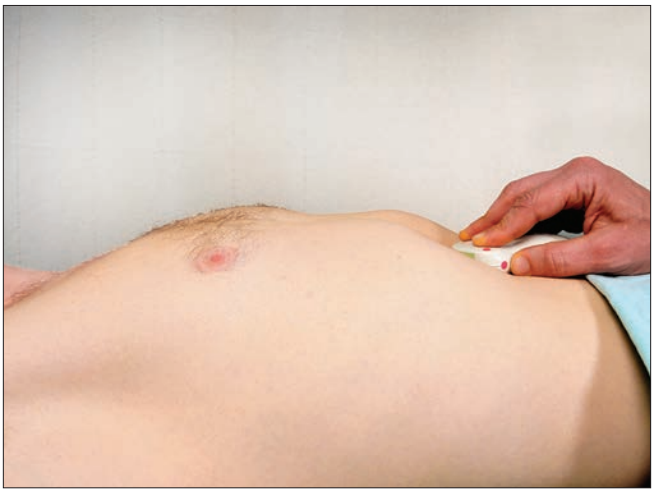


Figure 3: Keep the probe flat on the abdomen as you slide cephalad.

STEP 2

From your starting point, slide the probe up the midline, towards the head (Figure 1). As you do so, keep the probe virtually flat on the abdomen (Figure 3). Another natural tendency of beginners is to direct the probe towards the apex, probably because that is where your stethoscope has always gone. But as you know from looking at countless chest x-rays, the heart is a near-midline structure. To see the heart, you have to drive the probe up the midline.

While doing your slide, apply downward probe pressure towards the back. It should not be excessive. But if you hold the probe only lightly on the abdomen, the probe head will not make sufficient contact with the skin and your image will appear dark. Sufficient pressure will cause the skin to envelop the probe and create good contact. Do not be dismayed if part of the probe head does not touch the abdomen. So long as even a few millimeters of the probe are in contact with the skin, an acceptable image will be generated. If a patient has a rigid "six-pack" abdomen, you can get a slightly better view by flexing the legs (which relaxes the abdominal muscles). Lots of gel will help too.

STEP 3

As you slide up the abdomen, the liver will appear on the screen in the near field. At that point, the heart should come into view. The first thing you will notice will not be cardiac anatomy. It will be that there is a moving object on your screen!

In different patients, that moving object will first appear at different points in your slide. Sometimes it will appear when you are still distant from the ribs, and sometimes it will only appear once the probe is abutted against the costal margins. Anatomic differences between patients and the gastrointestinal contents of your patient at the time largely explain this variability.

What can you expect to see on the screen? When first learning Cardiac EDE, you will be looking at heart anatomy from an orientation that will seem unnatural. Why? Because medical school and residency are unlikely to have given you the skill to relate to internal anatomy from different angles and in three dimensions. It's time to unlearn what you have learned! Veteran physicians are often surprised to see that the heart and the liver are in contact with each other, probably because thoracic anatomy and abdominal anatomy are taught separately in medical school. Moreover, many beginners have difficulty with the spatial orientation of the image on the screen. In Cardiac EDE, this situation is exacerbated because the probe is pointing up (Figure 4). The near-field images are therefore inferior structures, while the far-field images are superior. Novices almost always equate the far field with the posterior part of the body, which leads to much initial confusion.

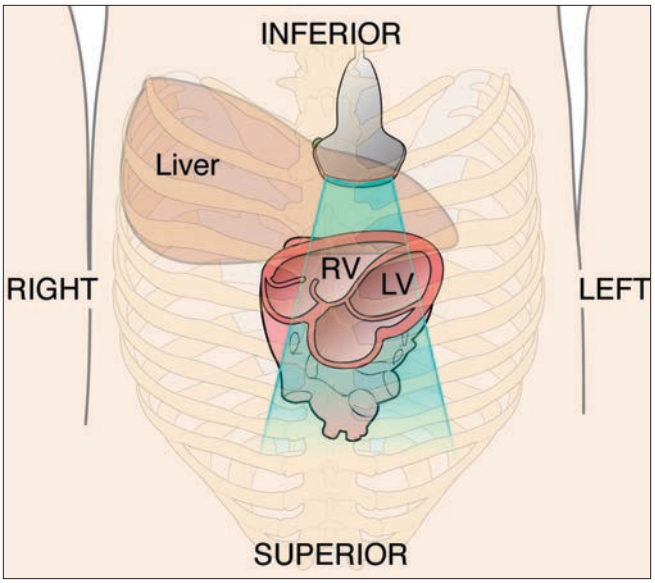


Figure 4: A view from the patient's back. The probe is on the abdomen. The illustration shows the structures encountered by the beam, reproducing what will be seen on the screen.

In an easy scan, the pericardium and cardiac chambers will be quickly recognized. If you have a great image on the screen, move to Step 4. If not, optimize your image. This means making the heart as clear as possible and centering it on the screen.

If you have not seen the heart at all to this point, perform an AP sweep (i.e., until the probe is almost flat on the patient's abdomen and then sweep slowly posteriorly). The natural reflex is to point the probe towards the patient's back. Remember you are looking up at an anterior structure in the chest. You are much more likely to see it with the probe flat on the abdomen.

CARDIAC EDE

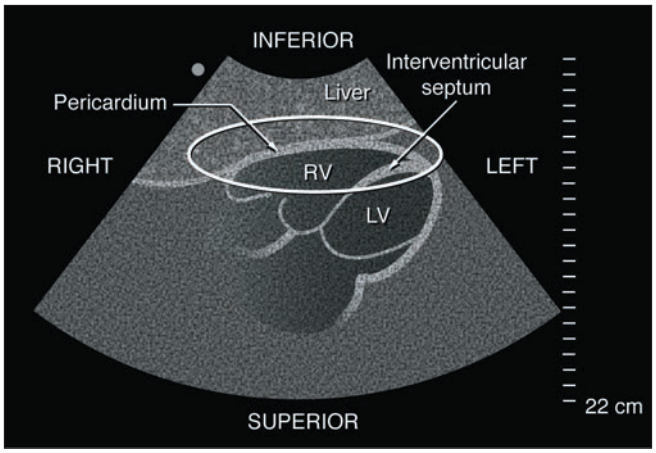


Figure 5: The typical appearance of the heart in the subxiphoid view. To declare a determinate scan, you must see and sweep the inferior pericardium from its most rightward point (which is to screen left) to where the right ventricular free wall meets the septum (see oval).

Once you see the heart, you will notice that it appears as a mostly black structure - because it is fluid-filled - within a bright, white envelope (Figure 5). Commonly, the heart will be too dark when it first appears; you will not see that white envelope well. Although increasing the gain is a good reflex, it should be the last thing you try. First, do you have enough gel? Next, are you applying sufficient pressure with the probe? Not only do you need probe pressure directed towards the back, but there should be some directed towards the heart. If you are already pressing against the costal margins and the patient is uncomfortable, you may need to slide a bit caudad, away from the ribs, and then re-apply probe pressure. Lastly, consider having the cooperative patient take a deep breath (see the Few Final Tips section below).

Once you have confidently identified your target, center the heart on the screen. If you have correctly started with maximum depth, you may now need to decrease the depth. This will move the heart down the screen and magnify it. In a subset of patients, no adjustment in depth is needed because the heart will already be centered at maximum depth. If the heart is too far to screen left or screen right, you may also need to center the heart by sliding or heeling the probe to patient right or left.

STEP 4

If you are searching for a PCE, the next step is to identify the pericardium (Figure 6). The pericardium, being a tough fibrous structure, provides an excellent interface for ultrasound waves. As such, it shows up as a bright, white, fairly thick line surrounding the heart. This can be made even more obvious by turning the gain higher than normal. To be more precise, the pericardium only surrounds the heart on three sides. There is no pericardium around the "top-right" corner of the heart (which would be the far-field and screen-left corner on the screen) because that is where the great vessels enter and exit the heart. Many beginners forget this and are frustrated by their inability to visualize the pericardium all the way around the heart.

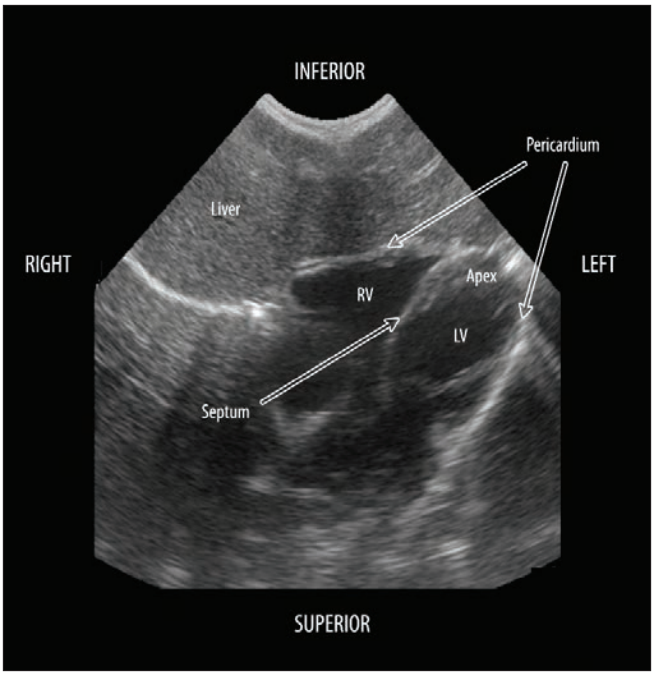


Figure 6: The pericardium is your Area of Interest.

Since the most dependent part of the supine patient's heart is found in the infero-posterior area, PCEs will first be visible in the near field. Because the PCE may only be visible through part of the sweep, it is important to define minimum criteria for an acceptable scan. The white line that lies between the ventricles is obviously the septum. If you can see the inferior pericardium all the way to the septum you have seen enough of the inferior

CARDIAC EDE

pericardium to declare the scan negative for PCE (Figure 5). It is not unusual for the gastric air bubble to produce scatter along the screen right (patient left) side of the pericardium, towards the apex. But this does not necessarily make your study indeterminate, providing you can see the point where the septum joins the inferior wall.

STEP 5

It is then necessary to sweep completely through the heart, passing from anterior to posterior and back again, watching the heart disappear completely at each extreme (Figure 7). This is called "sweeping through the Area of Interest." Get used to this expression, as you will hear it over and over again. Unlike elective ultrasound, computed tomography, or plain radiography, EDE is dynamic. It is necessary to pass completely through an area slooooowly to ensure that no pathology has been missed.

It is essential to confidently identify the pericardium. The rest (e.g., the heart chambers) is secondary. Once you are sure you have recognized the pericardium, the thing moving around inside it is… the heart. Pretty simple, eh? Once you have done this, you can address the two key questions of Cardiac EDE.

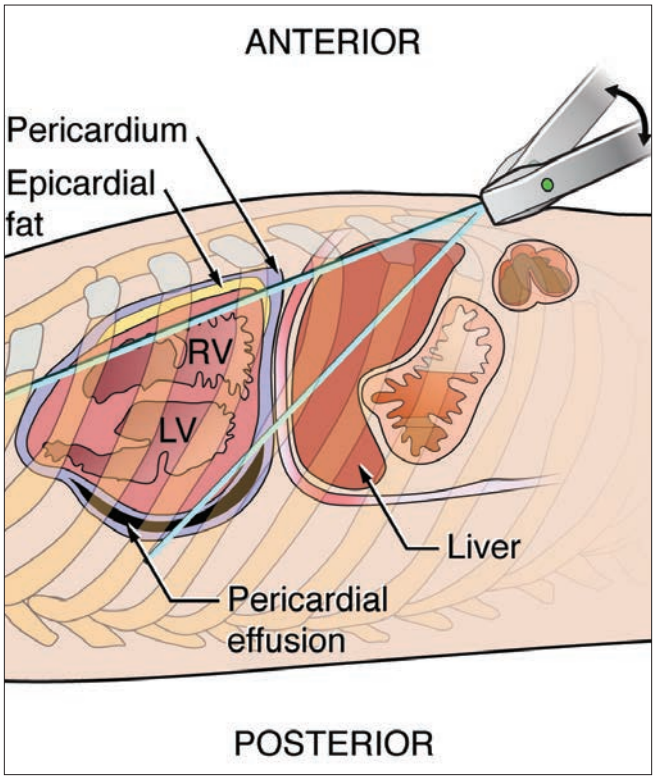


Figure 7: Sweep slowly through the heart. Epicardial fat is located anteriorly. A small pericardial effusion is most commonly seen posteriorly.

The Positive Scan

There are two positive scans in Cardiac EDE: cardiac standstill and PCE.

Cardiac Standstill

As you will see in demonstrations on normal models, recognizing grossly normal cardiac activity is simple. You can easily see the heart contracting at a frequency roughly equal to your own heart rate. Also, you can see fluid-filled structures (fluid is black on the screen) being squeezed and the black area diminishing greatly. This is the blood being squeezed out of the various chambers. It is not important to be sure whether one chamber is beating more effectively than another. It is only necessary to decide whether, as a unit, the heart is beating normally or not at all. Occasionally, you will only see the valves opening and closing weakly without movement of the myocardium. This is a pre-terminal phenomenon.

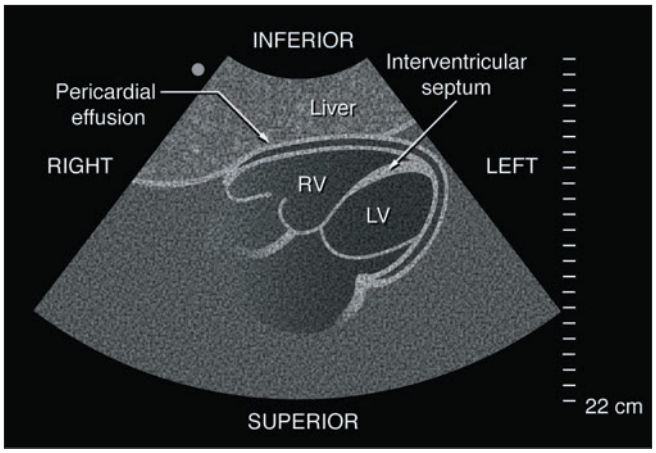
Evaluating the Pericardium

The goal here is to determine whether or not there is a PCE. The diagnosis of cardiac tamponade is a clinical one: the presence of hypotension, or at least pulsus paradoxus, is required.

While the pericardium normally contains up to 50 mL of lubricating pericardial fluid, this will not be easily appreciable on EDE. With the patient in the supine position, PCEs will become apparent at the following levels (5):

~100 mL: posteriorly, only in systole
100-300 mL: posteriorly, throughout the cardiac cycle
> 300 mL: anteriorly and posteriorly

The PCE will appear as an extra black area inside the pericardium which does not change in shape (or only changes slightly) during systole (Figure 8). Although the vast majority of PCEs will be black, a small minority will



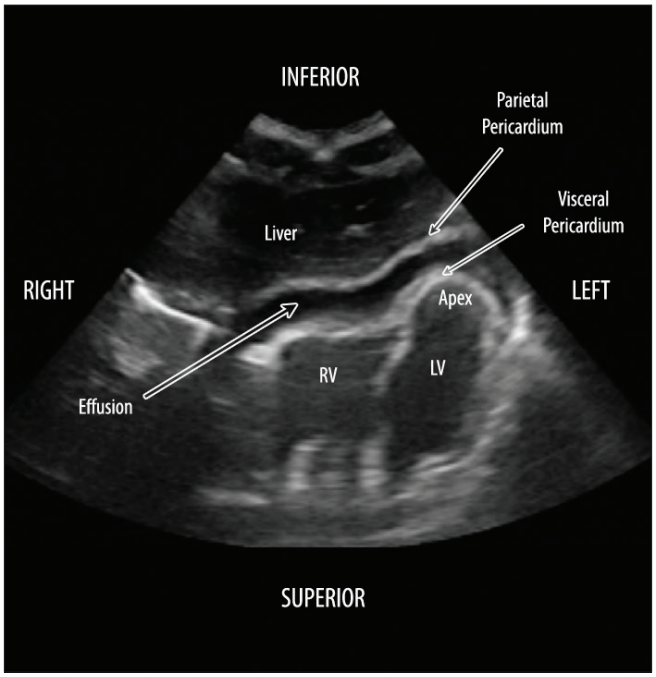


Figure 8: A pericardial effusion will commonly be seen wrapping around the ventricles. A small effusion may only be seen in the posterior part of your sweep.

demonstrate some faint echogenicity. This is consistent with clotted blood, solid pus, or other debris. As mentioned above, it is vitally important to scan through the entire heart.

Clinical Applications

Cardiac Activity

The search for cardiac standstill will take place in any resuscitation situation, where it can used to guide, or terminate, the team's efforts. Once you have determined whether cardiac activity is vigorous or absent, you go down one of two clear paths:

1) HEART NOT BEATING

Unless there is a defibrillatable rhythm on the monitor (e.g., ventricular fibrillation), this is cardiac standstill. This is not survivable. The patient is dead. Stop whatever you are doing. Consult pathology.

The one major exception to this would be the pediatric hypoxic arrest. Remember that kids are not dead until they are well-oxygenated and dead. There are less common exceptions, such as hypothermia and some overdoses (e.g., a massive beta-blocker overdose). As always, let your clinical judgment take precedence. If your gut tells you to carry on with the resuscitation, proceed!

For those who invite families into the resuscitation area, it is worth mentioning that many experienced EDE practitioners use Cardiac EDE to show families that further resuscitative efforts are futile. Place the probe on your own abdomen: even complete neophytes will recognize that something is moving inside your chest. Then show them the heart of the patient. This helps them accept that their loved one truly is gone.

2) HEART BEATING VIGOROUSLY

In the context of unexplained hypotension, this finding suggests that the cause is noncardiogenic and therefore potentially correctable. There are several readily reversible causes of this condition. First and foremost is hypovolemia. Be aggressive with your fluid resuscitation! You should also search for heretofore unsuspected blood loss. Sepsis, anaphylaxis, tension pneumothorax, and other diagnoses should also be considered and pursued.

There is of course the possibility that you will see something in between these two extremes: a heart beating, but in a way that does not seem normal. This would be the case in ischemic hypokinesis and metabolic derangements, among others. However, these are quite subtle findings and are beyond the scope of this chapter. In Cardiac EDE, you should be making the determination of vigorous cardiac activity or complete absence thereof. If you are unable to be certain of one these two findings, you must declare the scan to be indeterminate and proceed with the management of the patient without drawing any conclusions from said scan.

Pericardial Effusion

Cardiac EDE for PCE is the application where EDE most closely approximates the use of the stethoscope. Think about the number of times you place your stethoscope on the chest during an ED shift. How often does this lead to a change in management? Virtually never. But we do it routinely because it is non-invasive, practically cost-free and quick. So it should be with Cardiac EDE for PCE. But this requires a major paradigm shift.

Experienced physicians who bring EDE into their practice tend to use it as a replacement for elective ultrasound (echocardiography in the current case) when this modality is not immediately available. But when it is used properly, you should be performing Cardiac EDE on every patient who comes in with chest pain or shortness of breath, unless the etiology is absolutely clear. More than 99% of your scans will be negative, but your pickups will be life-saving at an early juncture.

If you discover a PCE, you now have to determine its cause and its effect. In trauma cases, the cause will be apparent, while in medical ones it may take a little digging.

Evaluating the effect of a PCE requires some clinical judgment. The normal pericardium can only accommodate 100-200 mL of fluid before hemodynamic compromise occurs, if it accumulates rapidly (5). In trauma cases, the patient most likely had a normal pericardium before being shot or run over. Unless there are other compelling diagnoses, it is reasonable to assume that the PCE is responsible for some, if not all, of the hypotension. This should lead you to perform an emergent pericardiocentesis (described in the Procedural EDE module).

In medical cases, where the accumulation may have taken place over weeks or months, the pericardium can stretch to accommodate several times more fluid than it can in the acute setting. Tamponade will come on slowly in these patients, and they will initially present with increasing shortness of breath on exertion and fatigue, rather than signs of shock. It is also possible that the PCE has nothing to do with the patient's vital sign abnormalities. For example, the presence of hypotension and a PCE, combined with bradycardia and a temperature of 34.2ºC, should suggest the diagnosis of myxedema.

There are echocardiographic signs of tamponade. However, in Cardiac EDE it is mandatory to describe PCEs as being only present or absent, and not to stray onto thinner ice. As mentioned at the beginning of this section, the diagnosis of tamponade should remain a clinical one. In trauma, the effusion is almost certainly to blame, while in medical cases it is only likely to be. Having said that, the converse holds true for both trauma and medical cases: no effusion, no tamponade.

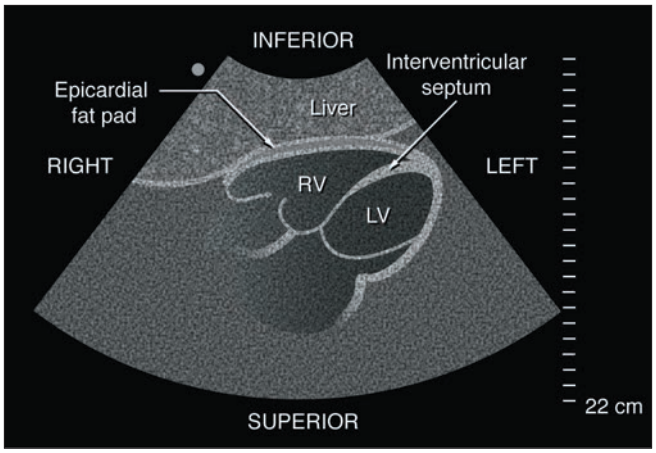
Pitfalls

Effusions Elsewhere

Possible false-positives include free fluid in the abdominal and pleural spaces. These are not a factor when using the subxiphoid approach. As there is no pleural reflection between the xiphoid and the heart, there can be no pleural effusion there either. As for abdominal free fluid, it may be found around the liver but it will not conform to the heart border. As mentioned above, the key structure to identify is the pericardium. This will enable you to be certain whether the fluid you are seeing is intrapericardial or not.

Epicardial Fat

A source of false-positives that cannot be avoided is the presence of epicardial fat (Figure 9). This strip of tissue is usually quite echolucent and can be remarkably thick. The giveaway is that it will appear anteriorly. Effusions



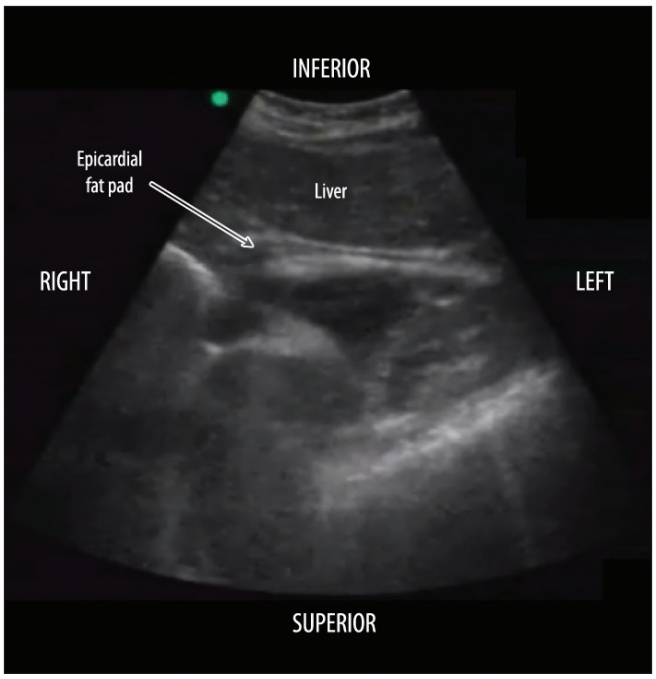


Figure 9: An epicardial fat pad often has some degree of echogenicity. This can be helpful in distinguishing it from a pericardial effusion, which is almost always very dark.

appear posteriorly first (due to gravity) and never only anteriorly. It is worth mentioning that epicardial fat pads are quite common and bear no relation to body habitus. They can be seen even in rake-thin children. It should also be added that epicardial fat usually possesses some mild degree of echogenicity, often appearing as white strands, whereas PCEs are almost always completely black.

A Few Final Tips

Respirations

If you are having trouble bringing the heart into view, there are a few things you can do to improve your image. First, you may be experiencing difficulty because the heart is too high in the chest. This is particularly true in the case of broad-chested persons. In these situations it can be very helpful to ask the person to breathe in slowly and to hold their breath. This drops the diaphragm and, by extension, the heart, bringing the target organ closer to the probe. This may not always be possible with an emergency patient, but it can make all the difference in someone who can cooperate. When using this trick, it is necessary to sweep the probe posteriorly a few degrees as the patient inspires (Figure 10). If you do not do so, the heart will pass under the beam.

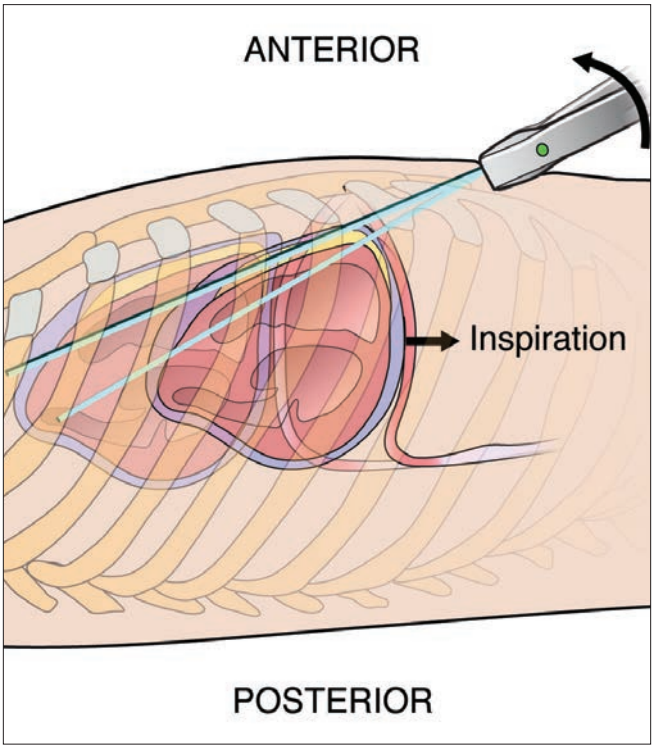


Figure 10: Sweep the probe as the patient breathes in order to follow the heart with your beam.

CARDIAC EDE

Slide to the Right

Some patients have a less-well developed left lobe of the liver (remember the liver is our acoustic window). In these cases, you may have to cheat over to patient right to get a better window. This involves two distinct movements: sliding the probe to patient right, then heeling it to the left to re-center the heart, hopefully now with a better view (Figure 11). This maneuver also helps when gas in the stomach is obscuring too much of the heart to obtain a determinate view.

Figure 11: Slide the probe to patient right and heel the probe back towards the heart to obtain a better hepatic window and avoid gas in the stomach.

Emphysema

Emphysema can also pose a problem by placing air (which scatters the ultrasound waves) between the probe and the heart. There is not much you can do about this apart from learning the other views taught in the Advanced Cardiac EDE module.

Massive Pericardial Effusion

Rarely, a massive PCE will create such a large "window" that the heart can be seen without passing the beam through the liver. Obviously, this would be a dramatically bad "miss." You can avoid falling into this trap by always starting your scan very low and identifying the liver first, before you look for the heart.

Stare at the Screen

In the difficult-to-scan patient, the appearance of the heart can be fleeting. Remember to stare at the screen and not your hand. If you are looking at your hand while moving the probe, the heart may come and go on the screen - unnoticed by you!

The Indeterminate Scan

In a small but significant minority, you will not be able to generate a determinate scan. Do not be dejected! For both the novice and the expert, it is simply impossible to generate an adequate subxiphoid view in a small subset of the population.

Clinical Suspicion Rules!

Finally, always remember that you must remain clinicians first and foremost and that EDE gives you information that is frozen in time. If a patient's condition deteriorates, redo the EDE to see if a previously absent PCE has developed in the interim.

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EDE 1 CONCLUSION

Maintenance

The ED is a hostile environment for an EDE machine. Rather than being ensconced in a dark corner of the radiology department from whence it shall never budge, the EDE machine is constantly being moved around, sometimes at a high rate of speed. When one then considers the physical layout of the ED, with all its angles, turns, nooks and crannies as well as the sharp edges one finds along stretchers, crash carts and other resuscitation-area paraphernalia, it is not surprising that EDE machines quickly acquire a goodly number of battle scars. There is little one can do to minimize this other than to urge all ED personnel to be as cautious as possible when driving the EDE machine around.

The most important aspect of maintenance is preventative. It must be clearly understood that 99% of the cost of each probe lies in the crystals directly behind the plastic head cover. When probes are dropped they invariably fall head first into the ground. The clear "ping" that you hear when the probe hits the ground is the sound of those crystals shattering and of ten thousand dollars flying out the window. It must be an absolute rule that a probe is never left unattended. It must be in its holster or in someone's hand at all times.

Maintenance of the actual probes is quite straightforward. In spite of this, it is remarkable how many emergency departments' EDE probes are in a rather shabby state. The ultrasound gel, while not particularly corrosive, certainly can gum up the works if not cleaned off promptly. After each patient contact the gel should be wiped off with a soft, smooth cloth. After this the probe must be cleansed with a non-corrosive disinfectant. Alcohol and other corrosive substances must be avoided, as they will gradually erode the delicate covering at the probe head.

Quality Assurance

To encourage the implementation of high standards for the use of ED Ultrasound, the Canadian Emergency Ultrasound Society (CEUS) was formed in 2002 by emergency physicians who were heavily involved in teaching this technique. The Society now has thousands of members, and the CEUS Independent Practitioner program offers the most rigorous training in emergency ultrasound available anywhere in the world.

All graduates of the EDE course are urged to visit the Society's website at www.ceus.ca. A detailed explanation of the Society's position is provided, as well as other resources such as a literature review, information on courses, pertinent bulletins and an email-based discussion group. All interested parties are encouraged to join. It's free, and it demonstrates that ED Ultrasound has the support of the EM community. More importantly, it also shows support for the Society's exacting standards.

A Few Final Words

Emergency Department Echo seeks to rule in or rule out conditions which can have an immediate impact on patient survival: non-cardiogenic shock, pericardial tamponade, intra-abdominal hemorrhage, ruptured abdominal aortic aneurysm, and ectopic pregnancy.

But the impact of EDE is not limited to those cases where it helps to make a life-threatening diagnosis in seconds and leads to a dramatic, life-saving change in management. There are also the far more numerous times when it is able to reassure the clinician that such a condition does not exist. This is where EDE's impact is most significant: the ability to rule out significant pathology and, by doing so, enhance patient safety while reducing the stress involved in dealing with such cases.

EDE 1 CONCLUSION

It is the essentially perfect availability of EDE which allows this situation to occur. We no longer have to seek approval for our studies, nor wait for the arrival of the operator. This dramatically drops the threshold at which one obtains an ultrasound study. Used correctly, EDE should become an extension of your physical exam.

We must also remember that we remain clinicians first and foremost. EDE is just an image, and must never be allowed to replace our clinical skills. History beats physical, history and physical beats labs and imaging. This has always been the case and all of our modern technology, including EDE, has not changed this. Never let EDE make a diagnosis for you. Always integrate the image you have generated into your diagnostic algorithm. If your index of suspicion is high and your EDE image is negative, trust your instincts.

EDE is now broadly recognized by the Canadian medical community as a vital addition to the practice of emergency medicine, both for its dramatic pick-ups and for its safe use (No false-negatives! No false-positives in OB EDE!). In early 2009, the advent of The EDE 2 Course introduced a wider scope of practice for this modality. This includes advanced cardiac, abdominal, thoracic and musculoskeletal indications as well as high frequency, near-surface ultrasound to guide vascular access and for the detection of foreign bodies and deep venous thrombosis. The course website (www.ede2course.com) can be consulted for further information.

In 2012, EDE is as essential a part of the Emergency Physician's armamentarium as the stethoscope. The goal this course set for itself over a decade ago has been accomplished.

The 10 Commandments of EDE

1) Nothing shall replace the primacy of your clinical skills.

2) Thou shalt only call a study negative when it is incontrovertibly so.

3) Thou shalt not hesitate to call a study inconclusive.

4) Thou shalt only use EDE in the appropriate clinical situations.

5) Thou shalt re-EDE patients whose initial scan is negative, should your clinical suspicion deem it necessary.

6) Thou shalt move your hand slowly and deliberately.

7) Thou shalt always be methodical in your approach to the EDE scan.

8) Thou shalt not drop the probe!

9) Thou shalt communicate effectively with your patients, ensuring they understand the limitations of your EDE scan.

10) Nothing shall replace the primacy of your clinical skills. Did I mention that already? Well, it's worth repeating.

EDE 1 CONCLUSION

THE EDE 2 COURSE MANUAL

INTRODUCTION - THE EDE 2 COURSE

Over the past 25 years, bedside ultrasound has become an indispensable clinical tool used by physicians, nurses, and paramedics worldwide. Bedside ultrasound has been integrated into the curricula of specialties dealing with the sickest patients: emergency medicine, critical care, anesthesia, and surgery. Many courses have been developed. Organizations, committees, and interest groups have formed. Position statements and guidelines have been drafted and re-drafted. Conferences have been held. Mountains of research are being performed, presented, and published. The setting of this research extends from physicians' offices to outer space and everywhere in between. The indications for bedside ultrasound have expanded as new uses have been found. What has been the driving force behind the development of bedside ultrasound? The desire to improve patient care, 24 hours a day, 7 days a week, 365 days a year.

The development of emergency ultrasound in Canada paralleled its development internationally, although we were delayed by a few years. In 2001, the first Emergency Department Echo (EDE) Course made its debut. A year later, the Canadian Emergency Ultrasound Society (CEUS) was formed. In those early days, the number of Canadian emergency departments using bedside ultrasound could be counted on one hand. Today, the landscape is very different. Over 7000 physicians have taken The EDE Course. This represents roughly half of the Canadian emergency medicine workforce! Well over 1000 physicians have attained CEUS Independent Practitioner status. The EDE 2 Course benefits from this groundwork. EDE 2 also benefits from the pedagogical style and principles established by the first EDE Course, which you will notice throughout this manual.

Many new and advanced indications for emergency ultrasound have been reported in the literature over the last decade. Many readers no doubt have investigated some of them. You may recall that the first EDE Course admonished you not to stray from the primary indications. This was and still is necessary for the novice sonographer. However, a physician who has reached the level of Independent Practitioner for the primary indications has gained the image-generating skills to go further.

If you are taking The EDE 2 Course, it means that you have a thirst to learn more and to take your EDE skills to the next level. Does that mean that you now need to learn about the piezoelectric effect? No, of course not! Despite your quest for advanced skills, EDE 2 will keep things simple.

There are three main skill sets that we are hoping to teach you during the course: image generation, image interpretation, and how to direct a needle or scalpel at a target of interest using EDE guidance. For diagnostic scans, image generation is a far greater challenge than image interpretation. Therefore, this text and the live course focus on image generation. Of course, you will learn image interpretation as well. However, once you learn how to put a determinate image on the screen, you will have no difficulty with image interpretation in the vast majority of cases.

As with the first EDE course, EDE 2 emphasizes several key principles. They are worth repeating and they are as important as ever.

As with EDE, EDE 2 focuses on binary answers. Your scan should yield a clear "Yes" or a clear "No". If you are not absolutely sure the scan is positive or negative, call your

scan "indeterminate" and carry on with the good emergency medical care that you have been doing to this point. Not only is it appropriate to do so, it is necessary in order to stay safe. Incorporating indeterminate scans into your clinical decision-making will lead to false-negatives and false-positives, both of which can harm your patient and your EDE program.

Even when you do generate a determinate image and a clear yes or no, EDE is only an image. It is but one data point. Combine it with other clinical information from your history, physical, and other tests to decide how to best manage your patient. If all of your other clinical information points in one direction but your EDE points in another that should give you pause, but do not blindly follow your EDE. Put everything together and perhaps obtain more information before deciding on a management plan.

Although EDE 2 introduces new indications and widens your scope of EDE practice, do not stray. Focus only on the questions that EDE can answer. There are many questions that elective ultrasound can address that you should not attempt to answer with EDE. Ultrasound technologists and radiologists often spend a year or more in ultrasound training, with a focus that is different from EDE. Respect your limits and the limits of EDE.

With the vast number of indications for EDE, it was difficult to decide which to include in The EDE 2 Course. Even in a 2-day course, we could not include everything. Various indications were left out for one of several reasons. In some cases, the scan is technically more challenging or infrequently used. In other cases, the research has not yet established sufficient clinical utility. In still other cases, the definition of a positive scan remains too nebulous. As the field of emergency ultrasound continues to evolve, we may add more modules in the future.

The EDE 2 Course is just a course. It cannot replace or obviate the need for further training. In the case of several EDE 2 indications, no research has as yet been performed regarding training requirements to attain competency. In these cases, training requirements would be based on expert opinion alone. It could be argued that the number of training scans needed for some of the EDE 2 indications approaches "see one, do one, teach one." However, in the case of other indications, based on the literature, 25-50 training scans would be more appropriate. Regardless, your emergency ultrasound path beyond this course should occur in the context of an ED ultrasound program with rigorous quality control. Until you are fully trained, prudence dictates that your scan be followed by other testing or consultation.

You will notice that we are using the term "training manual" in naming this collection of work that you are about to read. Different from a medical reference tome or evidence-based dissertation, *The EDE 2 Course Manual* seeks to promote learning in a manner more akin to a "how-to" guide. As we did in EDE 1, we have stripped away non-essential information that is more likely to foster confusion than clarity.

You will also notice that we are using the term "module" rather than "chapter" to describe each part of The EDE 2 Course. Although you may read through *The EDE 2 Course Manual* in order from front to back, we know that you will not incorporate all of the EDE 2 indications immediately into your practice. You or your emergency department may decide to use only some of the EDE 2 indications. This decision may be based on any number of practical issues: training, patient population, local politics, etc. The term "module" reflects that reality.

In 1816, Dr René Laennec of France invented the first stethoscope. Almost 200 years later, this common

EDE 2 CONCLUSION

In the Introduction, we harkened back to the past. Now we look forward.

What should you do the day after you take the EDE 2 Course? Start doing your EDE scans! You must maintain and develop the skills you will learn during EDE 2. But there are other steps that have to be taken. An adequate amount of supervised training must occur before you incorporate your scans into clinical decision-making. Until you are fully trained, your scans should be considered indeterminate. And therein, as the Bard put it, lies the rub.

Your training should be governed by local, regional, national, or international guidelines. At present, they are mostly informed by expert opinion, as much more research is needed in this area. For some of the EDE 2 scans, the training needs approach "see one, do one, teach one". This is particularly the case for someone with Independent Practitioner (IP) status with the Canadian Emergency Ultrasound Society. Other types of scans probably require 25-50 training scans.

The nature of the required training is also controversial. Is direct supervision needed for all scans? Can video review and feedback supplement the training? How many of the scans need to be positive? Do positive scans from continuing medical education sessions obviate the need for the "live positive"? Does the cross-training gained from IP status decrease the number of training scans required? If the possibility of expert mentoring does not exist, to what extent can personal learning with comparison to elective testing contribute to skill development? After all, that is how the leading experts in any field of medicine often learn a new skill.

These questions will all be answered in due course. For now, your training should not occur in isolation, regardless of the form it takes. Departmental oversight is the key to ensuring quality and uniformity of the training, acceptance of the applications in the broader medical community and, most importantly, patient safety.

Now let's look a little further into the future…

Just as with the stethoscope in the 1800s, the use of bedside ultrasound will spread throughout the world as health-care practitioners discover its utility in their daily battle against injury and disease. The time line for this paradigm shift is anyone's guess. But there will come a day when graduating medical students will know more about bedside ultrasound than any of us do now. They will surpass us. But they will do so only by standing on our shoulders, and that means your shoulders as well. By taking The EDE 2 Course now, you are a leader. Our collective task is to ensure that EDE is used safely and effectively. When ultrasound is recognized by all physicians as an indispensable tool, just as the stethoscope is, we will have attained our goal.

Thanks for being part of EDE 2!

The EDE 2 Team
June 2012

EDE 2 CONCLUSION

"THE EDE BOOK"

EDE2

www.ede2course.com

Since 2001, The Emergency Department Echo Course and The EDE 2 Course have taught EDE (pronounced "Eddie") to over 7000 physicians. The most distinctive aspect of The EDE Courses has been the focus on image generation. When emergency physicians first began investigating the possibility of using ultrasound themselves, a big secret was concealed from them: image interpretation is easy. The real challenge is image generation: putting the image on the screen. Before The EDE Courses, physicians learned image generation mostly by trial and error. EDE brought a rigorous methodology to the scanning of each area of the body, dramatically reducing the time needed to master this new skill.

Point-of-Care Ultrasound for Emergency Physicians combines The EDE Course manuals which have been written and re-written for over a decade to give emergency physicians the clearest and most concise approach to emergency ultrasound.