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Current Issues with Emergency Cardiac Ultrasound Probe and Image Conventions

Chris Moore, MD, RDMS, RDCS

Abstract

As emergency physicians (EPs) and other noncardiologists incorporate bedside ultrasound (US) and bedside echocardiography (echo) into their practice, confusion has resulted from the differing imaging conventions used by cardiac and general imaging. The author discusses the origin of these differences, current cardiac imaging conventions, and controversies in emergency medicine (EM) regarding adoption of imaging conventions. Also discussed in detail are specific echo windows and experience with different approaches. While there is no perfect solution to merging the differing conventions, it is important that those performing and teaching bedside US and echo have a thorough understanding of the issues involved, and adopt a consistent approach.

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The use of bedside clinician-performed ultrasound (US) and echocardiography (echo) is increasing among noncardiologists. Emergency physicians (EPs), critical care physicians, surgeons, and anesthesiologists all represent specialties that are now using bedside US and bedside echo.[1–5] Within emergency medicine (EM), the use of bedside echo is well established in trauma, cardiac arrest, and the diagnosis of pericardial effusion.[6–9] Newer applications include use of echo in determining left ventricular function and to aid in the diagnosis and therapy of patients with undifferentiated dyspnea, sepsis, and shock.[10–14]

As the prevalence of physicians who perform general and cardiac US increases, there is the potential for confusion due to differing imaging conventions in echo and general US. This article will discuss the origins of these issues, controversies in EM, specific windows, and experience with different approaches.

HISTORY

The first published work on US of the heart appears to have been in 1954, when Inge Edler, the "Father of Echocardiography," published work about the use of a "reflectoscope" for continuous recording of cardiac motion.[15] Cardiologists became more widely aware of its diagnostic potential in the 1960s, and it became a standard tool by the 1970s.[16,17] US for gynecologic and other medical applications developed along parallel tracks, with initial publications in the 1950s progressing to more widespread adoption by the 1970s.[18,19] In the 1980s, the first published reports of bedside US by EPs began to emerge. Bedside emergency ultrasound (EUS), both of the heart and other body areas, has spread rapidly and is now recognized as a standard EP skill.[20]

As cardiac US and general (medical and gynecologic) US developed, each adopted its own imaging conventions. While general US is typically performed from the patient's right, echo is usually performed from the patient's left, closer to the heart. Additionally, cardiology adopted a different imaging convention for the US probe relative to the screen images. It is unclear why a differing probe-to-screen orientation was adopted, but was probably simply a result of two independent approaches from an early stage.

Each orientation convention is internally consistent, but problems arise when physicians use US for general and cardiac imaging in the same patient. An example might be an EP seeking to find the cause of shock in a patient with undifferentiated hypotension, where imaging of the aorta, peritoneal spaces, and heart are all performed as parts of an integrated goal-directed examination[11,21]; or the focused assessment with sonography in trauma (FAST) examination, where physicians

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are looking for fluid in both the peritoneal and the pericardial spaces.[22]

CURRENT CARDIAC CONVENTIONS

There are two key issues regarding the orientation of anatomic structures as they are viewed on the screen: relationship of the probe indicator to the image on the screen (indicator-to-screen) and relationship of the probe indicator to the patient (indicator-to-patient). The standard US image is a plane directed through various areas of the body. The top of the screen typically represents the probe face. General US uses an imaging convention where the indicator (a bump or groove) on the probe corresponds to the left side of the screen as it is viewed. However, in cardiology echo the indicator corresponds to the opposite (right) side of the screen (Figure 1).

Anatomic orientation follows based on where the indicator is directed on the patient. For example, in general imaging when the indicator is directed to the patient's right, right sided structures will be seen on the left side of the screen (transverse plane); when the probe is turned towards the patient's head (longitudinal plane), the left side of the screen will then correspond to the patient's head. Most general imaging takes place in this 90° arc, with the indicator directed to the patient's right, or head. The indicator can also be considered to be on the *examiner's* left as he or she "looks through" the body from below or from the patient's right. Conversely, transthoracic echo by cardiologists is performed from the patient's left, using an opposite screen orientation as well as opposite indicator directions for most windows.

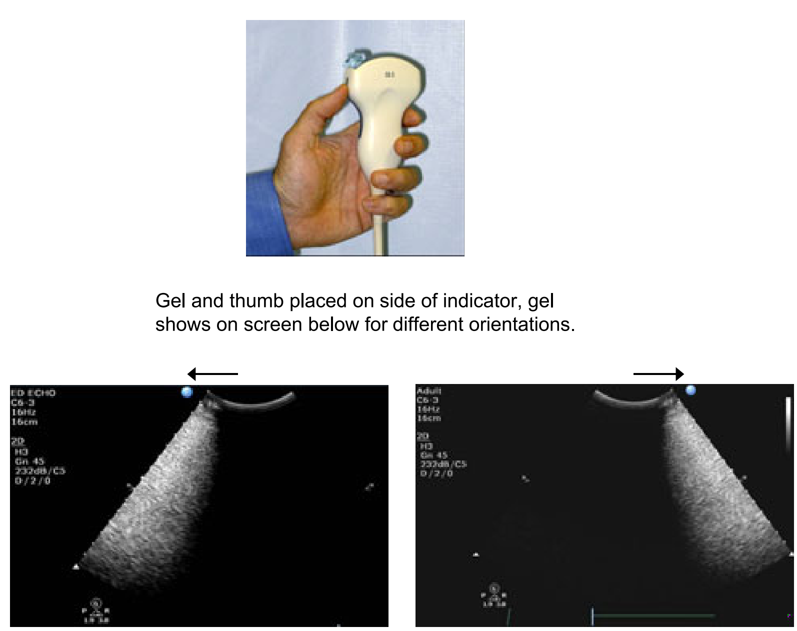
CONTROVERSY IN EMERGENCY MEDICINE

When imaging the heart, the sonographer must be aware of both indicator-to-screen and indicator-to-patient orientation to fully grasp how cardiac anatomy is represented on the US screen. Unfortunately, because of the differing imaging conventions, there have been different approaches to echo within EM.

When transitioning from general to cardiac imaging or vice versa, there are two possible choices regarding indicator-to-screen orientation: perform echo in a cardiology screen orientation, being aware of the reversal in indicator-to-screen orientation relative to other US, or scan the heart using a general imaging screen orientation.

There is significant variation in teaching and practice regarding which indicator-to-screen orientation should be chosen. One of the earliest texts in EUS mentions differing imaging conventions, but does not clearly explain them and appears to use both conventions, showing a backward subcostal image.[23] A more recent review article describes using the cardiology screen orientation, but states the incorrect probe orientation for the apical four-chamber view.[24] Other texts have ignored the issue, alternated between general and cardiac imaging, used one or the other, or discussed both, often with inconsistencies.[25,26] In a recent informal

Arrow on top of image shows screen orientation relative to indicator. Also note position of P on the screen.



Gel and thumb placed on side of indicator, gel shows on screen below for different orientations.

General Orientation. The indicator corresponds to the left side of the screen as it is viewed.

Cardiology Orientation. The indicator corresponds to the right side of the screen as it is viewed.

Figure 1. Indicator-to-screen orientation for general and cardiology imaging.

survey, two-thirds of respondents used a general indicator-to-screen orientation, and this is the recommendation recently published in the 2006 Emergency Ultrasound Imaging Compendium.[27,28]

The second issue is indicator-to-patient (and/or indicator-to-sonographer) orientation. A consistent orientation is important in allowing correct anatomic interpretation and integration of hand–eye–image coordination. Positioning of the examiner relative to the patient is important. Most EUS is done from the patient's right and can be thought of as looking through the patient from the feet upward, or from the right side. Conversely, if cardiac imaging is done from the patient's left, it can be thought of as looking through the patient from the left side. Probe positions differ based on imaging convention and window and are summarized in Figures 2 and 3. There are three primary cardiac windows that are typically utilized by EPs for transthoracic cardiac imaging: the subcostal, apical, and parasternal windows. Of these, the parasternal long axis has proven the most problematic, as in the cardiology convention it requires reversing the probe to obtain an image that is reversed. Probe orientation for specific windows is discussed below.

SPECIFIC WINDOWS

Subcostal Window

This window is probably the most familiar to EPs and surgeons and is most frequently included as the

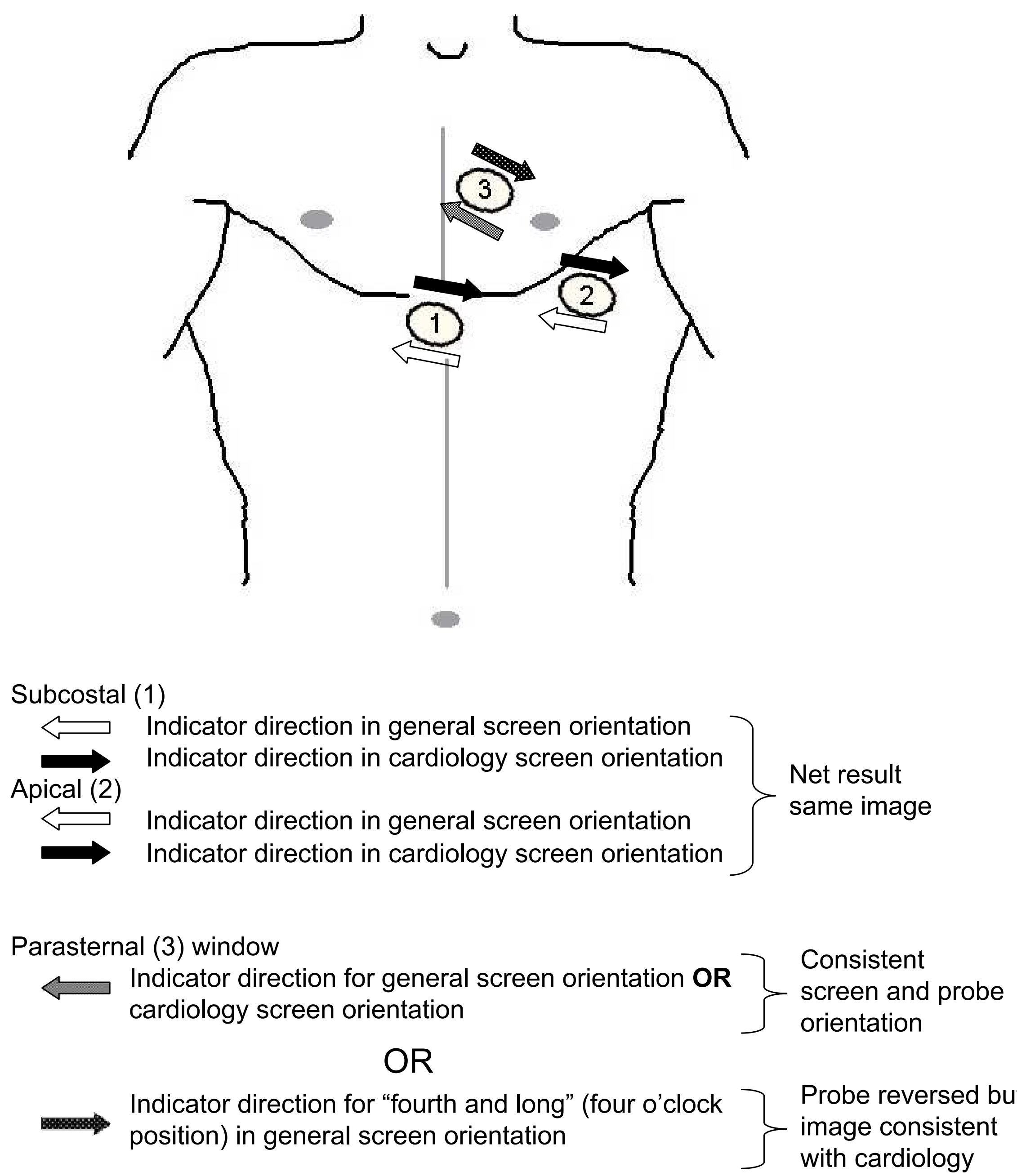


Figure 2. Indicator-to-patient directions for three primary cardiac windows.

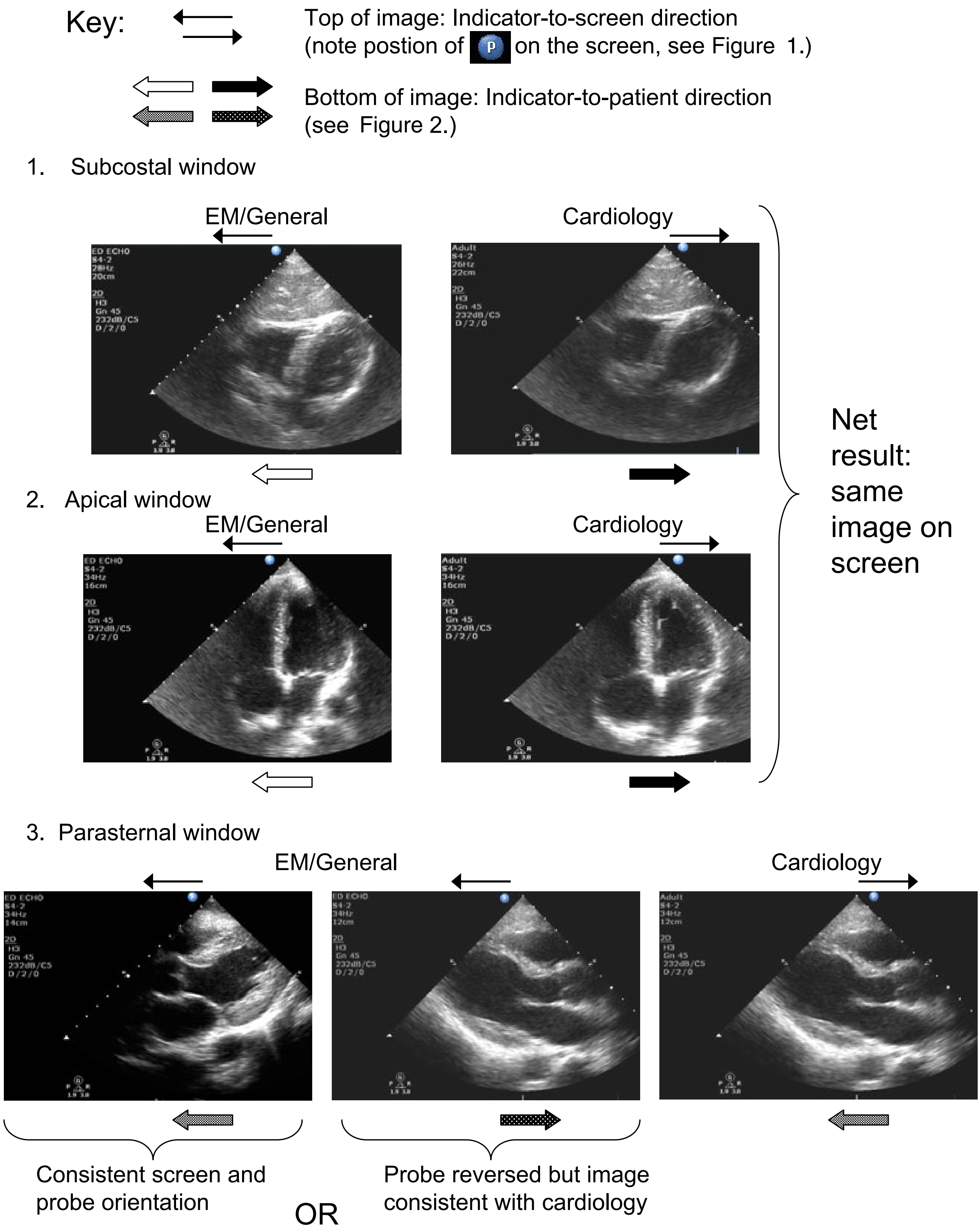


Figure 3. Primary cardiac windows.

primary view of the heart in the FAST examination. The window is obtained by placing the probe under the xiphoid process and angling the plane of the US into the left chest. The view should include both atria and ventricles. The apex of the heart, a left-sided structure, should be seen on the right side of the screen as it is viewed, with the right-sided structures toward the left of the screen and adjacent to the liver. In a cardiology orientation, the probe indicator should be directed to the patient's left, while in a general imaging orientation it should be directed to the patient's right, resulting in the same image on the screen.

Apical Window

This window is obtained by placing the probe at the apex of the heart, typically slightly inferior and lateral to the nipple in males and under the breast in females. While probably the most difficult of the three primary windows to consistently visualize, it provides some of the best information when correctly obtained. The four-chamber view includes both ventricles and atria, with the apex at the top of the screen and the interventricular septum running vertically down the screen. In a cardiology orientation, the probe indicator is directed to the patient's left (or down to the bed when patient is in a supine position), while in a general imaging orientation the probe indicator is directed to the patient's right (or toward the ceiling in a supine patient). The net result is that in either convention, the same image is seen on the screen, with the left side of the heart on the right side of the screen as it is viewed and the right side of the heart on the left side of the screen as it is viewed.

Parasternal Window

The parasternal window is one of the most consistently available windows to the heart. The long axis view is obtained by placing the probe just to the left of the sternum in the second or third intercostal space with the US plane running from the base to the apex of the heart. The view should include the right ventricle anteriorly and the left atrium, ventricle, and aortic outflow tract posteriorly.

The parasternal view is obtained in cardiology by directing the probe to the patient's *right* shoulder (opposite to the probe direction in other cardiology views) providing an image that is reversed from other windows, with the apex (a left-sided structure) on the left of the screen as it is viewed. This indicator direction makes sense when the examiner is on the patient's left, as the view can be thought of as looking *down* through the long axis of the heart. However, this orientation is not intuitive when scanning from the patient's right (where other US examinations are typically performed from) and essentially involves switching the probe indicator direction in order to obtain an image that is reversed from other cardiac images.

There are two potential solutions for the parasternal window when scanning from the patient's right using a general imaging screen orientation. An attempt can be made to mimic the cardiology screen image by pointing the indicator to the patient's left hip. This is sometimes called the ''fourth-and-long'' approach, as it involves directing the indicator to the 4 o'clock position (or left hip) to obtain the long axis view. This is based on a partial but incomplete adoption of the cardiology approach and will result in an image that mimics what is seen in cardiology and many emergency medicine texts.

An alternate approach is to orient the indicator to the patient's right in a general screen orientation, consistent with the indicator direction for the other windows to the heart. This provides an image that is flipped from that commonly seen in cardiology texts, but allows for a consistent probe orientation with consistent position of anatomic structures on the US screen, (i.e., the apex [patient's left] on the right side of the screen as it is viewed). This approach has been previously described in the literature and is listed as an alternate approach in the Emergency Ultrasound Imaging Compendium.[28,29]

Other Windows

Similar principles apply to other windows. Using a general indicator-to-screen convention, windows such as the parasternal short axis (indicator to right hip) and subcostal long axis (indicator to head) will produce images consistent with cardiology as well as with EM orientation conventions.

ADVANTAGES, DISADVANTAGES, AND EXPERIENCE WITH DIFFERENT APPROACHES

Adopting a standard indicator-to-screen orientation for all exams (cardiac and noncardiac) results in less confusion as it does not require either physically or mentally switching the indicator-to-screen orientation when changing applications. Some physicians have been reluctant to do this because choosing the ''Echo'' preset, which is standard on many machines and results in better cardiac images, defaults to a cardiology indicator-to-screen orientation. However, it is usually straightforward to create an ''ED Echo'' preset on the machine, which maintains cardiac settings while using a general imaging orientation. This is consistent with the way most EPs use both FAST and cardiac US and is backed by the Imaging Criteria Compendium,[28] although it is not consistent with the cardiology convention.

Using the general indicator-to-screen orientation allows for the subcostal and apical views of the heart to be obtained using an indicator direction that is consistent with other EUS (directed to patient's right). Directing the probe to the patient's left (4 o'clock) for the parasternal long axis will provide an image consistent with those seen in cardiology texts. However, it has the disadvantage of both reversing the probe direction from other views and obtaining a screen image that is reversed from other US images. Unless the physician is physically positioned on the patient's left, the image and hand movements will be counterintuitive from other scanning.

The alternate approach of directing the indicator to the patient's right shoulder to obtain a parasternal long axis is currently less widely used, but has the advantage of not having to remember to switch either the probe orientation or the screen orientation for any type of scanning. Utilizing a consistent probe orientation (i.e., indicator to patient's right) allows for quicker assimilation of cardiac orientation and anatomy and integration of cardiac scanning into US scanning as a whole. This method provides an image that is consistent with the other views: a parasternal window in this orientation is very similar in appearance to the subcostal window, only higher, including the aortic root rather than the right atrium. There are situations where a nontraditional window may be the only one available; windows such as a low parasternal/high subxiphoid/medial apical view, and obtaining these windows does not require switching the indicator direction.

The drawback to this alternate approach is that the parasternal image seen on the screen will appear differently from that currently seen in many textbooks. There is concern that using a different convention will result in problems communicating images with cardiologists, although cardiologists versed in echo usually grasp the issue quickly. Within cardiology, the Mayo Clinic, one of the leading teaching and research echo labs in the country, uses a probe orientation convention that differs from the standard cardiology approach for the apical four chamber view.[30]

A benefit of a consistent approach is that physicians do not have to remember to switch the probe direction for certain windows and not others. In addition to consistent anatomic orientation on the screen, this helps to ensure that other windows will not be inadvertently switched. In the apical four-chamber view in particular, it can be critical to distinguish left from right side, and when physicians are confused about probe direction, they can easily mistake right for left heart or vice versa.

Differentiating right from left heart may not be problematic in nonpathologic hearts, but can be critical in sicker patients. In particular, the identification of right and left ventricular pathology may be of diagnostic or prognostic importance in patients with undifferentiated shock or dyspnea, suspected pulmonary embolism, myocardial infarction, or congestive heart failure, among other pathologies.[12,21,31–36] Specifically, a pathologic right heart may be missed when it is thought to be the left side, an error that occurs when images are oriented based on how they appear on the screen rather than using a consistent approach to probe placement. Errors such as this are unlikely to be reported in the literature; while the widespread use of echo by EPs for these conditions has not yet been realized, they are likely to increase as training and equipment improve.[2,37] Adopting consistent habits early on will ensure correct application.

Using a consistent indicator to patient orientation also means that the hand–eye coordination that is ingrained from other types of scanning is not upset. This may be of critical importance during procedural guidance, such as US-guided pericardiocentesis, when it is crucial to direct the probe based on image orientation. We are aware of a center who recently adopted a consistent probe orientation after difficulty was encountered directing the needle correctly, using an image with the probe reversed.[38]

RESOLUTION

Consensus is unlikely to be achieved as long as EPs are trying to mimic both cardiac and general imaging conventions on the same patient, and unfortunately, confusion is likely to continue when the cardiology approach is partially adopted. While adopting a consistent approach to all EUS that is unique but merges the two conventions is possible, differences exist in how to approach this issue. It is the goal of this article to explain the origins and possible approaches, particularly to physicians who are in the position of teaching others how to perform this exam.

CONCLUSIONS

Early on, cardiac and general US imaging adopted conventions that differed from each other. As cardiac US scanning is reassimilated into use by physicians who scan all parts of the body, it is reasonable to adopt a consistent orientation and approach to all parts of the body, rather than trying to use two disparate US approaches on a single patient. In either case, it is essential to understand the issues regarding US image orientation in both diagnostic and procedural uses of US.

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