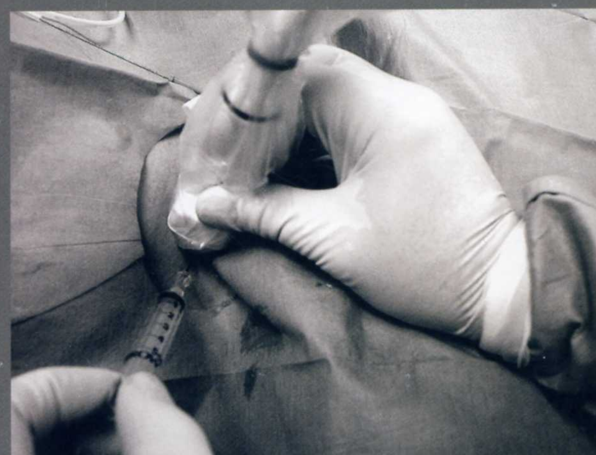

The Handbook of *Ultrasound* in Trauma and Critical Illness

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SECTION 2

THORACOABDOMINAL TRAUMA

CHAPTER 5

THE FAST EXAM

INTRODUCTION

The evaluation of the trauma patient with thoracoabdominal trauma is often a diagnostic challenge for the emergency physician and trauma surgeon. Physical examination of the trauma patient cannot always be relied on as a sensitive modality for detecting significant internal injuries. This lack of reliability has led physicians to depend on ancillary tests to detect potentially life-threatening internal injuries in these patients.

The use of ultrasound (US) in the evaluation of the trauma patient was first reported in the German literature in 1971 and was followed by numerous studies over the next two decades.[1-10] In 1988, the German Association of Surgery included mastery of US in its guidelines for surgical resident education.[11] Today, US has virtually replaced diagnostic peritoneal lavage (DPL) as a primary imaging modality for trauma patients in Europe and Japan.

The first American report on the use of US in the evaluation of blunt abdominal trauma (BAT) was published in 1992 by Tso and colleagues.[12] Since that first study in 1992, numerous studies have been published in this country favoring the use of US in the evaluation of the trauma patient with BAT.[13-20] In 1997, the American College of Surgeons included the use of US in the Advanced Trauma Life Support (ATLS) secondary survey.[21] That same year, an international panel of experts met to discuss key issues related to performing the FAST exam (Focused Assessment with Sonography for Trauma) in order to allow broader recognition of the test and its applications.[22]

The acronym FAST first appeared in the trauma literature in 1996 and originally stood for "Focused Abdominal Sonography for Trauma". This was felt to inaccurately describe the exam since the exam was not limited to evaluation of the abdomen. In 1997, the FAST Consensus Conference Committee concluded that the acronym should stand for "Focused Assessment with Sonography for Trauma". [22]

This chapter will discuss how to perform the four views of the FAST exam. Since the main goal of the FAST exam is detection of hemopericardium and hemoperitoneum, special attention will be paid to understanding free fluid movement within the peritoneal cavity and the sonographic appearance of blood.

GOALS/TERMINOLOGY

The current standardized FAST exam has been developed to be a bedside, screening exam for the detection of hemopericardium and hemoperitoneum. The FAST exam is not meant to be a formal, multi-organ study that will identify all sonographically detectable pathology. Its success and growing widespread popularity is largely due to the fact that the exam is noninvasive, accurate, limited in scope and can easily be performed with minimal training.

The current standardized FAST exam consists of four sonographic windows: 1. Pericardial, 2. Perihepatic, 3. Pelvic, and 4. Perisplenic. Consistency of terminology has been advocated, and terms such as right upper quadrant and left upper quadrant are no longer recommended.

ANATOMIC CONSIDERATIONS

The use of the FAST exam is based on the assumption that clinically important abdominal and cardiac injuries will be associated with free fluid. The detection of hemopericardium is relatively straightforward since the fluid is confined between the parietal and visceral layers of the pericardium and can be readily detected with US. However, the detection of hemoperitoneum is dependent on factors such as body habitus, injury location, history of prior surgeries, presence of clotted blood, patient position, and the amount of fluid present. Free intraperitoneal fluid continually circulates throughout the peritoneal cavity and will preferentially collect in dependent intraperitoneal compartments formed by mesenteric attachments and peritoneal reflections.[23] A basic understanding of the fluid movement from various locations within the peritoneal cavity is essential and will help improve the performance and interpretation of the FAST exam (Figure 34).

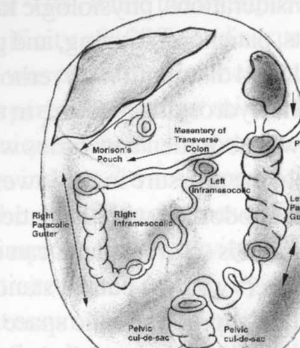

Figure 34. An illustration of the pattern of free-fluid movement within the peritoneal cavity.

The peritoneal cavity consists of the greater sac and lesser sac. The greater sac is the main part of the cavity and it extends from the diaphragm to the pelvis. The lesser sac, which is a diverticulum of the greater sac, is confined largely to the left side of the upper abdomen, and communicates on the right with the greater sac through a passage known as the epiploic foramen. The greater sac is divided into supramesocolic and inframesocolic compartments with the transverse colon and its mesocolon being used as the boundary. The rectovesicular pouch is the most dependent area in the supine male, while the rectouterine pouch (pouch of Douglas) is the most dependent area in the supine female. The most dependent supramesocolic location in both the supine male and female is the hepatorenal fossa (Morison's pouch).

The paracolic gutters connect the supramesocolic and inframesocolic compartments. The right paracolic gutter is wider and deeper than the left paracolic gutter and it connects the pelvis with Morison's pouch and the right subphrenic space. In comparison, the left paracolic gutter is shallower and its course to the left perisplenic space is blocked by the phrenicocolic ligament.[24] The falciform ligament prevents fluid from traveling between the left and right subphrenic spaces.

In addition to anatomic considerations, physiologic factors such as intraperitoneal pressure gradients, patient positioning, and gravity will all have an effect on intraperitoneal fluid distribution. Overholt, using an animal model, demonstrated that the hydrostatic pressure in the upper abdomen is less than that of the lower abdomen and varies with respiration.[25] Drye, in his study, found that the pressure in the lower abdomen is three times as great as in the upper abdomen with the patient in the erect position.[26] This pressure gradient is so great that it can even result in fluid traveling up the paracolic gutters with the patient standing.[27]

Fluid introduced into the right supramesocolic space has been shown by Meyers to preferentially flow directly into Morison's pouch in the supine patient with overflow fluid traveling to the right subphrenic space and ultimately to the pelvis via the right paracolic gutter.[24] Less commonly, fluid will travel to the splenorenal fossa via the epiploic foramen. The falciform ligament will prevent fluid from traveling directly between the right and left subphrenic spaces.

Fluid introduced into the left supramesocolic space has been shown by Meyers to preferentially flow cephalad to the subphrenic space in the supine patient.[24] Overflow fluid will extend caudally to the splenorenal fossa, across the epiploic foramen to Morison's pouch, and ultimately, to the pelvis via the right paracolic gutter. This suggests that the subdiaphragmatic region must be visualized on the perisplenic view when scanning a patient with a suspected splenic injury.

Fluid introduced into the inframesocolic space (pelvis) has been shown by Meyers to almost immediately travel to the rectovesicular pouch in the supine male and the pouch of Douglas in the supine female.[24] Overflow fluid will ascend up the paracolic gutters, with the majority going up the right side to Morison's pouch. As previously mentioned, fluid meets more resistance in the left paracolic gutter and will preferentially travel up the right.

Trauma scanning has been performed using as many as six and as few as one acoustic windows. The fact that Morison's pouch is a common site of fluid accumulation has made it a popular scanning site for hemoperitoneum. Ma and colleagues compared the sensitivities, specificities, and accuracies of the single-view and multiple-view techniques for detecting hemoperitoneum in a supine patient.[18] The single-view technique had a sensitivity of 51%, specificity of 100%, and accuracy of 93%, while the multiple-view technique had a sensitivity of 87%, specificity of 100%, and accuracy of 98%. The single-view technique was performed in one minute while the multiple-view technique was performed in four minutes. They concluded that the multiple-view technique was much more sensitive, but the addition of the paracolic windows did not improve the sensitivity.

The use of five degrees of Trendelenburg positioning has been shown to improve the sensitivity of fluid detection in the single-view (perihepatic) exam.[28] A study by Abrams and colleagues used a DPL model that assumed an inframesocolic source of bleeding. They found that using five degrees of Trendelenburg positioning decreased the threshold for fluid detection from 700cc to 400cc. While this study shows that five degrees of Trendelenburg positioning improves sensitivity for fluid detection when the single, perihepatic window is used, its results cannot be extrapolated to a supramesocolic source of bleeding, such as the liver or spleen. Based on the knowledge of preferential fluid pathways within the peritoneal cavity, it would seem unlikely that the addition of the Trendelenburg position would decrease the threshold for supramesocolic fluid detection. It is this author's belief that performing the multiple-view examination adds little extra time, requires minimal extra training and provides the most information. If the other abdominal windows cannot be performed on a patient, the use of the Trendelenburg position could be considered. It is also important to remember that the single, perihepatic window will not provide any information about pericardial fluid.

SONOGRAPHIC APPEARANCE OF BLOOD

Blood in the acutely liquefied state will sonographically appear as an anechoic area (Figures 35A and 35B). The presence of clotting will result in echoes within the anechoic appearing blood. After 48 hours, a well-localized collection of blood will have an echogenic appearance that may closely resemble the echogenicity of the surrounding parenchyma.

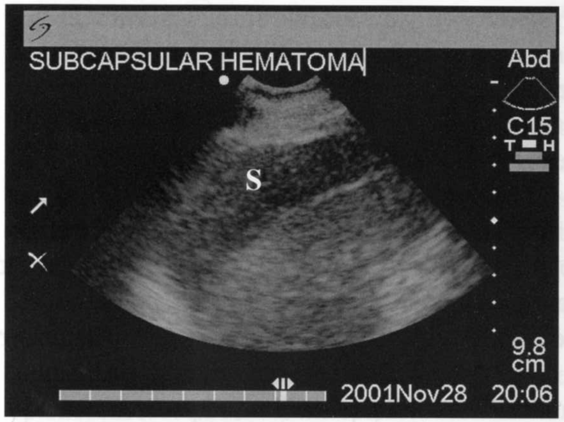

Figure 35A. Anechoic subcapsular hematoma(s) in a patient with an acute injury. Notice the presence of low-level echoes within the fluid due to clotting. Reverberation artifact is also present.

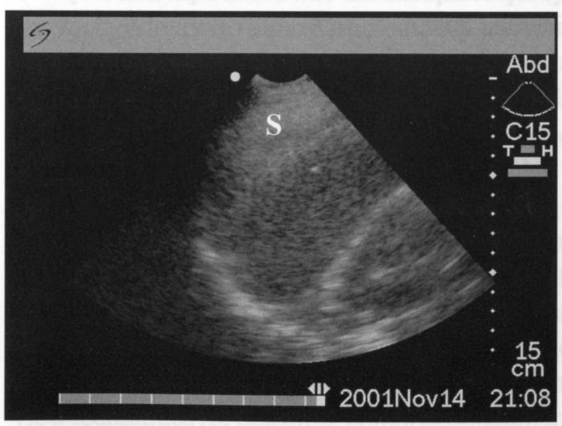

Figure 35B. Echogenic subcapsular hematoma(s) in a patient with a subacute injury.

SONOGRAPHIC TECHNIQUE/FINDINGS

Introduction

The FAST exam consists of four sonographic windows: Pericardial, Perihepatic, Perisplenic and Pelvic (Figure 36). A 2.5-5.0MHz curvilinear or sector transducer with a small enough footprint to allow intercostal scanning can be used to obtain all 4 windows. The patient can be kept in the supine position throughout the entire examination.

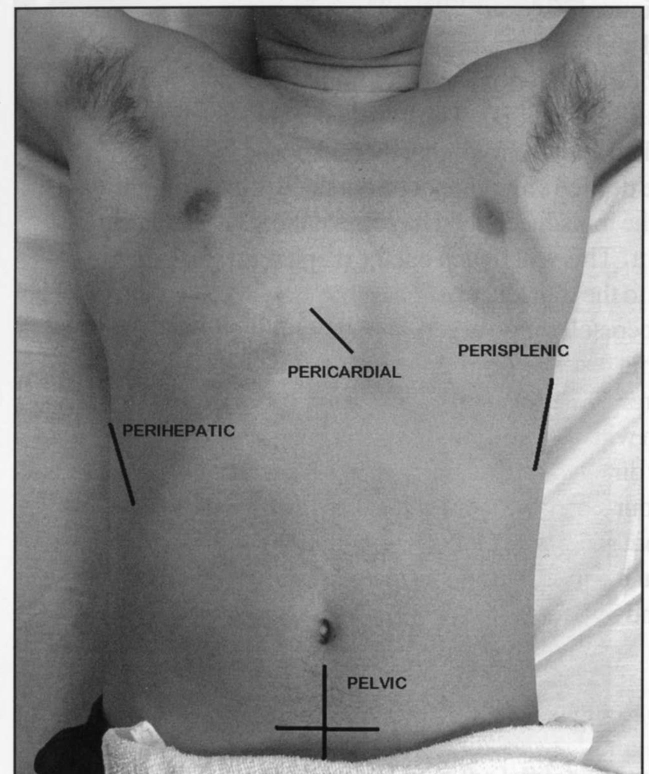

Figure 36. The four sonographic windows of the FAST exam.

PERICARDIAL

Sonographic Technique

The pericardial view is obtained using a subcostal or transthoracic window. The subcostal window is easier to perform and will provide information about hemopericardium, gross chamber enlargement, and gross wall motion abnormalities. Begin with the pericardial, subcostal window by placing the transducer in the subcostal space with the transducer indicator directed toward the patient's right scanning directly posterior using the left lobe of the liver as a window (Figures 37A and 37B). The inferior vena cava (IVC) is located and the transducer is gently angled in a cephalad direction following the inferior vena cava until it goes into the right atrium (Figures 38A and 38B). The transducer can then be gently angled and/or tilted until the four-chamber subcostal view is identified. If the desired view cannot be obtained through slight movements of the transducer, then have the patient take in a deep breath and hold it. This will flatten out the diaphragm and bring the heart closer to the transducer.

The subcostal window can also be obtained in the sagittal orientation. This orientation is frequently described in the trauma surgery literature.[29] To obtain this view, the transducer is placed in the subcostal region with the beam angled slightly cephalad with the transducer indicator directed toward the patient's head. This orientation will not give you a four-chamber view of the heart and will not provide information about gross wall motion abnormalities or gross chamber size enlargement, but it will tell you about the presence of pericardial fluid (Figures 39A and 39B).

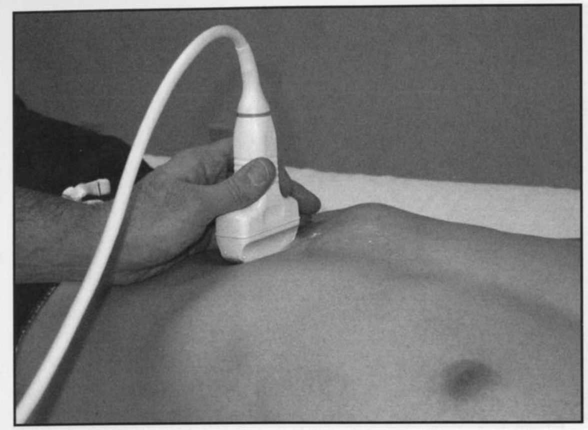

Figure 37A. Transducer placement for visualization of the left lobe of the liver and inferior vena cava.

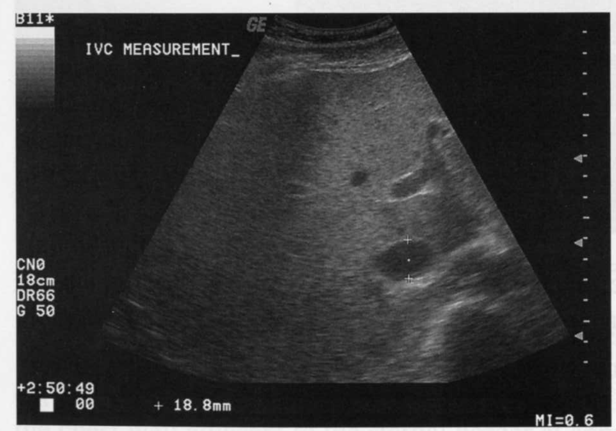

Figure 37B. Subcostal view depicting the left lobe of the liver and inferior vena cava.

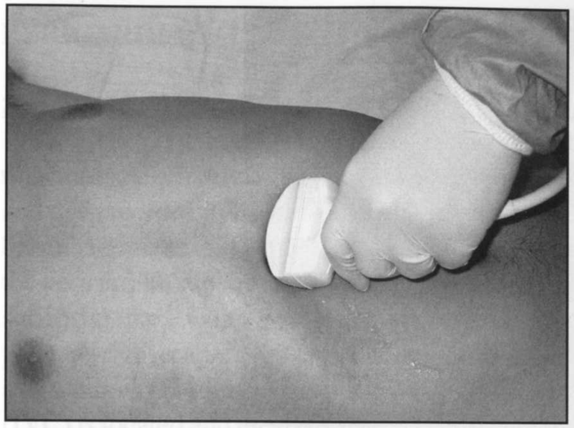

Figure 38A. Transducer placement for the subcostal window.

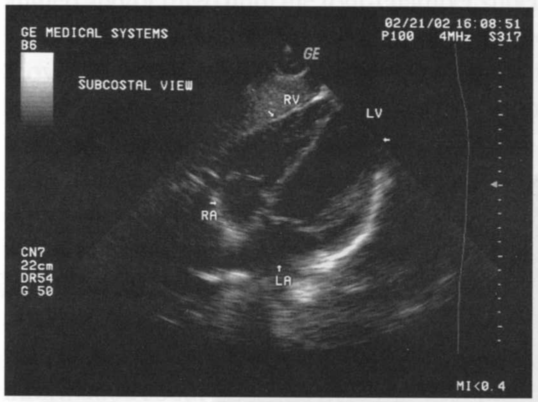

Figure 38B. Subcostal view of the heart. RV= right ventricle, LV= left ventricle, LA=left atrium, and RA=right atrium.

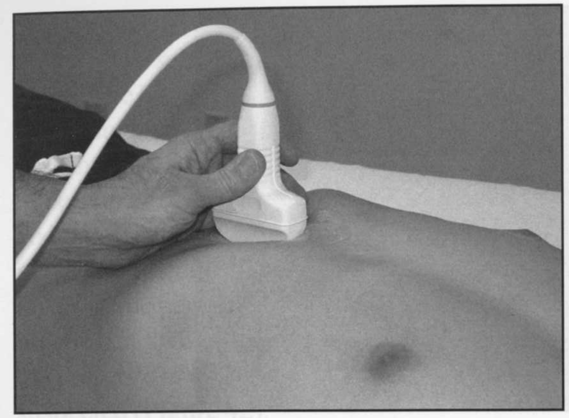

Figure 39A. Transducer placement for sagittal, subcostal window.

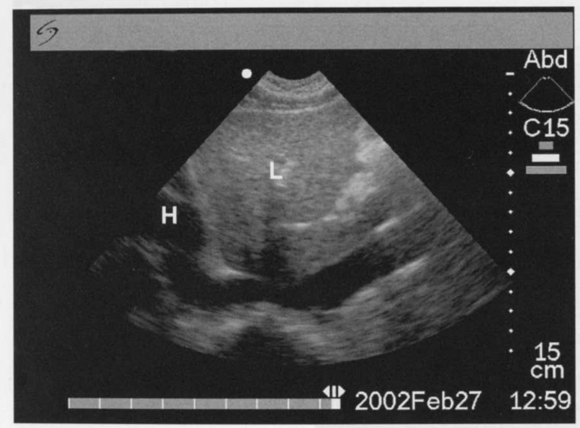

Figure 39B. Normal sagittal, subcostal window. L=liver, H=heart.

The transthoracic window can be performed using different views. The one we will be discussing in this chapter is the parasternal, long-axis view. This is obtained with the transducer on the chest wall adjacent to the sternal border at approximately the level of the 3rd intercostal space. The transducer is in the plane of the right shoulder/left hip with the indicator directed toward the left hip (Figure 40A and 40B). The echocardiographic orientation, unlike the abdominal orientation, has the cephalad direction toward the right of the screen on the long-axis views. This is different from the traditional abdominal/pelvic orientation.

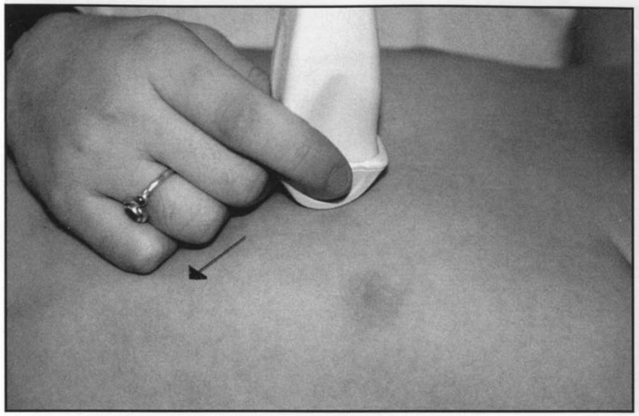

Figure 40A. Transducer placement for parasternal long-axis window. The arrow indicates the direction of the probe indicator.

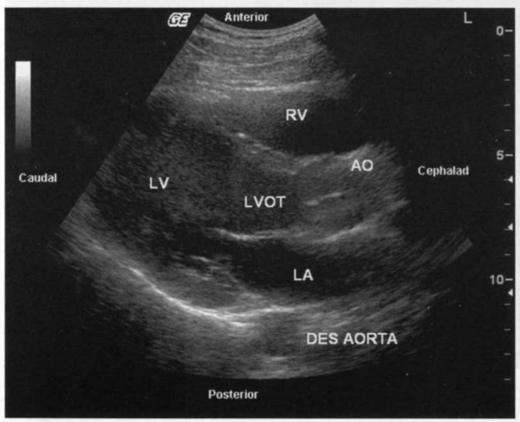

Figure 40B. Normal parasternal, long-axis window. RV=right ventricle, LV=left ventricle, LVOT=left ventricular outflow tract, AO=aorta, DES AORTA=descending aorta.

Sonographic Findings

The subcostal window will provide a four-chamber view of the heart. The hyperechoic pericardium will be seen surrounding the heart. Some fluid may be present in normal individuals, but if there is fluid present in a nondependent area, it is definitely abnormal. The presence of hemopericardium will be demonstrated by separation of the visceral and parietal pericardial layers (Figure 41). Normally, there is only one hyperechoic line seen surrounding the heart, which represents both layers of the pericardium. If two hyperechoic lines are seen surrounding the heart without the presence of anechoic fluid between the lines, the presence of an isoechoic or echogenic fluid collection should be suspected (Figure 42).

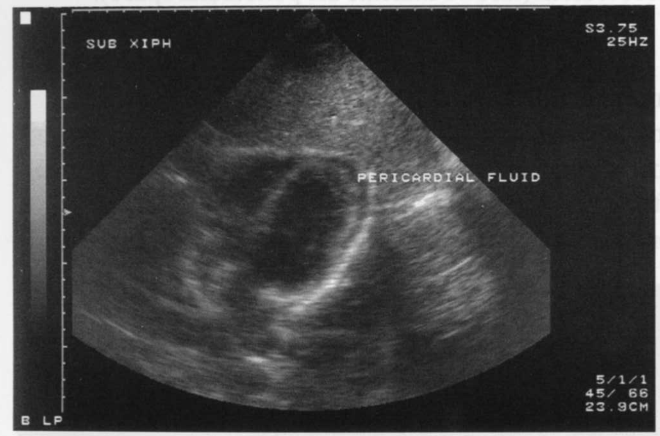

Figure 41. Subcostal window with a small amount of anechoic fluid in the pericardial space.

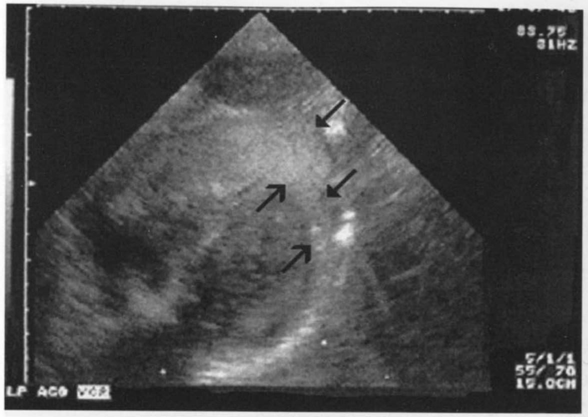

Figure 42. Echogenic hemopericardium in a patient with a stab wound to the precordium (arrows indicate the pericardial space).

The presence of a pericardial tamponade will be demonstrated sonographically as a circumferential fluid collection with diastolic collapse of the right ventricle or atrium (Figure 43). Isolated left atrial or left ventricular collapse may occur in localized left-sided compression or in severe pulmonary hypertension.[30]

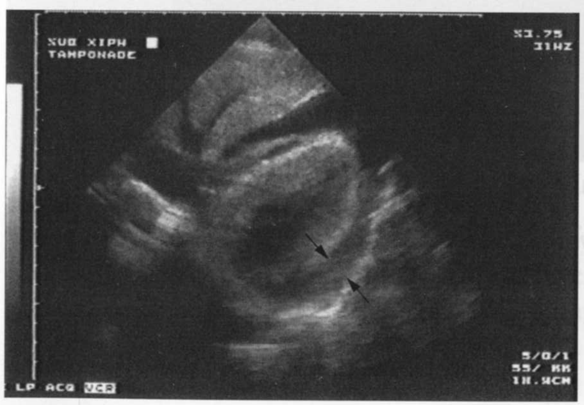

Figure 43. Subcostal window with a large amount of fluid seen in the pericardial space. Echoes within the fluid represent blood clots (arrows). On real-time imaging there was diastolic collapse of the right ventricle consistent with pericardial tamponade.

Other sonographic findings of pericardial tamponade include a swinging heart, dilated IVC with lack of inspiratory collapse, abnormal mitral valve motion, and abnormal septal motion (Figures 44A and 44B).[31] Pericardial tamponade develops secondary to increasing pericardial contents, leading to raised intrapericardial pressure with progressive limitation of ventricular diastolic filling and subsequent reduction of stroke volume and cardiac output. The cardiac effects of the fluid collection are more important than the thickness of the pericardial fluid collection or the absolute amount of fluid present. As little as 50cc of fluid that accumulates quickly could cause significant hemodynamic embarrassment, so do not judge the significance of the fluid collection based on its thickness. Echocardiographic detection of pericardial tamponade frequently precedes overt clinical findings.

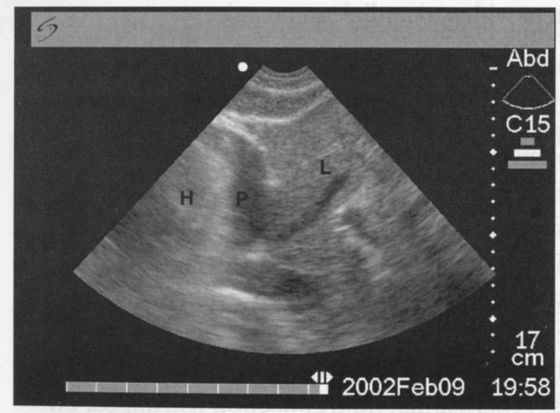

Figure 44A. Sagittal, subcostal window with anechoic fluid noted between apex of heart and pericardium. H=heart, L=liver, P= pericardial fluid.

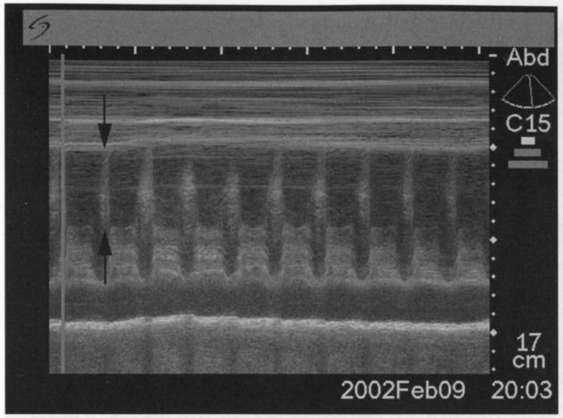

Figure 44B. M-Mode.

Figures 44A and 44B. The M-mode depicts the swinging of the heart (arrows) and the lack of collapse of the inferior vena cava with sniffing which is consistent with pericardial tamponade.

Pitfalls

The presence of an epicardial fat pad can be confused with a pericardial effusion.[32] Epicardial fat is the occurrence of fat over the apical portion of the heart that is visualized between the liver and the myocardium on a subxiphoid window (Figure 45). An epicardial fat pad usually contains low-level echoes that can help distinguish it from pericardial fluid, but occasionally it can appear anechoic and pose a diagnostic dilemma. The use of the parasternal, long-axis window will be helpful in these cases. A pericardial fluid collection will appear on this window as an anechoic region between the posterior wall of the left ventricle and the descending aorta (Figure 40B).

Figure 45. Subcostal window with an epicardial fat pad (arrows) present.

Although the peritoneal and pleural windows are limited on the subcostal window, a large hemothorax or large subphrenic fluid collection can be mistaken for a pericardial effusion (Figure 46).[29] The key to preventing this mistake is to always visualize the hyperechoic pericardium and assess the fluid in its relationship to the pericardium. Fluid is formless and shapeless and must take the shape of the container it is in. The subphrenic fluid or a hemothorax will not be located within the layers of the pericardium. If a large hemothorax is present, rescan the patient after tube thoracostomy drainage has occurred and reassess for a pericardial fluid collection.

Figure 46. End stage renal failure patient with large pericardial fluid collection. Note the anechoic fluid collection caudal to the diaphragm that represents intraperitoneal fluid (ascites) (arrow).

PERIHEPATIC

Sonographic Technique

The perihepatic window is obtained using an intercostal window. The transducer is placed in the midaxillary line somewhere between the 8^{th} and 11^{th} ribs, with the transducer indicator directed toward the patient's axilla (Figures 47A and 47B). Rotating or angling the transducer slightly can be done if the desired view is not obtained prior to moving the transducer to another location. Since fluid may accumulate in the subphrenic space, it is important that the diaphragm be visualized. This may require taking two images in technically difficult patients. The transducer can be moved caudally and oriented in a coronal plane to visualize the lower pole of the liver since fluid in transit is frequently found in the right anterior subphrenic space (Figures 48A and 48B). In the study comparing single-view and multiple-view examinations by Ma and colleagues, there was one patient who had a positive right intercostal coronal window with a negative perihepatic window, so it may be worthwhile to scan this area if the perihepatic

window is negative.[18] The right paracolic gutter is clearly one of the preferential fluid pathways in the peritoneal cavity and may harbor fluid that has not yet made it to one of the standard viewing locations. It may also be beneficial to turn the transducer 90 degrees counterclockwise in order to obtain a transverse view of the right upper quadrant. Small amounts of fluid in Morison's pouch may be detected by obtaining a transverse view through Morison's pouch (Figure 49).

Figure 47A. Transducer placement for the perihepatic window.

Figure 47B. Normal perihepatic window. L=liver, K=kidney, and D=diaphragm.

Figure 48A. Transducer placement for right intercostal coronal window.

Figure 48B. Normal right intercostal coronal window.

Figure 49. Transverse view through Morison's pouch revealing a small amount of fluid. Note how this small pocket of fluid (arrow) could easily be missed on the traditional perihepatic window depending on the position of the transducer and the direction of the beam.

<u>Sonographic Findings</u>

The perihepatic window will provide fractional views of the liver and right kidney and will allow visualization of fluid in Morison's pouch (the potential space between Glisson's capsule of the liver and Gerota's fascia of the kidney), the subphrenic space, the right pleural space, and the retroperitoneal space (Figure 47B). In this chapter we will be only be discussing the standardized FAST exam and therefore will only focus on hemoperitoneum. Hemoperitoneum in the perihepatic region will appear as an anechoic area in Morison's pouch or in the subphrenic space (Figures 50A, 50B and 50C).

Figure 50A. Perihepatic window with anechoic fluid noted in Morison's pouch.

Figure 50B: Perihepatic window with small stripe of fluid in Morison's pouch (arrow). L=liver, K=kidney, P=perinephric fat.

Figure 50C. Right intercostal coronal window with a large amount of fluid noted in the paracolic gutter.

Pitfalls

Fluid in adjacent structures, such as the gallbladder, hepatic flexure of the colon, and duodenum, can be mistaken for hemoperitoneum (Figure 51).[33] Careful inspection for the presence of peristalsis during real-time imaging and demonstration of an echogenic border surrounding the fluid is essential to prevent making this error (Figures 52A and 52B). Be certain that you are in the desired window since mistakes are frequently made when an anechoic region is noted in an unfamiliar window. It is important to remember that the majority of ED physicians and trauma surgeons doing this exam have limited sonographic training and are looking for familiar sonographic patterns, such as fluid between the liver and kidney. Getting into unfamiliar territory can easily lead to overcalling or undercalling pathology, so the take home point is: Do NOT call it positive or negative unless you are in the desired window!

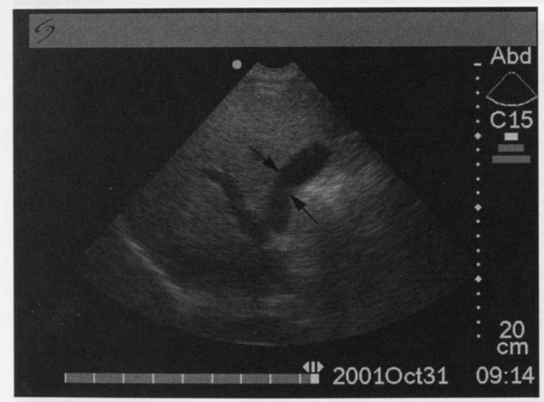

Figure 51. A right upper quadrant window (NOT the perihepatic window) in which the gallbladder (arrows) was visualized and mistaken for free fluid. Note the presence of an echogenic wall surrounding the fluid in the gallbladder and the fact that it does not expand caudally as you would expect free intraperitoneal fluid to do. Fluid is formless and shapeless and must take the shape of the container it is in. Think of this any time you are assessing a fluid collection!

Figure 52A. RUQ image obtained from a more anterior approach. Note the appearance of the gallbladder between the liver and kidney. Also, note the presence of echogenic walls of the gallbladder (arrows).

Figure 52B. Perihepatic window of a 45-year-old male with splenic rupture and a prior history of laparotomies and known adhesions. Note the contained appearing echogenic fluid collection between the liver and kidney which could easily be misinterpreted as being the gallbladder. Unlike Figure 52A, note the absence of an echogenic border surrounding this fluid collection.

Also, perinephric fat has been confused with clotted hemoperitoneum. However, unlike the splenorenal recess, pelvis and the pericardial sac, where blood can clot and appear completely echogenic (Figure 53), the blood in Morison's pouch will not appear completely echogenic (Figure 54).

Figure 53. Transverse view of pelvis in patient with ruptured ectopic revealing large echogenic mass (clotted blood). U=uterus, C= clotted blood.

Figure 54. Perihepatic window with both hemoperitoneum and perinepheric fat present. Small arrow-Glisson's capsule of liver, Large arrow-Gerota's fascia, Arrowhead-true capsule of kidney, h=hemoperitoneum, p=perinephric fat.

PELVIC WINDOW

Sonographic Technique

The pelvic window is obtained by placing the transducer in the suprapubic region in either the longitudinal or transverse plane (Figures 55A, 55B and 55C). If the transverse plane is used, the longitudinal plane must also be imaged. Since the bladder is used for a sonographic window, the pelvic window is best accomplished when the bladder is full. In patients who are undergoing Foley catheterization, clamp the catheter to prevent complete bladder drainage. Although time-consuming, the foley catheter can be used for retrograde filling of the bladder if the patient has an empty bladder.

Sonographic Findings

The pelvic window provides only an intraperitoneal window and utilizes the bladder as a sonographic window (Figures 55B and 55C). Hemoperitoneum on the pelvic window in a male patient will appear as an anechoic area in the rectovesicular pouch or cephalad to the bladder (Figure 56). In a female patient, fluid will appear as an anechoic area in the pouch of Douglas just posterior to the uterus (Figure 57A and 57B). In their study, Nyberg and colleagues found that subtle pelvic fluid collections may occur over the uterine fundus creating a fundal "cap", and that small amounts of fluid in the pouch of Douglas can be masked by an overdistended bladder.[34] Having the patient partially void or partially empty the bladder after foley catheterization may unmask small fluid collections in the pouch of Douglas. It is important to note that US will show you there is the presence of an abnormal fluid collection, but it will not tell you what it is. Premenopausal females frequently will have small amounts of fluid in the pouch of Douglas, so clinical correlation is essential (Figure 57A). Localized extraperitoneal fluid collections (pelvic hematomas) or bladder hematomas associated with pelvic fractures can be mistaken for hemoperitoneum (Figure 58).

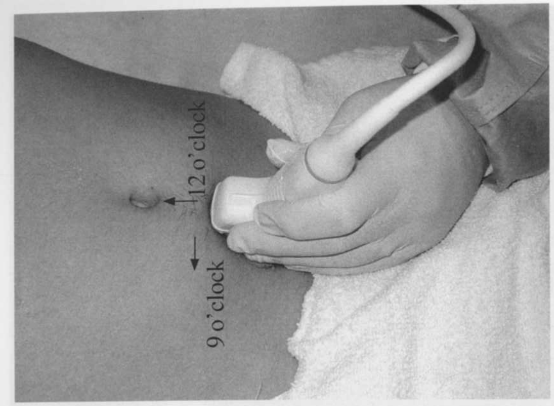

Figure 55A. Transducer placement for pelvic window (longitudinal). In the longitudinal plane, the probe indicator is directed toward the patient's head (12 o'clock position) while in the transverse plane, the probe indicator is directed toward the patient's right (9 o'clock position).

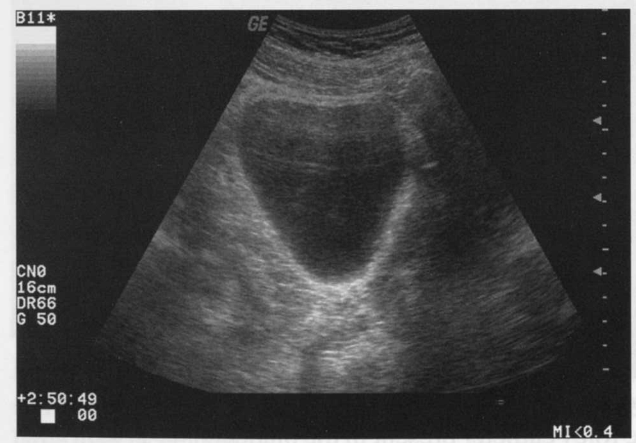

Figure 55B. Normal pelvic window (longitudinal plane).

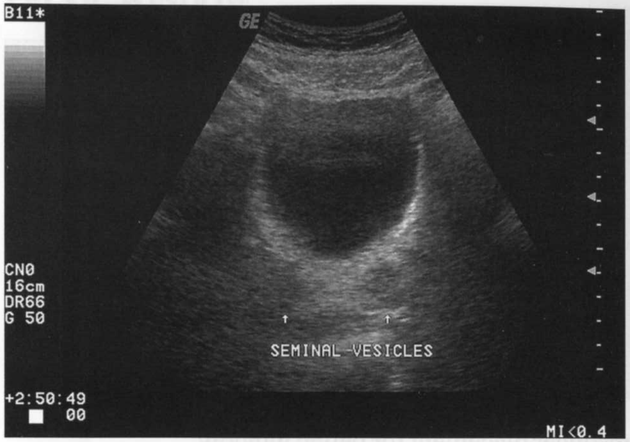

Figure 55C. Normal pelvic window (transverse plane) with seminal vesicles labeled.

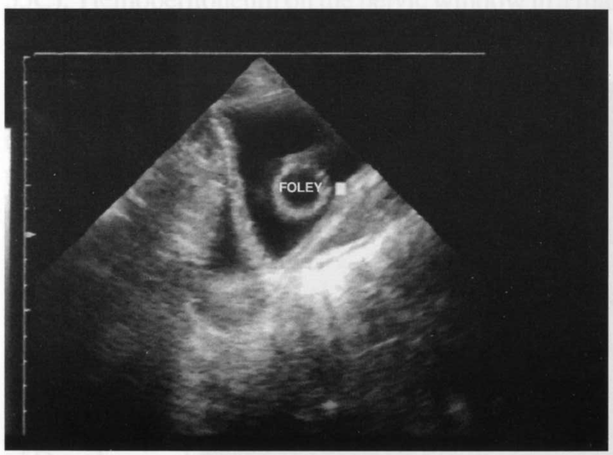

Figure 56. Hemoperitoneum present in a male patient cephalad to the bladder. Note the foley catheter present in the bladder.

Figure 57A. Small amount of fluid (physiologic) in the cul-de-sac of a premenopausal patient.

Figure 57B. Pelvic window showing a large amount of free fluid (arrow) in the cul-de-sac in a patient with hemoperitoneum from a large liver laceration.

Figure 58. Irregular shaped bladder with layered echoes noted within the bladder in a patient with a pelvic fracture and gross hematuria. The CT scan revealed no hemoperitoneum.

Pitfalls

In male patients, the seminal vesicles can be mistaken for hemoperitoneum on the transverse pelvic window (Figure 55C).[33] The seminal vesicles are paired structures that are usually hypoechoic but can have variable echogenicity, including an anechoic appearance. They can be distinguished from hemoperitoneum based on their appearance between the bladder and prostate and by the fact that on the longitudinal window, the seminal vesicles taper off in the cephalad direction and do not extend beyond the bladder like hemoperitoneum does (Figure 56). Again, going back to the basic principles, fluid is formless and shapeless and must take the shape of the container. Hemoperitoneum would not taper in the cephalad direction, so the longitudinal window can be helpful.

PERISPLENIC WINDOW

Sonographic Technique

The perisplenic window is obtained using an intercostal approach with the transducer being placed in the posterior axillary line somewhere between the 8th and 11th ribs, with the transducer indicator directed toward the patient's axilla (Figures 59A and 59B). Rotating or angling the transducer slightly can be done if the desired view is not obtained on the initial attempt and should be attempted before moving the transducer to another location. As with the perihepatic window, the subphrenic space must be visualized since this is a common location of fluid accumulation. In the technically difficult patient, obtaining two views are acceptable and often saves time if the entire perisplenic window cannot be visualized in one image. Remember, if the diaphragm and subdiaphragmatic space are not clearly visualized the exam is indeterminate. Avoid having the patient take in a deep-breath since this will result in a "curtain-effect" with dirty-shadowing from air in the lung preventing visualization of the desired perisplenic window.

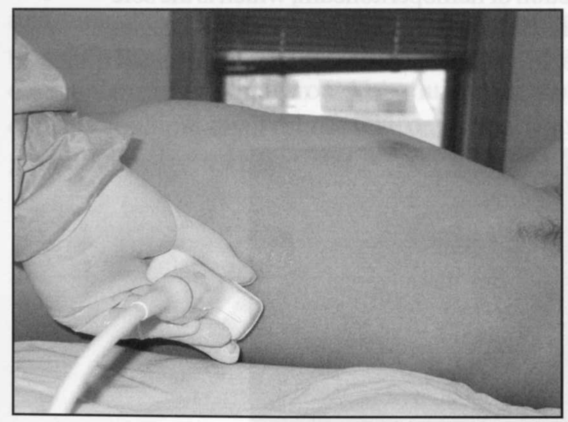

Figure 59A. Transducer placement for the perisplenic window.

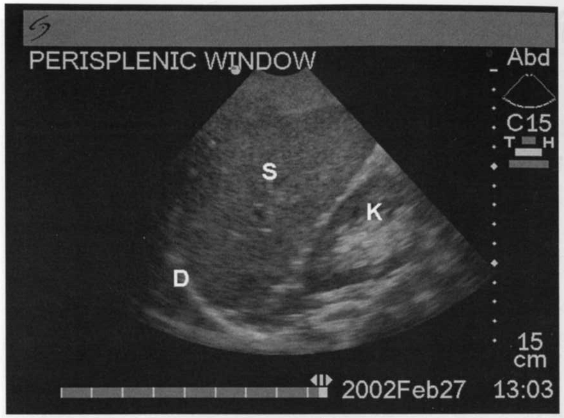

Figure 59B. Normal perisplenic window. S=spleen, K=kidney, and D=diaphragm.

Sonographic Findings

The perisplenic window will provide fractional views of the spleen and left kidney and will allow visualization of fluid in the subphrenic space, the splenorenal fossa, the left pleural space, and the retroperitoneal space (Figure 59B). The detection of hemoperitoneum, which is the sole intraabdominal goal of the FAST exam, will be made by visualizing anechoic fluid in the subphrenic space or in the splenorenal fossa (Figures 60A and 60B).

Figure 60A. Perisplenic window with fluid (arrow) noted surrounding the spleen.

Figure 60B. Perisplenic window with fluid and blood clots (arrows) present in the subdiaphragmatic space.

Pitfalls

Fluid in adjacent structures, such as the stomach and the splenic flexure of the colon, can be mistaken for hemoperitoneum (Figure 61).[33] Careful inspection for the presence of peristalsis during real-time scanning and demonstration of an echogenic border surrounding the fluid in the stomach or splenic flexure of the colon is essential to prevent this error. Also, fluid in the stomach usually contains multiple small echoes with or without ring-down artifact from gas bubbles.

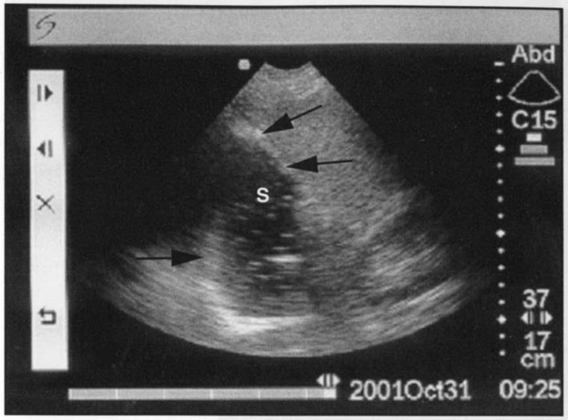

Figure 61. Fluid in the stomach(s) mimicking a positive perisplenic window. Note the presence of multiple small echoes within the fluid and the presence of the echogenic wall of the stomach (arrows). In real-time scanning, peristaltic movement of the fluid was readily noted.

INTERPRETATION OF THE FAST EXAM

The interpretation of the FAST exam is straightforward:

Positive- Free fluid noted on any of the four windows.
Negative- Absence of free fluid on all four windows.
Indeterminate- Not all four windows adequately visualized.

NOTE: Indeterminate is not the same as negative.

CLINICAL APPLICATIONS

GENERAL

The two main clinical roles which will be discussed below are the patient with suspected cardiac injury with a positive pericardial window and the hypotensive patient with a positive intraabdominal window.

CARDIAC

In patients with suspected cardiac injury, US can be a very useful test to guide patient management.[29,35-37] US is very sensitive for detecting even small amounts of pericardial fluid. In their study of 261 patients with possible penetrating cardiac wounds, Rozycki and colleagues found that US was 100% sensitive, 96.9% specific, and 97.3% accurate in the detection of hemopericardium.[29] The patients with false-positive studies were all found to have a benign pericardial effusion, and it was felt that surgery was appropriate in these cases based on their presentation and documentation of pericardial fluid on US. An earlier study reported similar numbers with significant reductions in morbidity and mortality. Concerning was their finding of two false-negative studies due to isodense hemopericardium.[35]

Rozycki and colleagues have concluded, based on their study, that cardiac US is highly accurate and should be the initial modality for the evaluation of patients with suspected penetrating cardiac wounds.[29] Due to its high sensitivity and specificity, important clinical decision-making, such as operative intervention, can be based on the results of the pericardial window. Rozycki and colleagues recommend immediate operative intervention in patients with a positive cardiac ultrasound, regardless of stability.[29] Patients with a negative pericardial window warrant a minimum of six hours of observation with repeat scanning later in the hospital course. Patients with an equivocal or indeterminate pericardial window warrant formal echocardiography or a subxiphoid pericardial window, based on patient stability (Figure 62).

A retrospective chart review of a 22-year experience of penetrating cardiac trauma at a Level 1 trauma center concluded that rapid transport from the field, use of surgeon-performed US in modestly hypotensive and normotensive patients, and earlier operative intervention are the only current approaches likely to lower mortality.[37] A comparison of morbidity and mortality was made between the two 11-year periods. Since surgeon-performed cardiac US began in 1994, hemopericardium has been diagnosed correctly in 12 patients, with a resultant 100% survival rate.

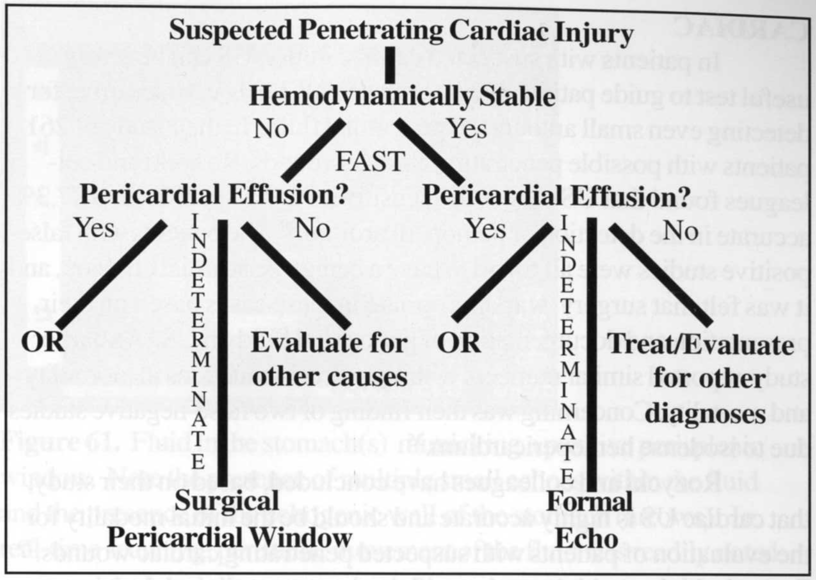

Figure 62. Algorithm using the FAST exam for the patient with suspected cardiac injury.

ABDOMINAL

As previously mentioned, the detection of pericardial fluid collections is much more sensitive with US than the detection of intraperitoneal fluid collections. The pericardial sac is obviously much smaller and is readily accessible with ultrasound making detection of abnormal fluid collections more likely. The large and irregular shape of the peritoneal cavity and the numerous anatomic and physiologic factors involved make detection of intraperitoneal fluid collections more difficult, thus requiring multiple sonographic windows. The FAST exam will be limited not only by the anatomic and physiologic factors, but also by factors such as solid-organ injury without hemoperitoneum and hemoperitoneum below the threshold level. The threshold level for detection is not definitively known but it is safe to say that it is most likely greater than 250cc.[3] Some have suggested that less than 100cc of localized bleeding can be detected with US.[38] A recent study by Paajanen and colleagues concluded that a small volume of free intraperitoneal fluid (10-50cc) can be detected with current US scanners but only near the site of injury.[3,39] It is, however, doubtful that the FAST exam will be consistently that sensitive since the US exams in these studies contained more windows

than the FAST exam. This is in contrast to other authors who, using a DPL model which assumes an inframesocolic source of bleeding, have found the minimum threshold for detection using a single, perihepatic window to be at least 600 cc.[40,41]

US in blunt abdominal trauma (BAT) has been well-studied, and reported sensitivities and negative predictive values for the FAST exam in detecting hemoperitoneum vary from 78-99% to 93-99%, respectively.[42] The detection of intra-abdominal injuries with the FAST exam is based on the assumption that clinically important injuries will be associated with hemoperitoneum. However, a study from Shock Trauma recently reported that in their study of 466 patients with visceral injuries, 34% of patients had no associated hemoperitoneum on US or CT.[42] Therefore, it is apparent from this study that reliance on the presence of hemoperitoneum as the sole indicator of abdominal visceral injury limits the value of the FAST exam as a screening modality in the patients with BAT, but doesn't completely negate its usefulness.

Recent studies have shed light on the issue of how the FAST exam can be incorporated into the clinical decision-making process.[43-44] Rozycki and colleagues found that US was the most sensitive and specific for the evaluation of patients with precordial/transthoracic wounds and hypotensive patients with BAT (sensitivity and specificity both 100%).[43] Wherrett and colleagues retrospectively evaluated the use of the FAST exam in BAT and concluded that since 86.4% of the hypotensive patients in their study required laparotomy, the FAST exam is an accurate indicator of the need for urgent laparotomy in the hypotensive patient with BAT.[44]

The hemodynamically stable patient with a positive FAST exam requires CT scanning to better define the nature of the injuries. With the exception of the hemodynamically unstable patient with a positive FAST exam, this is the only other clinical area in which the FAST Consensus Conference Committee came to a unanimous agreement.[22] Taking every hemodynamically stable patient with a positive FAST exam to the operating room would result in a very high non-therapeutic laparotomy rate.

Knowing the amount of free intraperitoneal blood present may affect the decision for operative vs. nonoperative management, but we are currently limited by general classifications, such as minimal, mild, moderate, and large. Correlating the fluid stripe in the perihepatic window with free fluid volume has not been found to be reliable.[40] The use of scoring systems to estimate free fluid volume has been proposed but there is no convincing evidence that they can better identify patients requiring operative therapy.[45,46]

The hemodynamically stable patient with a negative FAST exam requires a minimum of six hours of observation and a follow-up FAST provided they have no abdominal pain. An example would be the common scenario of the intoxicated patient following an MVC with a significant mechanism of injury but no obvious injuries. Rather than CT the patient's abdomen/pelvis during a period of observation, the patient could undergo serial FAST exams. If there is no abdominal tenderness noted when the patient sobers up and has a reliable exam, he could be discharged home. However, there is no definitive literature to support the application of the FAST exam to this class of patient and the final decision to discharge, observe, or perform further testing must be based on the clinician's sound judgement. The FAST exam will miss patients with hollow-viscus injuries, solid-organ injuries without hemoperitoneum, and hemoperitoneum below the minimum threshold.

The hemodynamically unstable patient with a negative FAST exam needs to be evaluated for other sources of hemorrhage. A negative FAST exam in this setting can be very helpful to the clinician by guiding them to look for extra-abdominal sources of hemorrhage. Even assuming that the minimum threshold for the detection of hemoperitoneum is 250cc, it would be unlikely that hemorrhage below this amount would be responsible for hypotension. Repeat scanning in these high-risk patients later in the resuscitation is necessary to detect any ongoing hemorrhage (Figure 63).

The use of the FAST exam in the evaluation of the pediatric trauma patient has not been widely studied, and there are no definitive guidelines for use of the modality in these patients. Although not a definitive study, the study by Thourani and colleagues showed that the FAST exam is useful in determining the need for laparotomy in the hemodynamically unstable child.[47] A study by Holmes and colleagues found that the FAST exam used solely for the detection of hemoperitoneum in pediatric blunt trauma patients has modest accuracy and has the best test performance in those children who are hypotensive.[48]

The use of the FAST exam in the pregnant blunt trauma patient has only been studied on a limited basis. There has been some concern that intra-abdominal changes that occur during pregnancy could adversely affect the FAST exam. Goodwin and colleagues found in their study of 120 patients that the sensitivities and specificities were similar to that seen in nonpregnant patients.[49]

The use of the FAST exam in penetrating abdominal trauma has recently been evaluated.[50] Although further studies will be needed, it appears that the main utility of the FAST exam in penetrating trauma is in the detection of hemoperitoneum. The presence of hemoperitoneum is a strong predictor of need for operative management. Unfortunately, the sensitive of the FAST exam, in this study of penetrating abdominal trauma, was only 45%.[50] Therefore, the FAST exam should not be used to rule out intra-abdominal injuries requiring operative management.

Several studies have also shown that the FAST exam is efficient and cost-effective in the diagnosis of intra-abdominal injuries.[51,52] As expected, the time to disposition is much less in those undergoing the FAST exam and the total procedural cost is higher in the CT/DPL group. McKenney and colleagues found an eight-fold reduction in the use of DPL, and a two-fold reduction in the use of CT in those patients who had a FAST exam peformed.[52]

The Eastern Association for the Surgery of Trauma (EAST) recently developed an evidence-based, systematic diagnostic approach to blunt abdominal trauma using the FAST exam, CT scanning, and DPL (Figures 64A and 64B).[53]

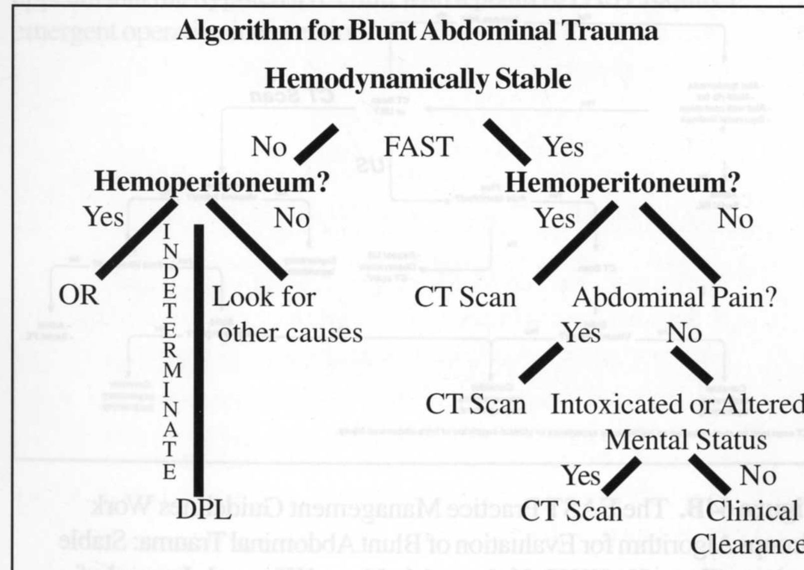

Figure 63. Algorithm using the FAST exam for patients with suspected intra-abdominal injury.

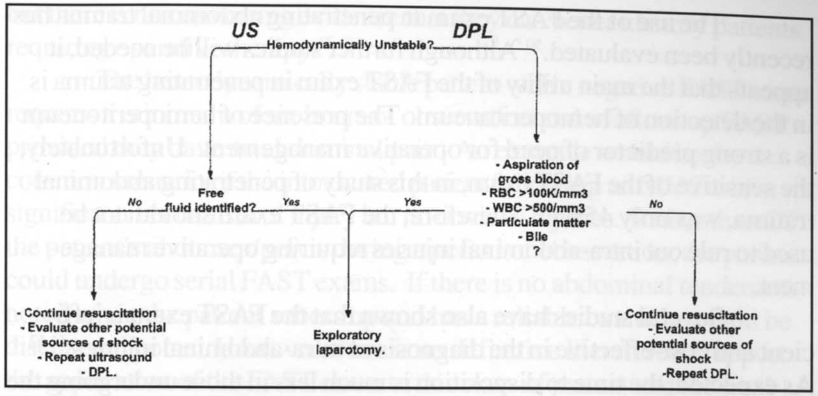

Figure 64A. The EAST Practice Management Guidelines Work Groups Algorithm for Evaluation of Blunt Abdominal Trauma: Unstable Patient. (From Hoff WS, Holevar M., Nagy KK, et. al. Journal of Trauma, Lippincott, Williams and Wilkins. 2002; 611.)

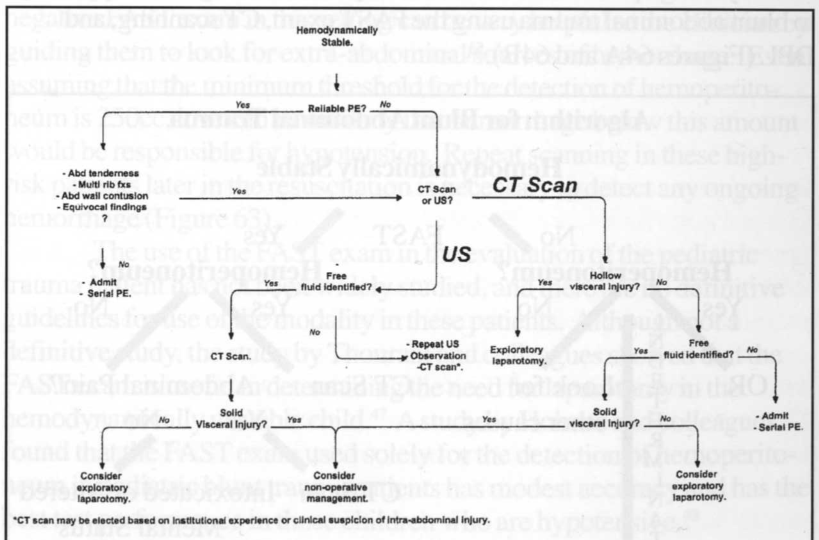

Figure 64B. The EAST Practice Management Guidelines Work Groups Algorithm for Evaluation of Blunt Abdominal Trauma: Stable Patient. (From Hoff WS, Holevar M., Nagy KK, et. al. Journal of Trauma, Lippincott, Williams and Wilkins. 2002; 611.)

CONCLUSIONS

The FAST exam is an accurate, noninvasive modality for the detection of hemoperitoneum. Patients undergoing the FAST exam are less likely to undergo DPL and are less likely to undergo CT scanning. The patient with suspected cardiac injury who is found to have pericardial fluid, regardless of stability, needs emergent operative therapy (Figure 62). This will significantly decrease morbidity and mortality. The patient with suspected intra-abdominal injury who is found to have free intraperitoneal fluid and is hemodynamically unstable requires emergent operative therapy while the hemodynamically unstable patient with a negative FAST exam requires an aggressive search for extra-abdominal hemorrhage (Figure 63). The hemodyamically stable patient with a positive FAST exam requires CT scanning to further delineate the injury, while a hemodynamically stable patient with a negative FAST exam requires sound clinical judgment since there are no guidelines in place for these patients. Pregnant patients appear to have the same sensitivities and specificities for the detection of hemoperitoneum as nonpregant patients do. Further studies are required in pediatric patients, but based on limited studies it appears that the hypotensive child with a positive FAST requires emergent operative intervention.

REFERENCES:

1. Kristensen JK, Buemann, B, Kuehl E. Ultrasonic scanning in the diagnosis of splenic hematomas. *Acta Chir Scan* 1971;137:653-656.

2. Asher WM, Parvin S, Virgillo RW, et al. Echographic evaluation of splecin injury after blunt trauma. *Radiology* 1976;118:411-415.

3. Tiling T, Bouillon B, Schmid A, et al. Ultrasound of blunt abdominothoracic trauma. In: Border JR, ed. *Blunt Multiple Trauma.* New York: Marcel Dekker; 1990:415-433.

4. Gruessmer R, Mentged B, Duber C, et al. Sonography versus peritoneal labage in blunt abdominal trauma. *J Trauma* 1989;29:242-246.

5. Bode PJ, Niezon RA, van Bugt AB, et al. Abdominal ultrasound as reliable indicator for conclusive laparotomy in blunt abdominal trauma. *J Trauma* 1991;34:27-31.

6. Goletti O, Ghiselli G, Lippolis PV, at al. The role of ultrasonography in blunt abdominal trauma: Results in 250 consecutive cases. *J Trauma* 1994;36:178-181.

7. Hoffman R, Nerlich M, Muggia-Sullam M, et al. Blunt abdominal trauma in cases of multiple trauma evaluated by ultrasonography: A prospective analysis of 291 patients. *J Trauma* 1992;32:452-458.

8. Forster R, Pillasch J, Zielke A, et al. Ultrasonography in blunt abdominal trauma: Influence of the investigator's experience. *J Trauma* 1993;31:20-23.

9. Kimura A, Otsuka T. Emergency center ultrasonography in the evaluation of hemoperitoneum: A prospective study. *J Trauma* 1991;31:20-23.

10. Rothlin MA, Naf R, Amgwerd M, et al. Ultrasound in blunt abdominal and thoracec trauma. *J Trauma* 1993;34:488-495.

11. Boulanger BR, Rozycki GS, Rodriguez A. Sonographic assessment of traumatic injury: Future developments. *Surg Clin North Am* 1999;79:1297-1314.

12. Tso P, Rodriquez A, Cooper C, et al. Sonography in blunt abdominal trauma: A preliminary progress report. *J Trauma* 1992;33:39-43.

13. Rozycki GS, Ochsner MG, Schmidt JA, et al. Prospective study of surgeon-performed ultrasound as the primary adjuvant modality for injured patient assessment. *J Trauma* 1995;39:325-330.

14. McKenney M, Lentz K, Nunez D, et al. Can ultrasound replace diagnostic peritoneal lavage in the assessment of blunt abdominal trauma? *J Trauma* 1994;37:439-441.

15. McKenney MG, Martin L, Lentz K, et al. 1,000 consecutive ultrasounds for blunt abdominal trauma. *J Trauma* 1996;40:607-612.

16. Rozycki GS, Ochsner MG, Jaffin JH, et al. Prospective evaluation of surgeons' use of ultrasound in the evaluation of trauma patients. *J Trauma* 1993;34:516-527.

17. Rozycki GS, Ochsner MG, Feliciano DV, et al. Early detection of hemoperitoneum by ultrasound of the right upper quadrant: A multicenter study. *J Trauma* 1998;45:878-883.

18. Ma OJ, Kefer MP, Mateer JR, et al. Evaluation of hemopoeritoneum using a single- vs. multiple-view ultrasonographic examination. *Acad Emerg Med* 1995;2:581-586.

19. Boulanger BR, McLellan BA, Brenneman FD, et al. Emergent abdominal sonography as a screening test ina new diagnostic algorithm for blunt trauma. *J Trauma* 1996;40:867-874.

20. Healy MA, Simons RK, Winchell RJ, et al. A prospective evaluation of abdominal ultasound in blunt trauma: Is it useful? *J Trauma* 1996;40:875-883.

21. Han DC, Rozycki GS. Schmidt JA, et al. Ultrasound training during ATLS: An early start for surgical intersn. *J Trauma* 1996;41:208-213.

22. Scalea TM, Rodriguez A, Chiu WC, et al. Focused assessment with sonography for trauma (FAST): Results from an international consensus conference. *J Trauma* 1999;46:L466-472.

23. Meyers MA. Distribution of intra-abdominal malignancy seeding; dependency on dynamic flow of ascitic fluid. *AJR* 1973;119:198-206.

24. Meyers MA. The spread and localization of acute intraperitoneal effusion. *Radiology* 1970;95:547-554.

25. Overholt RH. Intraperitoneal pressure. *Arch Surg* 1931;22:691-703.

26. Drye JC. Intraperitoneal pressure in the human. *Surg Gynecol Obstet* 1948;87:472-475.

27. Autio V. The spread of intraperitoneal infection. Studies with roentgen contrast medium. *Acta Chir Scand Suppl* 2964;321:1-31.

28. Abrams BJ, Sukumvanich P, Seibel R, et al. Ultrasound for the detection of intraperitoneal fluid: The role of Trendelenburg positioning. *Am J Emerg Med* 1999;17:117-120.

29. Rozycki GS, Feliciano DV, Ochsner MD, et al. The role of ultrasound in patients with possible penetrating cardiac wounds: A prospective multicenter study. *J Trauma* 1999;46:543-552.

30. Fusman B, Schwinger ME, Charney R, et al. Isolated collapse of left-sided heart chambers in cardiac tampon ade: demonstration by two-dimensional echocardiography. *Am Heart J* 1991;121:613-6.

31. Tsang TS, Oh JK, Seward JB, et al. Diagnostic value of echocardiography in cardiac tamponade. *Herz* 2000; 8:734-40.

32. Blaivas M, DeBehnke D, Phelan MB. Potential errors in the diagnosis of pericardial effusion on trauma ultrasound for penetrating injuries. *Acad Emerg Med* 2000;7:1261-1266.

33. McKenney KL, Nunez DB, McKenney MG, et al. Ultrasound for blunt abdominal trauma: Is it free fluid? *Emerg Radiol* 1998;5:203-209.

34. Nyberg DA, Laing FC, Jeffrey RB. Sonographic detection of subtle pelvic fluid collections. *AJR* 1984; 143:261-263.

35. Plummer D. The sensitivity, specificty, and accuracy of ED echocardiography (abstr). *Acad Emerg Med* 1995;2:339-340.

36. Plummer D, Brunette D, Asinger R, et al. Emergency department echocardiogaraphy improves outcome in penetrating cardiac injury. *Ann Emerg Med* 1992;21: 709-712.

37. Thourani VH, Feliciano DV, Cooper WA, et al. Penetrating cardiac trauma at an urban trauma center: A 22-year perspective. *Am Surgeon* 1999;65:811-818.

38. Kawaguchi S, Toyonaga J, Ikeda K, et al. Five point method: An ultrasonographic quantification formula of intra-abdominal fluid collection. *Jpn J Acute Med* 1987;7:993-997.

39. Paajanen II, Lahti P, Nordback I. Sensitivity of transabdominal ultrasonography in detecton of intraperitoneal fluid in humans. *Eur Radiol* 1999;9:1423-1425.

40. Branney SW, Wolfe RE, Nils A. The reliability of estimating intraperitoneal fluid volume with ultrasound (abstr). *Acad Emerg Med* 1995;2:345.

41. Jehle D, Guarino J, Karamanoukian H. Emergency department ultrasound in the evaluation of blunt abdonimal trauma. *Am J Emerg Med* 1993; 34:516-527.

42. Shanmuganathan K, Mirvis SE, Sherbourne CD, et al. Hemoperitoneum as the sole indicator of abdominal visceral injuries: A potential limitation of screening abdominal US for trauma. *Radiology* 1999;212:423-430.

43. Rozycki GS, Ballard RB, Feliciano DV, et al. Surgeon-performed ultrasound for the assessment of truncal injuries: Lessons learned from 1,540 patients. *Ann Surg* 1998;41:815-820.

44. Wherrett LJ, Boulanger BR, McLellan BA, et al. Hypotension after blunt abdominal trauma: The role of emergent abdominal sonography in surgical traige. *J Trauma* 1996;41:815-820.

45. McKenney KL, McKenney MG, Nunez DB, et al. Interpreting the trauma ultrasound: Observations in 62 positive cases. *Emerg Rad* 1996;3:113-116.

46. Huang MS, Liu M, Wu JK, et al. Ultrasonography for the evaluation of hemoperitoneum during resuscitation: A simple scoring system. *J Trauma* 1994;36:173-177.

47. Thourani VH, Pettitt BJ, Schmidt JA, et al. Validation of surgeon-performed emergency abdominal ultrasonography in pediatric trauma patients. *J Pediatr Surg* 1998; 33:322-328.

48. Holmes JF, Brant WE, Bond WF, et al. Emergency department ultrasonography in the evaluation of hypotensive and normotensive children with blunt abdominal trauma. *J Pediatr Surg* 2001;36:968-73.

49. Goodwin H, Holmes JF, Wisner DH. Abdominal ultrasound examination in pregnant blunt trauma patients. *J Trauma* 2001;50:689-93.

50. Udobi KF, Rodriguez A, Chiu WC, et al. Role of ultrasonography in penetrating abdominal trauma: a prospective clinical study. *J Trauma* 2001;50:475-479.

51. Arrillaga A, Graham R, York JW, et al. Increased efficiency and cost-effectiveness in the evaluation of the blunt abdominal trauma patient with the use of ultrasound. *Am Surg* 1999;65:31-5.

52. McKenney MG, McKenney KL, Hong JJ, et al. Evaluating blunt abdominal trauma with sonography: A cost analysis. *Am Surg* 2001;67:930-4.

53. Hoff WS, Holevar M, Nagy KK, et al. Practice Management Guidelines for the Evaluation of Blunt Abdominal Trauma: The EAST Practice Management Guidelines Work Group. J Trauma 2002;53;602-615.