Point Of Care Ultrasound (POCUS)

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What is POCUS?

• Point-of-care ultrasound (POCUS) is defined as a goal-directed, bedside ultrasound examination performed by a healthcare provider to answer a specific diagnostic question or to guide performance of an invasive procedure.
Clinical Applications

- **Procedural guidance:**
  - Vascular access, thoracentesis, paracentesis, pericardiocentesis, lumbar puncture and arthrocentesis.

- **Diagnostics:**
  - A POCUS exam is aimed at answering a specific question through a focused, goal-directed exam in urgent or emergent situations.
  - Generally, the goal is to “rule in” or “rule out” a specific condition or answer a “yes/no” question.

- **Resuscitation:**
  - POCUS can direct emergent interventions by rapidly detecting cardiac tamponade, massive pulmonary embolism with acute right ventricular failure, significantly reduced LV systolic function and tension pneumothorax.

- **Monitoring:**
  - Serial ultrasound exams
  - Common applications include
    - monitoring inferior vena cava distention and collapsibility as a surrogate for central venous pressure during fluid resuscitation,
    - monitoring left ventricular contraction in response to inotrope initiation, and
    - monitoring for resolution or worsening of a pneumothorax or pneumonia on lung ultrasound.
POCUS
Basic Ultrasound Physics Principles in POCUS

• Higher-frequency transducers produce higher-resolution images but penetrate shallower.

• Lower-frequency transducers produce lower-resolution images but penetrate deeper.

• Optimal gain settings are needed to correctly identify anechoic structures, such as blood, and differentiate hypoechoic, isoechoic, and hyperechoic structures.

• If the POCUS machine does not allow an adjustment of the focal zone, adjusting the view and the depth of the image to place the structure of interest in the center of the screen often gives the best resolution.

• Using M-mode to display movement of structures over time is helpful to assess RV collapsibility, inferior vena cava collapsibility, and lung and pleural sliding.
Artefacts in POCUS

• Artifacts are false images, or parts of images, that do not represent true anatomic structures.

• Artifacts arise when one or more properties of sound are violated.

• True pathology should be visualized in at least two planes.

• Suspected pathology that is not seen in multiple planes is most likely an artifact.
Useful Artefacts in POCUS

• Reverberation can be diagnostic in the case of A-lines seen in the lung.

• Acoustic shadowing can be diagnostic for stones and plaque.

• Acoustic enhancement can be diagnostic for cysts or masses.
Utilization of POCUS

• Majority of the use of POCUS is in *Procedural guidance*

• *In trauma patients, POCUS has been used for evaluation of internal hemorrhage.*

• *Several protocols exist for use of POCUS in patient’s with trauma.*
  
  • *FAST - Focused Assessment with Sonography in Trauma and has become synonymous with beside ultrasound in trauma*
  
  • *EFAST – Extended Focused Assessment with Sonography*
  
  • *FATE - Focus Assessed Transthoracic Echocardiography*
Rapid Ultrasound for Shock and Hypotension – RUSH Exam

• Weingart et al. came up with the concept of the RUSH exam in 2006.

• For non-trauma patient with undifferentiated shock.

• Recommend doing the exam as early as possible in the clinical course of the patient’s care.

• RUSH was designed to be rapid and easy to perform with portable machines found in most ICU and ER units.

The components of the exam are views of the:

• Heart,
• Inferior vena cava (IVC),
• Abdomen
• Thorax
• Aorta.
RUSH Exam

• This entire exam can be completed in less than 2 minutes using readily available portable machines.

• Weingart et al. (HI-MAP acronym)

• 1. **Heart**: Parasternal long and then 4 chamber cardiac views, with the general purpose or cardiac probe
• 2. **IVC** view with the same probe
• 3. **Morison’s** and splenorenal views with thorax images and then examine the bladder window.
• 4. **Aorta** above and below the renal artery with four views.
• 5. Scan both sides of the chest for **Pneumothorax**
POCUS in patient with Shock

RUSH Exam Sequencing

1. Parasternal Long Cardiac View
2. Apical Four-Chamber Cardiac View
3. Inferior Vena Cava View
4. Morison’s with Hemothorax View
5. Splenorenal with Hemothorax View
6. Bladder View
7. Aortic Slide Views
8. Pneumothorax View
9. Pneumothorax View

Use Curvilinear Array for 1-7
Use High-Frequency Array for 8 & 9
POCUS – Lung Exam
Basic Lung Ultrasound in Emergency (BLUE) protocol

- Imaging is performed at 4 points on each hemithorax.

- Point 1 is located on the mid-clavicular line at approximately the second intercostal space.

- Point 2 is located on the anterior axillary line at approximately intercostal space 5

- Point 3 is located along the diaphragm in mid-axillary line.

- Point 4 is also called the posterolateral alveolar pleural syndrome (PLAPS) point and is the most posterior point along the diaphragm.
Imaging Considerations
BLUE protocol

• Varying depth settings are required when examining the thorax.

• When focusing primarily on pleural line abnormalities, such as over the anterior chest wall, a maximum depth of 7.5–10 cm should be used to optimize pleural line resolution and avoid attenuation of diagnostic artifacts.

• When scanning the lower lung fields, where the majority of consolidation and fluid accumulation occurs, depth of at least 13–15 cm should be used to adequately visualize the diaphragm and thoracic structures.
Normal Lung Exam – A lines

- Horizontal, hyperechoic lines that are equidistant repetitions of the pleural line are called A-lines.

- A-lines are reverberation artifacts created by repetitive reflection of ultrasound waves between the pleural line, a strong reflector, and the transducer.

- A-lines are best seen when the transducer is positioned perpendicularly to the curved surface of the lung.
Normal Lung Exam

• In normal, healthy lungs, ultrasound examination of the pleural surface reveals “lung sliding”, a shimmering or sliding of the visceral pleura against the parietal pleura during respiration.

• When this shimmering or sliding occurs synchronous with the heartbeat, it is called lung pulse.

• These can be appreciated both on 2D exam and on M mode exam of the lung.
M mode exam – normal lung
“Seashore Sign”

The near field of the image displays the static appearance of the chest wall layers (the “sea”), and the far field displays the motion pattern of dynamic pleural sliding (“the shore”).
Normal lung exam

• Presence of A-lines along with sliding lung
• Suggests that the lung is normally aerated and the pleura is devoid of air.
Exam of lung in Pneumothorax
Absence of lung sliding

• Absence of lung sliding in pneumothorax is due to air interposed between the two pleural surfaces that prevents ultrasound waves from propagating from the parietal pleura to the visceral pleura.

• Although the visceral pleura is likely still moving, it is no longer moving against the parietal pleura.

• Only the immobile parietal pleura is imaged by ultrasound.

• On M mode, this is seen as the “Bar Code” sign.
Bar Code Sign – Absence of lung sliding

Static pattern in both the near and far field, signifying the absence of any motion deep to the parietal pleura.

This “bar code” appearance or “stratosphere sign” is consistent with the absence of lung sliding.
M mode of lung - Comparison
Absence of lung sliding

• Can occur with both pneumothorax (PTX) and prior history of pleurodesis

• The main utility of lung sliding is to rule out PTX, given that lung sliding cannot be seen in PTX.
Abnormal Lung Exam – B lines

- B-line pattern are also called “lung rockets” or “comet tails.”

- Occur due to propagation of ultrasound waves through interlobar septa that have been widened due to fluid accumulation.

- To be pathologic, three or more B-lines in a single rib interspace must be present.

- Fissures can also produce a single B-line
B-line pattern - “lung rockets” or “comet tails.”

• B-lines are seen when interstitium is widened with fluid or scarring

• Acute conditions: pulmonary edema, pneumonia, acute lung injury

• Detection of B-lines at multiple symmetric points on the anterior chest (bilateral B profile) almost always represents pulmonary edema.

• Focal and asymmetric interspaces revealing multiple B-lines suggest pneumonia, acute respiratory distress syndrome (ARDS)

• B lines can also occur in chronic lung diseases which are associated with scarring of the septa secondary to fibrosis, interstitial lung disease, or old infections
Abnormal Lung Exam – C Profile
Alveolar Consolidation Pattern

• When the alveoli are filled with fluid or cellular debris or are collapsed, such as in pneumonia or atelectasis, the decreased acoustic impedance due to lack of air beneath the pleural surface facilitates propagation of ultrasound waves allowing visualization of the lung.

• Lung parenchyma becomes well defined with echogenicity similar to the liver, referred to as hepatization, or the C profile

• Large basilar consolidations are easily detected by ultrasound while often remaining occult on portable chest radiographs.

• Note that the “alveolar consolidation pattern” is descriptive and not diagnostic.

• Can occur due to multiple possible etiologies such as pneumonic consolidation, compressive atelectasis, and resorptive atelectasis.
Abnormal Lung Exam – C Profile
Alveolar Consolidation Pattern

Alveolar consolidation pattern with echogenicity similar to liver, “hepatization” of lung.
Abnormal lung exam – Pleural effusion

• Diagnosis the presence of a pleural effusion on POCUS exam requires 3 things:

• 1. Identification of anatomic boundaries: diaphragm, subdiaphragmatic organs (liver or spleen), chest wall, and lung

• 2. Presence of an Anechoic space

• 3. Dynamic changes:
  • (A) typical movement of the lung in a pleural effusion, also called “lung flapping” or the “jellyfish sign,” and
  • (B) diaphragmatic movements
Abnormal lung exam – Pleural effusion
RUSH Protocol – RUQ View
RUSH Protocol – LUQ view
RUSH Protocol – Bladder View

Bladder

Free Fluid
RUSH Protocol
Aortic views
POCUS exam
Cardiac Evaluation
Standard Views
POCUS exam – Cardiac Evaluation

• 1. *Pericardial effusion* — Evaluation of presence or absence of pericardial effusion/ tamponade.

• 2. *Left ventricular size and function* — Evaluation of overall systolic function and evaluation for presence or absence of regional wall motion abnormalities (RWMA)

• 3. *Right ventricular size and function*

• 4. *Intravascular volume status* — IVC diameter and variation, filling of LV and RV

• 5. *Valvular abnormalities* — 2D imaging for severe restriction in motion of the aortic, mitral valves. Color flow Doppler screening for severe valvular regurgitation
POCUS Exam – Pericardial Effusion/ Tamponade

• Pericardial and pleural effusion can be present together and hence it is important to be able to distinguish the two.

Both a pericardial effusion and left pleural effusion are demonstrated in this parasternal long-axis view. The pericardial effusion is seen anterior to the descending thoracic aorta (DTA), while the pleural effusion is posterior to the DTA.
POCUS Exam – Pericardial Effusion/ Tamponade

- Measurement of the maximum fluid dimension measured in diastole allows quantification of the size of the pericardial effusion

- A. Small: <1 cm
- B. Moderate: 1–2 cm
- C. Large: >2 cm
POCUS Exam
Pericardial Effusion/ Tamponade
POCUS Exam
Pericardial Effusion/ Tamponade

- *RV diastolic collapse*
- *RA systolic collapse*: Inversion of the RA free wall for greater than a third of ventricular systole
- *Reciprocal respiratory variations in ventricular volumes*
- *Plethora of the inferior vena cava (IVC)*
RA systolic collapse: Inversion of the RA free wall for greater than a third of ventricular systole.
RV diastolic collapse
Plethora of the inferior vena cava (IVC)
Reciprocal respiratory variations in ventricular volumes:
When visually estimating LV systolic function, attention is paid to all LV segments with particular focus on three characteristics:

1. **Endocardial excursion**. Does the endocardium move symmetrically toward the center of the LV chamber during systole?

2. **Myocardial thickening**. Does the myocardium increase in thickness by approximately 40% in all LV segments during systole?

3. **Sextal motion of the anterior leaflet tip of the mitral valve** (E-point septal separation). Does the anterior leaflet tip of the mitral valve come within 1 cm of the septum, which corresponds with an ejection fraction >40%?
POCUS exam – RV exam.

- Standard views for evaluation of the right ventricle.
- **A**, Parasternal long-axis assessment.
- **B**, Parasternal short-axis assessment.
- **C**, Apical 4-chamber assessment.
- **D**, Subcostal 4-chamber assessment.
POCUS exam – RV exam.

- An apical 4-chamber image of the right ventricle should be acquired at its greatest dimension (line 1).

- Off-axis imaging can lead to significant errors in right ventricular size and function assessment (lines 2 and 3).
Evaluation of RV size

- **Normal**: RV < 2/3 of LV size
- **Moderate dilation**: RV > 2/3 of LV size
- **Severe dilation**: RV > LV size
Presence of D shaped septum

Comparison of a normal interventricular septum (A) and a flattened septum bowing into the left ventricle in a patient with right ventricular failure (B) from a parasternal short-axis view.
POCUS Exam
IVC size and respiratory collapse

<table>
<thead>
<tr>
<th>IVC Diameter and Collapse (%)</th>
<th>Central Venous Pressure (mean) (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal: ≤2.1 and &gt;50%</td>
<td>0–5 (mean 3)</td>
</tr>
<tr>
<td>IVC findings other than those seen with normal or high</td>
<td>5–10 (mean 8)</td>
</tr>
<tr>
<td>High: &gt;2.1 and &lt;50%</td>
<td>10–20 (mean 15)</td>
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</tbody>
</table>
POCUS in patient with Shock

RUSH Exam Sequencing

1. Parasternal Long Cardiac View
2. Apical Four-Chamber Cardiac View
3. Inferior Vena Cava View
4. Morison’s with Hemothorax View
5. Splenorenal with Hemothorax View
6. Bladder View
7. Aortic Slide Views
8. Pneumothorax View
9. Pneumothorax View

Use Curvilinear Array for 1-7
Use High-Frequency Array for 8 & 9
<table>
<thead>
<tr>
<th>Cardiac status (Pump)</th>
<th>IVC &amp; Lungs (Tank)</th>
<th>Aorta (Pipes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A- Pericardial sac for tamponade</td>
<td>A- IVC for collapsibility</td>
<td>A- Aorta for aneurysm and dissection</td>
</tr>
<tr>
<td>B- LV size and contractility for cardiogenic shock</td>
<td>B- Lungs for pneumothorax, pulmonary edema and pleural effusion</td>
<td>B- Femoral and popliteal veins for DVT</td>
</tr>
<tr>
<td>C- RV size for pulmonary embolism</td>
<td>C- Abdomen for free fluid</td>
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</tbody>
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Table 1
Rapid Ultrasound in SHock (RUSH) protocol: ultrasonographic findings seen with classic shock states

<table>
<thead>
<tr>
<th>RUSH Evaluation</th>
<th>Hypovolemic Shock</th>
<th>Cardiogenic Shock</th>
<th>Obstructive Shock</th>
<th>Distributive Shock</th>
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</thead>
<tbody>
<tr>
<td>Pump</td>
<td>Hypercontractile heart</td>
<td>Hypocontractile heart</td>
<td>Hypercontractile heart (early sepsis)</td>
<td>Hypercontractile heart (late sepsis)</td>
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<tr>
<td></td>
<td>Small chamber size</td>
<td>Dilated heart</td>
<td>Pericardial effusion</td>
<td>Cardiac tamponade</td>
</tr>
<tr>
<td>Tank</td>
<td>Flat IVC</td>
<td>Distended IVC</td>
<td>Distended IVC</td>
<td>Normal or small IVC (early sepsis)</td>
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<td></td>
<td>Flat jugular veins</td>
<td>Distended jugular veins</td>
<td>Distended jugular veins</td>
<td>Peritoneal fluid (peritonitis)</td>
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<tr>
<td></td>
<td>Peritoneal fluid (fluid loss)</td>
<td>Lung rockets (pulmonary edema)</td>
<td>Absent lung sliding (pneumothorax)</td>
<td>Pleural fluid (empyema)</td>
</tr>
<tr>
<td></td>
<td>Pleural fluid (fluid loss)</td>
<td>Pleural fluid (effusions)</td>
<td>Peritoneal fluid (ascites)</td>
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<tr>
<td>Pipes</td>
<td>Abdominal aneurysm</td>
<td>Normal</td>
<td>DVT</td>
<td>Normal</td>
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<td></td>
<td>Aortic dissection</td>
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Abbreviations: DVT, deep venous thrombosis; IVC, inferior vena cava; RV, right ventricle.
Summary

• 1. POCUS is a goal directed exam
• 2. There are several protocols for scanning in POCUS
• 3. In addition to its use for procedural guidance and in patients with trauma, POCUS has a very important role in evaluation of patient with shock.
• 4. The components of the RUSH exam are remembered by the acronym HI-MAP.
• 5. With practice, the RUSH exam can be completed within a few minutes.
• 6. Attention to adequate training, certification and continued quality improvement are critical to any successful POCUS program.
Questions
Additional Slides:

- **Point-of-care ultrasound: seeing the future.** Morris, Amy E. Current problems in diagnostic radiology (Jan 2015). VOL 44, ISSUE: 1
- Soni, Nilam J et al. Text Book: Point of Care Ultrasound: Expert Consult. 01/01/2014
- **SonoSpot: Topics in Bedside Ultrasound.** Laleh Gharahbaghian, MD
<table>
<thead>
<tr>
<th>Cardiac exam</th>
<th>Hypovolemic Shock</th>
<th>Cardiogenic Shock</th>
<th>Obstructive Shock</th>
<th>Distributive Shock</th>
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<tbody>
<tr>
<td></td>
<td>LV : Hyperdynamic function</td>
<td>LV : Severe reduced function (all views)</td>
<td>LV : Tamponade :</td>
<td>LV : Hyperdynamic function</td>
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<td></td>
<td>• - End-systolic effacement (PLAX, PSAX)</td>
<td>Dilated chamber</td>
<td>• - Hyperdynamic function</td>
<td>• - Hyperdynamic or normal function (early sepsis)</td>
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<td></td>
<td>RV :</td>
<td>RV :</td>
<td>Pericardial effusion with RA or RV diastolic collapse</td>
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<td></td>
<td>• - Possible dilated chamber</td>
<td>• - Possible dilated chamber</td>
<td>RV :</td>
<td>• - Hypocontractile function (late sepsis)</td>
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<td></td>
<td>Valves :</td>
<td>Valves :</td>
<td>• - Pulmonary Embolism :</td>
<td>RV :</td>
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<td>Dilated, strained RV (A4C, S4C)</td>
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<td>Possible severe MR or AR detected by color flow Doppler</td>
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<td>D-shaped septum (PSAX)</td>
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<td>Possible AS by 2D exam</td>
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## POCUS in patient with Shock


<table>
<thead>
<tr>
<th>Pulmonary exam</th>
<th>Hypovolemic Shock</th>
<th>Cardiogenic Shock</th>
<th>Obstructive Shock</th>
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<tr>
<td>Lungs:</td>
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<td>Lungs:</td>
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<td>A-line predominance</td>
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<td>• Pneumothorax:</td>
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<td>Pleura:</td>
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<td>No pleural effusion</td>
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<td>Lung sliding absent in pneumothorax</td>
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<tr>
<td>Lungs:</td>
<td>• -</td>
<td>• B-line predominance</td>
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<tr>
<td>Pleura:</td>
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<td>A-line predominance</td>
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<td>Possible bilateral pleural effusions</td>
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<td>Pleura:</td>
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<td>Possible small pleural effusion, small sub pleural consolidations (infarcts)</td>
<td>Possible pleural effusion (pneumonia, empyema)</td>
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<tr>
<td>IVC exam</td>
<td>Collapsed IVC</td>
<td>Distended IVC</td>
<td>Distended IVC</td>
<td>Normal/collapsed IVC</td>
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POCUS in patient with Shock

<table>
<thead>
<tr>
<th>Supplementary exams</th>
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<tbody>
<tr>
<td>Abdomen</td>
<td>-</td>
<td>Abdomen:</td>
<td>Vascular:</td>
<td>Abdomen:</td>
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<td>Abdominal aortic aneurysm</td>
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<td>Abdomen:</td>
<td>LE DVT study (PE)</td>
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<tr>
<td>Aortic dissection</td>
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<td>Abdomen:</td>
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<td>-</td>
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<tr>
<td>Intra-abdominal hemorrhage (FAST exam)</td>
<td>-</td>
<td>Peritoneal fluid in chronic right or left heart failure</td>
<td>Distended IJ vein (tamponade)</td>
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<tr>
<td>Vascular:</td>
<td>-</td>
<td>Peritoneal fluid in chronic right or left heart failure</td>
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<td>Possible peritoneal fluid (peritonitis)</td>
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<tr>
<td>Collapsed veins (internal jugular, femoral veins)</td>
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</table>
Additional Questions

• If you have any further questions, please feel free to get in touch with me at barya@bcm.edu

• Good Luck with the ASE Echo Boards.